Mad River Reach Assessment and Restoration Strategy

DRAFT REPORT

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Mad River, near Ardenvoir, WA - October, 2017.

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1. Introduction

1.1 PROJECT OVERVIEW AND PURPOSE

The Mad River Reach Assessment and Restoration Strategy evaluates existing aquatic habitat and watershed process conditions along the lower 4.3-miles of the Mad River. Endangered Species Act (ESA) listed species targeted for potential habitat improvements within the assessment area include Upper-Columbia Steelhead (*Oncorhynchus mykiss*), Upper-Columbia Chinook (*Oncorhynchus tshawytscha*), and Columbia River bull trout (*Salvelinus confluents*). The assessment area extends from the mouth of the Mad River at its confluence with the Entiat River 4.3 river miles to its confluence with an unnamed tributary (river right) near Pine Flats campground.

This project was completed on behalf of the Yakama Nation as part of their efforts to improve native aquatic fisheries within the Columbia River Basin. Conducting the assessment involved collecting field data of the area and combining it with existing available information on the Mad River and the Entiat watershed. Existing available information utilized in this assessment includes, but is not limited to the Entiat Water Resource Inventory Area (WRIA 46) Management Plan ((CCCD), 2005), Biological Overview for the Entiat River Tributary Assessment (Archibald, 2009), Entiat Subbasin Plan (Peven et al., 2004), available digital and paper geologic maps, past habitat assessment results, and Inter-Fluve's Tillicum Creek Habitat Restoration Project Report (2018). This report does not attempt to re-create the work accomplished in existing documents but summarizes that material and adds detail where appropriate. New data collection and analysis performed as part of this effort include a geomorphic assessment of the mainstem channel, side channels, and floodplain surfaces, as well as an aquatic habitat inventory, characterization of landforms and human impacts, and identification of habitat restoration opportunities.

Specific goals of this project include:

- Compile an assessment of the existing geomorphic and aquatic habitat conditions and trends in order to provide the technical foundation for development of an effective stream habitat restoration strategy.
- Develop a restoration strategy that identifies and prioritizes restoration actions that protect and improve aquatic habitat and supporting ecological processes, with an emphasis on culturally significant riverine species.

This assessment is organized with a watershed to reach-scale perspective. The watershed-scale information is provided to give context to the 4.3 miles of channel included in the assessment area. Assessment area characteristics are described and then the area is divided into reaches to identify localized geomorphic and ecologic trends and conditions. Reach and site-specific restoration opportunities are presented that address habitat and ecological process limitations. This framework allows for the identification of restoration activities at discrete locations while considering broader scale physical and ecological factors that influence the assessment study area.

1.2 SETTING

The Mad River is a primary tributary within the Entiat River watershed, which flows directly into the Columbia River. The watershed is located within the eastern foothills of the Cascade Mountains in central Washington along the western border of the Columbia Plateau (Figure 1). The Mad River flows southeast through the foothills and joins the Entiat River approximately 11 river miles (RM) upstream of where the Entiat meets the Columbia River. The Mad River is approximately 23 river miles long from its headwaters to its confluence with Entiat River. At the mouth of the Mad River channel elevation is approximately 1,250 feet and at the headwaters it is approximately 5,900 feet.

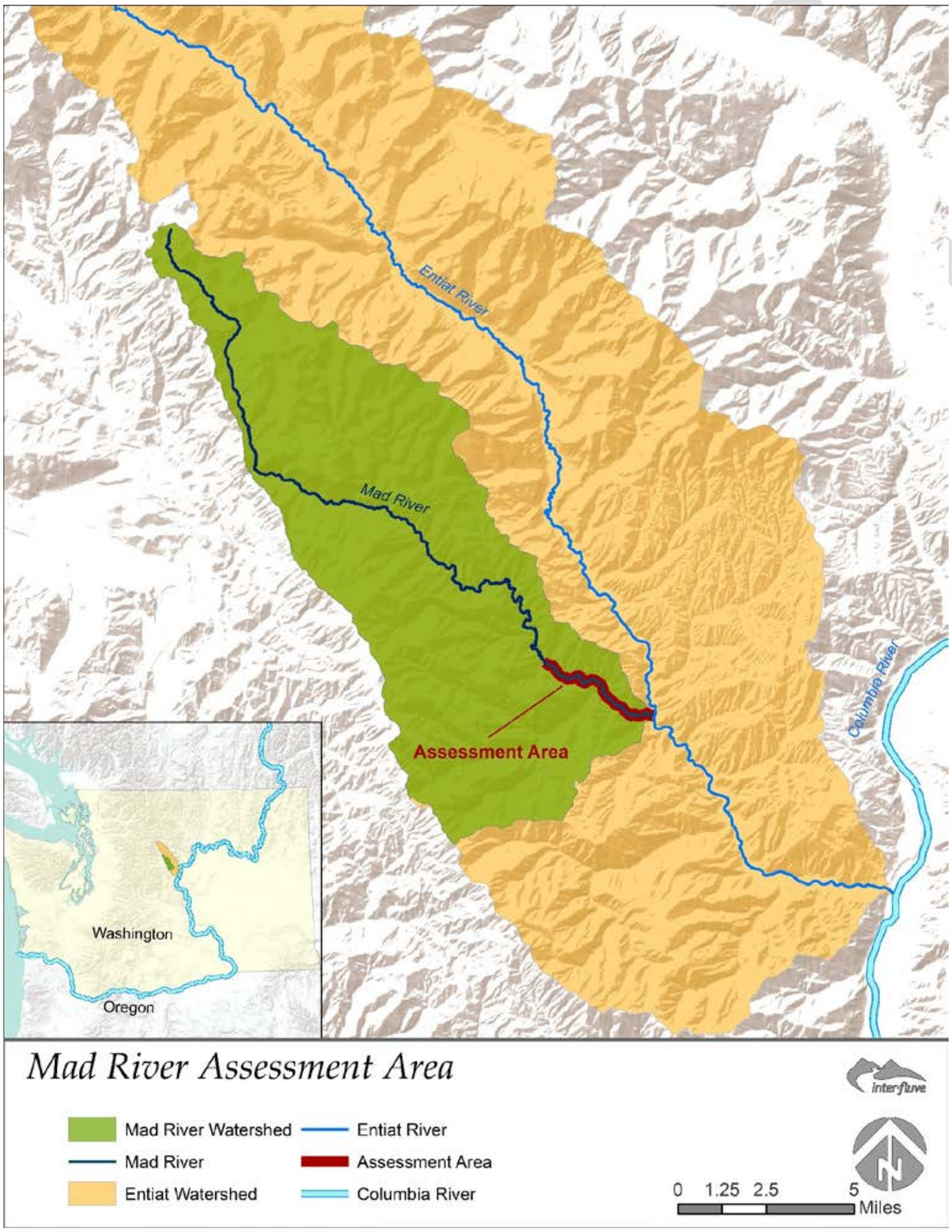


Figure 1. Assessment area locator maps. Basemaps: ESRI world terrain maps and Bing imagery.

The Yakama Nation has identified the lower 4.3 river miles of the Mad River for assessment and potential restoration. The assessment area was divided into four distinct geomorphic reaches to facilitate description and discussion of local channel characteristics and restoration needs. Reaches were delineated at major physical transitions in channel form, gradient, degree of sinuosity, confinement, bedload and floodplain connectivity. Reaches are numbered from downstream to upstream within the assessment area.

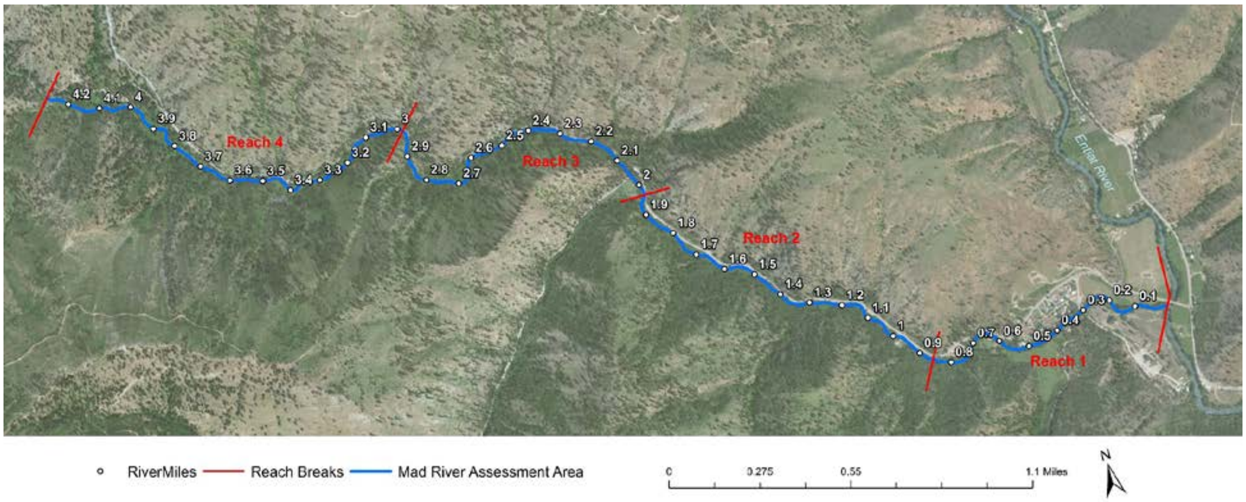


Figure 2. Reach breaks and river miles within the assessment arear on the Mad River, WA.

2. Fish Use and Status

The Entiat Subbasin currently supports anadromous runs of native spring chinook and steelhead (Mullan, Williams, Rhodus, Hillman, & McIntyre, 1992). The lower Mad River, including the study area, supports spawning and rearing habitat for endangered Upper Columbia spring Chinook salmon and Upper Columbia steelhead. Coho were once present in the watershed but have since been extirpated (Nehlsen, Williams, & Lichatowich, 1991). Other resident species in the sub-basin include salmonids such as bull trout, westslope cutthroat trout, redband trout, and rainbow trout, as well as mountain whitefish and eastern brook trout. In the lower Mad River, the primary focal species for restoration efforts include spring Chinook salmon and steelhead trout. Bull trout are also listed under the ESA as threatened, but primarily reside upstream of the study area.

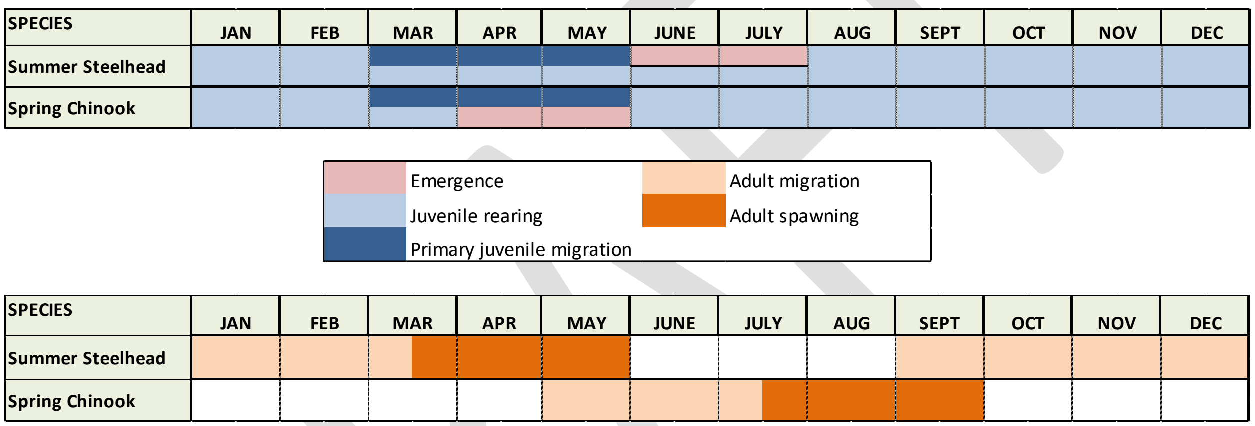


Figure 3. Life history timing of steelhead and Chinook Salmon in the Entiat River.

2.1 STEELHEAD

Steelhead (*Oncorhynchus mykiss*) enter and ascend the Columbia River in June and July, arriving near their spawning grounds 9 to 11 months prior to spawning. Adult steelhead overwinter in the mainstem Columbia, the Entiat or smaller tributaries where there are deep pools with overhead cover. Spawning survey data from the Mad River during the 2000–2008 spawning seasons showed that spawning occurred between late March and early May with a peak observed in late April (Archibald, 2009). Egg survival is highly sensitive to intra-gravel flow and temperature (Peven et al., 2004) and is particularly sensitive to siltation earlier in the incubation period. Fry emerge from the redds 6-10 weeks after spawning (Peven et al., 2004).

Age-0 juveniles spend their first year primarily in shallow riffle habitats, feeding on invertebrates and utilizing overhanging riparian vegetation and undercut banks for cover (Moyle, 2002). Age-0 steelhead use slower, shallower water than Chinook Salmon, preferring small boulder and large cobble substrate (Hillman & Miller, 1989). Older juveniles prefer faster moving water including deep pools and runs over cobble and boulder substrate. Juveniles outmigrate between ages one and three, though some hold over and display a resident life history form. Smolts begin migrating downstream from natal areas in March (Peven et al., 2004).

2.2 SPRING CHINOOK

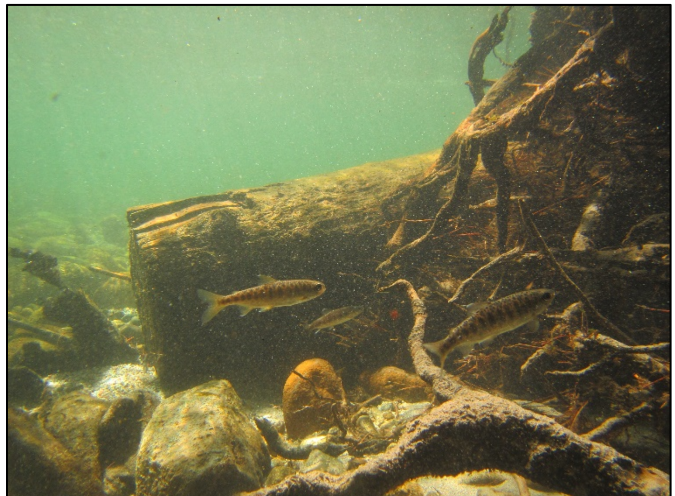


Figure 4. Chinook Salmon parr resting behind a constructed log jam in the Entiat River mainstem between feeding forays.

Spring Chinook (*O. tshawytscha*) are reported to use the lower Mad River for spawning. Adult spring Chinook enter the Entiat basin in May, holding in deep pools under overhead cover in the Entiat or Mad Rivers. Spawning occurrs from very late July through September with a peak in mid to late August. Spawning typically begins when temperatures drop below 16°C (Healy, 1991; Peven et al., 2004). Eggs are very sensitive to changes in oxygen levels and percolation, both of which are affected by sediment deposition and siltation in the redd (Peven et al., 2004). Fry emerge in the spring, which coincides with the rising hydrograph. High water forces juveniles to seek out backwater or margin areas with lower velocities, dense cover, and abundant food (Quinn, 2005). Fry are extremely vulnerable in these systems when they emerge, because their swimming ability is poor and flows are high. Near-shore areas with eddies, large woody debris, undercut tree roots, and other cover are very important for post-emergent fry (Healy, 1991; Hillman & Miller, 1989). Age-1 parr utilize deeper pools with resting cover in mainstem habitats more than post-emergent individuals (Figure 4). Spring Chinook typically express a stream-type life history where they rear for 1 year in freshwater before out-migrating as yearlings. Out-migration typically begins in March (Healy, 1991; Peven et al., 2004).

2.3 BULL TROUT

Bull trout (*Salvelinus confluentus*) spawn and rear in the middle and upper Mad River, upstream of the study site. The Mad River supports the largest populations of bull trout in the Entiat Basin. Bull trout from both areas were listed as threatened under the ESA in 1999 (U.S. Fish and Wildlife Service, 1999).

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

Bull trout normally reach sexual maturity in 4 to 7 years and can live 12 or more years. Bull trout typically spawn from August to November during periods of decreasing water temperatures.

Preferred spawning habitats are generally low gradient stream reaches or in areas of loose, clean gravel in higher gradient streams (Fraley & Shepard, 1989) and where water temperatures are between 5 to 9° C (41 to 48° F) in late summer to early fall (Goetz, 1989). Spawning areas are often associated with cold-water springs, groundwater infiltration, and are typically the coldest systems in a given watershed (U.S. Fish and Wildlife Service, 1999).

Depending on water temperature, egg incubation can last between 100–200 days, and juveniles remain in the substrate after hatching. Fry normally emerge from early April through May, depending upon water temperatures and increasing stream flows (U.S. Fish and Wildlife Service, 1999).

3. Assessment Area Characterization

3.1 GEOLOGY

The geology and landscape history of the assessment area and its surroundings are important components of ongoing local geomorphic processes. The Mad River Basin is located within the eastern portion of the North Cascades Geologic Province – a complex assemblage of lithologic types shaped by millions of years of tectonic activity. The formation of the province was and is powered by subduction along the western margin of the North American Plate resulting in volcanic processes along the Cascades. The geology in the vicinity of the assessment area has been shaped by strike-slip and thrust faulting, bedrock metamorphism, and plutonic emplacements. The Entiat River Watershed, in which the Mad River resides, contains fault-bound geologic terranes characterized by unique stratigraphic and structural histories. The assessment area is located within the Chelan Block, characterized by crystalline metamorphic and igneous bedrock. Specifically, the study area is located on deposits of intrusive, Cretaceous-aged tonalite and migmatite of the Chelan Mountains Terrance (Tabor etal., 1987).

Bedrock within the Mad River watershed is dominated by (1) late Cretaceous metamorphic rocks, and (2) Late Cretaceous to Early Tertiary granitic rocks. The bedrock character of the Mad River watershed is crystalline and erosion-resistant. Protoliths (original lithology types) of today's bedrock are marine/near-shore sediments and emplaced volcanic rocks. Through metamorphic processes, the original marine sediments and volcanic rocks were transformed into the gneiss and schist that are present in the watershed today. During the Late Cretaceous and early Tertiary periods, multiple granitic plutons occurred within the watershed, that are now visible via processes of erosion along the Mad River. A few locations within the Mad River watershed have accumulations of unconsolidated sediments (alluvium and colluvium) – in particular, the small valleys in the uppermost section of the watershed, at Tillicum Creek's small alluvial fan where it joins the Mad River at RM 2.0, and in the lowermost section of the Mad River at its paleo alluvial fan where it meets the Entiat River Valley. Otherwise, sediment accumulations are found as small narrow pocket floodplains and terraces, where valley confinement allows.

Tectonic compression, which resulted in folding of underlying bedrock, is manifested in northwest-southeast trending synclines and anticlines in the Mad River Watershed. A series of roughly northwest-southeast trending thrust faults are present in the bedrock schist and gneiss of the Mad River Terrane (Figure 5). This is evidence of northeast-southwest compression after the rocks were metamorphosed (Tabor et al., 1987). The Mad River itself follows a northwest-southeast directional trend, likely stemming from the tectonic history of the area.

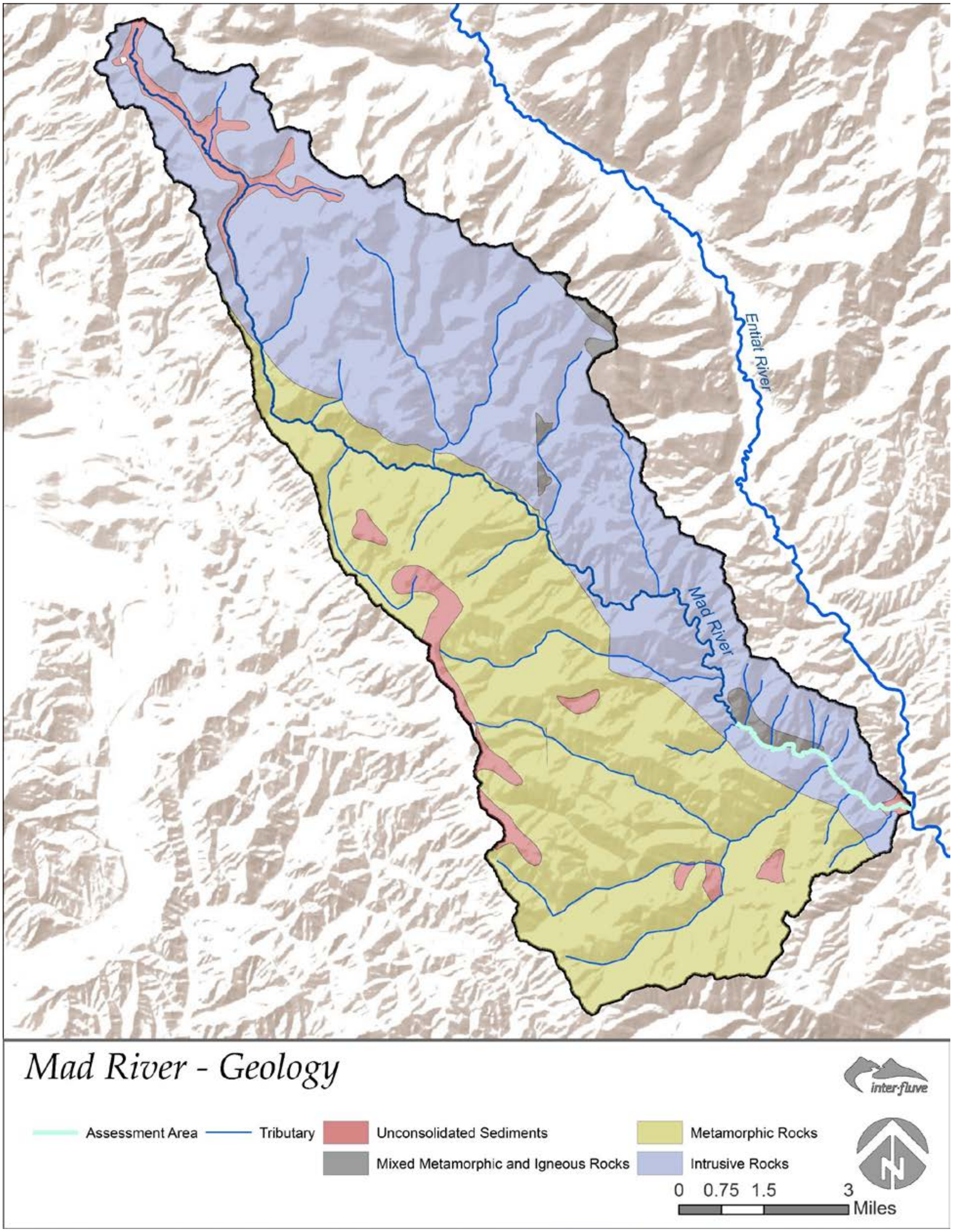


Figure 5. Surficial geology of the Mad River watershed (Geology unit map source: WDNR, 2010).

3.1.1 Pleistocene Glaciation

Early Quaternary glacial processes contributed to the surficial deposits and topography of the Mad River watershed. Although the Cordilleran ice sheet did not extend into the Mad River, and alpine glaciation did not advance down-valley to the location of the assessment area (RM 0 – 4.3), the uppermost section of the watershed shows evidence of small-scale alpine glaciation. Cirques located below Klone Peak and Kelly Mountain are examples of early Quaternary alpine glaciation in the headwaters of the Mad River. Ultimately, however, the impact of glaciation on the Mad River watershed was relatively minimal compared to nearby drainages such as the Entiat River. Instead, the topography of the Mad River has been shaped by underlying geology, mass wasting (landslides) and fluvial processes. As a result, the river valley is generally v-shaped with varied depths of sediment accumulations on the floor. Hillslope coupling to channel processes is evident throughout, except in the downstream-most 1 mile where the valley widens and meets the Entiat River Valley.

3.1 SOILS

Soils on the adjacent hillslopes and valley floor of the assessment area are derived from the underlying bedrock and some aerial inputs of volcanic material. A map of the soils that border the assessment area is provided in Figure 6. The hillslopes on the north (river left) side of the Mad River are dominated by granitic rock outcroppings and talus covered slopes. The south (river right) side is a mix of soils that are predominantly either a stony or gravelly sandy loam. Except for the low gradient alluvial deposits at the mouth of the Mad River, across the Tillicum Creek fan, and a section near Pine Flats, the soils are relatively shallow. All the soil types present are considered well-drained.

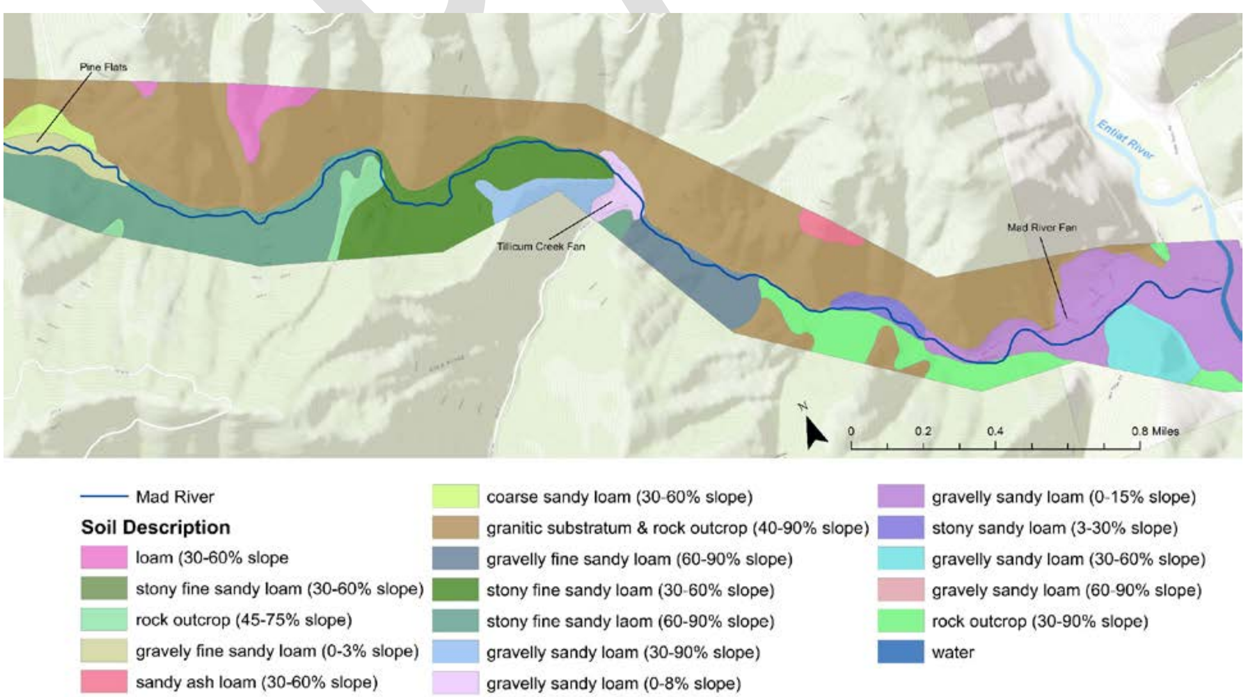


Figure 6. Soil types along the assessment area. (Source: USDA/NRCS, 2017)

3.2 CLIMATE

The climate of the Mad River Basin generally consists of dry, warm summers and cold, relatively wet winters. The majority of the precipitation throughout the basin falls as rain and snow in the winter and spring. However, the annual precipitation received varies across the basin from headwater to river outlet (Figure 7). The headwaters to the west receive over 46 inches of precipitation on average annually, while the eastern portions of the basin, near the confluence with the Entiat River, receive only about 15 inches annually (PRISM Climate Group, Oregon State University, 2017).

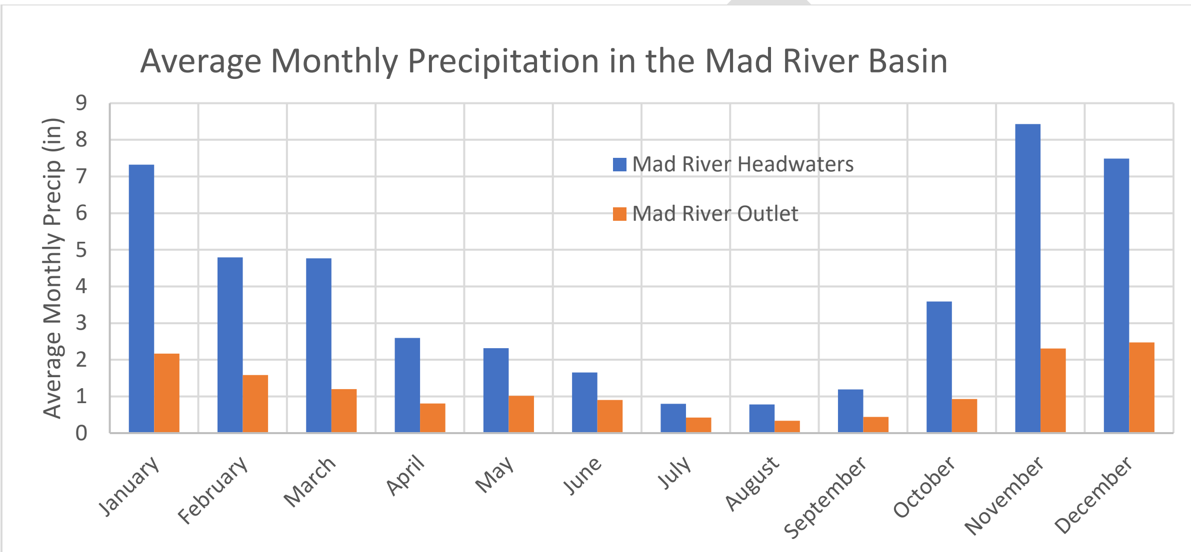


Figure 7. Monthly average precipitation in the Simcoe Basin at the headwaters (west side) and near the confluence with the Toppenish River (east side).

Near the mouth of the Mad River, monthly air temperatures reveal moderately cold winters and moderately warm summers (Figure 8). Average daily air temperatures throughout the winter are 32°F, although they occasionally drop as low as 10°F or rise up to as much as 50°F. As a result, snow accumulations within the assessment area vary from year to year. Average daily air temperatures in the summer months (June – August) typically fluctuate between 60-85°F (PRSIM Climate Group, Oregon State University, 2017). Average air temperatures in the winter months decrease upstream as elevation increases. As a result, the headwater areas that receive notably more precipitation in the winter receive more of it as snow. The snow accumulations in the upper watershed supply water to the channel throughout the spring and summer months.

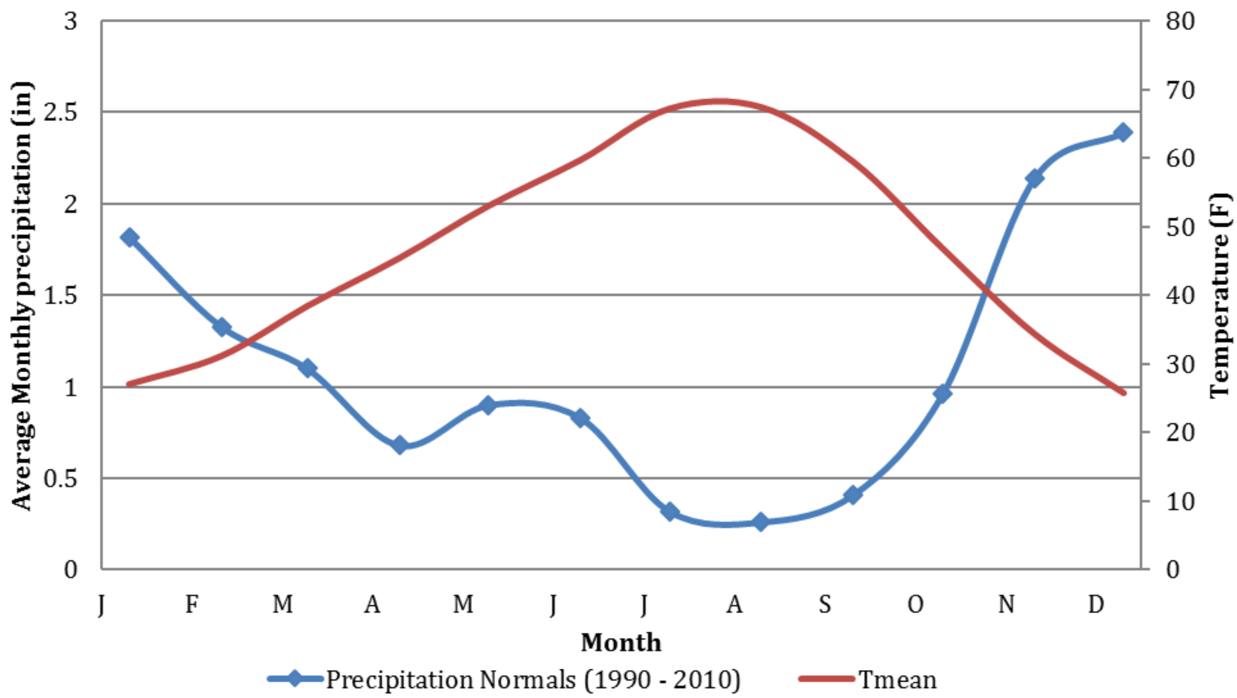


Figure 8. Average monthly (30 yr. normal) and mean daily temperatures (Tmean) near mouth of the Mad River at Ardenvoir, WA (PRISM 2017).

Global climate models used to accurately capture the 1.4°F warming measured in the Pacific Northwest over the 20th century have been applied to predict future climate trends (Srinivasan et al., 2007). These models predict an average increase in annual temperature of 2.0° F by the 2020s, 3.2° F by the 2040s, and 5.3°F by 2080 (Mote & Salathé, 2010). Climate simulations indicate precipitation and streamflow in the Pacific Northwest will respond to a changing climate through increased intensity of winter storm events resulting in higher streamflow, and decreased summer precipitation resulting in longer periods of, and decreased, low streamflow (Mantua et al, 2009). These changes are predicted to have the most substantial implications for *transient*— influenced by both autumn rains and spring snowmelt – and snowmelt driven watersheds.

The Entiat watershed, a transient watershed, is predicted to see an increase in summer streamflow temperatures. These increases are predicted to shift temperatures into the stressful-to-salmon range (64-70°F) by 2020s and fatal-to-salmon range (70-75°F) by 2080s. In addition to stressors associated with temperature, the extended low streamflow period during the summer season will have implications for stream-type lifecycle salmon habitat, while the enhanced winter flooding will likely result in reduced egg-to-fry survival (Mantua et al. 2009).

3.3 HYDROLOGY

3.3.1 Basin Characteristics

The Mad River flows approximately 23 river miles southeasterly from its headwaters at Mad Meadow (5,900 feet above sea level) to its confluence with the Entiat River near the community of Ardenvoir (1,250 feet above sea level). The drainage area of the Mad River watershed is approximately 91 square miles, with a mean basin elevation of 4,370 feet above sea level (USGS Streamstats, 2018). The Mad River initiates in mid-montane meadows then flows through a series of steep confined and partially confined valleys until it eventually reaches its paleo-alluvial fan that gradually opens near the community of Ardenvoir onto the Ential River Valley. Immediately upstream of the assessment area the Mad River flows through a confined v-shaped valley with steep hillslopes composed of the metamorphosed schists and gneisses of the Mad River Terrane.

3.3.2 Assessment Area Hydrology

The assessment area (RM 0 – 4.3) receives all the upstream hydrologic watershed inputs as well as inputs from within the study area. Figure 9 provides a map of the Mad River watershed and its contributing tributaries. The largest contributing tributary in the Mad River watershed is Tillicum Creek. This creek meets the Mad River at approximately RM 2.0, in the middle of the assessment area. Otherwise, contributing tributaries within the assessment area have relatively small contributing upstream drainage areas.

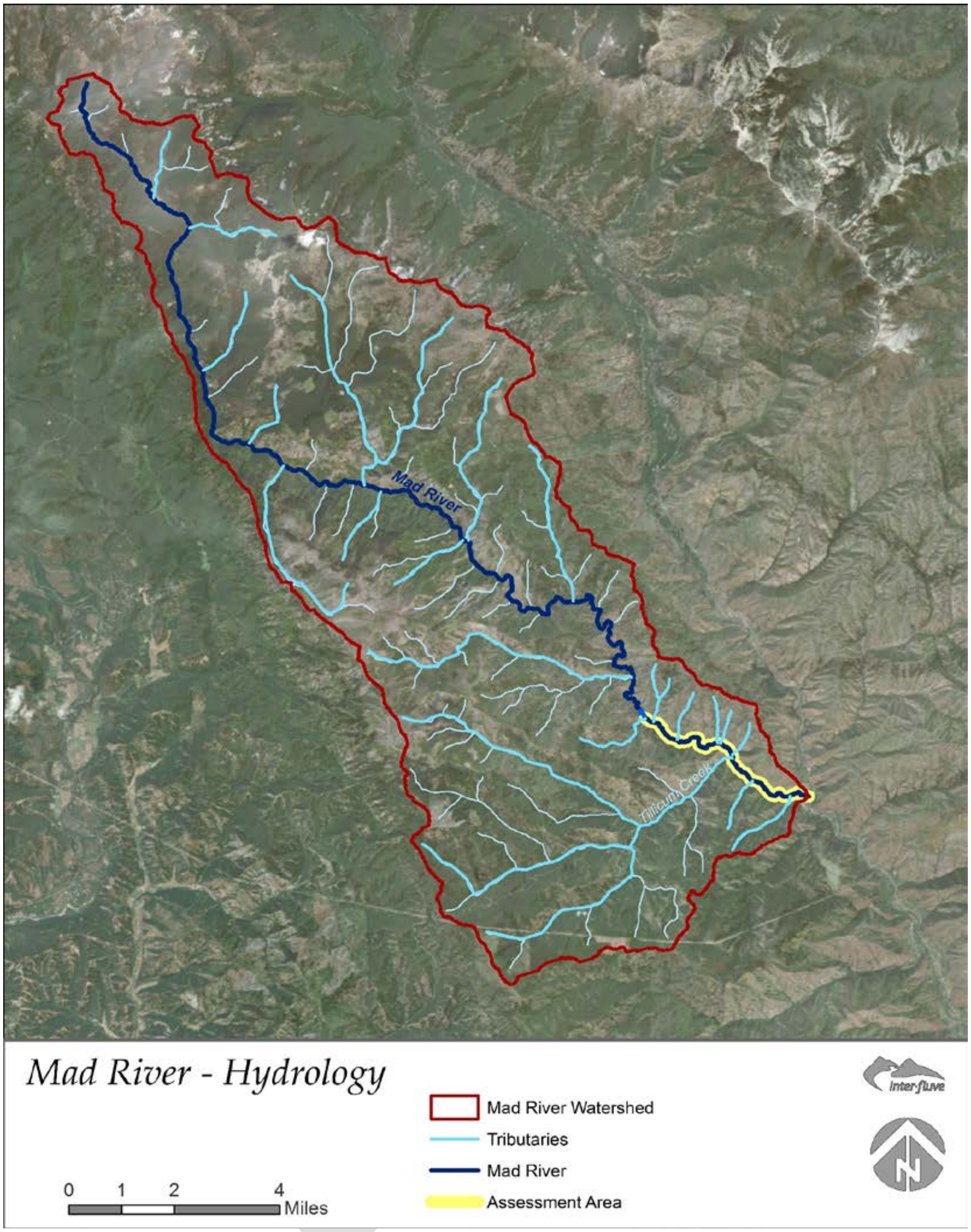


Figure 9. Mad River watershed and tributaries.

3.3.3 Surface Water

The average annual discharge of the Mad River watershed follows a snowmelt runoff pattern typical of east-slope Cascade Mountain streams. A USGS gage located near the mouth of the Mad River, at Ardenvoir, WA (USGS 12452890) provides surface water discharge data from 2002 – 2017 (Figure 10). The hydrograph depicts elevated spring flows most likely generated by rain on snow events. Base-flow is relatively constant August through October. Autumn and winter rain events usually produce only small peaks November through February, prior to the snow-pack melting in spring.

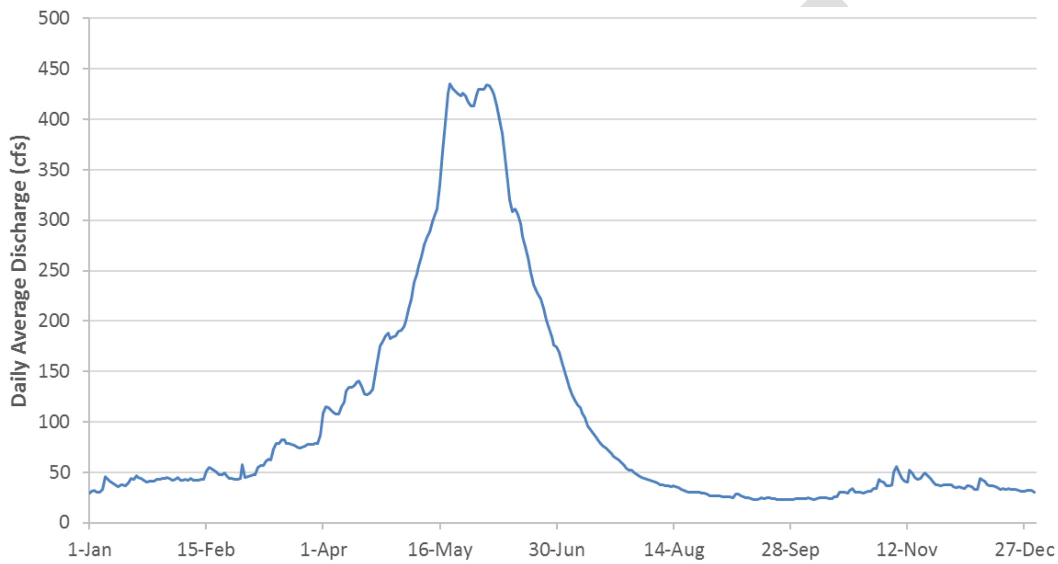


Figure 10. Daily average mean discharge at Ardenvoir 2003 - 2017 (USGS gage 12452890 Mad River).

3.3.4 Peak Flows

Recorded peak flow data on the Mad River at the USGS gage near Ardenvoir is limited to 2002 – 2017 and range from 269 cfs in 2015 to 965 cfs in 2006. Although the data is limited to 16 years of record, a Log-Pearson Type III statistical distribution analysis was performed using annual peak flood events to estimate flood frequency discharges (2, 5, 10, 25, 50, and 100-year flood events). Flood frequency discharges were also estimated in StreamStats (USGS, 2017), which uses regional regression equations developed by the USGS (Mastin et al., 2016). The standard error reported for these estimates range between 96% for the 2-year return period event to 52% for the 100-year return period event. Given the large standard error of the peak flow estimates and the ephemeral nature of contributing streams, these results should be considered with caution. Both estimated peak discharge event results are provided in Table 1. The peak flood events for the period record at the Ardenvoir gage (2002-2017) are plotted in Figure 11 with the StreamStats flood estimates.

Table 1. Estimated discharge for selected recurrence flood events.

Flood Return Period	Estimated Peak Discharge (cfs) Log-Pearson Type III	Estimated Peak Discharge (cfs) USGS StreamStats
2- year	650	658
5-year	843	809
10-year	952	896
25- year	1,075	995
50-year	1,151	1,060
100-year	1,226	1,120

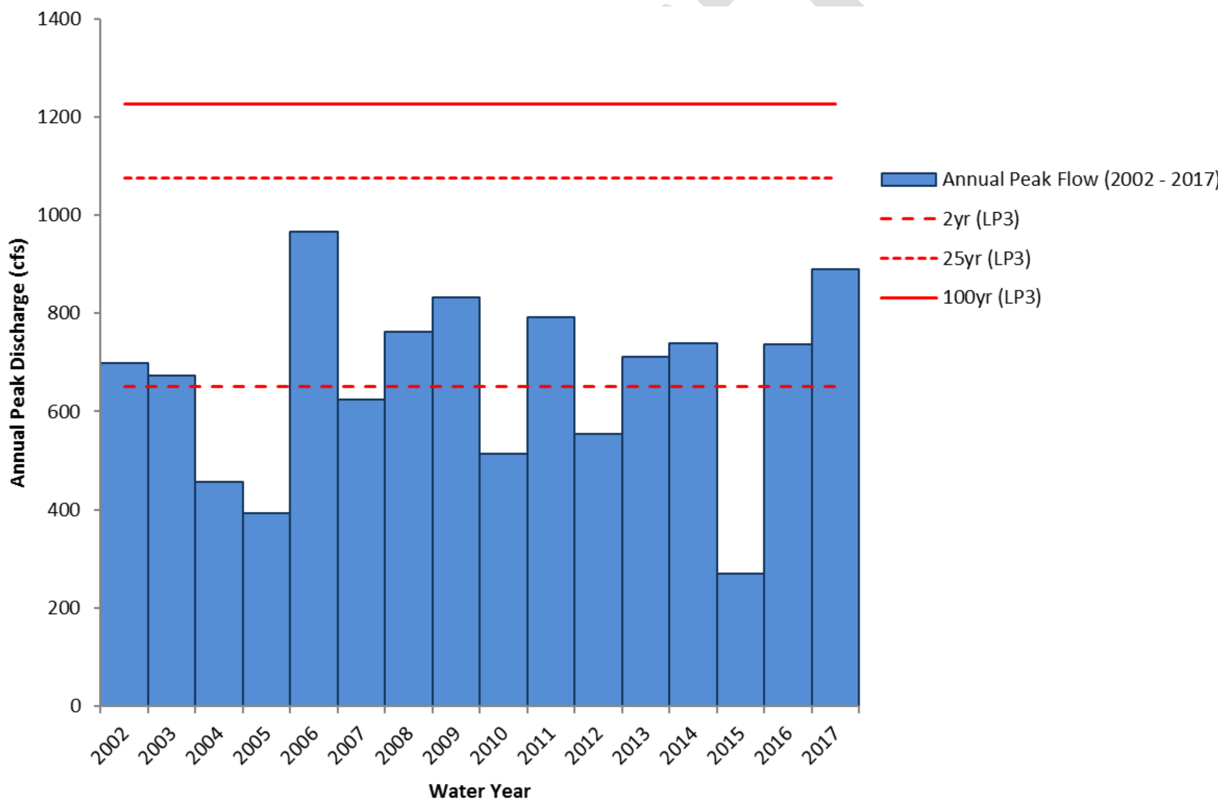


Figure 11: **Annual peak flows at Ardenvoir, WA, from 2002 – 2017 (blue bars) and Log-Pearson Type III estimated flood events (red lines).**

3.4 GEOMORPHOLOGY

Developing a successful habitat restoration strategy requires an understanding of the geomorphic processes and trends of the modern channel, floodplain, and contributing hillslopes. This section provides an overview of the geomorphology of the watershed as well as a summary discussion on the primary geomorphic features within the assessment area (RM 0 – 4.3). The information presented here is based on field-based survey observations (Oct 24-26 and Nov 9-10, 2017 and April

25, 2018) combined with available digital and printed data and reports (as referenced). Detailed discussions of geomorphic conditions and trends at the reach-scale are provided in Section 4.

The Mad River watershed is a relatively steep montane system that initiates off the ridges and high meadows of the Entiat Mountains located in the eastern foothills of the Cascades. Except for a handful of small headwater meadows, almost all of the upper 19 miles (RM 4.3-23) of the channel are hillslope or bedrock confined. The channel is single-thread with a planform defined by the pathway the river has cut into the underlying geology over millennia and the resulting hillslope and tributary contributions. Debris flows and/or landslide colluvium have, in places, appeared to have periodically blocked or temporarily confined the channel. These contributions also supply sediment to and create sediment sources for the system, including floodplain development and bedload. Immediately upstream of the assessment area (upstream of RM 4.3), channel gradient steepens and confinement increases. Here, bed load material that is smaller than gravels appears to be readily flushed through the system or stored temporarily in small pools or pocket eddies found near large boulders or large wood jams. Otherwise, bedload is a mix of coarse-grained (cobble-boulder) alluvium or colluvium contributed from the hillslopes.

Within the assessment area, downstream of RM 4.3, the channel flows through alternating sections of partially and completely confined sections until it exits the watershed’s mountains onto the Entiat River Valley. The Mad River Road occupies a portion of the valley floor throughout much of the reach, increasing natural confinement and impeding, to some degree, riparian vegetation and hillslope contributions from the river-left (north) side of the river valley. When the Mad River exits the mountains, it passes through its paleo alluvial fan before it meets the Entiat River. A brief discussion on the primary geomorphic features (see Figure 13) in the assessment area are provided below (hillslopes, valley, floodplains, terraces, and channel) followed by a summary of the presence of large wood surveyed in the channel.

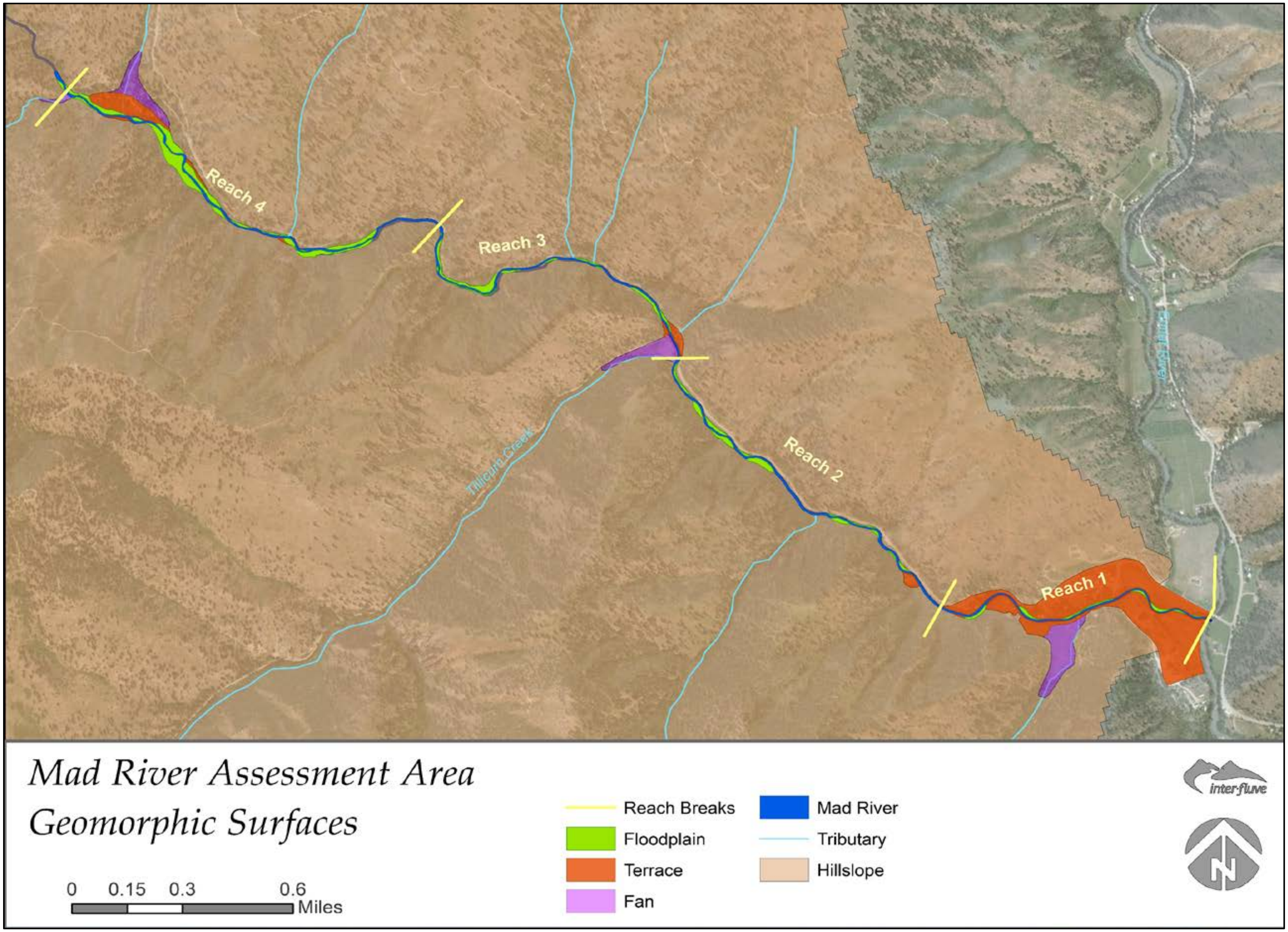


Figure 12. Geomorphic surfaces of the Mad River assessment area (RM 0 - 4.3)

3.4.1 Hillslopes and Valley

The hillslopes that contribute sediment to and host tributaries of the Mad River assessment area are relatively steep. Their geologic composition is mostly granitic as well as gneiss and schists from metamorphosed sedimentary and volcanic parent material (see Geology, Section 3.1). These bedrocks are generally erosion resistant and thus often form high, steep hillslopes and walls over millennia of channel downcutting. The hillslopes and valley of the Mad River were created by the gradual process of downcutting via fluvial erosion, mass wasting, and subtle faulting. Glaciers did not extend into the assessment area during the last glacial period. As a result, hillslope-valley form is basically "V" shaped instead of "U" shaped. As a result, there is a high degree of hillslope channel coupling that controls channel form, shape, confinement, and sediment supply. Hillslope and tributary contributions in the form of landslides, rock-fall, debris flows, and bedload has, and will continue to, influence river morphology through sediment and wood routing into the channel. Land use (i.e. logging and road building) as well as wildfires (natural and human started) are known to trigger increased temporary sediment and wood inputs into steep montane systems similar the Mad River (Beschta et al., 2004; Silins et al., 2009).

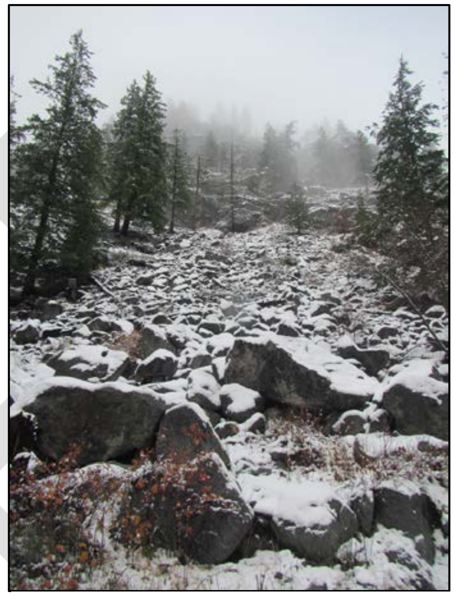


Figure 13. Hillslope along the Mad River, (Photo: IFI 11/9/2017)

The valley floor of the Mad River is confined within its hillslopes. The width of the modern valley floor ranges from approximately 280 ft to 25 ft within the assessment area. The downstream-most 0.86 river miles flows through the Mad River alluvial fan and into the relatively wide Entiat River Valley. The floor of the Mad River valley is composed of alluvial (river deposited) and colluvial (hillslope contributed) materials. Valley width and localized gradient is influenced by the presence of substantial sediment contributions, most extensively at alluvial and debris fans located at the mouths of its larger tributaries. Floodplains and terraces exist in the wider, less-confined, valley sections.

3.4.1 Terraces and Floodplains

Terraces are alluvially created or re-worked surfaces that are no longer connected to the channel via flood flow inundation. Terraces, if adjacent to the channel, can continue to contribute sediment from their banks and nutrients from the established riparian vegetation on its surface. The naturally-formed terraces in the upstream section of the assessment area are the result of substantial sediment contributions from tributaries and/or upstream inputs that infilled the valley. The river has been gradually working its way through the available sediment and, in its contemporary form, has incised to the point where historical channel and floodplain surfaces have been abandoned (e.g., up-slope part of Pine Flats Campground). The small terraces near the Tillicum Creek alluvial fan would have likely undergone similar processes. However, the construction of a dam, road, bridge, homesite, and related bank armoring at the fan toe exaggerated entrenchment at this site, making it difficult to discern without more research the difference between natural vs anthropogenic terrace development. Similarly, the terrace surfaces in the downstream sections of the assessment area are a mix of natural and anthropogenic process. For example, the alluvial fan on river right in Reach 1 would likely have resulted in terrace development along its toe where it contacted the Mad River as flow regimes and sediment supply decreased through the Holocene (last 12 thousand years). However, levees, roads, bridges, and bank armoring along most of the channel in the downstream portion has exaggerated channel entrenchment and floodplain abandonment.

The active floodplain surfaces of the Mad River are generally discontinuous and occupy the remaining portion of the valley floor not occupied by the channel or the Mad River Road. Almost all floodplain surfaces are well vegetated but the maturity and composition of that vegetation varies depending on land-use. Vegetation, elevation, observed high-water indicators, and channel form suggest that the floodplain surfaces are partially inundated during high flow events at least every 1-5 years. The surfaces are composed primarily of alluvial deposits, but it is not uncommon for colluvium to be present. Floodplain materials generally include a boulder and cobble base strata that is topped with gravels, sands, and sometimes fines. The composition of the floodplain and active bar material indicates that hyporheic flow exchange is expected.

3.4.2 Tributaries and Channel

The mainstem channel of the Mad River through the assessment area is a montane system that alternates between confined and partially confined. Channel form is straight to sinuous with an average profile slope of 0.0165 (1.65%) through the assessment area. Substrate is primarily gravel-cobble-boulder alluvium and size distribution varies depending on proximity to active sediment sources, gradient, and geomorphic complexity. For example, an extended riffle in a low gradient, entrenched section may have a cobble-boulder substrate composition (i.e., lack finer sediments and gravels), while a boulder or log-step in a higher gradient section will have localized accumulations of gravels. This reflects a mixed-size bedload transport capacity (i.e., coarse sand to small boulder) throughout that is driven both by stream power and local sediment supply, or lack thereof. Bedrock contacts on the adjacent hillslope next to the channel occur periodically in Reaches 2-4 but no channel-spanning bedrock grade-control was observed in the bed of the channel. Large boulder colluvium in the channel do act as grade control in a few locations as well as add geomorphic complexity where they occur throughout the assessment area.

The tributaries of the Mad River assessment are both ephemeral and perennial, depending on their upstream drainage area. Several unnamed ephemeral streams contribute seasonal flows to the Mad River assessment area. These tributaries are steep and pose minimal influence on contemporary channel processes in the way of discharge. However, it is likely that the ephemeral tributaries have been routes in the past to deliver hillslope contributions (debris flows or landslides) to the valley floor and may be activated for these purposes again at some point in the future. The larger perennial tributaries, most notably Tillicum Creek, contribute discharge year-round and input some quantity of sediment into the mainstem Mad River. A small unnamed tributary near the upstream boundary of the assessment area has produced debris flow contributions into the mainstem channel from river-right that are influencing contemporary local geomorphic processes

3.4.3 Large Wood Material (LWM)

Pieces of wood (≥ 6 inches diameter) in a channel contribute nutrients, shade, cover, and promote habitat complexity suitable for many riverine species (Langford et al., 2012). Quality large woody material (LWM) (≥12-in dbh and at least 35 feet long) in a channel can influence local geomorphic processes and increase channel complexity by promoting scour and erosion relative to induced flow hydraulics around them and by redirecting or splitting flow pathways (Grabowski & Gurnell, 2016; Langford et al., 2012; Montgomery & Piégay, 2003). The quantity of LWM within a riverine system depends on the presence of mature or maturing forests upstream and locally, as well as the processes of recruitment (infall from banks, debris flows or landslides off hillslopes, in-channel transport, etc.) occurring within the watershed. Tree size (length and diameter) compared to active channel width, channel form, and flow regimes control retention and accumulation patterns of LWM.

Within the assessment area on the Mad River, LWM currently plays a moderate to minor role in the modern geomorphology and habitat complexity of the channel, depending on the reach. A total of 286 pieces of channel-influencing LWM were counted during field surveys (Oct 24-26, 2017) within the 4.3 river miles included in the assessment area (see Section 3.4 in Appendix A). Of the LWM identified in the 2017 survey, Reach 4 (RM 3.14-4.3) contained 48% (137 pieces), Reach 3 (RM 1.93-3.14) contained 31% (89 pieces), Reach 2 (RM 0.86-1.93) contained 17% (49 pieces), and Reach 1 (RM 0-0.86) had only 4% (11 pieces). Only four large wood jams (>10 pieces of LWM) were surveyed in 2017. Of the four, three of the jams were located in Reach 4 while one was in Reach 2. Prior to the construction of Mad River Road, most of the area that the road now occupies along the channel would have been forested with mature conifers. Home building and vegetation clearing further reduced available mature forest contributions in the downstream reaches of the assessment area. In addition, maintenance and safety requirements associated with human-built infrastructure such as irrigation outtakes, bridges, utility crossings, etc. has likely resulted in periodic "cleaning" of wood from the channel, further reducing natural retention of LWM contributions from the existing riparian areas and hillslopes.

3.1 HISTORICAL HUMAN DISTURBANCE

White settlers began establishing homesteads in the Entiat and Mad River Valleys in the late 1880s and sheep-grazing and trapping were common practice at that time (CCCD, 2005). According to early agricultural records (Plummer, 1902), between 13,000 and 16,000 sheep grazed in the Entiat Valley in the late 1800s and early 1900s, with more than 60,000 sheep at the headwaters of the Mad River. Grazing was regulated in the 1940's when grazing on federal land was reduced from two to three bands to only one band annually (Peven et al., 2004).

In 1932, the Harris Mill moved from Mud Creek to the Entiat River at mile 10.5 near present day Cooper's General Store which is located just downstream from the mouth of the Mad River. The mill was constructed on the valley floor between the Mad and Entiat Rivers. The 13.5 feet-high Harris Mill Dam and related reservoir were built in conjunction with a bridge across the Entiat River to access the mill. The reservoir extended upstream 1,300 feet, very close to the mouth of the Mad River. The Harris Mill dam washed out in the 1948 flood and was not rebuilt, but the Harris mill and a mill pond was re-built shortly thereafter (Peven et al., 2004). The Harris Mill (also referred to as the Ardenvoir Mill) was the last mill to close in the Entiat Valley in 1979 (CCCD, 2005) – see Figure 14.

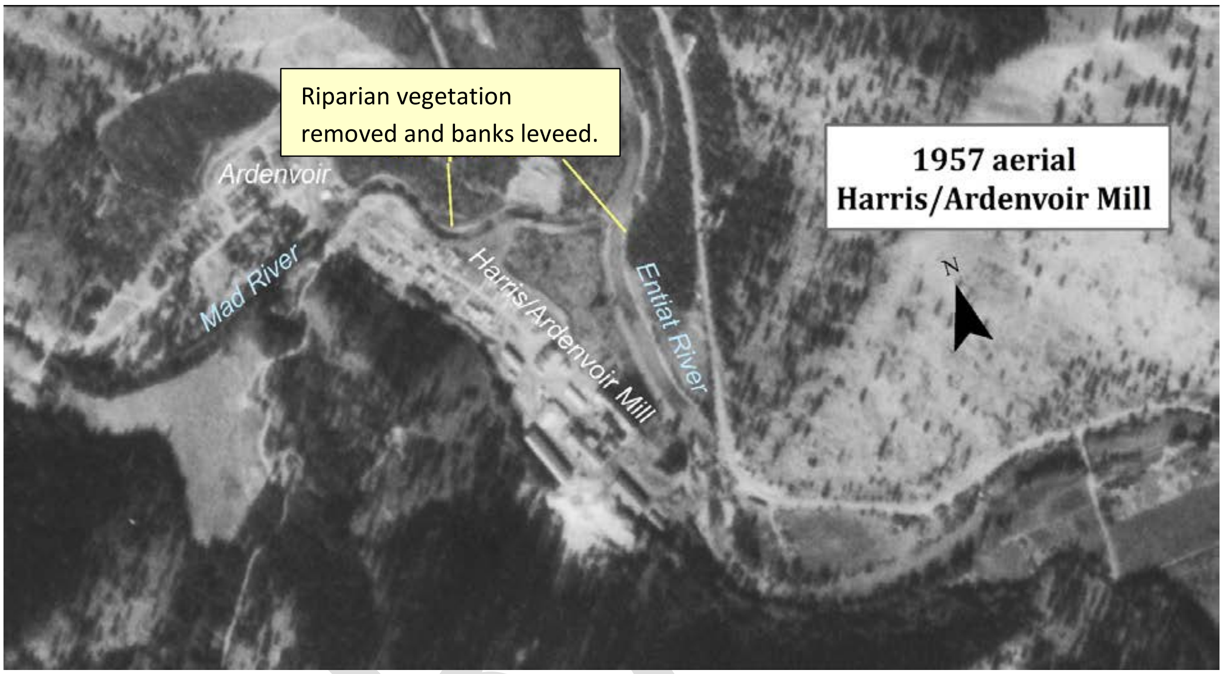


Figure 14. Harris/Ardenvoir Mill site – 1957 aerial image.

At the old homestead site located on the toe of the Tillicum Fan at RM 2, a dam was constructed on the mainstem Mad River. The date of construction and deconstruction of this dam are unknown. A local resident described it as "about 10 feet high and not good for fish wanting to get upstream" (conversation with unnamed resident at the site on 11/09/2017). The dam is visible in historical aerial imagery from 1967 (Figure 15). It is likely that this dam was a fish barrier for the duration of its existence.

Figure 15. Tillicum Fan - 1967 aerial photo. On the Mad River at RM 2. Historical dam and homestead identified.

Along most of the Mad River assessment area, from its mouth to Pine Flats Campground (RM 0-4.3), road, residential, and agriculture development have resulted in a loss of riparian connectivity and function. The modern effects of these activities at the watershed scale are considered relatively minor but important at the reach and local scales. The lower 4.3 river miles of the Mad River are expected to provide for chinook spawning and approximately 50% of the steelhead spawning habitat in the watershed. However, the poorest ecological conditions within the watershed exist within the assessment area (RM 0 - 4.3). The lower 1 mile of the Mad River has been impacted by levee construction, home and road development associated with the town of Ardenvoir, and the historical mill site.

3.2 EXISTING BUILT FEATURES

Human-built features have the potential to influence or inhibit geomorphic and ecologic processes depending on their proximity to a channel and its floodplain. Human-built features include constructed components on the modern landscape such as roads, bridges, culverts, irrigation structures or piping, buildings, riprap and other bank protection, and utility crossings. Figure 16 displays the mapped built features within the assessment area that are in close enough proximity to the channel to potentially impose direct influence on it or adjacent floodplain processes.

Although the Mad River is considered a rural watershed with relatively low population density at its mouth and no permanent residence upstream of river mile 1.0, human-built features do influence natural channel processes and thus impact natural aquatic habitat conditions. The Mad River Road that runs along the channel through much of the assessment area occupies a notable portion of available valley floor in confined sections. The road is constructed with large boulder riprap where it borders the channel. The road and multiple bridge crossings control and confine channel form and pathway. Culverts built under the road convey surface flow (tributaries and hillslope surface flow) from the other side of the road into the channel at a single location instead of dispersing it naturally.

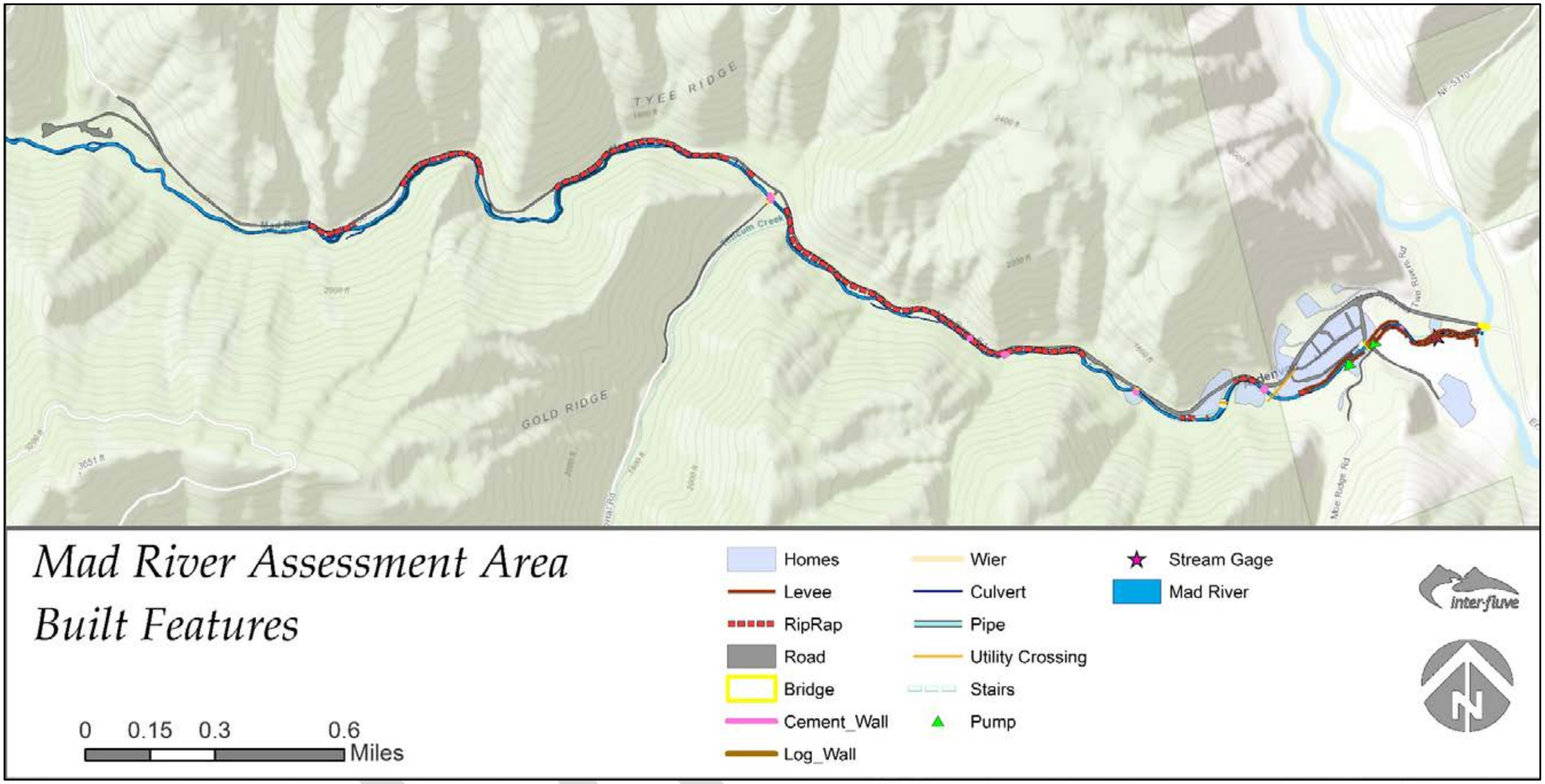


Figure 16. Human-built features: Mad River - RM 0-4.3.

Land-use practices along and upstream of the Mad River result in impacts to both channel and floodplain processes. For example, surface grading and vegetation clearing near homes and agricultural areas have altered floodplain contributions (large wood and nutrients) and thus further reduced habitat complexity. Levee construction and channel dredging along the downstream portion of the channel impede floodplain connectivity and natural lateral channel processes. Upslope logging and associated road building likely made the steep slopes of the watershed more prone to erosion, increasing sediment inputs and perhaps landslide frequency. A common historical practice in the region was/is to remove large wood and wood jams from the channel to reduce flood potential and minimize infrastructure damage. This activity has further simplified aquatic habitat in the assessment area.

3.3 VEGETATION

Riparian vegetation in the lower Mad River generally consists of a mid-seral stage coniferous overstory with a frequently dense shrub/sapling understory. The primary overstory species included Douglas fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*) and some large cottonwoods (*Populus trichocarpa*) scattered throughout the riparian area of the lower Mad River. Generally, tree age and size increase upstream through the project area with the largest size class of overstory tree canopy, "mature tree", recorded in Reach 4. Understory species increase in diversity and density upstream as a reflection of human land use impacts. In Reach 4, western red cedar (*Thuja plicata*) was recorded both as an overstory and understory species. Understory canopy in Reach 1 was primarily grasses and small shrubs as a result of the increased density of human land use and vegetation clearing within the riparian area. Understory canopy in Reaches 2, 3, and 4 primarily consisted of small deciduous trees, saplings, and shrubs dominated by willow (*Salix* spp.), alder (*Alnus* spp.), redosier dogwood (*Cornus sericea*), and bigleaf maple (*Acer macrophyllum*).

3.4 AQUATIC HABITAT CONDITIONS

Habitat conditions in the lower Mad River include limited deep pools and a large proportion of higher-velocity riffles. Based on field observations, spawning areas and refugia are limited as a result of channel simplification. The presence of large wood is minimal, particularly in the lower reaches of the study area. The few channel-spanning log jams occurring on the Mad River locally reduce channel gradient, facilitating sediment storage and thus create better spawning gravel areas, but these tend to be transitory influences in the higher-energy, confined channels. Micro-pools located behind large boulders in the channel may provide some velocity refuge for salmonids migrating upstream or holding in the system, depending on the flows. Temperatures do not seem to be a contemporary issue in the Mad River but that may shift with climate change impacts if more precipitation is delivered as rain instead of snow to the upper watershed. For more information on habitat conditions, please see Appendix A.

3.5 REACH-BASED ECOSYSTEM INDICATORS

This section presents an overview and summary of the Reach-based Ecosystem Indicators (REI) analysis, which is presented in more detail in the REI Report (Appendix B). A summary table of the REI analysis results is provided below in Table 2. 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 later in this document. The rating definitions, and explanations of how the ratings were made, can be found in Appendix B.

Reaches 1 and 2 were generally the most impacted reaches, having the highest number of Unacceptable ratings. Reach 3, though it had fewer Unacceptable ratings, still had a high number of At Risk ratings due to historic impacts from human disturbances such as timber harvests and instream large wood removal. Reach 4 was the least impacted, with seven Adequate ratings and only two At Risk and two Unacceptable ratings.

The ratings relating to salmonid habitat ranged from Adequate to Unacceptable across the study area. Reaches 3 and 4 were given Adequate ratings for the Habitat Access Pathway- Main Channel Barriers indicator since there were no barriers within the main channel that completely excluded fish passage. Reaches 1 and 2 were given At Risk ratings due to the presence of man-made irrigation and boulder weirs in Reach 1 and cement debris in the channel in Reach 2 that may limit access at certain flows.

Reaches 1 – 3 were given At Risk ratings for the Dominant Substrate/Fine Sediment indicator due to the relatively large grain size and limited retention of smaller gravels in the system. Reach 4, with more large wood in the channel, had higher amounts of smaller gravels and cobbles appropriate for spawning and was therefore given an Adequate rating.

LWM ratings increased from Unacceptable in Reaches 1 and 2 to Adequate in Reach 4. The lower reaches had low numbers of large wood pieces or lacked potential large wood recruitment. Pool frequency was rated Unacceptable in all reaches due to the very low pool frequency and occasionally low quality of the pools (low residual depths and minimal/no large wood cover or habitat). Off-channel Habitat indicator was rated as Unacceptable for Reaches 1 – 3 and At Risk for Reach 4 due to either the complete lack or very infrequent occurrence of connected alcoves and side channels.

Riparian vegetation condition indicators – Structure and Canopy Cover – were both rated Unacceptable for Reaches 1 and 2. Reach 3 received an Unacceptable structure rating due to the relatively young seral stage of the overstory and a rating of At Risk for canopy cover. Reach 4 was the opposite, with riparian vegetation structure rated as At Risk, owing to some areas of very young riparian vegetation and canopy cover classified as Unacceptable. Human disturbance was rated as Adequate in Reaches 2 – 4, due to minimal roads and development located within the riparian zone of these reaches. Reach 1, however, was rated as At Risk due to the number of residences and developed areas within the riparian zone of the lower Mad River near the town of Ardenvoir.

Channel dynamics for Reaches 1 and 2 are unsatisfactory. Reach 1 received Unacceptable ratings and Reach 2 received At Risk ratings in all three categories. Floodplain connectivity and Bank

Stability/Channel Migration were rated At Risk in Reach 3, though Vertical Channel Stability was categorized as Adequate. Reach 4 was the only reach to receive an Adequate rating for all three Channel Dynamics indicators.

For the study area as a whole, Unacceptable was the most common rating (18), followed by At Risk (15), then Adequate (11).

Table 2. Summary table of the Reach-based Ecosystem Indicators (REI) analysis results. (See Appendix B for details)

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

4. Reach-Scale Conditions

The assessment area was divided into four distinct geomorphic reaches to facilitate description and discussion of local channel characteristics and restoration needs. Reaches were delineated at major tributary confluences and by identifying physical transitions in channel form, gradient, degree of sinuosity, bedload and floodplain connectivity. Reaches are numbered from downstream to upstream within the assessment area. Geomorphologists walked each reach in the assessment area to characterize physical conditions and channel processes. Specifically, we focused on: 1) channel incision and channel evolution trends, 2) substrate type, distribution, and sediment availability, 3) surface and subsurface flow interactions, 4) channel bank composition and migration patterns, 5) floodplain and habitat connectivity, 6) occurrence and influence of large woody material, and 7) influence of past and current human structures and activities. Information from the reach-scale geomorphic assessment is used to inform the REI analysis. Table 3 includes a set of metrics used to help characterize each reach. In addition to a discussion of the metrics provided in Table 2, vegetation condition, and the location of human-built features that influence channel processes are provided below for each reach.

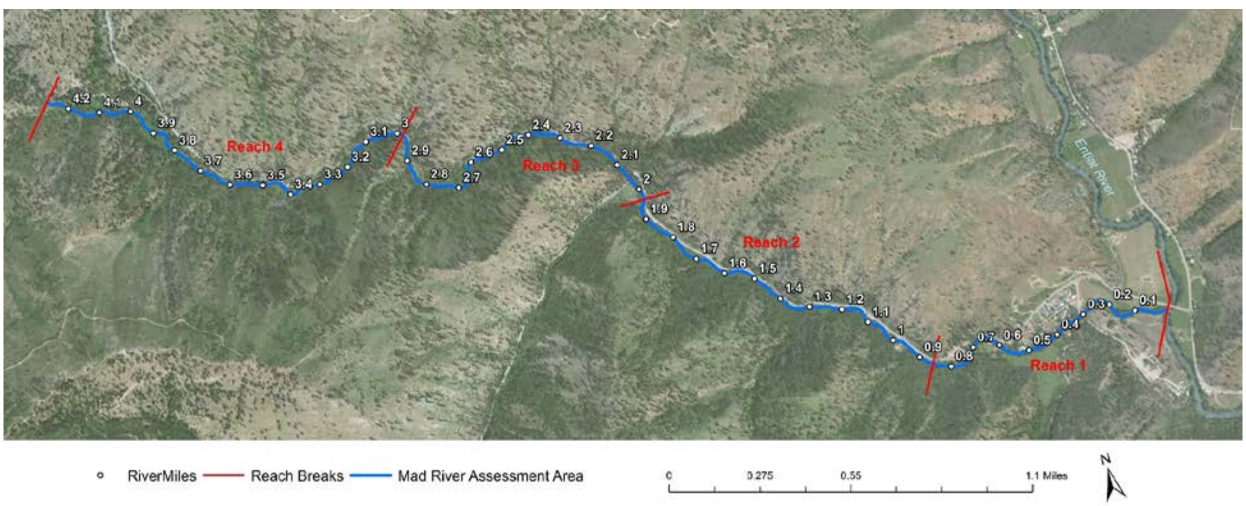


Figure 17. Mad River reach assessment area with reach boundaries and river miles. Basemap: ESRI

Table 3. Reach-scale metrics for Mad River – RM 0 to 4.3.

	METRIC	Reach 1	Reach 2	Reach 3	Reach 4
Channel and Floodplain	Length (miles)	0.86	1.07	1.05	1.32
	River Mile	0 - 0.86	0.86 - 1.93	1.93 - 2.98	2.98 - 4.3
	Stream Gradient (%)	1.54%	1.79%	2.35%	1.65%
	Sinuosity	1.18	1.07	1.33	1.20
	Dominant Channel Habitat Unit Type	Riffle	Riffle	Riffle	Riffle
	Average Bankful Width (ft)	41.0	51.3	48.0	52.5
	Dominant Substrate	cobble	cobble	cobble	cobble
Channel Habitat Area (%)	Pool	7%	8%	1%	7%
	Riffle	84%	79%	82%	87%
	Glide	9%	13%	17%	5%
	Side Channel	0%	0%	1%	1%

NOTES:

Average Bankfull Width and Channel Habitat Unit Types surveyed in the field per USFS Stream Inventory Guidelines (2015). See Habitat Assessment for analysis and results (Appendix A).

Dominant Substrate characterized by ocular field observations.

4.1 REACH 1 (RM 0 – 0.86)

4.1.1 Overview

Reach 1 is 0.86 river miles long and extends from the mouth of the Mad River at it confluence with the Entiat River to the top of the Mad River's paleo-fan, where the channel exits the mountains into the Entiat Valley. Through Reach 1 the river is a single-thread channel with a sinuosity of 1.14 and a reach gradient of 1.54%. Average bank-full width of the channel is 41.0 feet. The channel is entrenched and leveed through most of Reach 1. Even though this reach is located in a downstream-widening valley, the active floodplain surfaces (inundated ~1-5 years) exist as discontinuous narrow strips and pockets that support riparian vegetation (Figure 17). The terrace surfaces in Reach 1 are the Mad River's paleo-alluvial fan and are abandoned or only inundated during very large flood events. The terrace surfaces that occupy most of the valley floor have been graded and cleared for building and road construction or agriculture. Direct hillslope coupling with the channel occurs on river-right in the upstream-most section for approximately 200 feet. Vegetation clearing for homes, roads, and the historical Ardenvoir Mill site has altered the native vegetation of the valley floor from what historically was likely mature old-growth forest to grasses and sparse shrubs, orchard trees, and a few conifers. Today, the channel in this reach is lacking in large wood recruitment and retention.

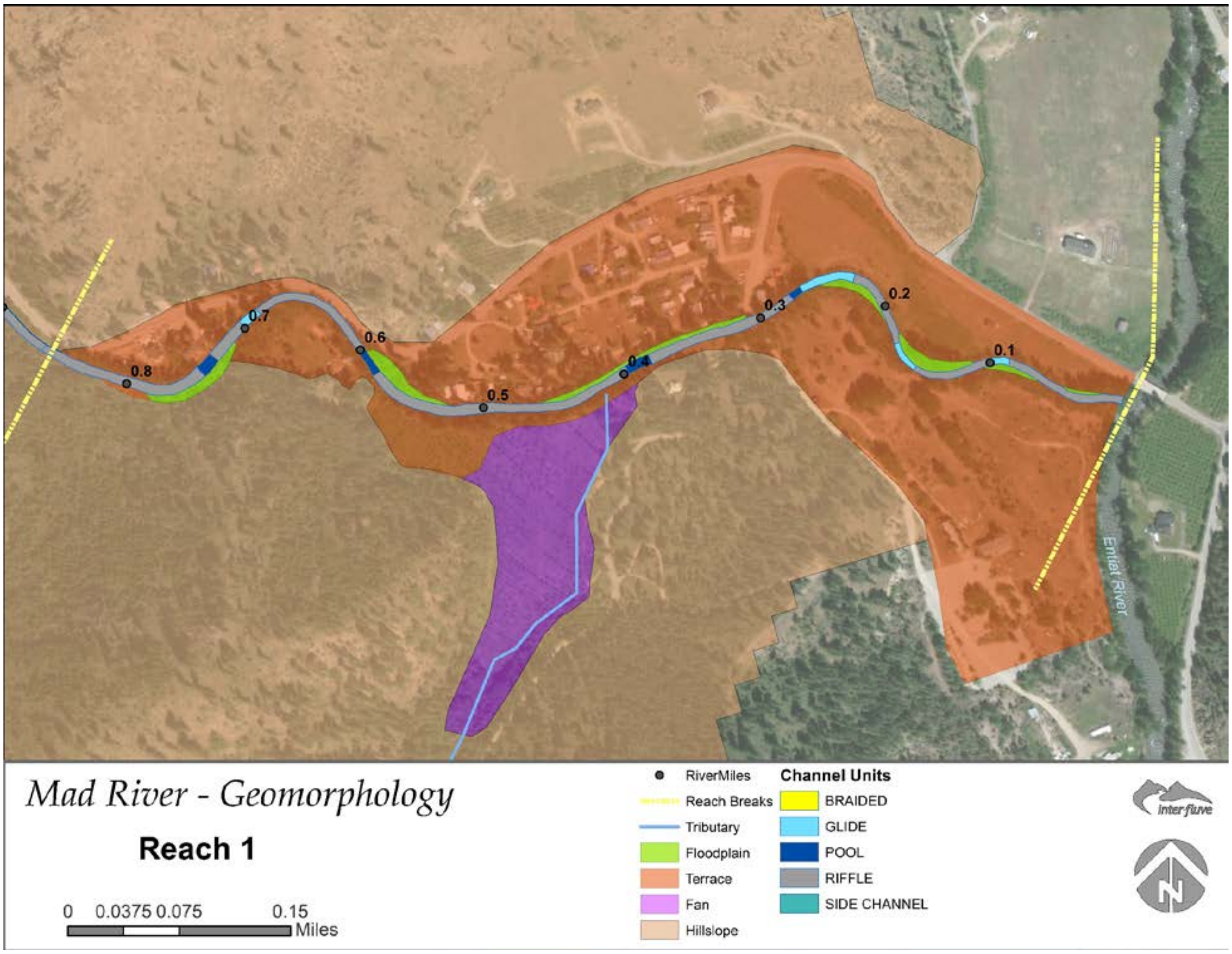


Figure 18. Reach 1: Geomorphic surfaces and channel units. Basemap: ESRI World Imagery

4.1.2 Channel and Floodplain Geomorphology

The Mad River in Reach 1 has a moderate gradient (1.54%) with a planform that alternates between straight and sinuous (Figure 17). The channel is entrenched into the paleo-floodplain throughout the reach. The levees along the channel from RM 0-0.55 appear to be constructed of material excavated from the bed of the channel, exaggerating entrenchment in this portion of the reach. Banks are composed of coarse alluvium (gravel to boulder) that is mixed and topped with sands and fines. Valley soils are gravelly sandy loam (USDA & NRCS, 2017). Floodplain surfaces range from 1 to approximately 4-5 feet above the elevation of the channel bed. Terrace surface banks are generally steeper than the floodplain banks and range from 5-12 feet above the elevation of the channel bed. Active lateral channel processes are minimal and historical aerial photos from 1957 confirm that the channel has been in basically the same position for over 60 years. A lack of lateral processes equates to minimal locally-generated sediment sources to contribute to bar or spawning habitat. The lack of lateral channel processes through the wide river valley is due to channel entrenchment, leveeing, bridges, and bank hardening materials such as cement slabs, wood, and riprap. Where established, tree roots and riparian vegetation contribute additional stability to the banks (Figure 18).

Figure 19. Looking downstream at RM 0.15. River right: outside meander, partially vegetated stabilized cobble-boulder bank topped with a levee; River left: vegetated floodplain pocket with small gravel-cobble point bar (partially inundated during spring flows). (Photo: IFI, 4/25/2017)

Channel complexity in Reach 1 is impaired. The 2017 Habitat Assessment (see Appendix ???) measured 84% of the channel as extended riffles while only 7% is pool habitat and the remaining 9% is glides. The four pools occur where large boulders and/or built features such as a collapsed bridge footing or an irrigation out-take weir create a stable grade control that produces scour on the downstream side. The bed of the channel is dominated by coarse alluvium (cobble and small boulders). Narrow gravel-cobble bars form at the inside bends of the subtle meanders at RM 0.15 and 0.22, as well as at the mouth of the channel. Otherwise, the only other gravel accumulations observed occur at the grade control and eddies associated with the four small pools – confirming that gravels are mobilized through Reach 1 but that retention is limited and local generation of sediment is likely minimal. Based on bed and bank material, hyporheic flow is expected to occur between the channel bed, bars, and floodplain surfaces.

Figure 20. Two of the four pools in Reach 1: A) Small pool downstream of Irrigation out-take weir and related boulder spur at RM. 0.27 (10/24/2017); B) Pool downstream of hillslope contributed boulders at RM 0.39 (11/9/2017).

4.1.1 Vegetation and Large Woody Material

Riparian vegetation in Reach 1 is a discontinuous narrow strip of trees and shrubs with open patches composed of grasses and forbes. The riparian strip is primarily a sparse overstory of cottonwood and Ponderosa pine with an understory of alder, dogwood, and willow (Figure 20). The native vegetation beyond the existing riparian strip has been cleared or partially cleared for homesite development, roads, and agriculture. The cleared areas are now vegetated primarily with grasses and forbes. Where they occur, the overstory trees are mostly classified as large (21 to 32-inch dbh) but are relatively sparse. Alder is the dominant riparian shrub/small tree and, in places, add stability to the banks. The understory vegetation is dense, where it exists, and is expected to provide a partial shade canopy for the channel during the summer. From RM 0.7 to 0.86 a pine-dominated forest grows on the adjacent steep hillslope along river right. It is probable that all riparian vegetation in Reach 1 was removed at some point in the last 100 years, including when levees were being constructed. The riparian strip that exists today is in the process of recovering and maturing.

Figure 21. Riparian vegetation strip at RM 0.3. (Photo: IFI 4/25/2018)

The lack of mature or large trees (21-32-inch dbh), narrowness of the vegetated riparian zone, and lack of lateral channel process limits local source and recruitment potential of large woody materials (LWM) into the channel. A total of only11 pieces of wood and no log jams were observed in the channel during the survey (10/24/2017). All 11 pieces were in the small size class (9 to 12-inch dbh). No quality large woody material (>12-inch dbh and at least 35 feet long) were observed in the channel (Figure 21). Due to the small size and scarcity of large wood material (LWM), it plays only a minor temporary role in aquatic habitat and geomorphic complexity in Reach 1. The lack of LWM in Reach 1 is the result of past riparian vegetation removal, lack of mature trees in the riparian corridor, lack of channel migration capacity, and periodic "cleaning" of wood from the channel. Clearing large wood from the channel has been a common practice in places were infrastructure such as bridges or culverts exist.

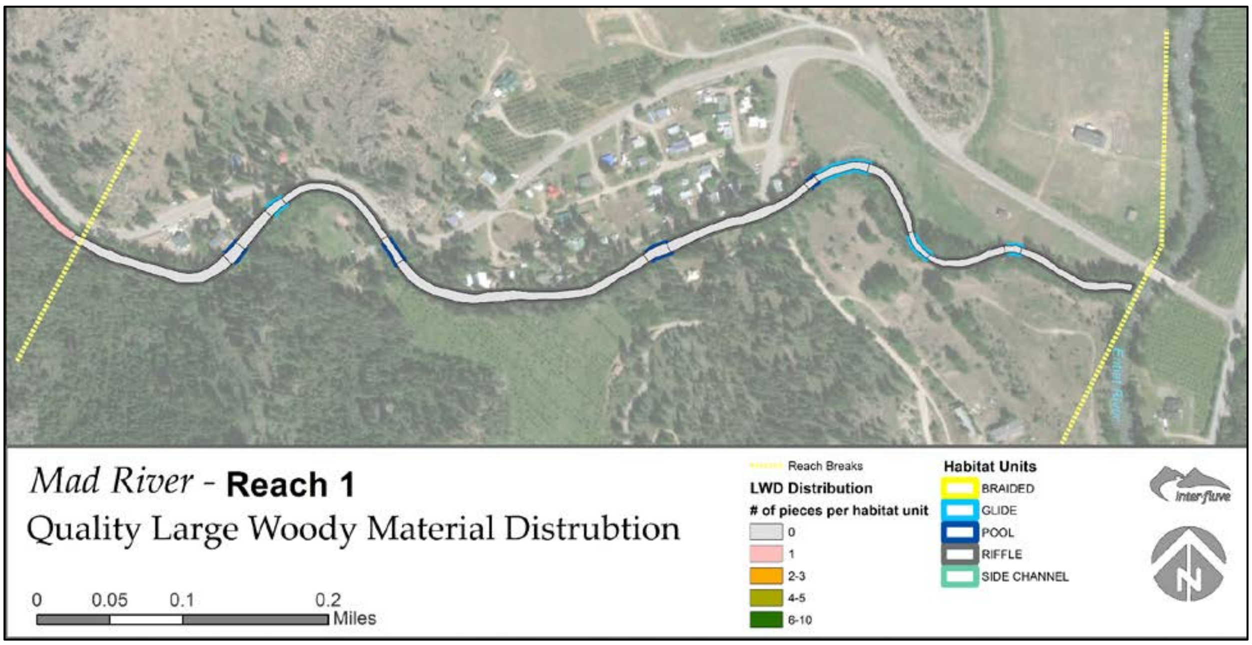


Figure 22. Reach 1 – Quality Large Woody Material (>12-inch dbh and at least 35 feet long) distribution by number of pieces per mapped habitat unit per the 2017 survey.

4.1.2 Human Alterations

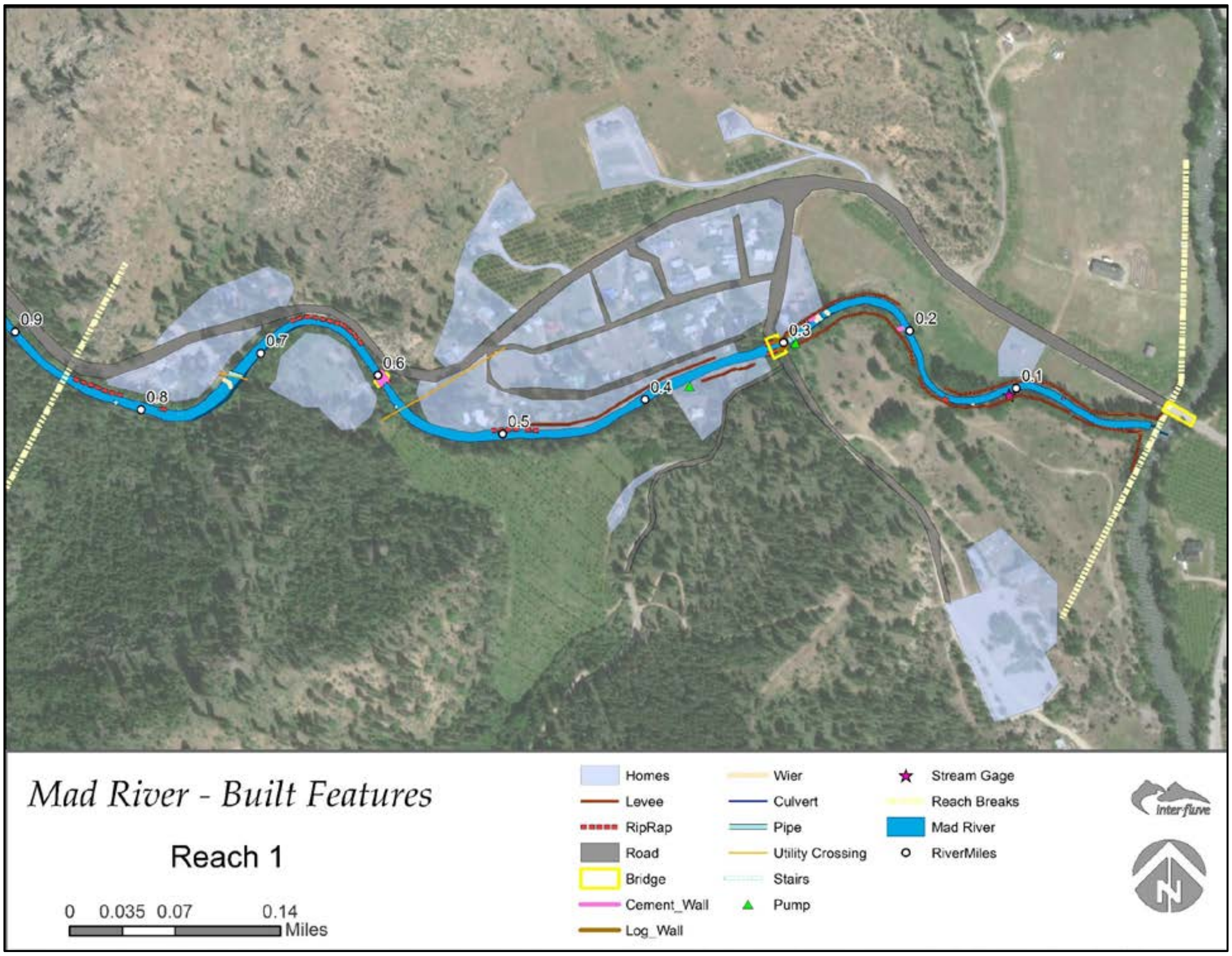


Figure 23. Reach 1: anthropogenic built features. Basemap: ESRI World Imagery

Reach 1 contains the most anthropogenic built-feature impediments compared to the other reaches in the assessment area. In addition to clearing and altering the valley floor and riparian vegetation, anthropogenic features in Reach 1 include buildings, roads, bridges, levees, bank protection, weirs, irrigation, and utility crossings (Figure 22). Levees of up to 3.5-feet high and constructed of material excavated from the channel line both sides of the river bank from RM 0 – 0.3. Additional similarly-constructed levees exist on river right from RM 0.34 to 0. 36 and on river left from RM 0.35 to 0.49. Two railroad-car bridges have footings of cement, wood, and/or rock that protect the bank and confine the channel near RM 0.3 and RM 0.6 (Figure 23). At the bridge near RM 0.6, an old cement footing collapsed into the channel and remains in place under the bridge, armoring over half of the channel bed.

Figure 24. Railroad-car bridge crossings: A) near RM 0.3 with log, cement, and riprap footings and bank protection. Logs are old footings from historical bridge crossing, and B) near RM 0.6 with cement footings and large boulder riprap. (Photos: IFI 11/9/2017)

Additional bank protection occurs throughout Reach 1. Large boulder riprap has been placed along the banks at RM 0.28 in correlation with a cement-walled irrigation out-take and weir. Riprap is also present at RM 0.48 to 0.51 on river left in front of homes where the banks are low, at RM 0.63-0.67 and RM 0.82-0.85 on river left to protect the Mad River Road and homes (below), and at RM 0.15. On river left at RM 0.78, pieces of steal and cabling are buried into and protecting the bank. Cement blocks on river right at RM 0.2 also add bank protection to an already anthropogenically-confined reach.

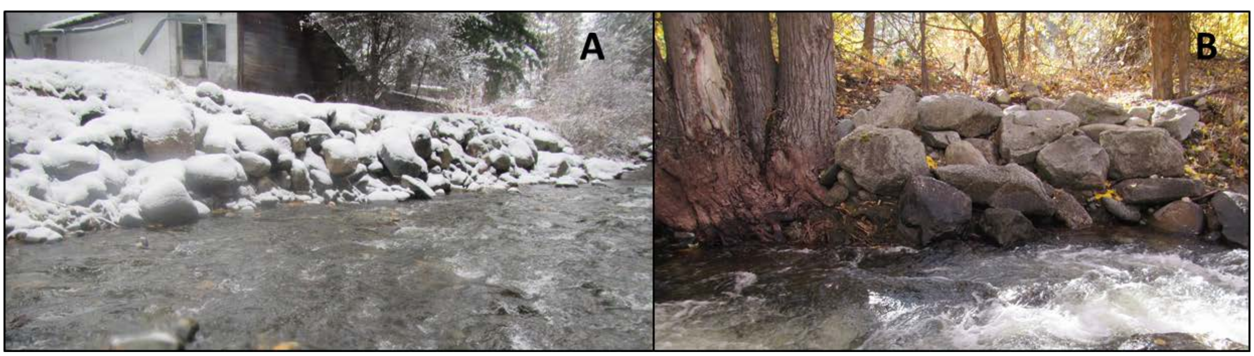


Figure 25. Riprapped banks: A) river left at RM 0.51 (11/9/2017), and B) river left at RM 0.28 (10/24/2017).

Other features that interact with the channel and its banks include built stairs, a hand-built rock weir, old steal piping that extends across the channel bed, and a modern utility line crossing, all located between RM 0.73-0.74. The USGS discharge gage on river right at RM 0.1, a groundwater pump next to the channel on river right at RM 0.37, and the fish-tag piping, pump, and data collection box at RM 0.29 impose minimal impacts to modern channel processes.

4.2 REACH 2 (RM 0.86 – 1.93)

4.2.1 Overview

Reach 2 is 1.07 river miles long and occupies a confined river-valley from the confluence with Tillicum Creek downstream to where valley begins to widen and stream gradient decreases at the border with Reach 1. Through Reach 2 the river is a single-thread channel with a reduced sinuosity (1.09) and increased reach gradient (1.79%) compared to Reach 1. However, average bank-full width of the channel is 51.3 feet, which is wider than Reach 1. Floodplain surfaces (inundated ~1-5 years) exist as alternating pockets in the upstream portion between RM 1.5 to 1.92 and as discontinuous narrow pockets between RM 1 and 1.3. Elsewhere, the channel is confined between hillslopes and the Mad River Road with virtually no floodplain. The existing floodplain surfaces are well-vegetated with riparian trees and shrubs. A small terrace surface at RM 0.95-1.1 on river right is occupied with a home. The construction of the Mad River Road along the valley floor has further confined and altered the native vegetation of the valley floor from what was likely mature old-growth forests. This reach is lacking in large wood recruitment and retention.

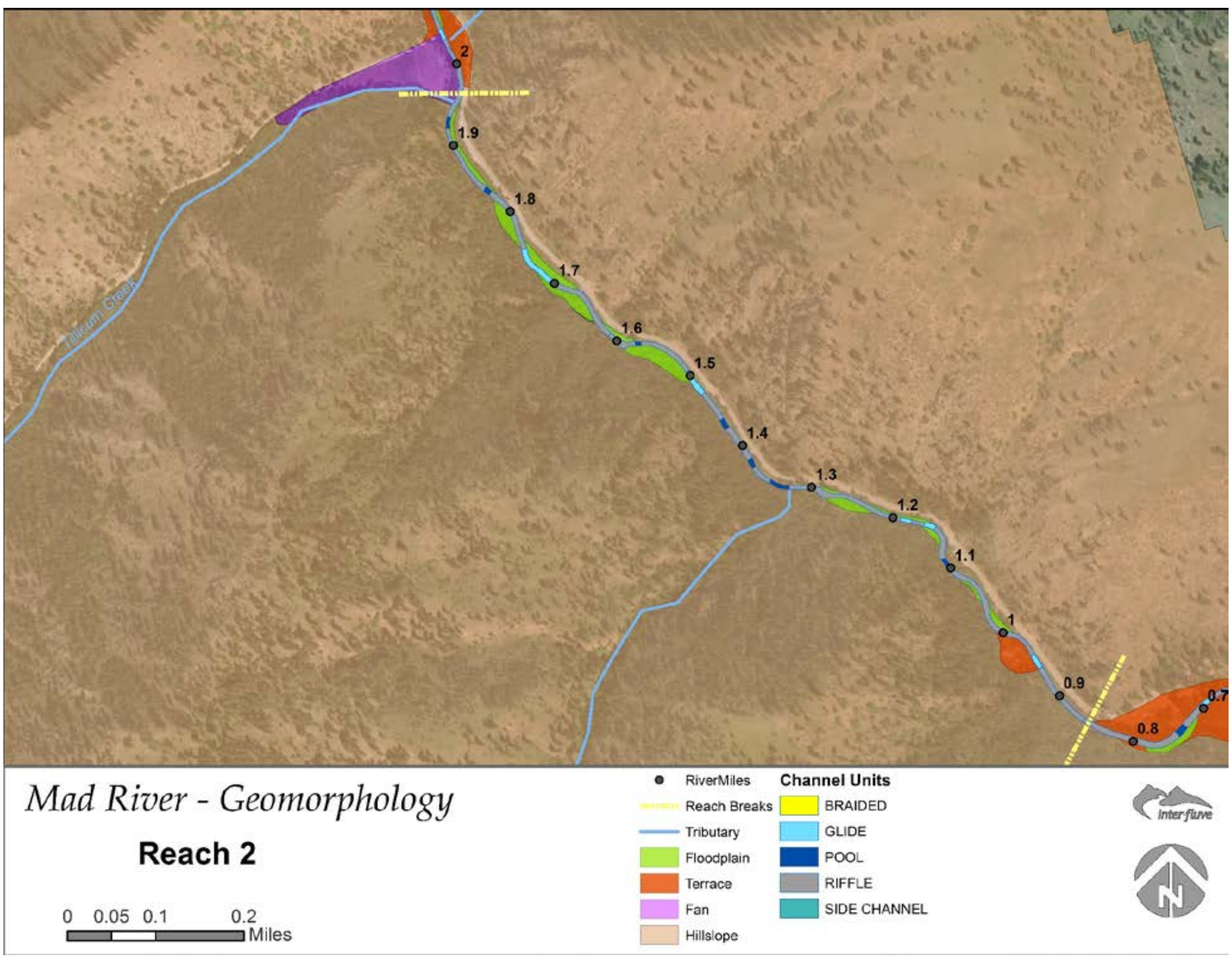


***Figure 26. Reach 2: Geomorphic surfaces and channel units**. Basemap: ESRI World Imagery*

4.2.2 Channel and Floodplain Geomorphology

The Mad River in Reach 2 has a moderate gradient (1.79%) with a generally straight planform (Figure 25). Planform is straightest where the channel is confined between hillslope and the Mad River Road (RM 0.86-0.95, 1.04-1.2, 1.3-1.49, and 1.82-1.93). In these sections, hillslope contributions of boulders add some complexity (scour pools and back eddies) to channel geomorphology. Channel substrate is composed of cobble and boulders with sparse gravels. Gravels were observed in back-eddies and pool-tailouts – indicating mobilization and periodic storage of spawning material in Reach 2. Based on bed and bank material, hyporheic flow is expected to occur between the channel bed, bars, and floodplain surfaces.

Figure 27. Reach 2 at RM 1.48, a hillslope and road confined section - looking downstream. (Photo: IFI, 4/25/2018)

In the less confined sections (RM 0.95-1.04, 1.2-1.3, and 1.5-1.82), the floodplain pockets alternate with hillslope or Mad River Road confinement on the outside bend of meanders. The floodplain pockets are well-vegetated with a mix of riparian vegetation. Based on exposed banks, the floodplains are composed of a cobble-boulder base topped with gravels that fine-upward to coarse sands. Soils in Reach 2 are described as gravely sandy loam in the downstream portion and a gravely fine sandy loam in the upstream portion (USDA & NRCS, 2017). Where floodplains exist, channel banks range from 1 to approximately 4 feet above the bed of the channel.

Figure 28. Reach 2 at RM 1.68, vegetated floodplain – looking upstream. (Photo: IFI 11/9/2017)

Channel complexity in Reach 2 is impaired. The 2017 Habitat Assessment (see Appendix ???) measured 79% of the channel as extended riffles while only 8% is pool habitat and the remaining 13% is glides. In general, the pools occur where large boulders create a stable grade control that produces scour on the downstream side. The bed of the channel is dominated by coarse alluvium (cobble and small boulders). A few small gravel accumulations were observed in eddies or pools behind boulders or upstream of large wood (Figure 28).

Figure 29. Spawning gravel accumulation at edge of pool behind boulders (with spawning fish) at RM 1.45. (Photo: IFI 11/9/2017)

4.2.3 Vegetation and Large Woody Material

Riparian vegetation in Reach 2 well established except where the channel is bordered by the Mad River Road. The riparian vegetation is primarily an overstory of fir trees, Ponderosa pine, and a few cottonwoods with a thick understory of alder and dogwood (Figure 29). Adjoining hillslope vegetation is dominated with conifers (fir and pine). Floodplain surfaces are densely vegetated with alder and dogwood with a sparse overstory of conifer or cottonwood. Only 33% of the overstory trees are considered large (21 to 32-inch dbh). However, the understory and small trees are thick enough that the existing vegetation provides a shade canopy for the channel during summer months, except in the less vegetated areas adjacent to the Mad River Road. It is probable that most of the riparian vegetation on river left in Reach 2 was removed in the past during the construction of the Mad River Road.

Figure 30. Riparian vegetation example in Reach 2, at RM 1.6. (Photo: IFI 11/24/2017)

Although adjoining hillslopes along river right are vegetated with conifers, the lack of large trees (>32-inch dbh) within the riparian corridor limits local recruitment potential of large woody materials (LWM) into the channel. In addition, the exaggerated confinement of the channel in Reach 2 by the construction of the Mad River Road limits lateral channel process that would promote natural wood recruitment and floodplain development.

A total of 49 pieces of woody material and only one log jam was observed in the channel during the survey (10/24/2017). Of the 49 pieces, only three classified as large size class (≥20-inches dbh and >35 feet long), 19 were classified as medium size class (12 to 20-inch dbh and at least 35 feet long), and the rest were all small size classified (9 to 12-inch dbh). See Figure 30 for distribution of quality large woody material (>12-in dbh and at least 35 feet long) per mapped habitat unit throughout the reach. The lack of LWM in Reach 2 is the result of past riparian vegetation clearing, lack of mature trees in the riparian corridor, lack of channel migration capacity (confined by road), and periodic "cleaning" of wood from the channel. Clearing large wood from the channel has been a common practice in places were infrastructure such as bridges or culverts exist.

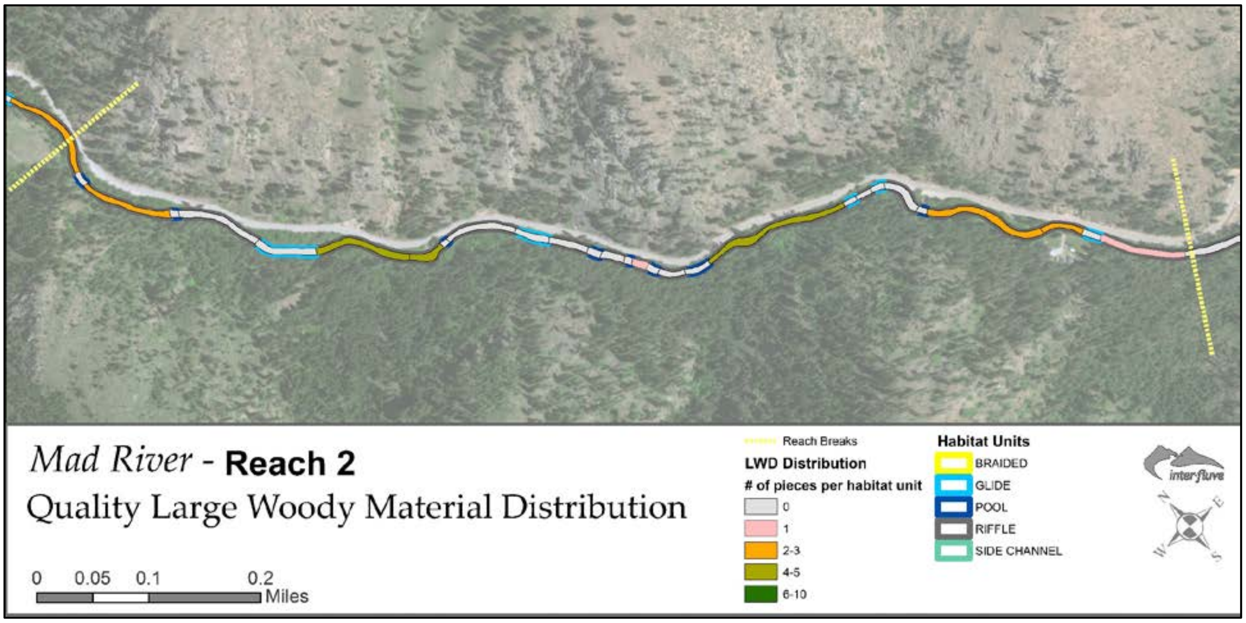


Figure 31. Reach 2 – Quality Large Woody Material (>12-inch dbh and at least 35 feet long) distribution by number of pieces per mapped habitat unit per the 2017 survey.

Only one log jam was observed and it contained just one large piece of wood and 9 small pieces (Figure 31). This indicates that Reach 2 is lacking in in-stream quality Large Woody Material (LWM) and riparian recruitment potential. As a result, LWM currently plays only a minor role in localized aquatic habitat and geomorphic complexity. Where it does exist, channel complexity is improved. The lack of LWM and jams in Reach 2 today is likely the result of past riparian vegetation removal for the construction of the Mad River Road and periodic "cleaning" of wood from the channel. Cleaning LWM from the channel has been a common practice in places were infrastructure such as roads and bridges exist.

Figure 32. Large wood jam at RM 1.19 in Reach 2. (Photo: IFI, 4/25/2018)

4.2.4 Human Alterations

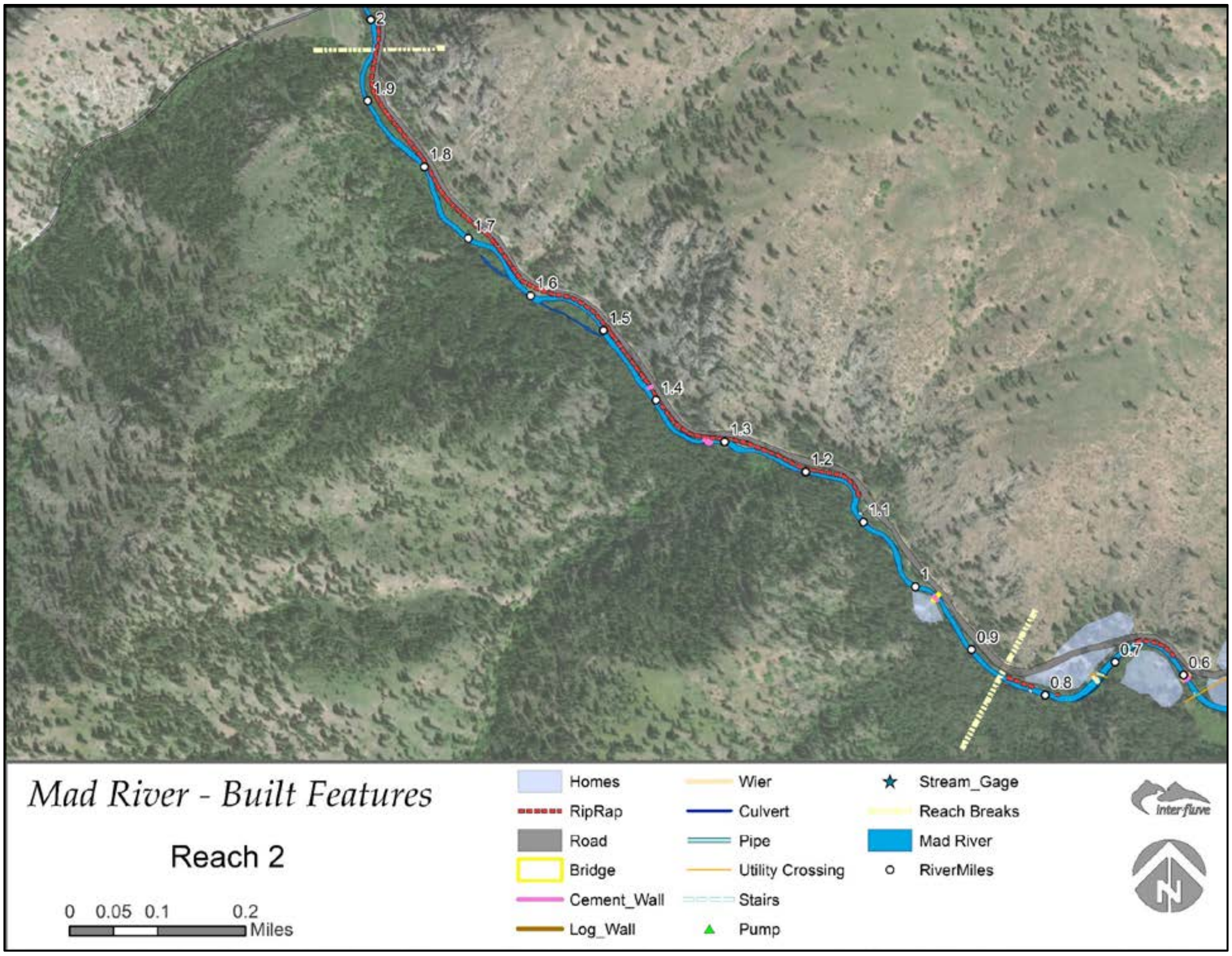


Figure 33. Reach 2: anthropogenic built features. Basemap: ESRI World Imagery

Anthropogenic features in Reach 2 include the Mad River Road, bank riprap, a bridge crossing, a homesite development, related vegetation clearing, and cement wall bank and bed armoring. The Mad River Road occupies approximately half of the available valley floor from RM 0.86 to 1.65 and from RM 1.65 to 1.93 it occupies approximately a third of it (Figure 33A). From RM 1.13 to 1.93 the road bank is armored with large-boulder riprap. The bridge crossing at RM 0.98 includes cement, steel beam, log, and large-boulder riprap footings and bank protection (Figure 33B). A homesite located on a low terrace on river right at the bridge crossing (RM 0.98) includes riparian vegetation clearing. A remnant cement wall extends from the road perpendicular to flow on the river-left bank at RM 1.42 but it does not contact the channel at normal or low flows (Figure 34A). Another cement slab was observed on the channel bed with steel pipe embedded into it at RM 1.33. The slab is creating a grade control with a step-pool on the downstream side and accumulated gravels and cobbles on the upstream side (Figure 34B).

Figure 34. A) Mad River Road along Reach 2 occupying ½ of valley floor at RM 1.55 (Photo: IFI 11/9/2017); B) bridge crossing at RM 0.98 (Photos: IFI 4/25/2018).

Figure 35. A) cement wall on bank at RM 1.42; B) cement slab on channel bed at RM 1.33. (Photos: IFI 11/9/2017)

4.3 REACH 3 (RM 1.93 – 2.98)

4.3.1 Overview

Reach 3 is 1.05 river miles long and occupies a river-valley that has confined and partially confined sections. The Reach extends from the confluence of Tillicum Creek (RM 1.93) upstream to RM 2.98, at a bedrock contact on river right. The channel is primarily single-thread throughout Reach 3, with the exception of two short side-channels in the upper portion. Reach-average sinuosity (1.33) and gradient (2.35%) are both higher than the other reaches in the assessment area. Average bank-full width of the channel in Reach 3 is 48 feet, which is slightly narrower than mostly confined Reach 2 downstream and Reach 4 upstream. Floodplain surfaces (inundated ~1-5 years) exist as discontinuous narrow strips within the confined channel section and as extended but narrow surfaces in the partially confined section (RM 2.6 to 2.85). The existing floodplain surfaces are well-vegetated with riparian trees and shrubs. The toe of the Tillicum Creek alluvial fan occupies the downstream section of the reach. The construction of Mad River Road has further confined the channel and limited vegetation establishment along the river-left side of the channel throughout the reach. Retention of large woody material appears to be temporary in most locations in the reach, but where it does occur, geomorphic complexity is increased.

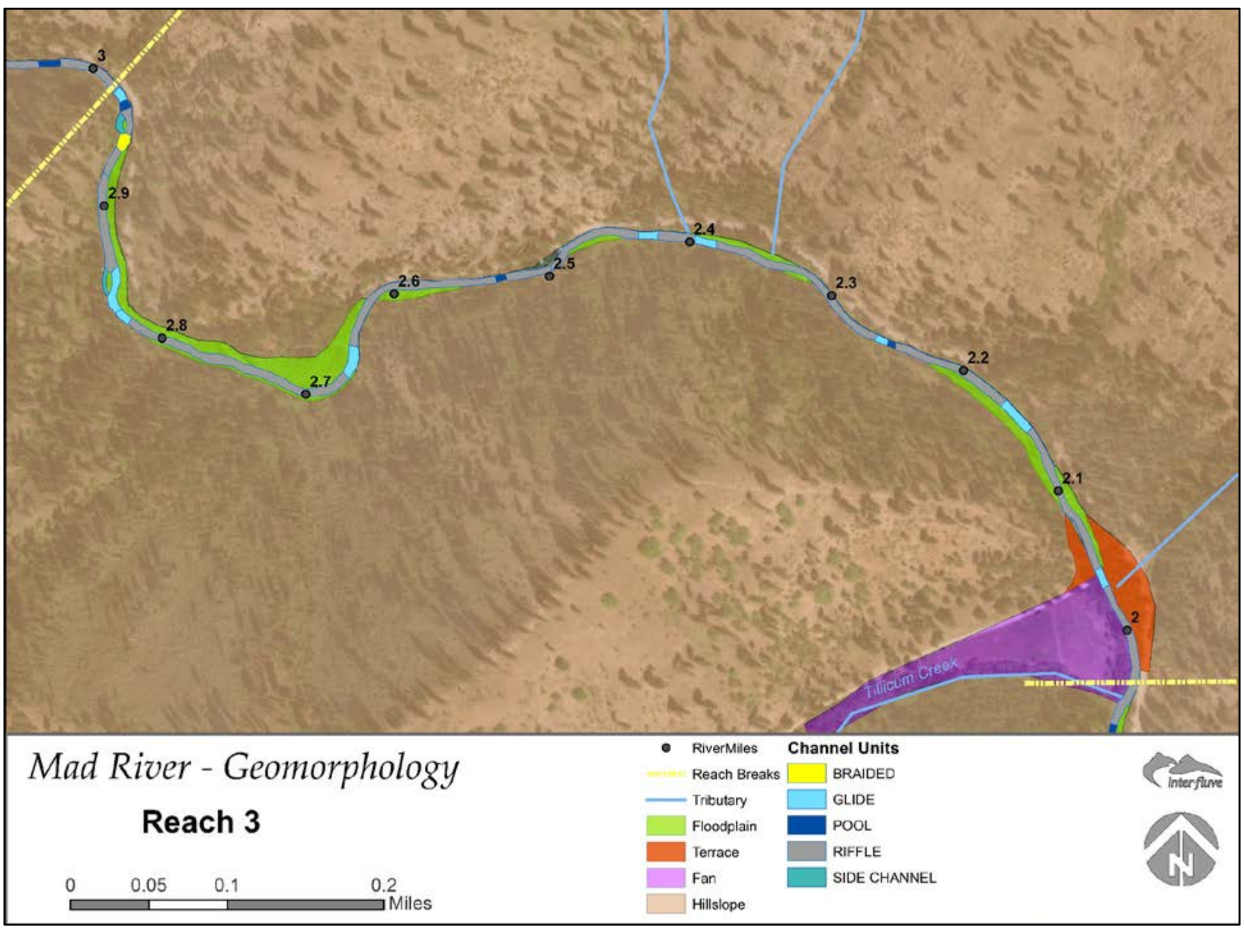


Figure 36. Reach 3: Geomorphic surfaces and channel units. Basemap: ESRI World Imagery

4.3.2 Channel and Floodplain Geomorphology

The Mad River in Reach 3 has a moderate gradient (2.35%) with a planform that alternates between straight and moderately sinuous (Figure 25). The relatively straight sections occur where the channel is completely confined between hillslopes and the Mad River Road (RM 2.23-2.32, 2.4-2.55, and 2.97-3.14). In the confined areas, local hillslope contributions of boulders add some complexity to channel geomorphology (steps, scour pools, and some wood accumulation). Hillslopes on river right include vegetated slopes, periodic bedrock bank contacts, and large boulder colluvium. River left is occupied by the Mad River Road. Bedrock contacts (25-100 feet long) occur along the right bank of the channel at RM 2.65 and 2.91. Boulder colluvium occurs along the river right side of the channel along the toe of most other confining hillslope contacts. Channel substrate in Reach 3 is composed of cobble and boulders with sparse gravels. Gravels and coarse sands were observed in depositional areas such as small eddies, pools tail-outs, and bars – indicating the presence of salmonid spawning material moving through the reach. Based on bed and bank material, hyporheic flow is expected to occur through the channel bed, and bars.

Figure 37. Mad River confined by hillslope and road at RM 2.45. (Photo: IFI 11/9/2017)

Split-flow conditions (side channels) occur near RM 2.85 and RM 2.95. In these locations woody material accumulations and/or boulders support mid-channel bar development and island maintenance. Geomorphic complexity of the channel is higher where split-flow conditions occur.


Figure 38. Mad River at RM 2.95 - split flow at wood accumulation. (Photo: IFI 4/24/2018)

The discontinuous floodplain strips alternate with hillslope or Mad River Road confining banks. The floodplain strips are generally composed of alluvium and colluvium that range in size from fines to boulders. Floodplain surfaces are approximately 1 to 4 feet above the bed of the channel and are well-vegetated with riparian shrubs and sparse trees. The contributing hillslopes in Reach 3 have soils described as stony fine sandy loam (30%-60% grade) on river right and granitic substratum and bedrock outcrops (40%-90% grade) on river left (USDA & NRCS, 2017).


Figure 39. Mad River at RM 2.7 looking upstream: hillslope on river right and vegetated floodplain on river left. (Photo: IFI, 11/25/2017)

At the downstream end of the reach (RM 1.93-2.09) the channel is relatively straight as it flows entrenched through terraced surfaces of the Tillicum Creek alluvial fan and under the Tillicum Road Bridge. This is the site where a small dam (resident estimated as ~10-feet high) was located for an unknown period of time until it was removed between 1970-1990 (unknown deconstruction date). Downstream of the bridge, the Tillicum Creek alluvial fan continues to border the channel. The terraces and alluvial fan are described as gravely sandy loam. These surfaces would be a good sediment source for the Mad River but historical damming, and modern road, bridge, and related bank armoring have constrained lateral movement and control channel location here. The Tillicum Creek Habitat Restoration Project Report (Inter-Fluve, 2018) provides a more detailed assessment of the geomorphic conditions and good habitat restoration potential for the Mad River along the distal end of the Tillicum Fan.

Figure 40. Extended riffle (~800 feet long), photo looking upstream at RM 2.75. (Photo: IFI 11/9/2017)

Channel complexity in Reach 3 is impaired. The 2017 Habitat Assessment (see Appendix ???) measured 82% of the channel as extended riffles while only 1% is pool habitat, 17% is glides, and 1% is side channels. The pools occur where boulders create a grade control or scour. The bed of the channel is dominated by coarse alluvium (cobble and small boulders). Only small pockets of coarse sand and gravel were observed in eddies and pools behind boulders and/or wood accumulations.

Figure 41. Boulder step, pool, and gravel accumulations at RM 2.96 behind boulders and wood accumulation (Photo: IFI 4/24/2017)

4.3.3 Vegetation and Large Woody Material

The riparian vegetation in Reach 3 is dominated by dense shrubs and sparse trees. The sparse overstory of trees is composed of ponderosa pine and fir while the understory is primarily alder, dogwood, and maple. Where the channel is bordered by the Mad River Road, riparian vegetation is marginalized and lacking in overstory trees. All of the overstory trees are considered small trees (9 to 21-inch dbh). However, the understory is mature and thick enough that the existing riparian vegetation does provide a partial shade canopy for the channel during summer months, except in the confined areas adjacent to the Mad River Road. It is probable that most of the riparian vegetation in Reach 3 was removed during the construction of the Mad River Road. In addition, the exaggerated confinement of the channel by the road and related bank protecting riprap limits lateral channel process that would promote large wood recruitment and floodplain development.

Figure 42. Riparian vegetation on floodplain at RM 2.84. (Photo: IFI 11/25/2017)

A total of 89 pieces of wood were observed in the channel during the survey (10/25/2017). Of the 89 pieces, fourteen pieces classified as large size class (≥20-inches dbh and >35 feet long), 30 were classified as medium (12 to 20-inch dbh and at least 35 feet long), and 45 were all small size classified (9 to 12-inch dbh). However, no wood accumulations that constitute a log jam were observed. See Figure 42 for distribution of quality large woody material (>12-in dbh and at least 35 feet long) per mapped habitat unit throughout the reach. Note that LWM distribution is correlated to less-confined sections with floodplains. Where LWM exist, it plays an important role in aquatic habitat and geomorphic channel complexity. According to the 2017 survey, Reach 3 is lacking in large wood jams. This is likely due to past riparian vegetation removal for the construction of the Mad River Road, lack of mature forests within the riparian corridor, increased confinement of lateral process by the Mad River Road, and potentially periodic "cleaning" of wood from the channel. Cleaning of LW from the channel has been a common practice where infrastructure such as roads and bridges exist.

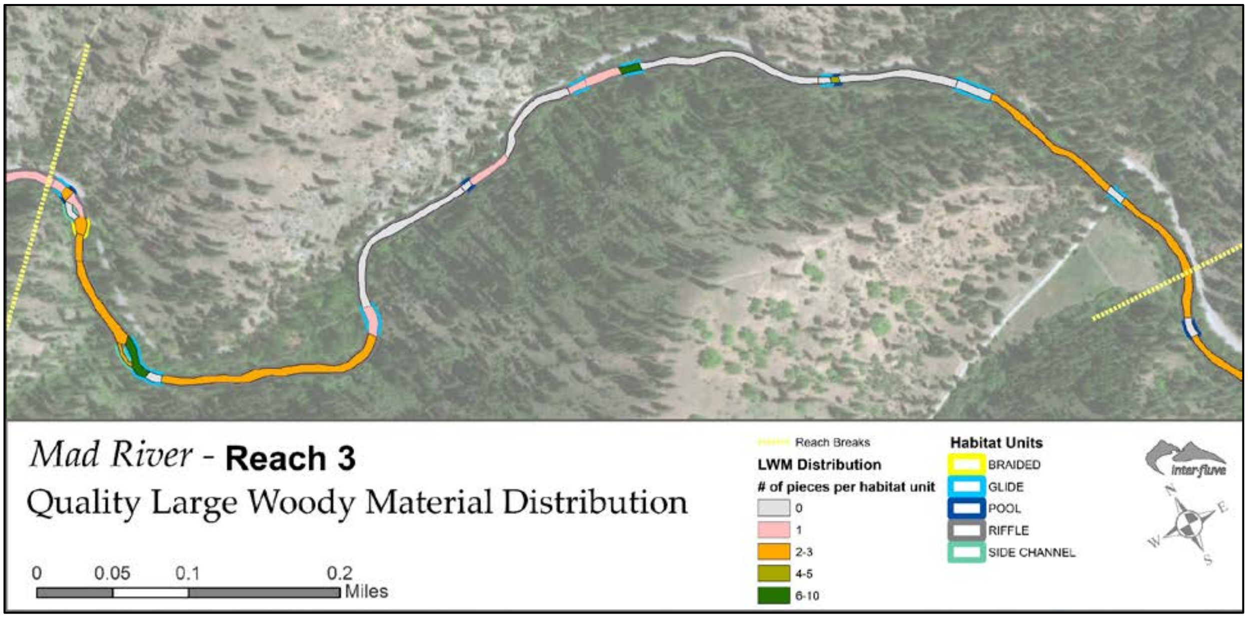


Figure 43. Reach 3 - Quality Large Woody Material (>12-inch dbh and at least 35 feet long) distribution by number of pieces per mapped habitat unit per the 2017 survey.

4.3.4 Human Alterations

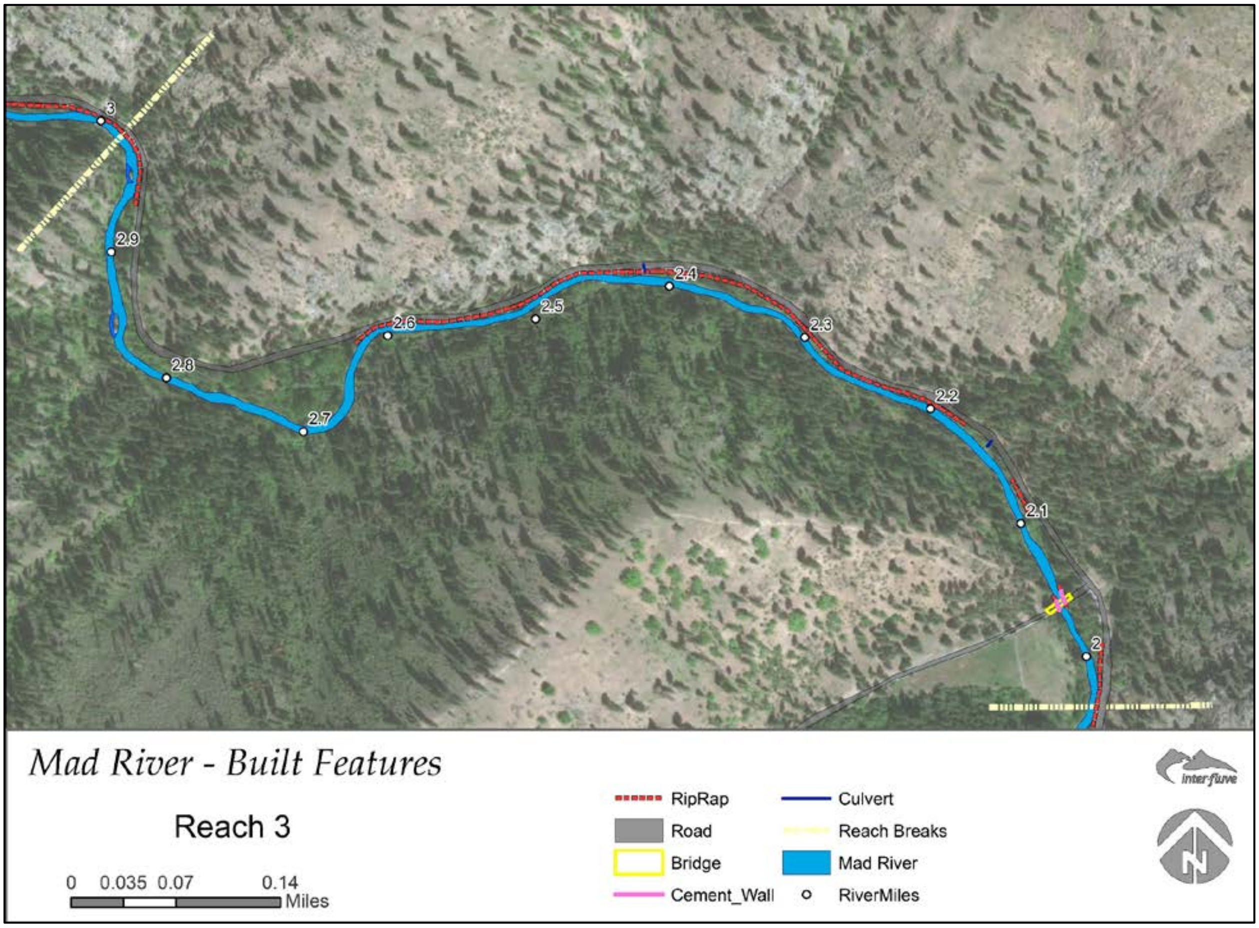


Figure 44. Reach 3: anthropogenic built features. Basemap: ESRI World Imagery

Anthropogenic features in Reach 3 include the Mad River Road, bank riprap, a bridge crossing, an abandoned homesite, and related vegetation clearing. The Mad River Road occupies up to half of the available valley floor in the most confined sections of Reach 3. From RM 2.1 to 2.13, RM 2.17 to 2.63, and RM 2.93 to 3.14 the road bank is armored with large-boulder riprap which further limits the bank from contributing sediment or supporting riparian vegetation. Culverts under the Mad River Road at RM 2.15 and 2.42 control surface water contribution points from the hillslopes into the Mad River. The Tillicum Road bridge crossing at RM 2.04 includes cement footings and large-boulder riprap bank protection that locally confine the channel and control its pathway. This, in conjunction with a dam that was located immediately upstream of the bridge until the 1970's, has resulted in channel entrenchment and simplification in this area. A public day-use area on river right, immediately upstream of the bridge, is the site of an historical homestead. The home has been removed but the area remains mostly cleared of vegetation. A public parking and day-use area on river left immediately downstream of the bridge is also cleared of surface vegetation.


Figure 45. Tillicum Road bridge crossing at RM 2.04, looking upstream. (Photo: IFI 11/25/2017)


Figure 46. Mad River Road occupying valley floor and the associated impaired riprapped channel bank. (Photo: IFI 4/9/2017)

4.4 REACH 4 (2.98 – 4.3)

4.4.1 Overview

Reach 4 is 1.32 river miles long and occupies a river-valley that is partially confined. The Reach extends from the border with Reach 3 to a confined higher-gradient section upstream of Pine Flats campground. The channel is primarily single-thread throughout Reach 4, with the exception of two side-channels near RM 3.3 and RM 4.05. Reach-average sinuosity (1.20) and gradient (1.65%) are lower than in Reach 3 but higher than both Reach 1 and 2. Average bank-full width of the channel in Reach 4 is 52.5 feet, which is wider than all of the downstream reaches – the result of a less confined floodplain. The channel has sections of continuous and alternating floodplain surfaces along most of its banks except in the confined downstream portion from RM 2.98 to 3.17. The floodplain surfaces are well-vegetated with riparian shrubs and trees. Alluvial and debris-flow fans from tributaries located near the upstream boundary of the reach historically contributed sediment directly into the channel and these deposits continue to be active sources of bank-derived sediment. The construction of the Mad River Road on the valley floor from RM 3.08 to 3.6 increases channel confinement and limits riparian vegetation in this downstream section of the reach. Reach 4 has an overall adequate quantity of woody material in the channel which includes three large wood jams. Where wood occurs, geomorphic complexity is increased.

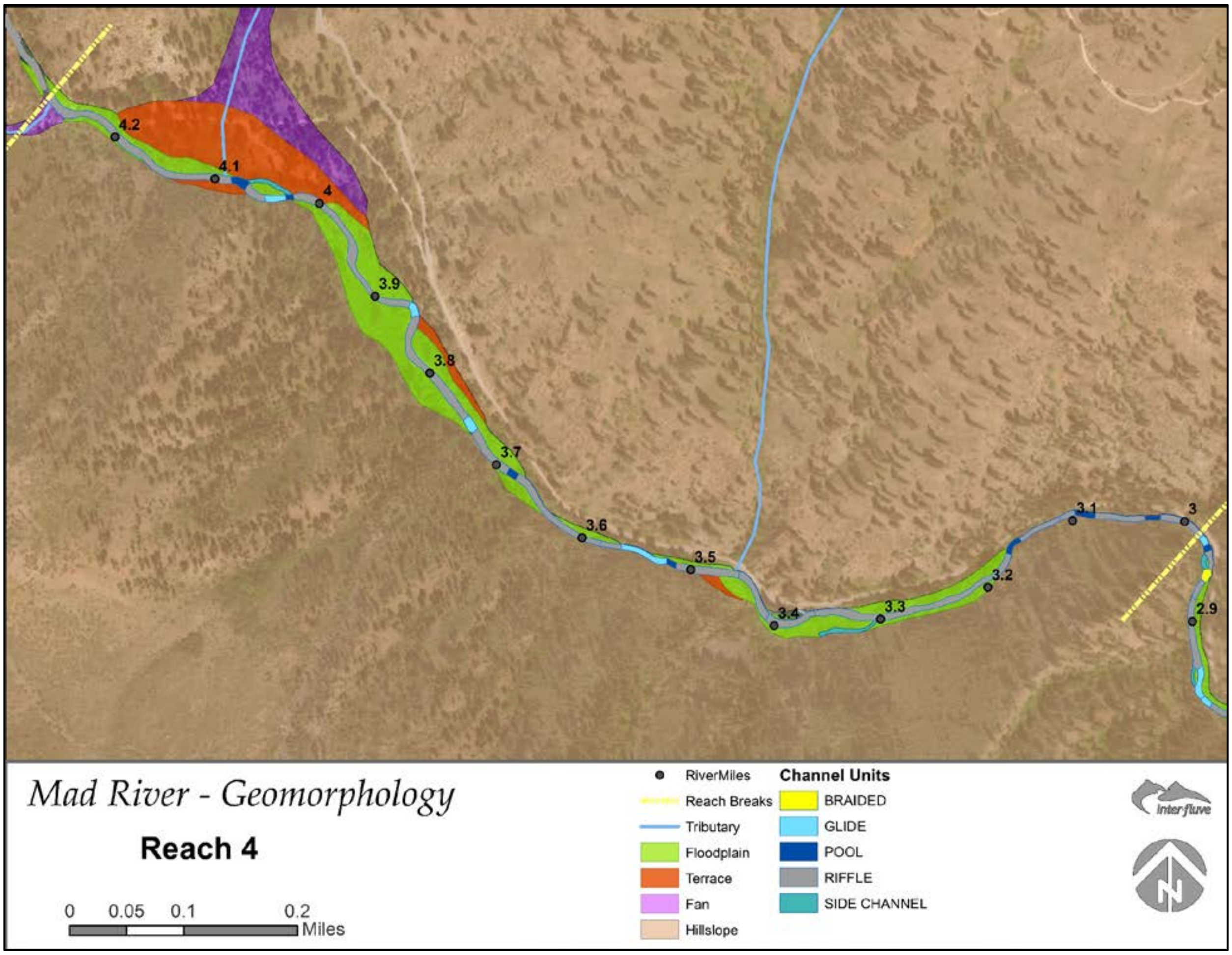


Figure 47. Reach 4: Geomorphic surfaces and channel units. Basemap: ESRI World Imagery

4.4.2 Channel and Floodplain Geomorphology

The Mad River in Reach 4 has a moderate gradient (1.65%) with a subtle sinuous planform (Figure 46). The channel is partially confined upstream of RM 3.17 and completely confined at the downstream end between the Mad River Road and hillslopes (RM 2.98 and 3.17). Channel habitat complexity in Reach 4 is impaired. The 2017 Habitat Assessment (see Appendix ???) measured 87% of the channel as extended riffles while only 7% is pool habitat, 5% is glides, and just 1% is side channels. The pools occur where boulders and/or large wood accumulations create a grade control or scour (see Figure 47). Based on ocular survey, channel substrate in Reach 4 is composed of gravels, cobbles, and small boulders. Plentiful gravels were observed in the upstream portion of the reach. Throughout, gravels and coarse sands were observed in depositional areas such as bars and upstream of large wood log jams. Local hillslope contributions of boulders add localized complexity (steps, scour pools, and wood retention) to channel geomorphology. Split-flow conditions occur near RM 4.05 and a hillslope and/or groundwater-generated side channel join the mainstem Mad River on river right at RM 3.3.

Figure 48. Boulder colluvium creating cascade step into small pool at RM 4.08. (Photo: IFI 10/26/2017)

The hillslopes in Reach 4 have relatively sparsely vegetated slopes. The hillslopes on river right contain bedrock exposures and/or large boulder colluvium toes that periodically contact the channel. Bedrock contacts (25-100 feet long) occur along the right bank of the channel at RM 3.0, 3.09, 3.4 and 4.3. Boulder colluvium occurs along the river right side of the channel along the toe of most other confining hillslope contacts. Hillslope-channel contacts on river right alternate with extended pockets of floodplain. Based on exposed banks, the floodplains are composed of a cobble-boulder base topped with gravels that fine-upward to coarse sands. Based on bed and band material, hyporheic flow is expected to occur through the channel bed, bars, and floodplain surfaces. Soils in Reach 4 are described as gravely fine sandy loam (USDA & NRCS, 2017). Floodplain surfaces range from 1 to approximately 4 feet above the bed of the channel. The floodplain surfaces are well-vegetated with a mix of riparian shrubs and trees.

Figure 49. At RM 3.86: Hillslope contact on river right, boulder colluvium, large wood piece with gravel bar accumulation in front of active floodplain on river left. (Photo: IFI 4/24/2018)

Contributing drainages and their fans are important sediment sources to the Mad River at the upstream end of Reach 4. Two steep drainages with unnamed tributaries have produced debris flows or sets of debris flows (unsorted rock and soil that flows downslope due to gravity and water content) that created fans on both sides of the channel between RM 3.96 and 4.21. The elevation and fan toe extents suggest that, at points in the past, debris flow deposits from one or both of these drainages have temporarily blocked the mainstem channel. Today, Pine Flats Campground occupies part of a terrace feature on river left which is the result of the channel working through debris flow fan deposits. The debris fan on river left is older than the debris fan deposits on river right. However, more research is needed to determine the age, sequence, and influence on the mainstem channel of debris flow deposits from the two drainages. Currently, new debris flow deposits on river right are relatively recent (2010 - 2012 – according to Google Earth aerial photos). The channel is actively eroding laterally and vertically into the deposits at RM 4.27, and at RM 4.07 the channel is actively eroding the river left bank into terrace and debris fan deposits (Figure 49). These are examples of good sediment source to the Mad River for generating bedload that includes gravels as well as materials for local and downstream floodplain development.

Figure 50. Sediment sources: A) debris fan on river right at RM 4.27, B) terrace & fan bank on river left at RM 4.07. (Photos: IFI 11/10/2017)

4.4.3 Vegetation and Large Wood Material

The riparian vegetation in Reach 4 is dominated by mature trees with an understory of dense shrubs. The overstory trees are composed of fir, cedar, ponderosa pine, and cottonwood. The understory is a mix of small trees and shrubs made up mostly of dogwood, alder, cedar, and maple. Where the channel is bordered by the Mad River Road in the downstream portion, riparian vegetation is marginalized and lacking in overstory trees (river left, RM 2.98-3.16. The existing overstory of large-mature trees and the established understory provide a shade canopy for the channel during summer months, except in patches adjacent to the Mad River Road. It is assumed that the riparian forest along the Mad River Road was removed during its construction. The well-vegetated floodplains and hillslopes upstream of the area confined by the Mad River Road offer large wood for recruitment potential to the mainstem channel.

Figure 51. Example of riparian forests in Reach 4 – at ~RM 4.0 looking downstream. (Photo: IFI 10/26/2017)

Figure 52. Channel-spanning LWM jam at RM 3.18 (Photo: Inter-Fluve, November 2017)

A total of 137 pieces of wood were observed in the channel during the habitat survey (10/26/2017). Of those pieces, 31 classified as large size class (>20-inches dbh and >35 feet long), 43 as medium (12 to 20-inch dbh and at least 35 feet long), and 63 as small (9 to 12-inch dbh). Three large wood jams were counted and additional small wood accumulations were observed along the channel margins. A channel spanning large wood jam at RM 3.18 created a grade control pool and upstream gravel accumulations (Figure 51). See Figure 52 for distribution of quality large woody material (>12-in dbh and at least 35 feet long) per mapped habitat unit throughout the reach. Note that LWM distribution is correlated to less-confined sections with vegetated floodplains. The availability of mature forests combined with lateral bank processes increases large wood recruitment potential in Reach 4 compared to downstream reaches.

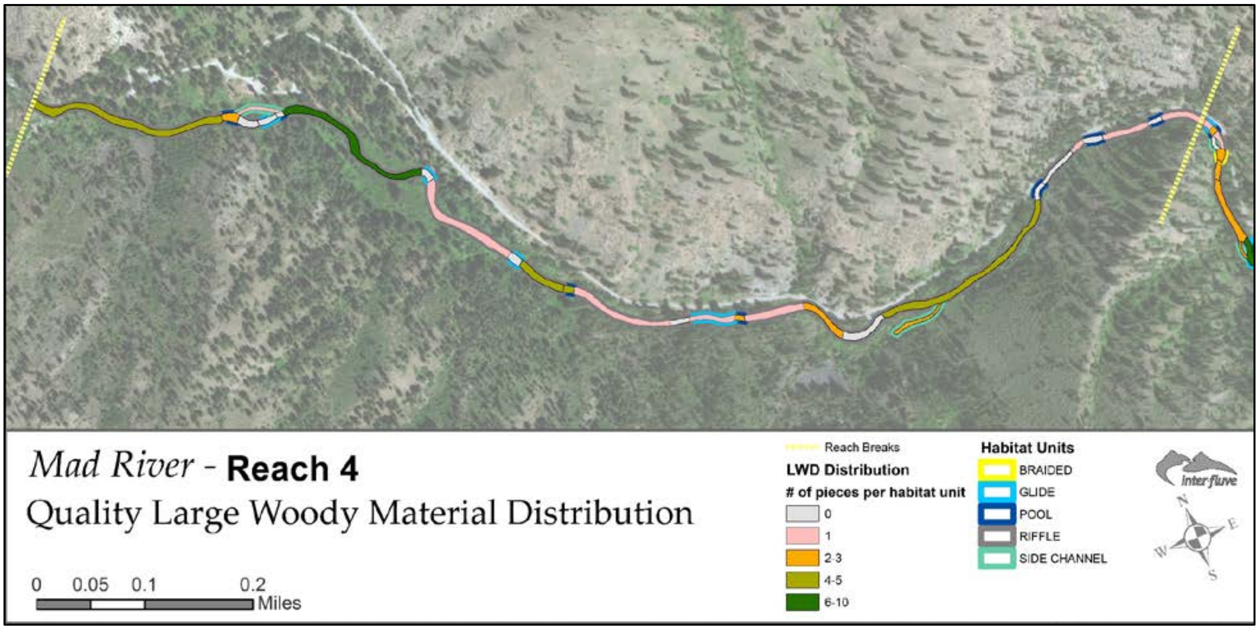


Figure 53. Reach 4 - Quality Large Woody Material (>12-inch dbh and at least 35 feet long) distribution by number of pieces per mapped habitat unit per the 2017 survey.

4.4.4 Human Alterations

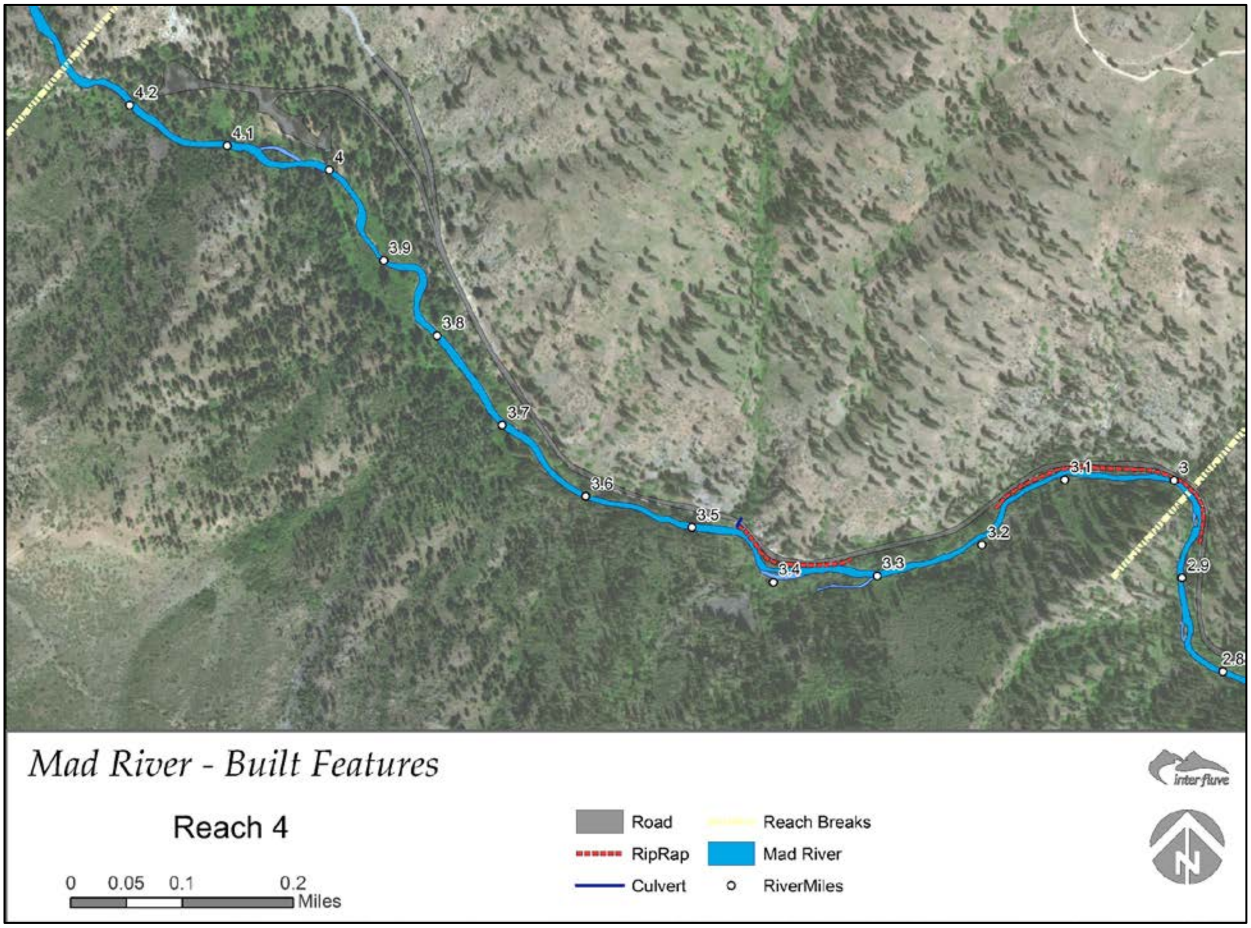


Figure 54. Reach 4: anthropogenic built features. Basemap: ESRI World Imagery

Anthropogenic features in Reach 4 include the Mad River Road, bank riprap, a culvert, Pine Flats Campground, and related vegetation management. The Mad River Road occupies up to half of the available valley floor from RM 2.98 to 3.16, exaggerating channel confinement here. Between RM 3.34 and 3.46 the Mad River Road and its related bank rip rap border the channel in this less-confined section before it leaves the floor of the valley and continues up-slope. A culvert passes hillslope surface water contributions under the Mad River Road at RM 3.16. Pine Flats Campground occupies the terrace and part of the floodplain on river left between RM 4.0 to 4.2. The campground includes cleared dirt and gravel roads, campsites, trails parking areas and a built pit outhouse. It is unknown if water quality issues exist related to the campground and outhouse but the porosity of the floodplain material suggests that periodic testing may be warranted.

4.5 STREAM POWER (HYDRAULICS) ANALYSIS

4.5.1 Stream Power

Stream power was estimated for a comparative analysis of flow energy between each reach. Stream power is the amount or rate of energy dissipated against the banks and bed of a channel from its flowing water. It is often used to measure driving forces acting on the channel bed and banks and to quantify a river's capacity to perform geomorphic work.

First, discharge (Q) was estimated at the downstream boundary of each reach. A set of peak flood events were estimated by scaling the Log-Pearson Typee II regression peak flow results to the upstream drainage area for each reach (see Table 4). Reach slope was determined by taking total elevation gain within the reach divided by channel length.

Stream power was calculated using: $\Omega = pgQS$
where p is the density of water, g is acceleration due to gravity, Q is discharge, and S is reach slope. Table 5 provides the results.

Table 4. Peak flood discharge estimates– derived by scaled Log-Pearson Type III regression done for the downstream boundary of each reach (see Table 1).

Flood Event	Estimated Discharge (cfs) Reach 1	Estimated Discharge (cfs) Reach 2	Estimated Discharge (cfs) Reach 3	Estimated Discharge (cfs) Reach 4
2-year	650	632	463	441
5-year	843	820	600	572
10-year	952	926	677	645
25-year	1075	1045	765	729
50-year	1155	1123	822	783
100-year	1226	1192	872	831

Table 5. Stream power (Watts) for each estimated flood event discharge. Above discharge values converted from cfs to si units for stream power calculations.

Stream Power (Watts)				
Flood Event	Reach 1	Reach 2	Reach 3	Reach 4
2-year	2778	3122	3016	2018
5-year	3603	4049	3912	2617
10-year	4068	4572	4418	2955
25-year	4595	5163	4989	3337
50-year	4936	5547	5360	3585
100-year	5239	5888	5689	3806

As assumed, stream power increases with increasing discharge. However, higher channel slopes in Reaches 2 and 3 results in higher stream powers in the middle-section of the assessment area, even though Reach 1 has a greater upstream drainage area and thus a greater estimated discharge for each flood event.

4.5.2 Specific Stream Power

Estimations of specific stream power have been used to quantify a river's capacity to transport sediment, investigate hydraulic thresholds of flood-related geomorphic response (Costa & O'Connor, 2013; Fonstad, 2003; Magilligan, 1992) and to classify and define channel-floodplain types and floodplain genesis (Nanson & Croke, 1992). Specific stream power takes the values calculated above for total stream power and normalizes them based on width. In this case, we use bankful widths as measured in the field for the Habitat Survey (see Appendix A and Table 2) as approximations of channel width

Specific stream power was calculated using: $\omega = \Omega/w$

where w is bankfull width.

Specific Stream Power (Watts/m²)

Flood Event	Reach 1	Reach 2	Reach 3	Reach 4
2-year	222	199	206	126
5-year	288	259	267	163
10-year	325	292	302	185

Based on Nanson and Croke's (1992) classification, all reaches in the assessment area are considered medium-energy systems at reach-average bankfull width for the 2-year estimated flood discharge (shaded green). Medium-energy systems (ω = 10-300 W/m²) are described as having non-cohesive floodplains, meanderings to braided form, and point bar or braid/multi-channel accretion processes that form floodplains. Note that Reaches 1, 2, and 3 have specific stream powers within the upper-range of what is considered medium-energy. Since estimated average bankfull width is used in this analysis, it is understood that stations with a narrower bankfull width would have higher specific stream power for the same discharge (Q) and wider areas would have lower specific stream power.

In the Nanson & Croke classification, high-energy systems (ω > 300 W/m²) have non-cohesive floodplains, confinement where lateral processes are inhibited, and vertical accumulations of coarse gravels and sands to form floodplains. It is plausible that bankfull width remains relatively constant as discharge increases in the fully confined sections or in the leveed portions of Reach 1. In this scenario using the same estimated bankfull width, specific stream energy for the 5 and 10-year estimated flood events approach and then become high-energy (shaded purple) for Reaches 1 - 3.

Based on this analysis, Reaches 1 and 3 are expected to be capable of transporting larger sized bedload material than Reachs 2 and then 4 for any given flood event. The channel and floodplain characteristics observed and surveyed as part of this assessment (see Reach-Scale Conditions above) confer that modern geomorphology in the lower three reaches is generally medium-high energy formed and medium-energy in reach 4.

5. References

(CCCD), C. C. C. D. (2005). *Entiat Water Resource Inventory Area (WRIA 46) Management Plan.* Entiat, WA.

Archibald, P. (2009). *Appendix H Biological Overview for the Entiat River Tributary Assessment*. Chelan County, Washington.

Costa, J. E., & O'Connor, J. E. (2013). Geomorphically effective floods. In J. E. Costa, A. J. Miller, K. W. Potter, & P. R. Wilcock (Eds.), *Natural and anthropogenic influences in fluvial geomorphology, Volume 89* (p. 239). American Geophysical Union.

Fonstad, M. A. (2003). Spatial variation in the power of mountain streams in the Sangre de Cristo Moutnains, New Mexico. *Geomorphology*, *55*(1–4), 75–96.

Fraley, J. J., & Shepard, B. B. (1989). Life History, Ecology and Population Status of Migratory Bull Trout (salvelinus confluentus) in the Flathead Lake and River System, Montana. *Northwest Science*, *63*(4), 133–143.

Goetz, F. (1989). *Biology of the Bull Trout, Salvelinus Confluentus: A Literature Review*. Willamette National Forest.

Grabowski, R. C., & Gurnell, A. M. (2016). Hydrogeomorphology- Ecology Interactions in River Systems. *River Research and Applications*, *22*(July 2011), 1085–1095. http://doi.org/10.1002/rra

Healy, M. C. (1991). Life History of Chinook Salmon (Oncorhynchus tshawytscha). In C. Groot & L. Margolis (Eds.), *Pacific Salmon Life Histories* (pp. 313–393). Nanaimo, British Columbia: UBC Press.

Hillman, T. W., & Miller, M. D. (1989). Seasonal Habitat Use and Behavioral Interaction of Juvenile Chinook Salmon and Steelhead. In *Summer and winter ecology of juvenile chinook salmon and steelhead trout in the Wenatchee River, Washington* (Final repo, p. 40). Wenatchee, WA: Don Chapman Consultants, Inc.

Inter-Fluve. (2018). *Tillicum Creek Habitat Restoration Project*. Toppenish, WA.

Langford, T. E. L., Langford, J., & Hawkins, S. J. (2012). Conflicting effects of woody debris on stream fish populations: Implications for management. *Freshwater Biology*, *57*(5), 1096–1111. http://doi.org/10.1111/j.1365-2427.2012.02766.x

Magilligan, J. F. (1992). Threshold and the spatial variability of flood power during extreme floods. *Geomorphology*, *5*(3–5), 373–390.

Mantua, N., Tohver, I., & Hamlet, A. (2009). Impacts of climate change on key aspects of freshwater salmon habitat in Washington State. In *The Washington Climate Change Impacts Assessment: Evaluating Washington's Future in Changing Climate* (p. 37). Seattle, WA: Climate Impacts Group, University of Washginton. Retrieved from https://cig.uw.edu/news-and-events/publications/impacts-of-climate-change-on-key-aspects-of-freshwater-salmon-habitat-in-washington-state/

Montgomery, D. R., & Piégay, H. (2003). Wood in rivers: interactions with channel morphology and processes. *Geomorphology*, *51*, 1–5. http://doi.org/10.1016/S0169-555X(02)00322-7

Mote, P. W., & Salathé, E. P. (2010). Future climate in the Pacific Northwest. In D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, & H. L. Miller (Eds.), *Climatic Change: The physical science basis* (Contributi, Vol. 102, pp. 29–50). New York, NY: Cambridge University Press. http://doi.org/10.1007/s10584-010-9848-z

Moyle, P. B. (2002). *Inland fishes of California: revised and expanded*. University of California Press.

Mullan, J. W., Williams, K. R., Rhodus, G., Hillman, T. W., & McIntyre, J. D. (1992). *Production and Habitat of Salmonids in Mid-Columbia River Tributary Streams*. Leavenworth, WA.

Nanson, G. C., & Croke, J. C. (1992). A genetic classification of floodplains. *Geomorphology*, *4*(6), 459–486.

Nehlsen, W., Williams, J. E., & Lichatowich, J. A. (1991). Pacific Salmon at the Crossroads: Stocks at Risk from California, Oregon, Idaho, and Washington. *Fisheries*, *16*(2), 4–21. http://doi.org/10.1577/1548-8446(1991)016<0004:PSATCS>2.0.CO;2

Peven, C., Rose, B., Trihey, W., & Walker, S. (2004). *Entiat Subbasin Plan*. Prepared for Northwest Power and Conservation Council.

Plummer, F. G. (1902). *Forest Conditions in the Cascade Range, WA: between the Washington and Mount Rainier Forest Reserve*.

PRISM (Oregon State University). (2017). PRISM Climate Group. Retrieved January 26, 2017, from http://www.prism.oregonstate.edu/explorer/

Quinn, T. (2005). The_Behavior_and_Ecology_of_Pacific_Salm.

Rieman, B. E., & Mclntyre, J. D. (1993). Demographic and habitat requirements for conservation of bull trout. *General Technical Report INT-302*, 42. http://doi.org/10.2737/INT-GTR-302

Srinivasan, J., others, Randall, D. A., Wood, R. A., Bony, S., Colman, R., … Shukla, J. (2007). Climate models and their evaluation. *Climate Change*, 589–662. Retrieved from https://wg1.ipcc.ch/publications/wg1-ar4/ar4-wg1-chapter8.pdf

Sumioka, B. S. S., Kresch, D. L., & Kasnick, K. D. (1998). Magnitude and Frequency of Floods in Washington, (97–4277), U.S. Geological Survey Water-Resources Investigati. http://doi.org/10.1080/10643387609381644

Tabor, R., Frizzell, V., Whetten, J., Waitt, R., Swanson, D., Byerly, G., … Zartman, R. (1987). *Geologic Map of the Chelan 30-Minute by 60-Minute Quadrangle , Washington*. Department of the Interior.

U.S. Fish and Wildlife Service. Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for Bull Trout in the Coterminous United States (1999).

USDA, & NRCS. (2017). Cashmere Mnt Area, Washington, Parts of Chelan and Okanogan Counties. Retrieved from https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

USFS. (2015). *Stream inventory handbook: level I & II, Pacific Northwest Region. Version 2.15*. Retrieved from https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3854765.pdf

USGS. (2017). StreamStats National Application. Retrieved January 26, 2017, from https://streamstatsags.cr.usgs.gov/v3_beta/

WDNR. (2010). *Digital Geology of Washington State at 1:250,000*.

Appendix A

Stream Habitat Assessment - *DRAFT*

Mad River Reach Assessment

DRAFT - July 2018

Habitat Inventory: Confluence with Entiat River (RM 0) to Pine Flat Campground (RM 4.3)

Survey: October 24 – October 26, 2017

Table of Contents

1 Introduction & Background

The Mad River is located within the eastern foothills of the Cascade Mountains in central Washington along the western border of the Columbia Plateau. The Mad River is approximately 23 river miles long from its headwaters to its confluence with the Entiat River. Flowing southeast through the foothills, it joins the Entiat River approximately 11 river miles (RM) upstream of where the Entiat meets the Columbia River. The Mad River Reach Assessment and Restoration Strategy evaluates existing aquatic habitat and watershed process conditions along the lower 4.3 miles of the Mad River and was completed on behalf of the Yakama Nation as part of their efforts to improve native aquatic fisheries within the Columbia River Basin. As part of the assessment process, Inter-Fluve conducted this 4.3-mile salmon habitat survey of Mad River from October 24 to 26, 2017 from RM 0 (confluence with the Entiat River near Ardenvoir, WA) to RM 4.3 (near Pine Flats Campground). A flow rate of 38.3 cfs was measured in the field on October 24th at the downstream boundary. A flow rate of 27.9 cfs was measured in the field on October 25th in Reach 3 above the Tillicum Creek confluence with Mad River. Insignificant precipitation was received over the survey period. Stream flow was not otherwise measured as part of this survey.

The objective of the Habitat Assessment is to characterize the habitat quantity and quality for salmonid species native to the Mad River by quantifying in-channel morphologic features, characterizing riparian conditions, and identifying anthropogenic features influencing aquatic habitat. This information is used to inform potential restoration and conservation actions and will provide a baseline for evaluating future habitat trends and measuring the effectiveness of restoration efforts to improve the quantity and quality of available habitat within the study area.

1.1 COMPARISON TO PREVIOUS SALMON HABITAT ASSESSMENTS

The earliest known record of a fisheries and habitat assessment on the Mad River is from a 1934 Bureau of Fisheries stream survey. Stream surveys by the Wenatchee National Forest have occurred on various portions of the Mad River in 1972, 1990, 1995, and 1997.

A modified Hankin-Reeves approach (Region 6 USFS standard stream survey protocol) was used for the stream surveys since the 1990s, therefore facilitating the capacity for a relatively direct comparison of recent historical data to the present stream habitat survey. The 1990 survey was from the mouth of the Mad River to Blue Creek (approximately RM 23), the 1995 survey was from the mouth to Young Creek (approximately RM 12.5), and the 1997 survey was done from Young Creek to Blue Creek.

Additional analyses in the greater Entiat basin include the Entiat Tributary Assessment (U.S. Bureau of Reclamation 2009), Entiat Subbasin Plan (Peven et. al, 2004), Lower Entiat Reach Assessment (U.S. Bureau of Reclamation 2012) and the Geomorphic Assessment of the Entiat Subbasin (Terraqua 2017). Further information on the Mad River can be found in the Mad Lake Survey (Rich and Jayson 1995), Wenatchee National Forest bull trout monitoring reports (Nelson, Kelly-Ringel, and Nelle 2008; Nelson 2013), WSFWS Chinook salmon spawning ground surveys (Hamstreet 2012; Hamstreet

2010), and in recent Intensively Monitored Watershed (IMW) reports for the Entiat and Mad Rivers (Johnsen et al. 2013; Potter et al. 2015; Potter et al. 2013). Some discussion of historic surveys and other aquatic data for the Mad River is included throughout this report, and a brief summary of the 1995 stream assessment results will be provided here, but for more information on the historical conditions in the Mad River the reader is encouraged to see the original aforementioned documents.

1.1.1 1995 Wenatchee National Forest Stream Inventory – Results Summary

In the 1995 stream survey by WNF (Rich and Jayson 1995), the river segment between the mouth of the Mad River (RM 0) and Pine Flats Campground (approximately RM 4.3) is referred to as Reach I. This is equivalent to the spatial extent of this current 2017 stream survey that recognizes four geomorphic reaches. The 1995 data is compared to the project area summary results of the 2017 data presented here.

In the 1995 survey, discharge of the Mad River on August 31 was measured at 45.3 cfs at Mill Camp Bridge in Ardenvoir (at RM 0.3). The average stream wetted width was 33 feet, with 7 pools per mile and an average residual pool depth of 1.6 feet. The number of large woody material was low; of 18 recorded pieces, 17% fell in the "large" category and 33% was classified as "small." A majority (93%) of the habitat (presented as stream surface area in the 1995 report) was categorized as riffle habitat with only 5% pool habitat and a low amount (2%) of side channels and other types of habitat, such as “falls.”

In 1995, riparian vegetation consisted of sparse overstory trees dominated by alder with an occasional willow, redosier dogwood, cottonwood, and cedar. Upslope vegetation was described as Douglas fir-Ponderosa pine stand interspersed with open areas. Orchards and lawns were the primary floodplain vegetation in the section closest to the confluence near Ardenvoir. It was estimated that the upper 20% of the riparian and surrounding vegetation in this reach were burned in the 1994 Tyee Fire.

In 1995, the dominant streambed substrate was reported as cobble with gravel as a subdominant. The side slopes were noted as steep (65-70%) and the channel gradient ranged between one and four percent slope. One chinook redd was observed (along with a chinook carcass). Potential spawning gravels for rainbow and bull trout were reported as scattered from RM 0 to RM 4.3. Fish hiding cover was low and was predominantly provided by substrate, with a small amount provided by turbulence. Rainbow trout were also observed.

In the 1995 survey, stream shade throughout the reach (RM 0-4.3) was relatively low (< 30%) and human disturbances rated as high. The greatest impacts noted in the survey include water diversions, garbage dumping, heavy fishing pressures, and channel confinement due to roads and residential uses.

2 Methods

In this habitat assessment, the study area (RM 0--4.3) was subdivided into four geomorphic reaches. The same reach delineations were used for both this habitat assessment as well as the geomorphic reach assessment (See main report) and restoration strategy (see Appendix A).

This survey employed the methods outlined in the US Forest Service Region 6 Level I & II Stream Inventory Handbook, Version 2.15 (USFS, 2015) and the "Eastside" protocol was used. All protocols were followed when safe, and most of the suggested forest inventory options were applied in the survey. However, due to the late-season timing and the arrival of inclement weather conditions, the survey had to be completed at discharge values slightly above summer base-flow and within a short time-frame. As a result, some of the USFS (USFS, 2015) protocols were adapted for safety purposes.

The survey protocol adaptations made in the field specifically for this survey are as follows: All reach and habitat unit lengths were measured in GIS from field recorded GPS data collected with a high-accuracy Trimble GeoExplorer GPS unit instead of measuring the distance between unit breaks with a tape in the field; Water temperature was only recorded once per day as ambient air temperature was in the 40s °F and therefore negated capturing water temperature at baseflow and the potential exceedances of seasonal water quality standards. Stream discharge was measured at the downstream border of the study area at the beginning of the survey and again upstream of the Tillicum Creek confluence.

The n^{th} channel unit (riffle, pool, glide) measurement frequency applied in the field for data collection initially was 100% for pools (due to the very low frequency of pool habitat units) and approximately 30%, or 1 unit measured in every 3, for fast-water units (riffles and glides). Following USFS protocol, once adequate nth channel units had been measured, the measurement frequency dropped to every 2^{nd} unit for pools and every 5^{th} unit (or one in five) for fast-water units. This choice was made to ensure that the n^{th} unit measurements were representative of the field area. In total, 30 n^{th} units were measured in Reaches 1-4.

At n^{th} units, the surveyors performed an ocular estimate of the wetted channel width and flood-prone width, and also recorded the wetted channel width with a 100-foot tape. At every channel unit measured, the length of unstable bank was estimated for both the left and right channel banks. Depth of pools, riffles, and glides was measured using a graduated stadia rod carried by the observer. Where water velocity or depth was unsafe for surveying (e.g. excessively deep pools), the observer either estimated depth and/or measured as close to the thalweg as possible.

For the riparian vegetation measurements, it is a "Forest Option" to designate a riparian corridor as either a single 100-ft wide zone or two adjacent riparian zones (inner and outer zones) totaling 100 feet in width (USFS, 2015). For this assessment, one single 100-ft wide riparian zone was designated for the Mad River study area. Survey methods dictate defining a dominant size class of vegetation type within the riparian corridor (e.g. small trees, shrubs), then defining the dominate species observed in the overstory and understory. Survey protocol differed from USFS protocol by collecting a dominant overstory and understory size class within the 100-foot wide riparian zone in addition to species.

For each of the four reaches, two gravel counts were completed by the habitat team to characterize the size distribution of sediment. In total, eight gravel counts were completed. Criteria for gravel count locations state that they must be representative of the general character of the individual reach and completed at a representative glide to riffle transition point. Due to safety reasons associated with extremely cold water and air temperatures as well as depth of water at the time of the survey, gravel counts were conducted on exposed point bars. This protocol modification provides data that represents the bedload wash at hydraulically-reduced accumulation zones within the mainstem channel. Mainstem channel substrate composition was characterized with ocular observations provided in Section 4 of the Reach Assessment.

For this habitat survey, we consider "side-channels" as naturally wetted flow paths connected to the mainstem channel at their upstream and downstream ends at average annual flow. Side channel units were identified when the main channel split to form a stable island with soil or fine sediment accumulations and with establishing vegetation older than 2 to 3 years. Each side channel was determined to be fast or slow, and its average width and length measured. Both total and wetted lengths were recorded using GPS and a 100-ft tape. Wetted lengths are used in this report unless otherwise noted.

A "braided" channel unit is defined as a series of three or more roughly parallel channels separated from each other by active bars during lower flows but relatively connected during bankfull flows. Within the assessment area for this survey only one "braided" unit was observed -- in Reach 3. All other channel unit designations (riffle, pool, glide, side-channel) were considered single-threaded.

Large woody material (LWM) was counted in the mainstem and side channels following the size class characterizations for "Eastside" forests. The forest option to count large wood pieces in the small size category was used. Tallies of Small (> 6 in. diameter, >20 ft long), Medium (>12 in. diameter, > 35 ft long) and Large (>20 in. diameter, >35 ft long) pieces of Large Wood were completed for each reach. For this report, Medium and Large pieces of LWM will be collectively referred to as "Quality Large Wood." Only four log jams were identified within the study area, one in Reach 2 and the remainder in Reach 4. Open-water wetlands on floodplains were not observed, measured, or recorded.

3 Summary of Results

This section summarizes the results of the four channel reaches surveyed from October 24 to 26, 2017 between RM 0 to 4.3 on the Mad River. Detailed descriptions of the survey results from the individual reaches are included in Section 4 of this report.

3.1 CHANNEL MORPHOLOGY

The surveyed reaches in the Mad River are dominated by extended riffle-cascade morphology with infrequent step pools. In general, channel form is single thread with a sinuosity $\leq$ 1.2 (straight to sinuous). Much of Reach 1 (RM 0-0.86) is entrenched and leveed while most of Reaches 2, 3, and the downstream half of Reach 4 (RM 0.68-3.6) experience increased valley confinement as a result of the Mad River Road. Overall, bedload wash surveyed at point bars consisted primarily of gravels (29-75%) and cobbles (22-57%) with 0-9% sand, 0-6% boulder, and 0% bedrock. Observed mainstem channel substrate was dominated by cobbles with minor gravels and boulders. Bedrock contacts (25-100 feet long) occur along the right bank of the channel at RM 2.65, 2.91, 3.0, 3.09, 3.4 and 4.3. Boulder colluvium occurs along the river right side of the channel along the toe of most other confining hillslope contacts.

Channel geometry varied within the study area. Overall, bankfull widths and depths increased going upriver. Mean bankfull depths ranged from 2.6 feet in Reach 1 to 3.7 feet in Reach 3 (Table 2) and widths ranged from 41 feet in Reach 1 to 52.5 feet in Reach 4 (Table 1). Floodprone widths reflect both geomorphic surface changes within the study area and human influenced incision (Table 3). The typical downstream increasing trend is not clearly observed in the study area, likely a result of the geomorphically confined nature of the study area. Instead, average floodprone width is greatest in Reaches 1 and 3 and the smallest floodprone width recorded in Reach 2.

Table 1. Mad River bankfull width results from habitat assessment.

Bankfull Widths (feet)				
	Reach 1	Reach 2	Reach 3	Reach 4
Max	46	55	60	53
Min	38	46	40	52
Mean	41.0	51.3	48.0	52.5
St Dev	3.5	3.6	7.9	0.7

Table 2. Mad River bankfull depth results from habitat assessment.

Bankfull Depths (feet)				
	Reach 1	Reach 2	Reach 3	Reach 4
Max	3.7	4.7	5.5	5
Min	0.9	0.6	1.8	1.4
Mean	2.6	2.7	3.7	3.2
St Dev	0.7	1.0	0.9	0.9

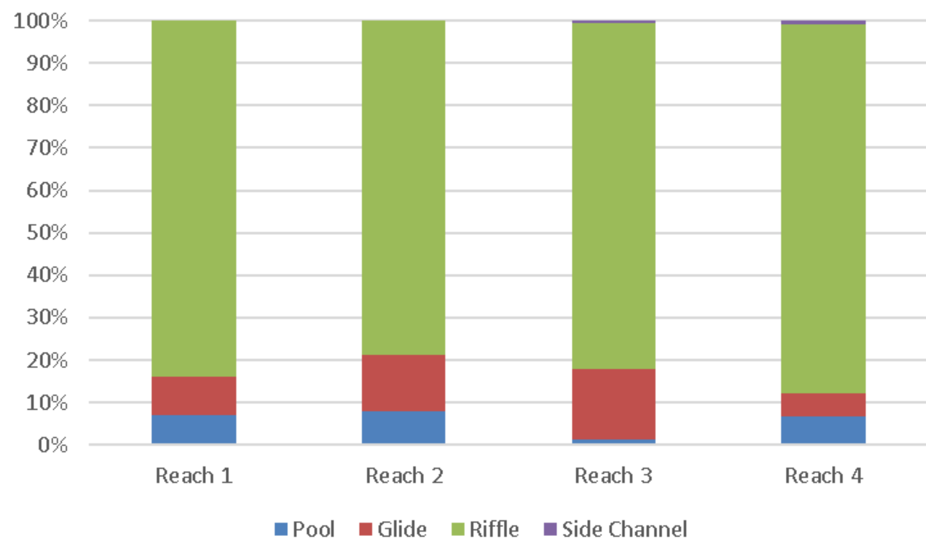
Table 3. Mad River floodprone width results from habitat assessment.

Floodprone Widths				
	Reach 1	**Reach 2**	**Reach 3**	**Reach 4**
Max	250	115	155	100
Min	65	70	100	70
Mean	137.5	82.5	125	85
St Dev	83.32	16.66	22.73	21.21

3.2 HABITAT UNIT COMPOSITION

Within the surveyed area, riffles are the dominant habitat type, comprising 83% of the total area of the channel. Glides comprise 11% of the area, and pools only 5%. Side channels comprise less than 1% of the channel area (Figure 1). Reach 2 maintains the highest percentage of pool habitat at nearly 8%, while Reach 3 is the lowest at 1.2%. Side channel habitat area was low overall across the study area but Reaches 3 and 4 maintain the most side channel habitat area at just 0.7 and 0.8%, respectively.

The mean residual pool depth for the entire study area was 1.9 feet, while the residual pool depth ranged from a minimum of 0.7 feet in Reach 4, to a maximum of 3.7 feet, also in Reach 4 (Figure 2). Pool frequency was uniformly low throughout the study area ranging from a minimum of 2.5 pools per mile (Reach 3), to 7.5 pools per mile (Reach 2), with an average pool frequency throughout the project of 4.9 pools per mile. On average, pools were < 3 feet deep at the time of the survey. Of the 22 pools identified, 91% were less than 3 feet deep. Reaches 1 and 3 both had no pools with residual depths greater than 3 feet, while Reaches 2 and 4 had one pool each with a residual depth greater than 3 feet (13% and 14%, respectively). Average pool spacing throughout the study area was 20.3 channel widths per pool, though there was high variability among the reaches. Reach 2 maintained the lowest average pool spacing with 14.2 channel widths per pool and Reach 3 maintained the highest pool spacing with an average of 43.4 channel widths per pool. The mean estimated wetted width of the main channel was 29 feet with a standard deviation of 8.4 feet. Mean riffle depths were also fairly uniform throughout the study area ranging from 1.1 feet in Reach 4 to 1.3 feet in Reach 2. In total, 71 fast water units (riffles and glides) were measured. A summary of all data recorded is provided in Table 15 in Section 4.6 Summary Data.



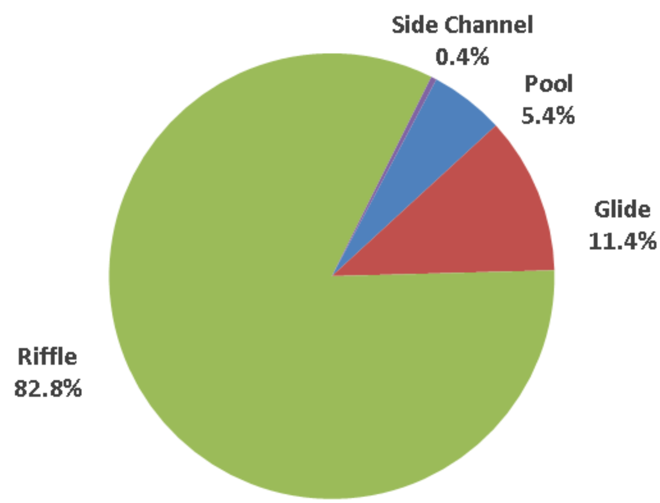


Figure 1. The top figure illustrates distribution of habitat unit composition of reaches 1-4; pool habitat composed a majority of the habitat area. The bottom figure displays habitat unit composition in the study area as a whole.

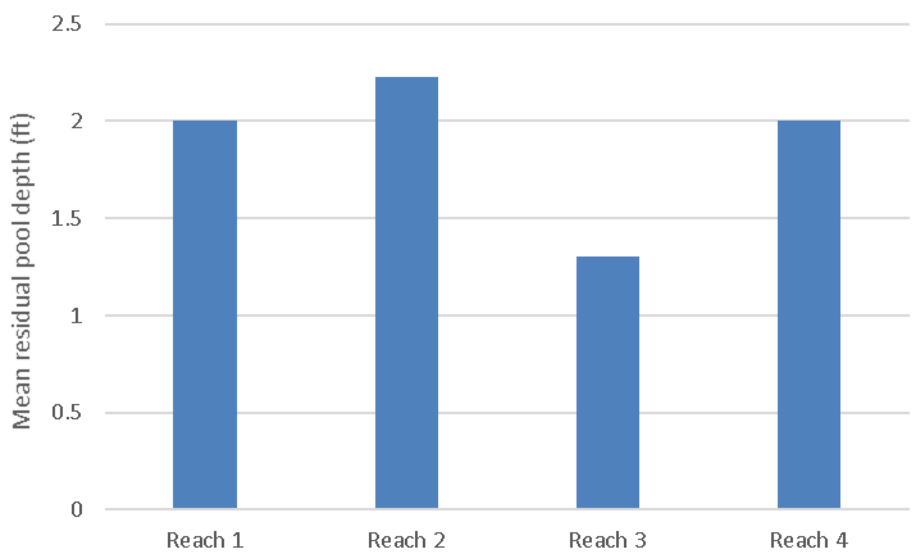


Figure 2. Mean residual pool depth by reach.

3.3 SIDE CHANNEL HABITAT

Side channel habitat area overall throughout the surveyed area was relatively low, accounting for less than 1% of the surface habitat area. In total, four side channel units were observed, averaging 1.1 side channels per mile of stream. The wetted side channels averaged 147 feet in length and 6 feet in width (wetted). Figure 3 is a photo of a slow-water side channel in Reach 4. The side channels maintained similar counts of LWM as the mainstem channel. In total, 12 pieces of LWM were counted in the 4 side channels, with approximately 45 pieces of medium and large wood per mile.

Figure 3. 300-foot long side channel in Reach 4 with low flows during the time of survey. (Photo: IFI staff – 10/26/2017)

3.4 LARGE WOODY MATERIAL

On average, 67 pieces of LWM per mile were counted in the project area; 51% were "small" pieces with diameters between 6 and 12 inches and lengths greater than 20 feet, 32% were "medium" pieces with diameters between 12 and 20 inches and lengths over 20 feet, and were 17% "large" pieces with diameters over 20 inches and lengths over 20 feet (Figure 4). Reach 4 maintained the most LWM in both number of pieces per mile (56.1 pieces of quality large wood per mile) and number of total pieces (137). Reach 1 maintained the least LWM with only 11 pieces identified, all in the small size class. Four log jams were identified in the study area.

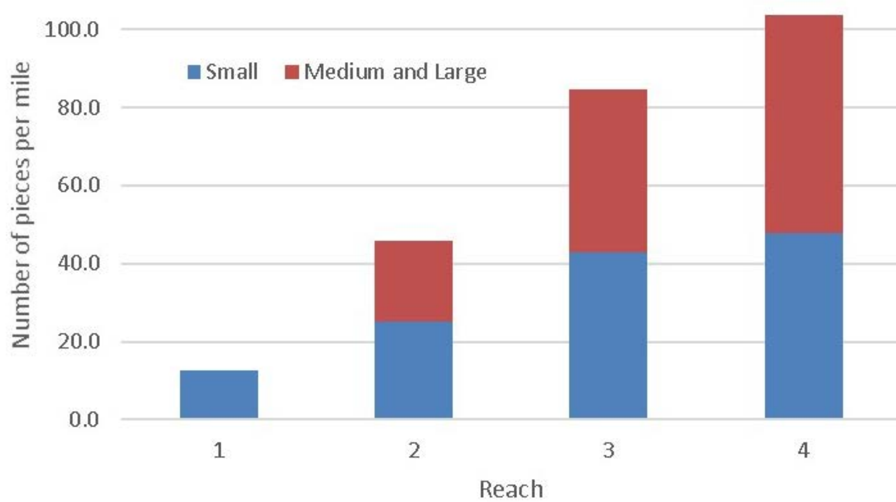


Figure 4. Pieces of large wood per river mile for Mad River reaches 1 – 4.

Based on thresholds established by Fox and Bolton (2007) for Eastside forests, the "adequate" threshold for LWM is >32 pieces per mile of quality – medium and large size class – wood, with additional woody debris available for short and long-term recruitment. There were 29.6 pieces of quality large wood per mile averaged across the whole study area. However, Reaches 1 and 2 are at "unacceptable risk" for LWM present and LWM recruitment, while Reaches 3 and 4 meet the criteria for "adequate" for LWM present (with 41.9 and 56.1 quality large wood per mile, respectively). Both Reaches 3 and 4 generally have good LWM recruitment potential.

Figure 5. Large in-channel woody material in Reach 4; photo by IFI staff on October 26, 2017.

3.5 SUBSTRATE & FINE SEDIMENT

Bedload wash characterization is based on eight gravel counts that were completed between Reaches 1 and 4. All gravel counts were completed at exposed representative active bars. Overall, the gravel count samples indicate that bedload wash is quite similar between all reaches, with predominately gravel and cobble present. Reach 4 had the largest proportion of gravels (60%, averaged between two counts), while Reaches 1 and 2 had approximately equal amounts gravel and cobble and 5% or less of sand. This indicates that fine sediment (<2mm), which can be harmful to salmonid survival in high concentrations at spawning grounds, is likely readily transported out of the system and thus pose minimal risk to aquatic habitat quality in the surveyed area. Sand was observed accumulating in elongate deep pools or behind large boulders. Sediment type is classified by the B-axis diameter of the clasts sampled (sand = < 2mm, gravel = 2.1-64 mm, cobble = 64.1-256 mm, boulder = >256.1mm). A low proportion of boulders were recorded on the bars (between 2 – 4%). Ocular observations reveal that channel bed substrate is dominated by cobbles but in higher gradients reaches more boulders are present.

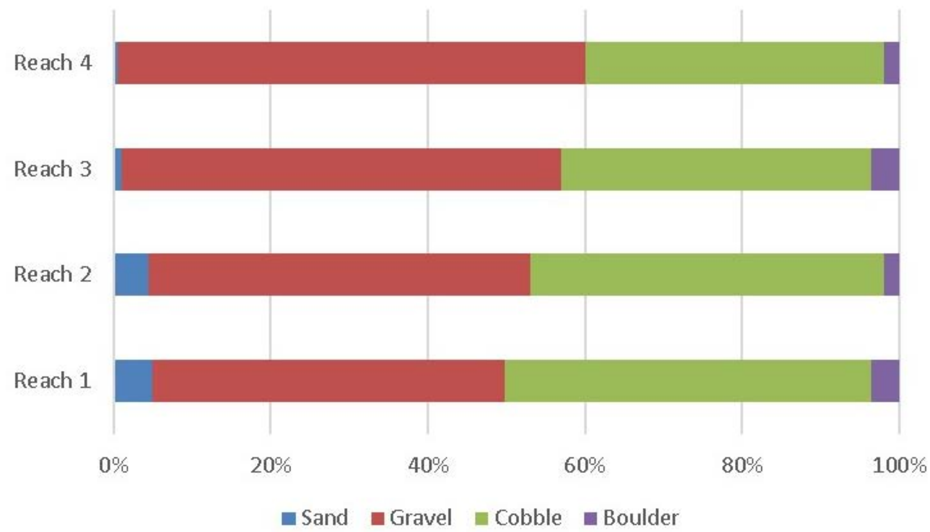


Figure 6. Gravel count classification of bar deposits by reach for Reaches 1-4. For each reach, two gravel counts were performed and then averaged.

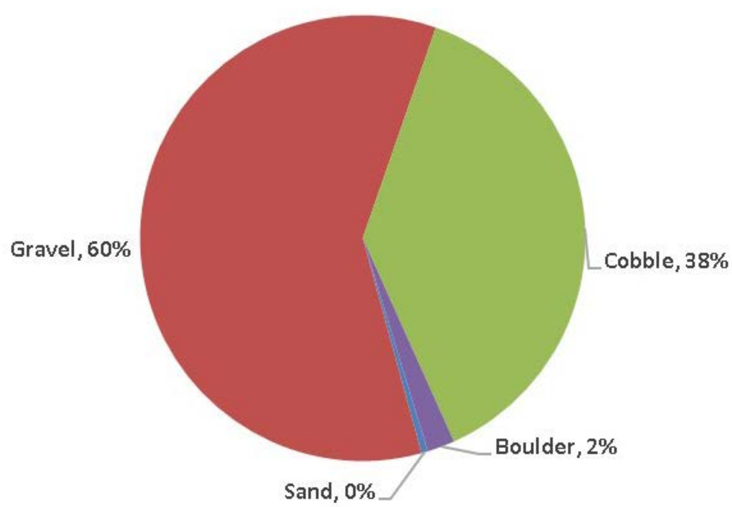


Figure 7. Gravel count of bar deposits clast size classification averaged for Reaches 1 – 4. Gravel is the dominant classification that was observed.

Figure 8. Gravel Count 4.1 (in Reach 4) location on an exposed bar. Photo by IFI staff on October 26, 2017.

3.6 BANK INSTABILITY

Reach 1 had the most human imposed impacts including levees, irrigation out-takes, home development, bridges, and weirs which has resulted in channel entrenchment and geomorphic simplification. Reaches 2 and 3 are confined on river left by the Mad River Road with Reach 3 having much of the road bank lined with large-boulder riprap. However, Reach 2 also has bridge crossings and riparian vegetation clearing. Reach 4 has the least modern human impacts imposed on it. None-the-less, the lower portion of Reach 4 is also confined by the Mad River Road with segments of rip rap. At the upstream end of Reach 4 relatively minor floodplain riparian vegetation clearing and grading has occurred in conjunction with Pine Flats campgrounds. See section 4 of the Assessment Report for detailed description of anthropogenic disturbance.

The habitat team estimated the extent of bank erosion (instability) on both the left and right banks at each channel unit. The length of the unstable (eroding) left and right banks was then divided by the total length (left and right bank) of each reach to determine the percentage of each reach that had eroding banks. Overall bank instability is low, averaging only 3.5% throughout the study area (Figure 9. Total percentage of right and left-bank erosion for each reach. Percentages are based on left and right bank ocular estimates measured at each unit throughout the study area.). The highest percentage of erosion was in Reach 3 on the river left bank (9.4%), while Reach 2 had no unstable banks on river right. Although large portions of it are protected with Mad River Rad riprap, river left generally had a higher proportion of unstable banks throughout the project area.

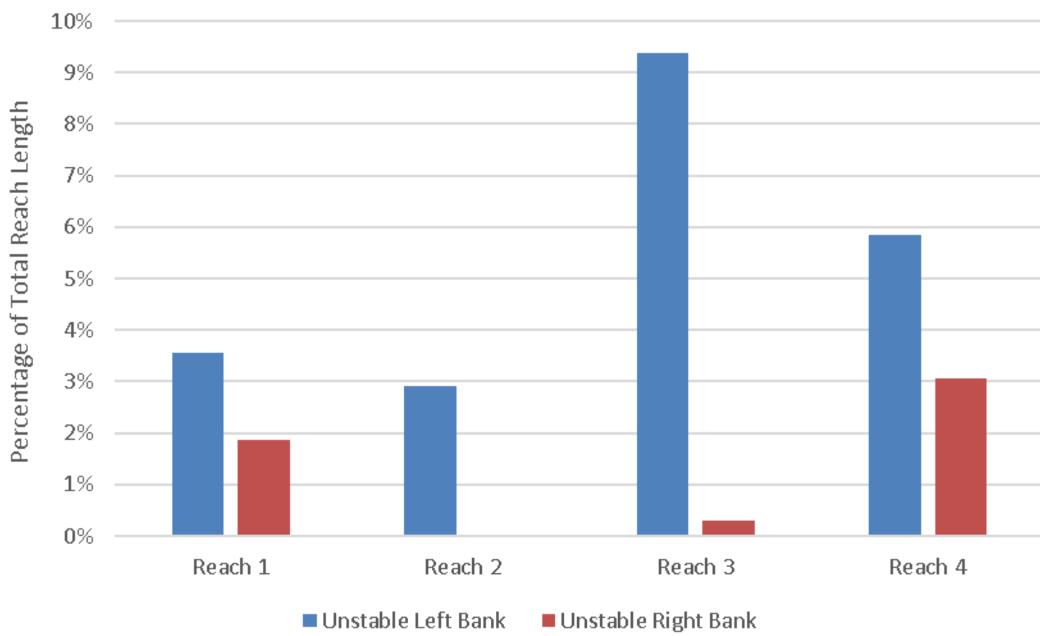


Figure 9. Total percentage of right and left-bank erosion for each reach. Percentages are based on left and right bank ocular estimates measured at each habitat unit throughout the project area.

Unstable banks indicate lateral and sometimes vertical processes and serve as sediment sources to the channel. Bank erosion is relatively low throughout the project area. Confining hillslopes on river right in Reaches 2, 3, and 4 often have colluvium at their toe that protects from bank erosion. Riprap along the Mad River Road also protects large portions of the bank on river left in these same reaches. Where bank erosion was present historically in Reaches 1, 2, and 3, riprap, cement slabs, pieces of metal, and logs were used to minimize it. The discontinuous pockets of floodplain provide areas for bank erosion to occur. Terrace banks and debris fan toes provide good bank sediment sources in Reach 4.

3.7 FISH PASSAGE BARRIERS

No anthropogenic fish passage barriers were observed in the mainstem channel during the habitat assessment. However, there may be velocity or passage barriers for some species and/or life stages at certain locations in the study area. In addition, the channel-spanning log jams may also act as a barrier for certain species or life stages during certain times of the year (Figure 10).

Figure 10. Looking downstream at a channel-spanning log jam that may act as a barrier for certain species or life stages at some flows.

3.8 RIPARIAN CORRIDOR

Of the 30 n^{th} units measured in Reaches 1-4, the dominant (58%) riparian vegetation size class was small tree (9.0 – 20.9-inch diameter at breast height (dbh)). Large tree (21 – 31.9-inch dbh) was the second most dominant class (28%). All recorded units in Reach 4 had mature tree (> 32-inch dbh) as the dominant class of overstory within the riparian corridor, while only one instance of a shrub/seedling (1.0 – 4.9-inch dbh) overstory was observed in Reach 1 (Figure 11). The dominant overstory species was Douglas fir (42%), followed by 33% of units with primarily ponderosa pine. Cottonwood-dominant overstory followed at 14% -- found mostly in Reach 1. Additional species in the overstory in a handful of habitat units included cedar (6%), willow (3%) or alder (3%) (Figure 12).

The dominant understory size classes were sapling/pole (5 – 8.9-inch dbh) (58%) and shrub/seedling (25%), small tree (8%) and grassland/forb (8%) (Figure 13). Alder was the most dominant riparian understory observed, accounting for 61% of the understory. Additional dominant riparian understory species included redosier dogwood (19%); grassland forbes (8%); bigleaf maple (6%); willow (3%); and cedar (3%) (Figure 14).

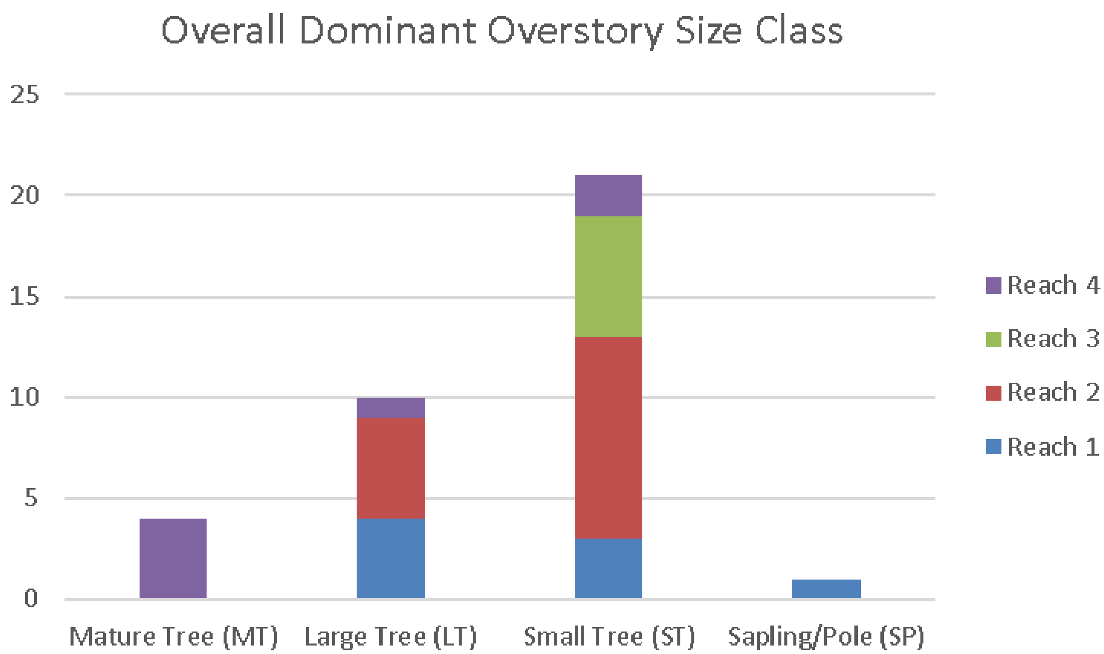


Figure 11. Distribution of dominant overstory size class category for the riparian zone, all reaches combined. Based on n[th] unit measurements from Reaches 1 – 4.

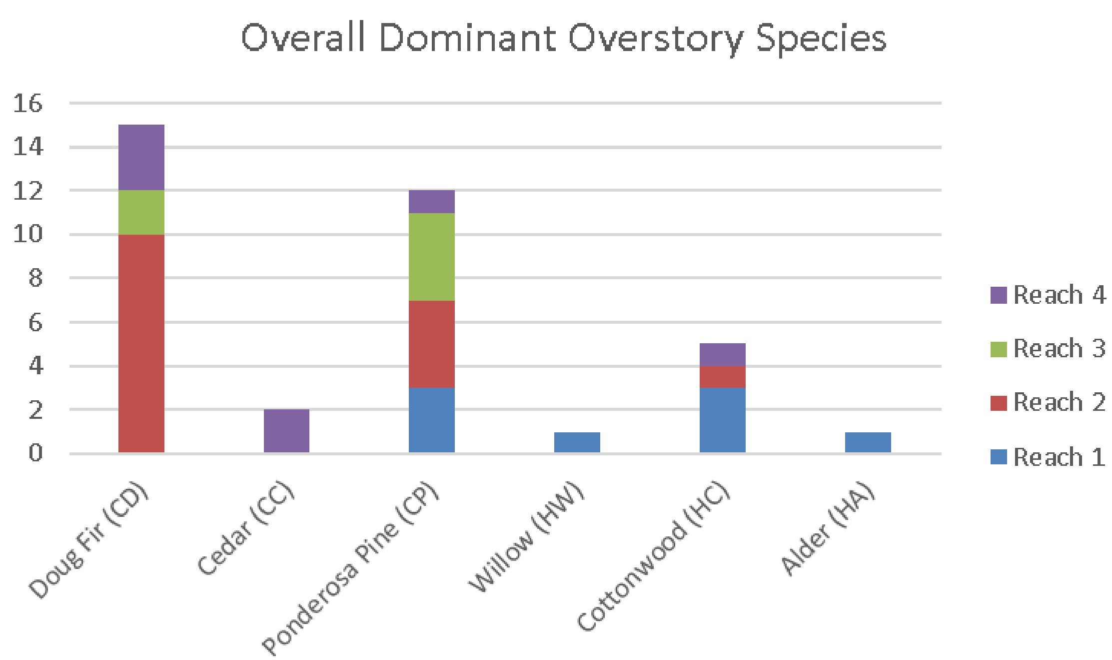


Figure 12. Dominant overstory species in the riparian zone, by reach. Based on n[th] unit measurements from Reaches 1 – 4.

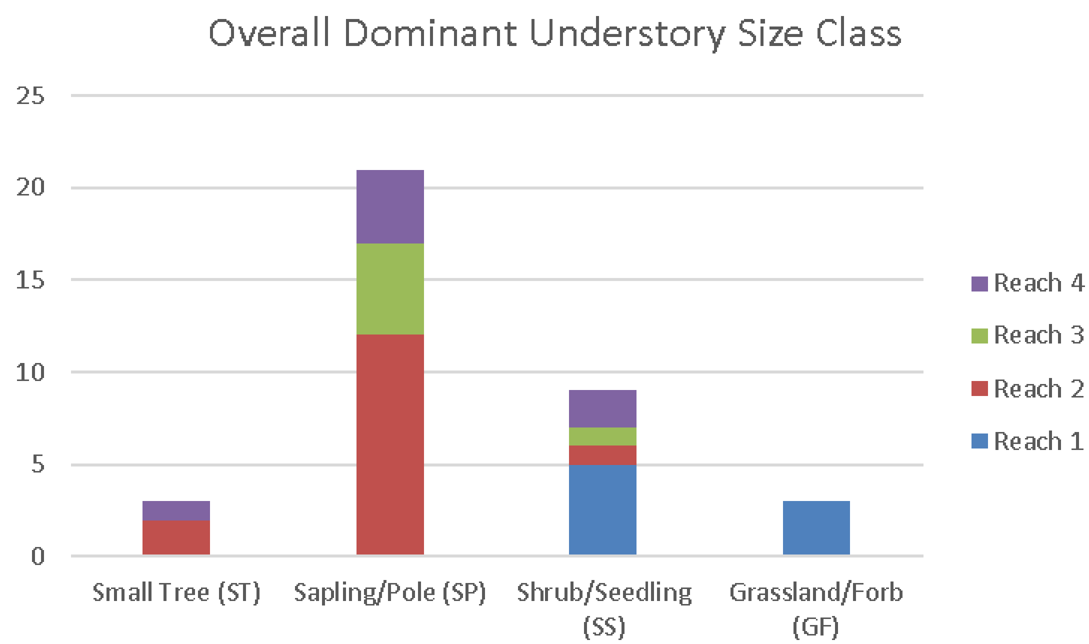


Figure 13. Distribution of dominant understory size class category for the riparian zone, all reaches combined. Based on n^{th} unit measurements from Reaches 1 – 4.

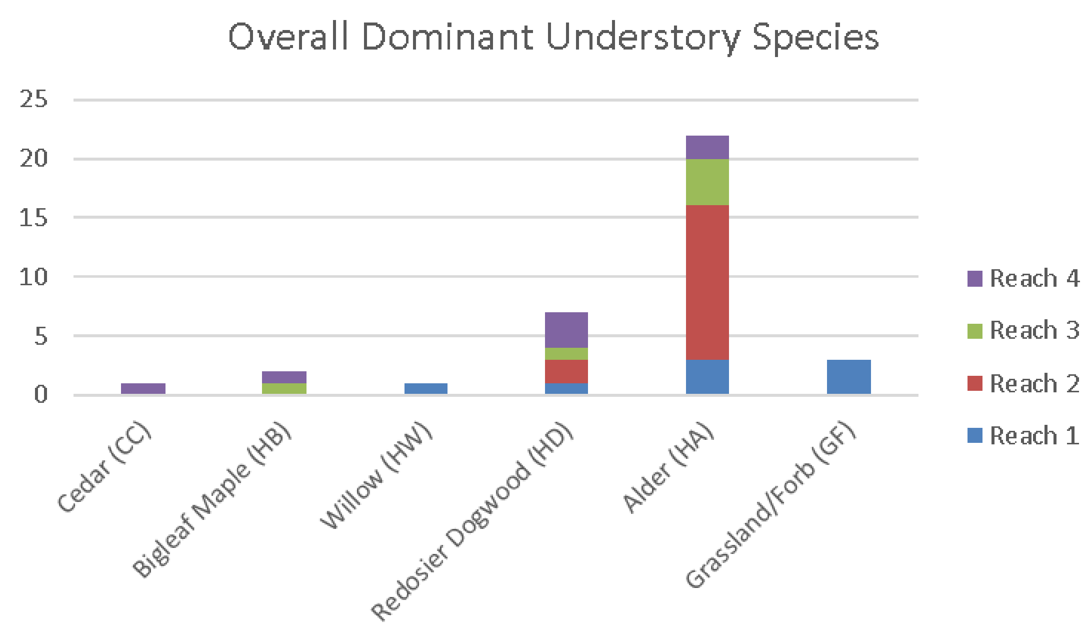


Figure 14. Dominant understory species in the riparian zone, by reach. Based on n^{th} unit measurements from Reaches 1 – 4.

4 Stream Habitat Reach Reports

4.1 REACH 1

Location: River mile 0 – 0.86
Total length: 0.86 miles
Survey date: October 24, 2017

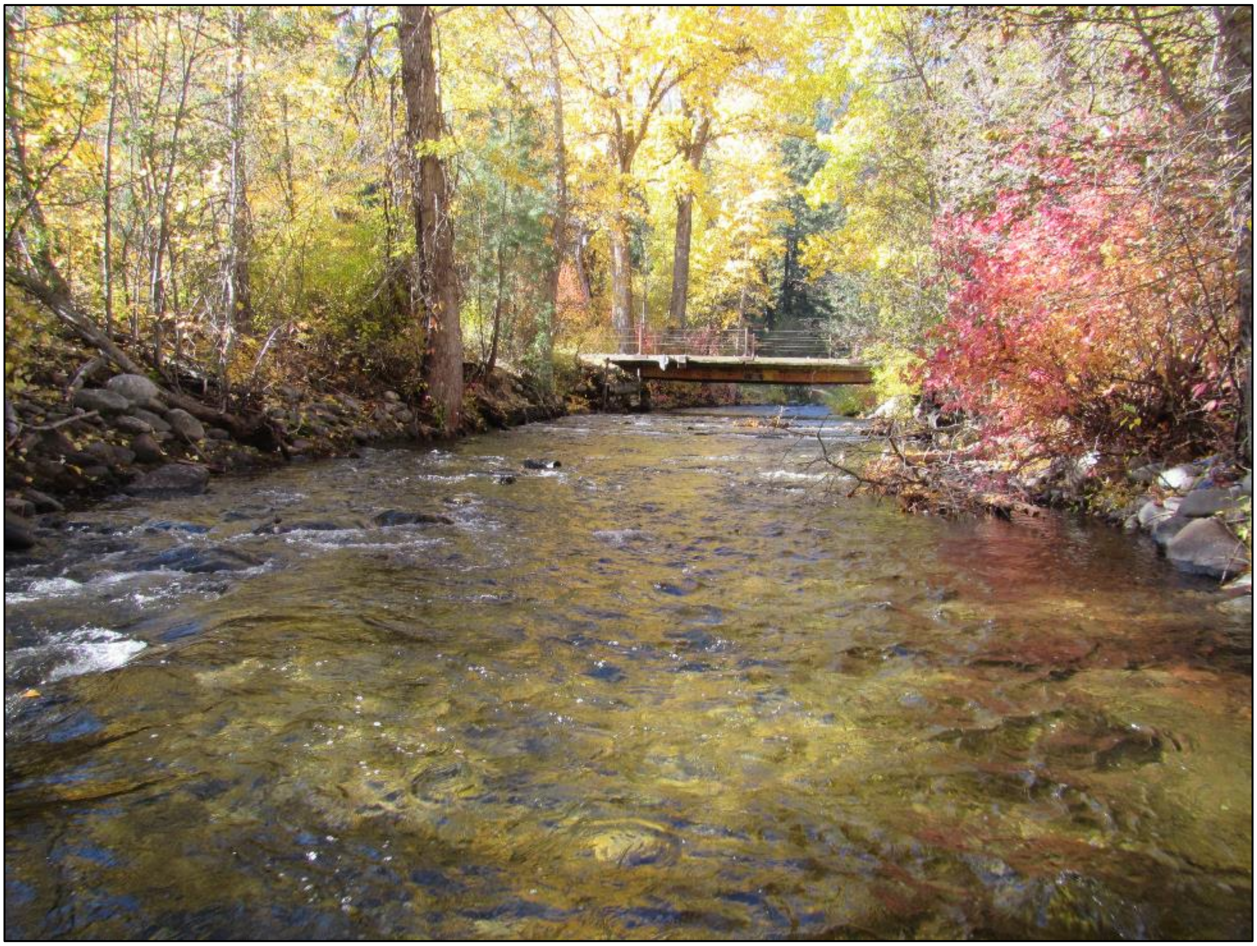


Figure 15. Representative view of Reach 1. Human disturbance within the channel and riparian area are most frequent in this reach. (Photo: IFI staff – 10/24/2017)

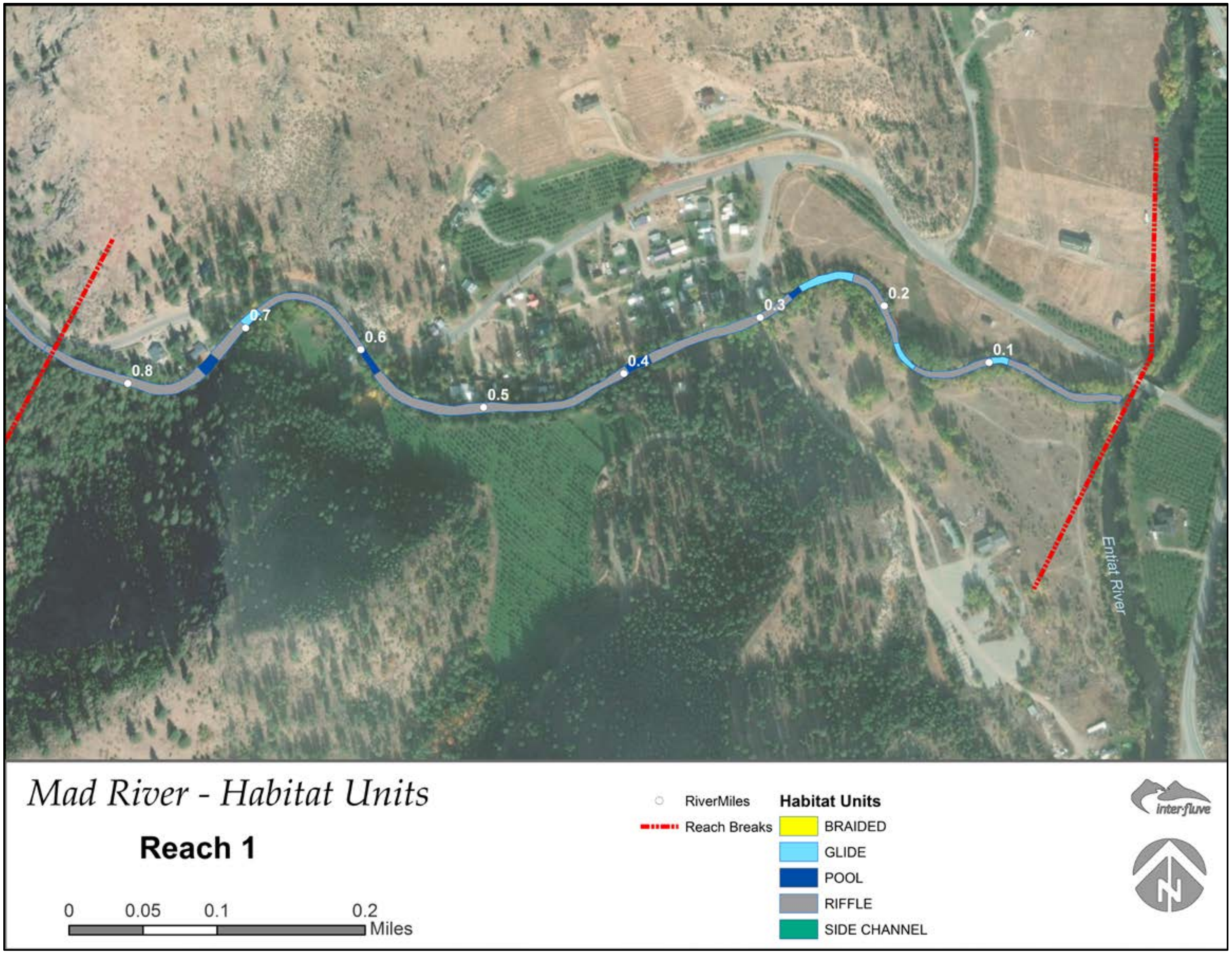


Figure 16. Mad River, Reach 1 -- channel unit distribution (RM 0 – RM 0.86). Basemap: ESRI Bing imagery

4.1.1 Habitat Unit Composition

Reach 1 is the shortest reach delineated in the study area at 0.86 miles. It maintains 84% of habitat area as riffle and the remaining habitat area is glide (9%) and pool (7%) (Figure 16). Reach 1 has the lowest stream gradient (1.54%) among all four reaches. No side channel habitat was observed in Reach 1. The channel is confined by residential land use, levees, bridges, and, at the upstram end, the Mad River Road.

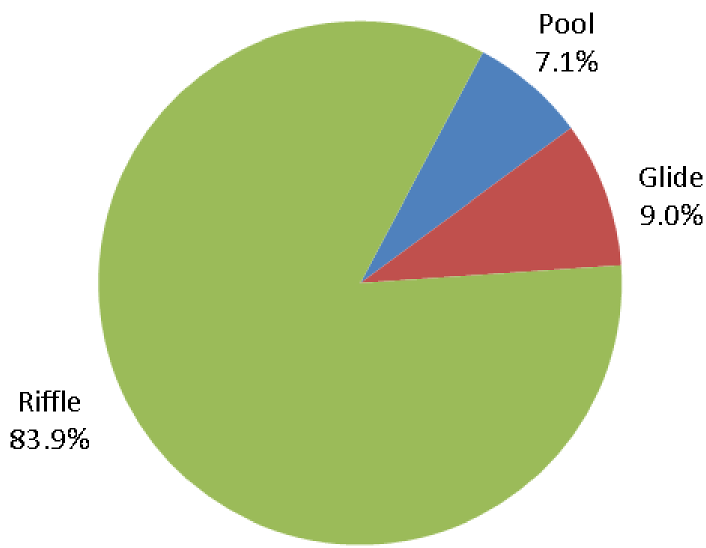


Figure 17. Stream habitat unit area composition of Reach 1.

4.1.2 Pools

Pool was the least common habitat type recorded in Reach 1 with only 7.1% of the habitat unit surface area identified as pools (Figure 17). A total of 4 pools were counted, averaging 4.6 pools per mile. The average pool depth was 3.2 feet with a max of 3.7 feet and minimum of 2.8 feet. Mean pool spacing in Reach 1 was 22 channel widths per pool, compared to an average of 20.3 channel widths per pool for the entire study area. Residual pool depth averaged 2.0 feet. Of the 4 pools identified, all maintained a residual depth of less than 3 feet and zero of the pools had a residual depth of more than three feet.

Figure 18. Pools occur in Reach 1 where large boulders added to the channel result in downstream scour. (Photo: IFI staff – 10/24/2017)

4.1.3 Side Channel Habitat

No side channels were identified in Reach 1.

4.1.4 Large Woody Material

LWM quantities in Reach 1 were the lowest of all four reaches with a total of only 11 pieces of LWM identified, equating to 12.8 pieces of wood per mile. All LWM pieces observed were in the "small" size class. No quality large wood (medium or large size class) was observed in Reach 1. No log jams were observed in Reach 1 (Table 4).

Table 4. Large woody material 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	11	-	-	11
Number of pieces per mile	12.8	-		12.8
Number of jams	-			0
Number of jams per mile	-			0

4.1.5 Substrate & Fine Sediment

A total of two gravel counts were conducted in Reach 1 on exposed depositional bars. The composition of material from the gravel counts combined was primarily gravel (80%) with 18% cobble and 2% sand. This distribution is comparable to the project area average of 78% gravel, 21% cobble, and 1% sand. The cumulative distribution and grain size composition of the gravel counts completed in Reach 1 are provided below in Figure 19 and Table 5. Both the D16 and D50 are slightly smaller than the study area average, but the D84 for Reach 1 is approximately the same as the study area average.

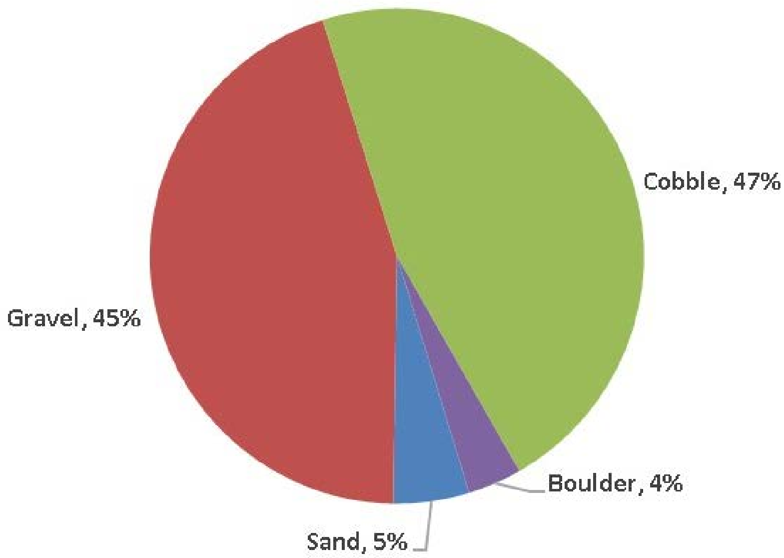
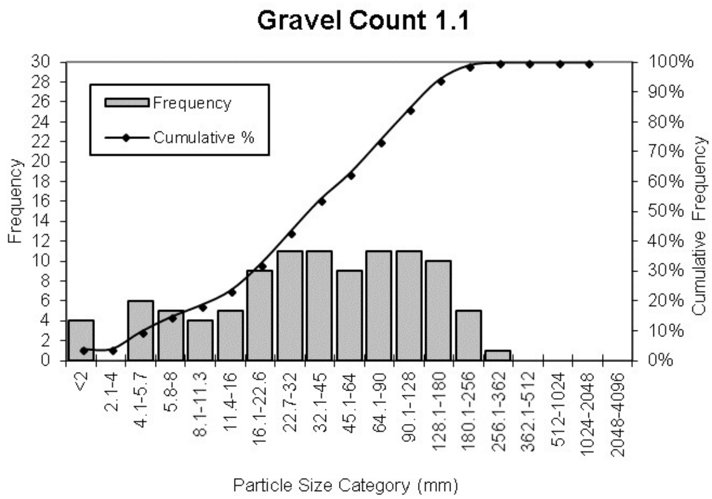


Figure 19. Combined percent composition sediment size type from two gravel counts on exposed bars in Reach 1.



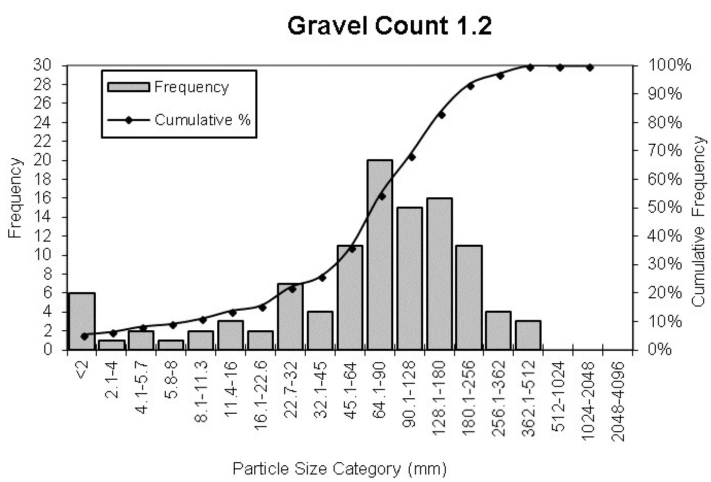


Figure 20. Cumulative grain size distribution for Gravel Count 1.1 and 1.2 (Reach 1).

Table 5. Grain size class for gravel counts 1.1 and 1.2

Size Class	REACH 1	
	GC # 1.1 Size % finer than (mm)	**GC # 1.2** Size % finer than (mm)
D16	21	22
D50	64	50
D84	154	90

4.1.6 Riparian Corridor

Reach 1 involved eight riparian vegetation unit evaluations. Overall, the dominant riparian vegetation class observed was large tree (50%), with the small tree category following at 37% and 13% (only a single unit) with sapling/pole as the dominant overstory vegetation class. Overstory species were a mix of cottonwood (38%), Ponderosa pine (37%), alder (13%) and willow (12%) (Figure 20). In 62% of the measured units, the understory was dominated by shrub/seedling-sized alder (38%), redosier dogwood (12%), and willow (12%). The remainder of the units were classified as a grassland/forb (38%) understory (Figure 21).

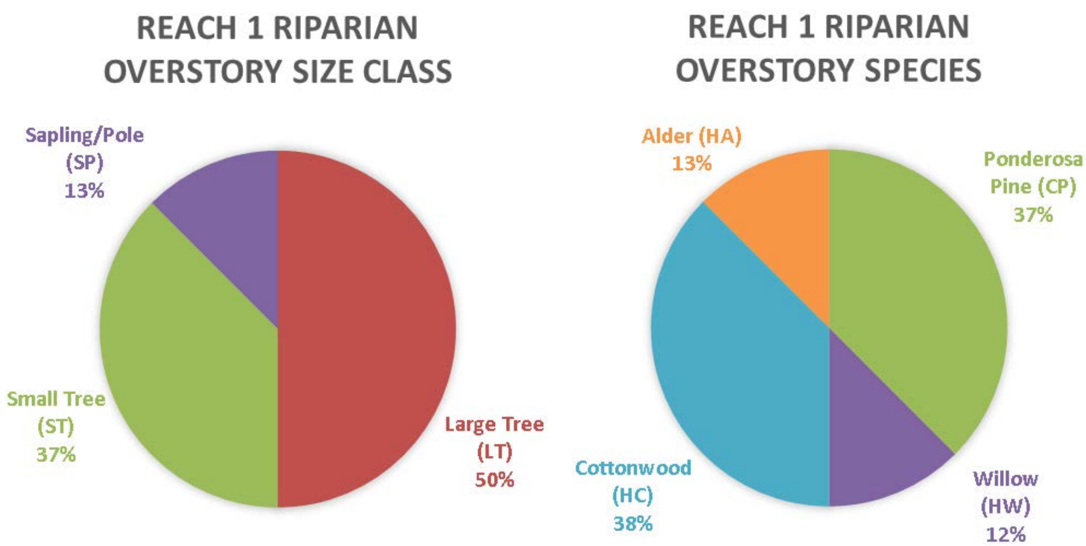


Figure 21. Dominant overstory riparian vegetation class and species identified within 100 feet of Mad River by ocular estimate.

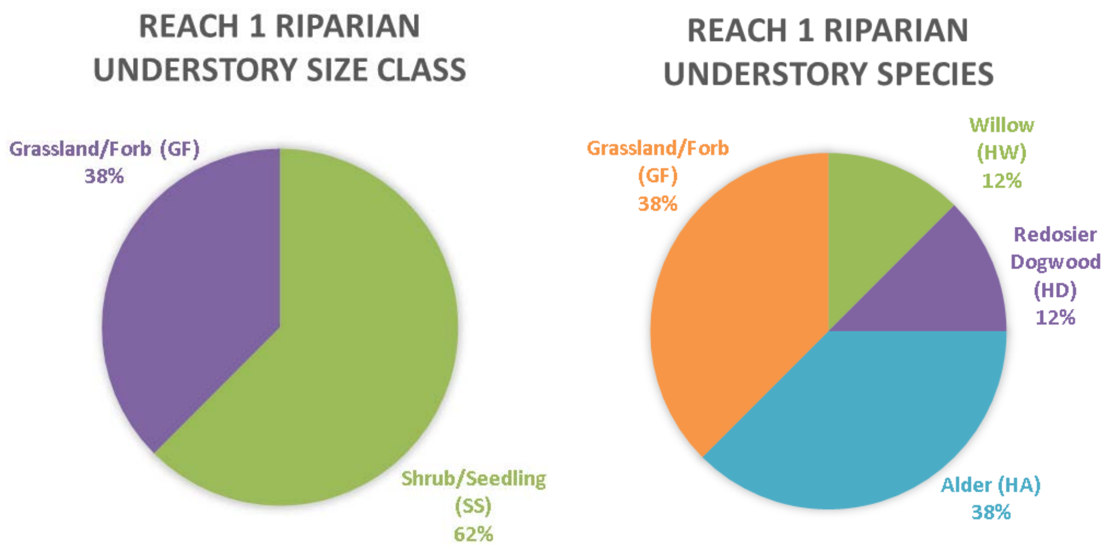


Figure 22. Dominant understory riparian vegetation class and species identified within 100 feet of Mad River by ocular estimate.

4.2 REACH 2

Location: River mile 0.86 – 1.93
Total length: 1.07 miles
Survey Date: October 24, 2017

Figure 23. Representative view of Reach 2. The reach has long riffle/cascades with large boulders present in the channel. (Photo: IFI staff – 10/25/2017)

4.2.1 Habitat Unit Composition

Reach 2 had the greatest proportion of pool habitat of all the reaches, with 8% pool habitat and 79% riffle habitat. The remainder of the habitat area was comprised of glide units (13%) (Figure 24). Reach 2 had the second highest stream gradient at 1.79%, compared to the average gradient across the entire study area 1.83%.

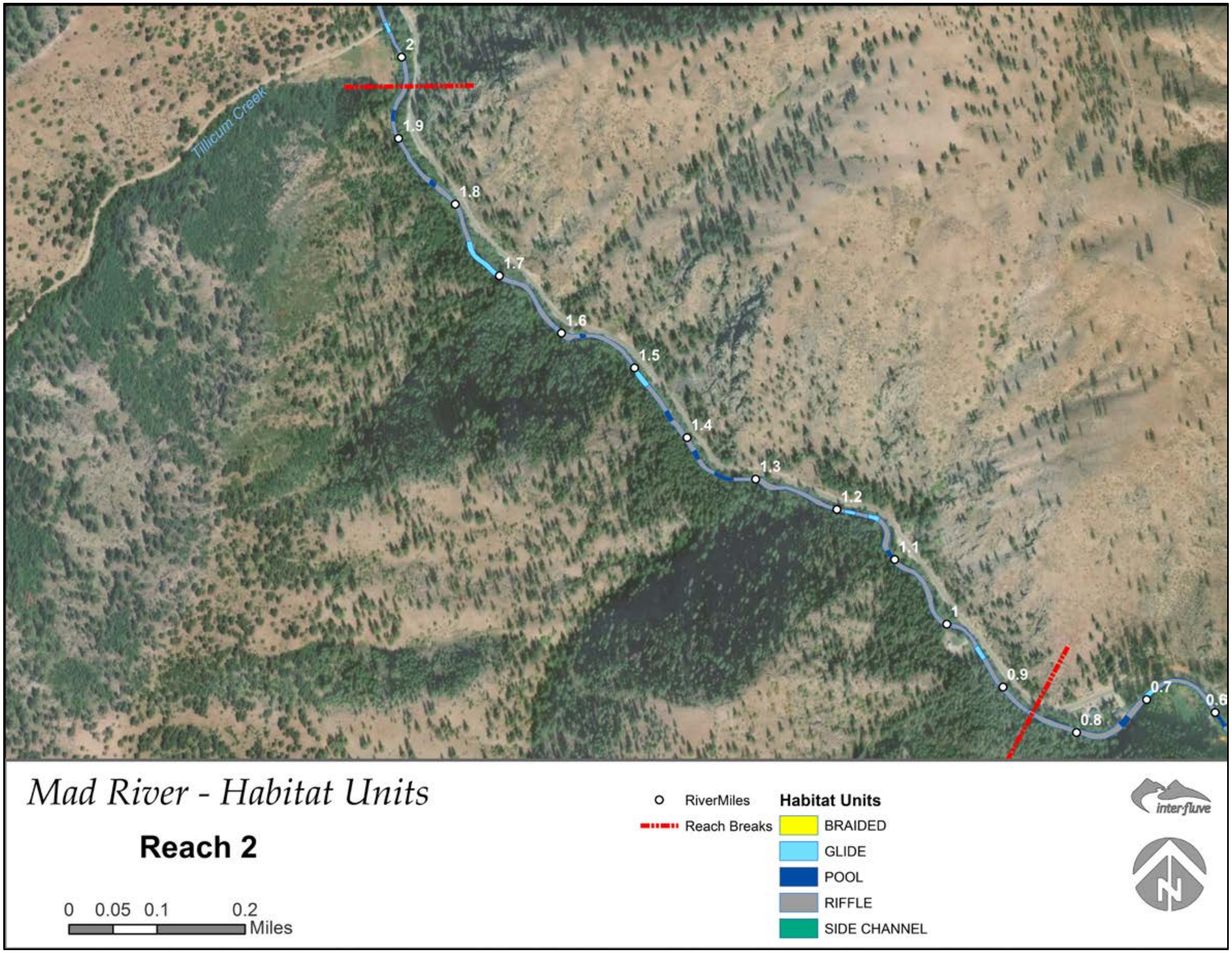


Figure 24. Mad River, Reach 2 - channel unit distribution: RM 0.86 – 1.93. Basemap: ESRI Bing imagery

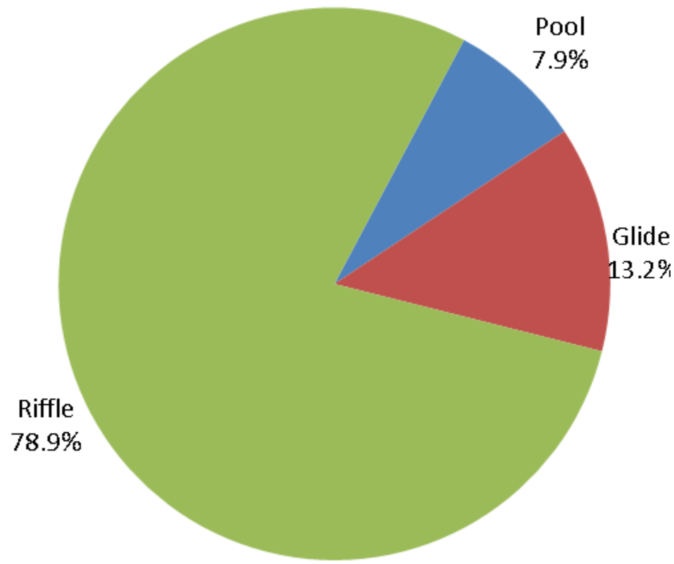


Figure 25. Stream habitat unit composition for Reach 2.

4.2.2 Pools

A total of 8 pools were identified in Reach 2, averaging 7.5 pools per mile. Residual depth of pools ranged from 1.5 feet to 3.5 feet. Of the 8 pools counted, seven (88%) had residual depths less than 3 feet and only one pool (12%) had residual depths greater than 3 feet. Mean pool spacing was 14.2 channel widths per pool, the lowest of all the reaches.

4.2.3 Side Channel Habitat

No side channels were identified in Reach 2.

4.2.4 Large Woody Material

LWM quantities in Reach 2 were the second lowest of all four reaches with a total of 49 pieces of LWM identified, equating to 45.7 pieces of wood per mile (Table 6). Of these 49 pieces, 19 were classified as medium (measuring more than 12 inches diameter and 35 feet in length) and only three pieces were in the large woody material category (greater than 20 inches diameter and at least 35 feet long). This equates to an average of 20.5 pieces of quality LWM per mile. One log jam was observed, consisting of a majority of small pieces (9) and a single large piece of wood.

Table 6. 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	27	19	3	49
Number of pieces per mile	25.2	20.5		45.7
Number of jams	1			1
Number of jams per mile	1			1

4.2.5 Substrate & Fine Sediment

Two gravel counts were conducted in Reach 2 on exposed bars. The composition of material from the combined gravel counts was nearly equal parts gravel and cobble (49% and 45%, respectively; Figure 25). A greater proportion of sand was present in this reach (similarly to Reach 1) compared to the upstream reaches. The cumulative distribution and grain size composition of the gravel counts completed in Reach 2 are provided below in Figure 26 and Table 7. Both the D16 and D50 are approximately the same as the rest of the study area, but the D84 for Reach 2 was the smallest size of all reaches at 108 mm.

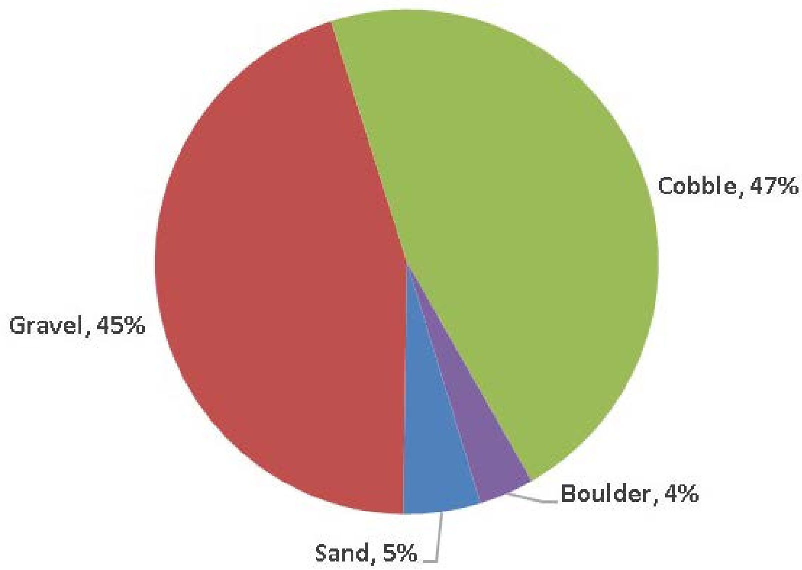
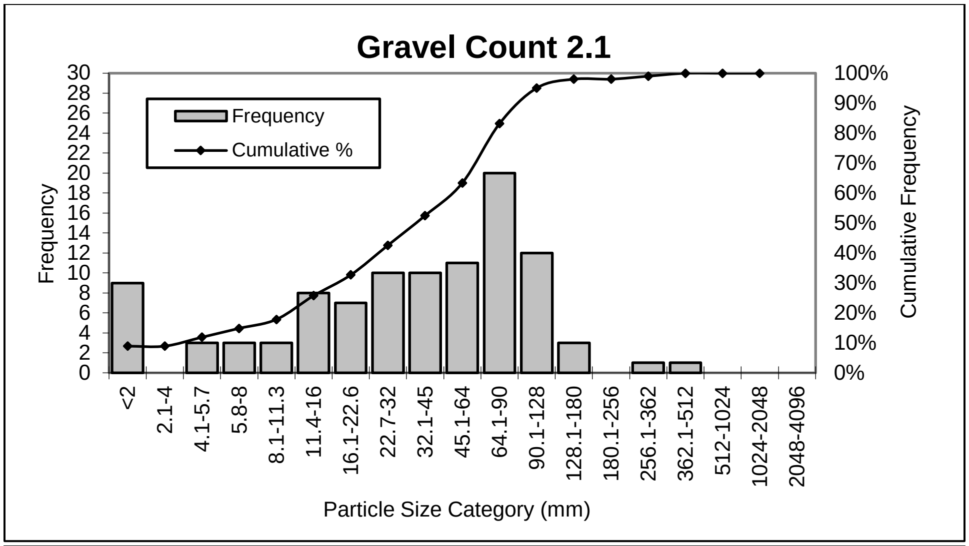


Figure 26. Combined percent composition sediment size type from two gravel counts on exposed bars in Reach 2.



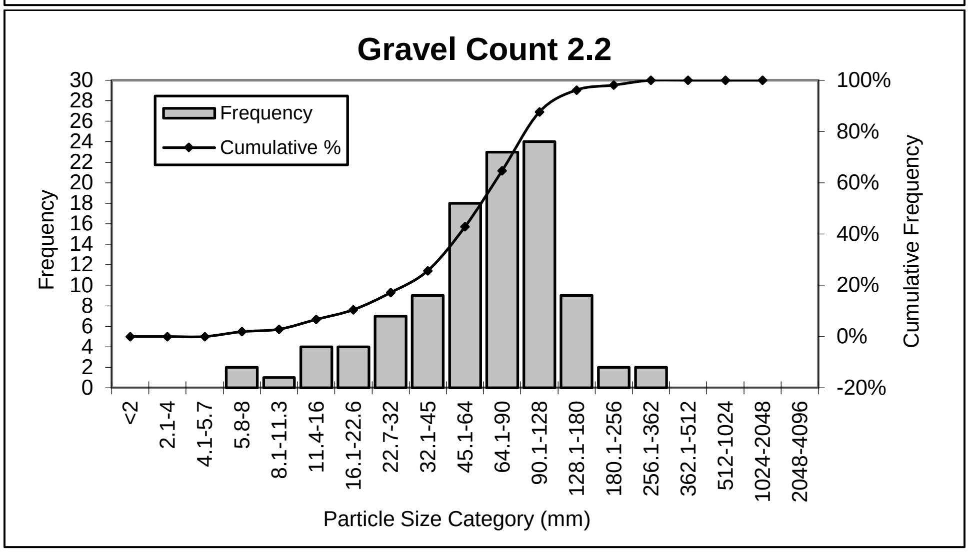


Figure 27. Cumulative grain size distribution for Gravel Count 2.1 and Gravel Count 2.2.

Table 7. Grain size class for Gravel Count 2.1 and 2.2.

Size Class	REACH 2	
	GC # 2.1 Size % finer than (mm)	GC # 2.2 Size % finer than (mm)
D16	9	30
D50	42	72
D84	93	122

4.2.6 Riparian Corridor

A total of 15 n[th] unit measurements were performed in Reach 2. A majority of the riparian vegetation within 100 feet of the river was identified as small trees (67%). The remaining 33% of vegetation was identified as large trees. The overstory species were primarily Douglas fir (67%) followed by 27%

ponderosa pine and 6% cottonwood (Figure 27). The understory was composed primarily of alder (87%) with some redosier dogwood (13%), and predominantly fell within the sapling/pole size class (80%) with some small trees (13%) and shrub/seedlings (7%) (Figure 28).

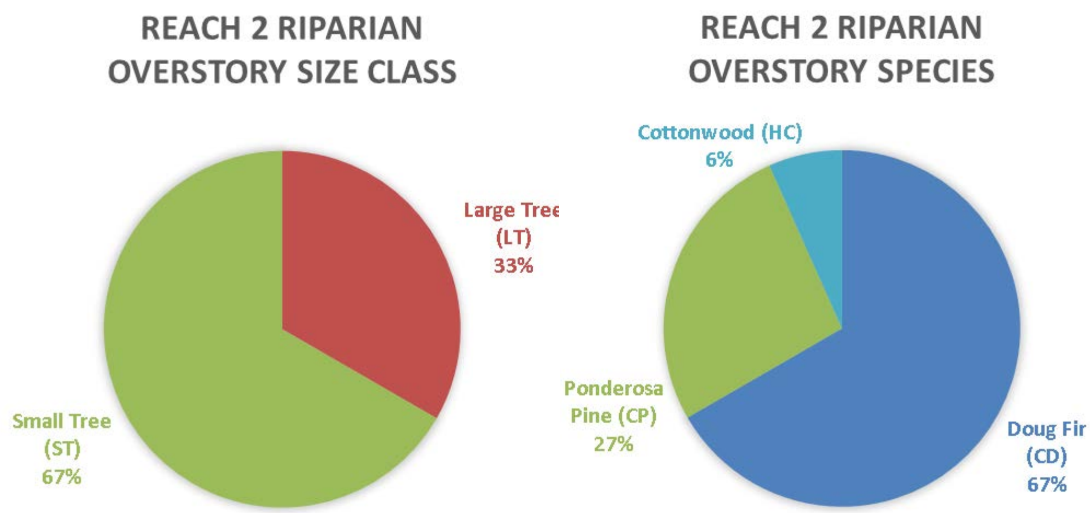


Figure 28. Dominant overstory riparian vegetation size and species identified within 100 feet of Mad River based on n^{th} unit ocular estimates.

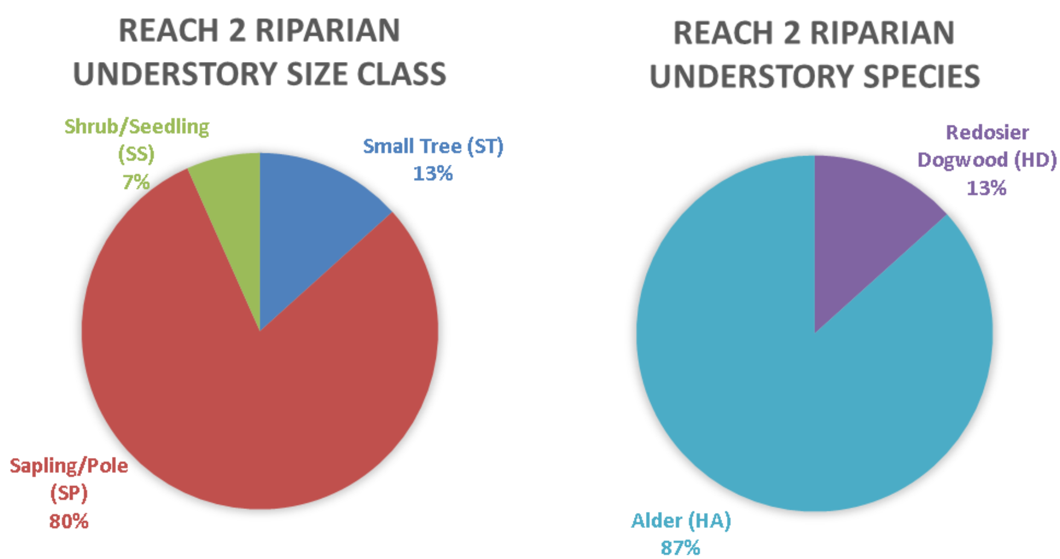


Figure 29. Dominant understory riparian vegetation size and species identified within 100 feet of Mad River based on n^{th} unit ocular estimates.

4.3 REACH 3

Location: River mile 1.93 – 2.98
Total length: 1.05 miles
Survey Date: October 24, 2017

Figure 30. Representative view of Reach 3. (Photo: IFI staff – 10/26/17)

4.3.1 Habitat Unit Composition

Reach 3 is the third longest reach delineated in the study at 1.05 miles long. Nearly all of the Reach 3 habitat area was identified as fast water, either riffles (82%) or glides (17%). Only 1% of the habitat area was identified as pools, the lowest of all reaches (Figure 31). The stream gradient of 2.35% in Reach 3 is the highest within the study area.

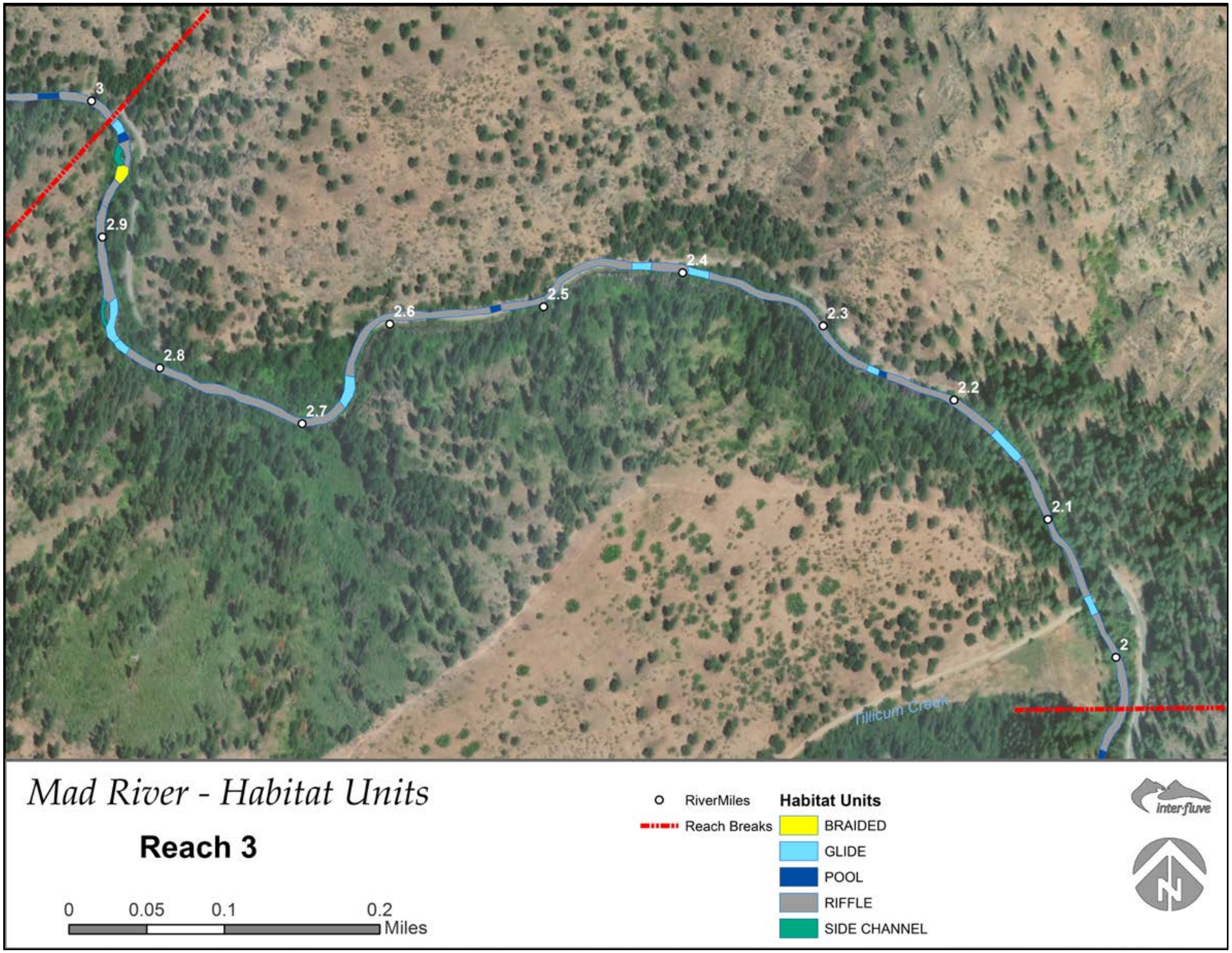


Figure 31. Mad River, Reach 3 -- channel unit distribution: RM 1.93 – 2.98. Basemap: ESRI Bing imagery

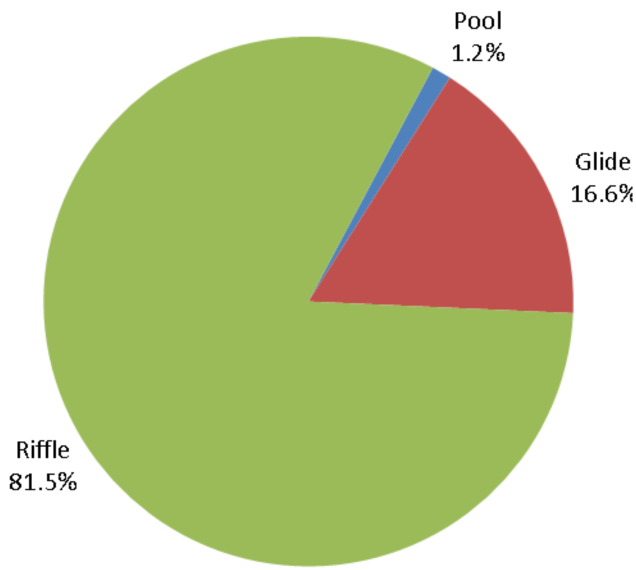


Figure 32. Stream habitat unit composition for Reach 3.

4.3.2 Pools

Reach 3 had a total of 3 pools and a pool frequency of 2.9 pools per mile, compared to an average of 4.9 pools per mile throughout the study area. Mean pool spacing for the reach is 43.4 channel widths per pool with the highest in the project area. Project area average pool spacing is 20.3 channel widths per pool. No pools in this reach maintained residual depths of greater than three feet.

4.3.3 Side Channel Habitat

Side channel habitat in Reach 3 accounted for 1% of the habitat area (Figure 32). Only two side channels were recorded, totaling 164 feet in length (Table 8). One side channel was identified as a slow water unit, while the other was identified as a predominantly fast water unit. Two pieces of medium LWM were observed in the slow side channel and one piece of small LWM in the fast side channel.

Table 8. Secondary channel habitat in Reach 3.

Location	Length (ft)	Dominant unit type	Wood count
SIDES1	83	Slow water	2
SIDEF2	81	Fast water	1
Total	164		3

4.3.4 Large Woody Material

LWM quantities in Reach 3 were the second highest of all four reaches with a total of 89 pieces of LWM identified, equating to 84.8 total pieces of wood per mile (Table 9). Of these 89 pieces, 30 were classified as medium (measuring more than 12 inches diameter and 35 feet in length) and 14 pieces were in the large woody material category (greater than 20 inches diameter and at least 35 feet long). This equates to an average of 36.3 pieces of quality large woody material per mile. No log jams were observed in Reach 3.

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	45	30	14	89
Number of pieces per mile	42.9	41.9		84.8
Number of jams	0			0
Number of jams per mile	0			0

4.3.5 Substrate & Fine Sediment

Two gravel counts were performed in Reach 3 on exposed bars. When the gravel counts are combined, gravel was the dominant substrate (56%) with 40% cobble, 4% boulder, and 1% sand in Reach 3 (Figure 33). The cumulative distribution and grain size composition of the gravel counts completed in Reach 3 are provided below in Figure 34 and Table 10.

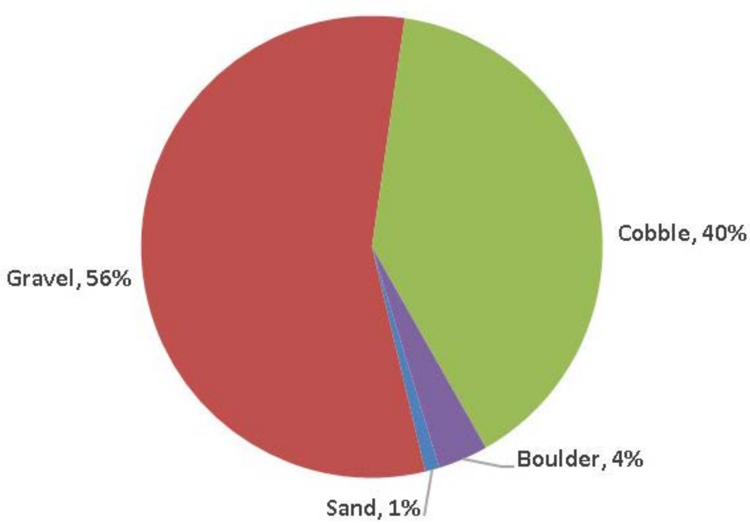
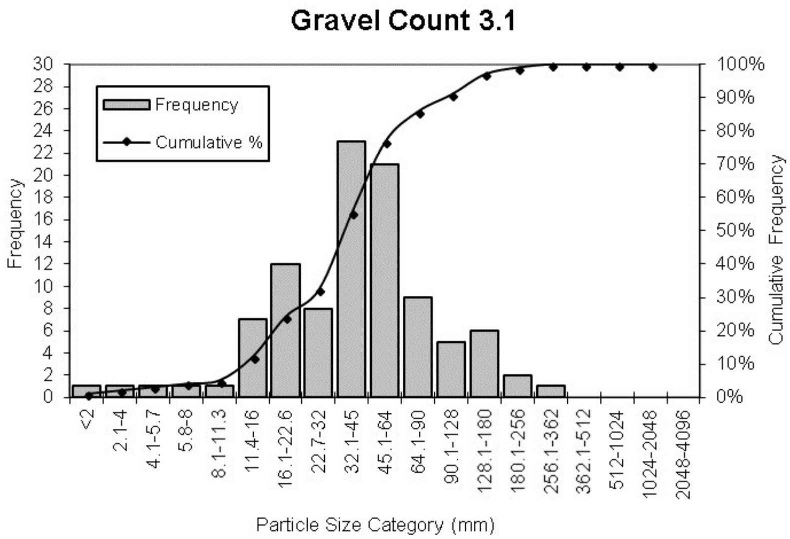


Figure 33. Percent composition of bed substrate based on two gravel counts at exposed bars in Reach 3.



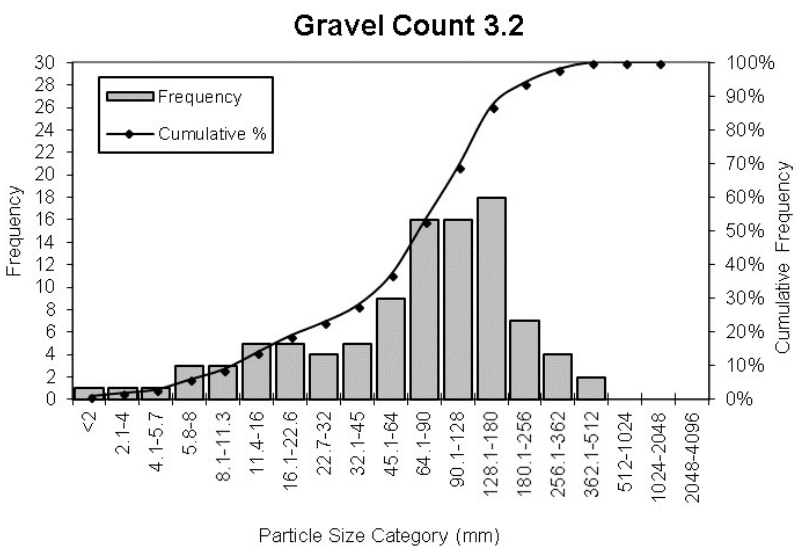


Figure 34. Cumulative grain size distribution for Gravel Count 3.1 and Gravel Count 3.2.

Table 10. Grain size class for Gravel Count 3.1 and 3.2.

Size Class	REACH 3	
	GC # 3.1 Size % finer than (mm)	**GC # 3.2** Size % finer than (mm)
D16	18	19
D50	42	85
D84	87	171

4.3.6 Riparian Corridor

Based on six n^{th} unit measurements, 100% of the riparian vegetation identified within 100 feet of the creek throughout Reach 3 was small tree (9.0 – 20.9 in. diameter). Ponderosa pine was the primary overstory species (67%), with the remaining 33% Douglas fir (Figure 35). The understory was mostly sapling/pole (83%; 5.0 – 8.9 in. diameter), with 17% shrub/seedling (1.0 – 4.9 in. diameter). The understory was dominated by alder (67%). Other species observed included dogwood (17%), and bigleaf maple (16%) (Figure 35).

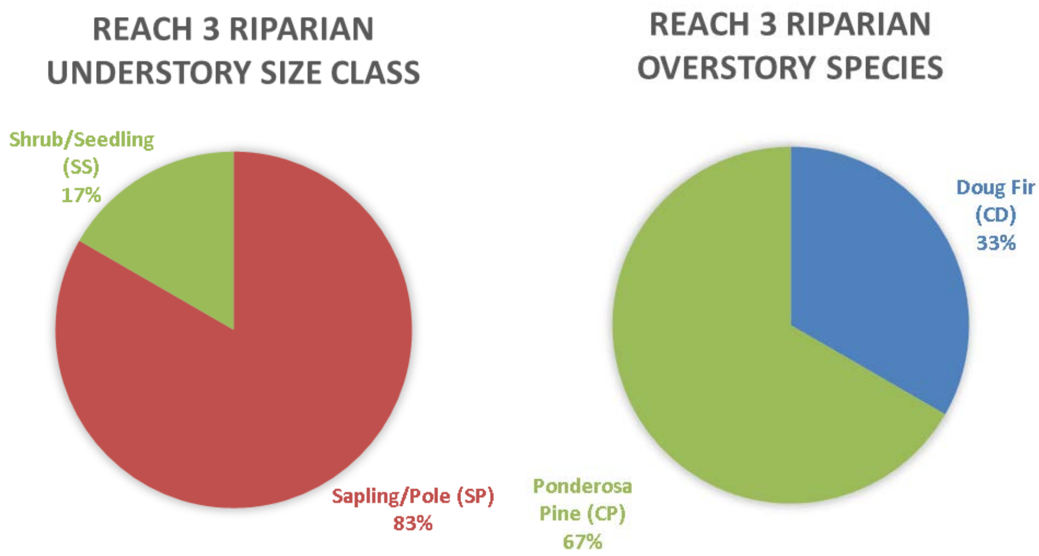


Figure 35. Dominant overstory riparian vegetation size and species identified within 100 feet of Mad River based on n^{th} unit ocular estimates.

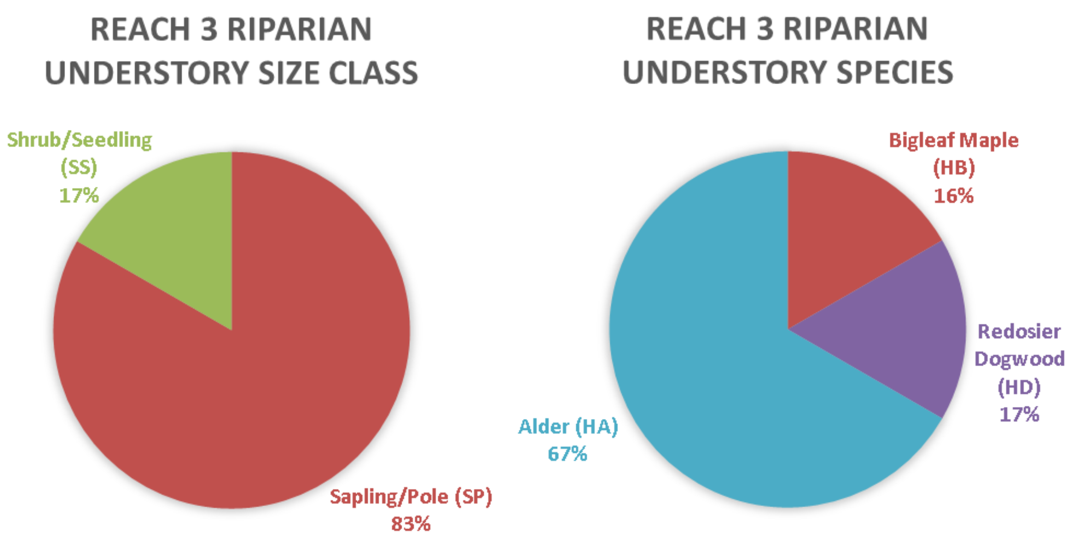


Figure 36. Dominant understory riparian vegetation size and species identified within 100 feet of Mad River based on n^{th} unit ocular estimates.

4.4 REACH 4

Location: River mile 2.98 – 4.3
Total length: 1.32 miles
Survey date: October 25, 2017

Figure 37. Representative view of Reach 4. (Photo: IFI Staff – 10/26/2017)

4.4.1 Habitat Unit Composition

Reach 4, the longest reach in the study area, is 1.32 miles long (Figure 38). This reach was riffle-dominated: composed of 87% riffle, 7% pool, 5% glide, and 1% side channel (Figure 39). Reach 4 has the third steepest gradient in the project area at 1.65%.

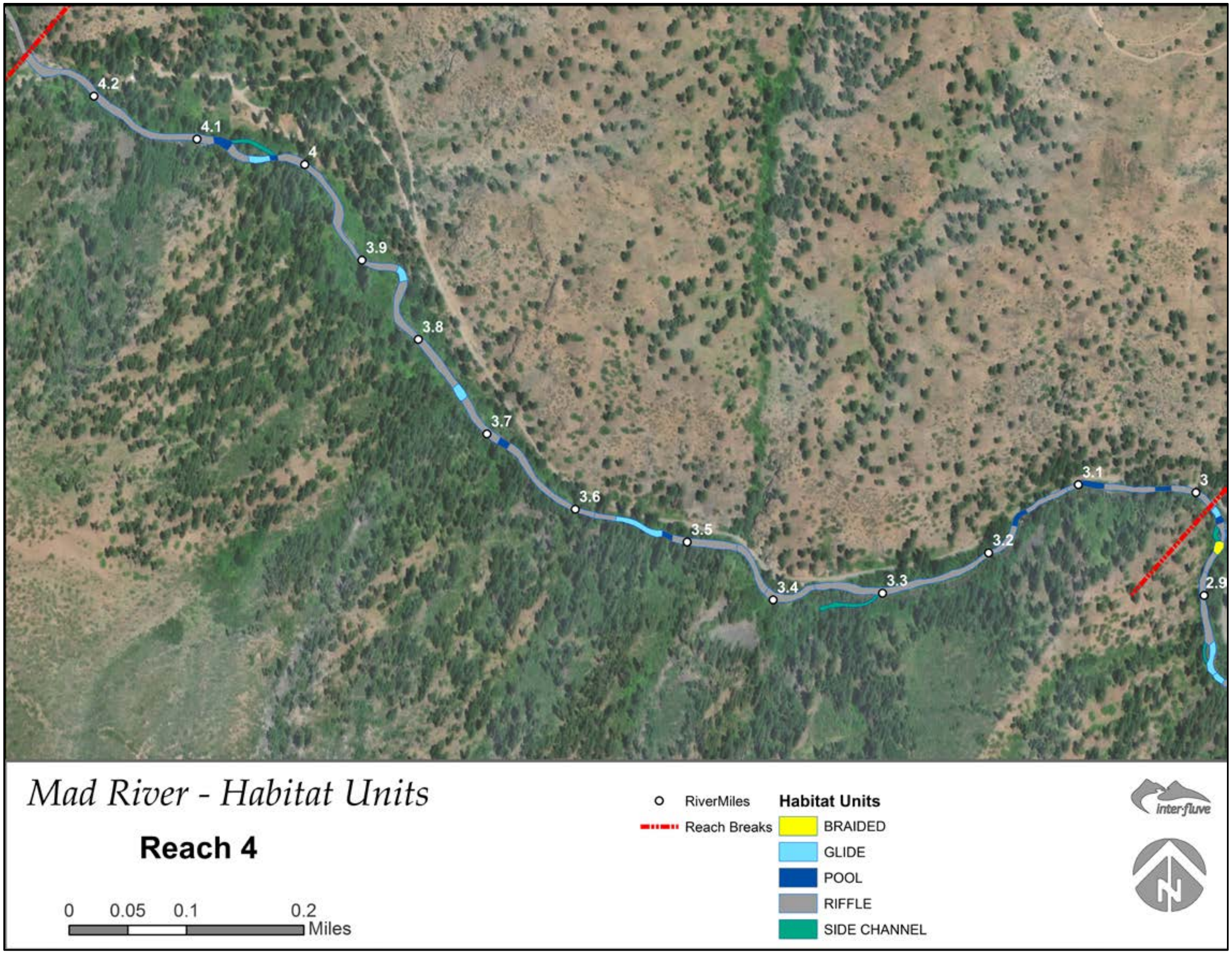


Figure 38. Mad River, Reach 4 -- channel unit distribution: RM 2.98 – 4.3. Basemap: ESRI Bing imagery

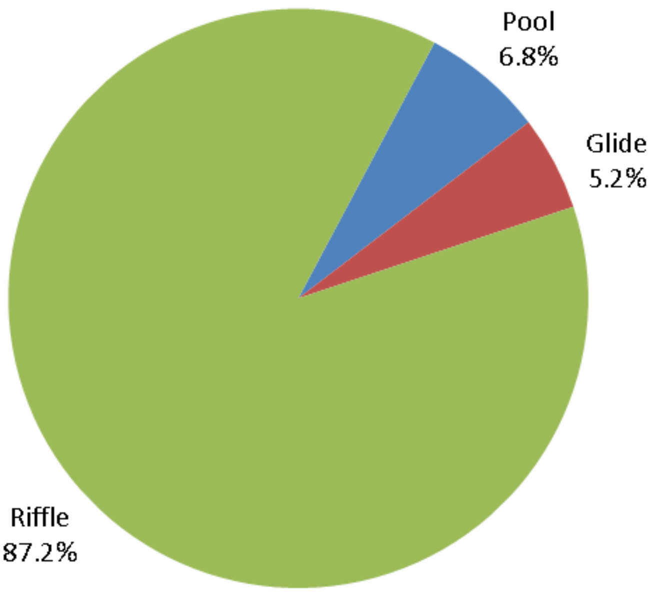


Figure 39. Stream habitat unit composition for Reach 4.

4.4.2 Pools

A total of 7 pools were identified in Reach 4, averaging 5.3 pools per mile. The average residual pool depth was 2.0 feet and mean pool spacing was 16 channel widths per pool, the second lowest mean pool spacing in the project area. Only one of the pools maintained a residual depth of greater than three feet deep.

4.4.3 Side Channel Habitat

Two side channels were identified in Reach 4 (Table 11) comprising less than 1% of the habitat area in the reach. Both of the side channels were identified as slow water units and had a total of 9 pieces of wood: one large piece, two medium pieces, and a majority small pieces.

Table 11. Secondary channel habitat in Reach 4.

Location	Length (ft)	Dominant unit type	Wood count
SIDES3	300	Slow water	7
SIDES4	125	Slow water	2
Total	425		9

4.4.4 Large Woody Material

A total of 137 pieces of LWM were identified in Reach 4, averaging 103.8 pieces per mile. Over half of those 137 pieces were classified as medium (43 pieces measuring more than 12 inches diameter and 35 feet in length) and large (31 pieces greater than 20 inches diameter and at least 35 feet long), two were small pieces and one was medium (Table 12). This equates to an average of 56.1 pieces of quality large woody material per mile. This was the highest wood count of the four reaches in the study area. Three log jams were observed in Reach 4, consisting of approximately one-third each of small (11), medium (15) and large (13) pieces of wood.

Table 12. Large woody material 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	63	43	31	137
Number of pieces per mile	47.7	56.1		103.8
Number of jams	3			3
Number of jams per mile	3			3

4.4.5 Substrate & Fine Sediment

Two gravel counts were performed within Reach 4 at exposed bars. The dominant substrate type observed was gravel (60%) with additional 38% cobble, and 2% boulder (Figure 40). No bedrock or sand were identified in either gravel count. The cumulative distribution and grain size composition of the gravel counts completed in Reach 4 are provided below in Figure 41 and Table 13.

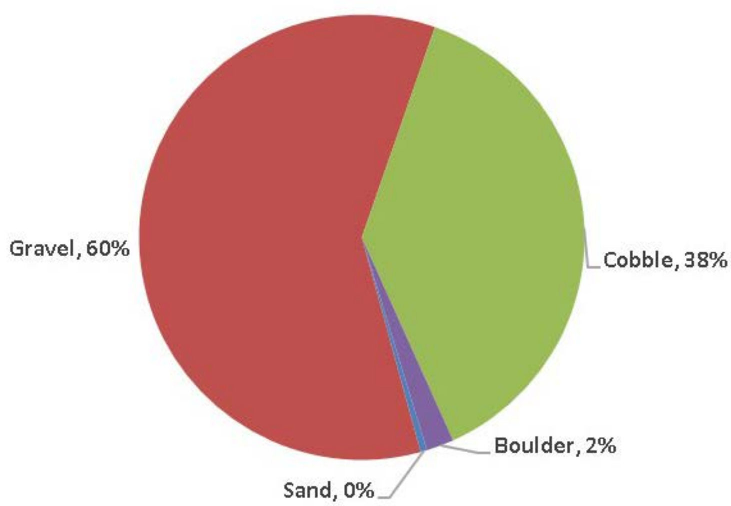
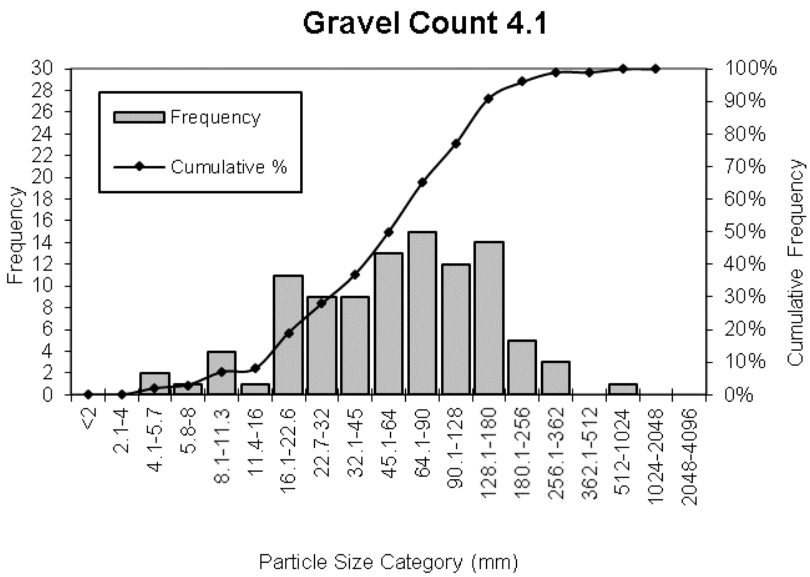


Figure 40. Percent composition of bed substrate based on two gravel counts at exposed bars in Reach 4.



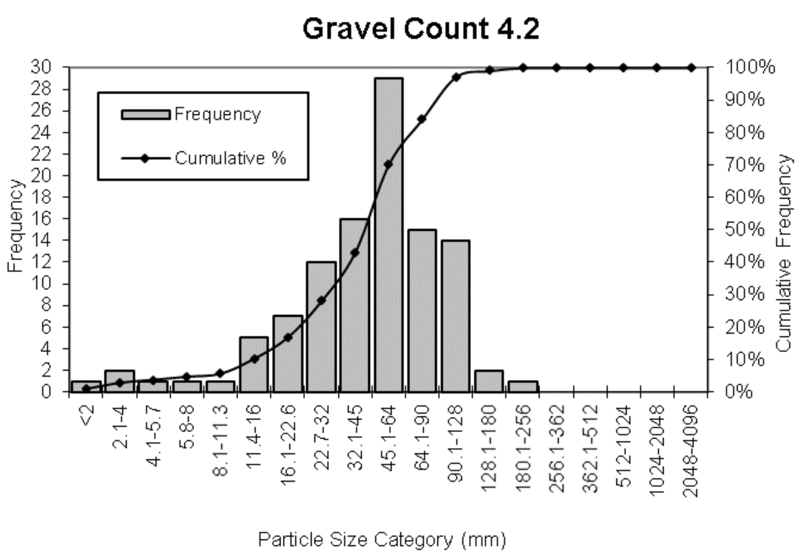


Figure 41. Cumulative grain size distribution for Gravel count 4.1 and Gravel Count 4.2.

Table 13. Grain size class for Gravel Count 4.1 and 4.2.

Size Class	REACH 4	
	GC # 4.1 Size % finer than (mm)	**GC # 4.2** Size % finer than (mm)
D16	21	22
D50	64	50
D84	154	90

4.4.6 Riparian Corridor

Based on seven n^{th} unit measurements, 76% of the riparian vegetation identified within 100 feet of the river in Reach 4 was shrub/seedling (1.0 – 4.9 in. diameter). The remaining vegetation observed was 14% grassland/forb and 10% small tree (5.0 – 8.9 in. diameter) (Figure 41). The understory was dominated by willow (76%) with 10% dogwood, 10% grassland/forbs, and 5% alder. Reach 4 maintained the highest percentage (62%) of no identifiable overstory in the project area. Observed overstory species included alder (29%), and oak (9%). Oak became visible in Reach 4 and prevalent on floodplain and terrace surfaces but oak was rarely the dominant overstory species, especially within the 100-foot riparian buffer.

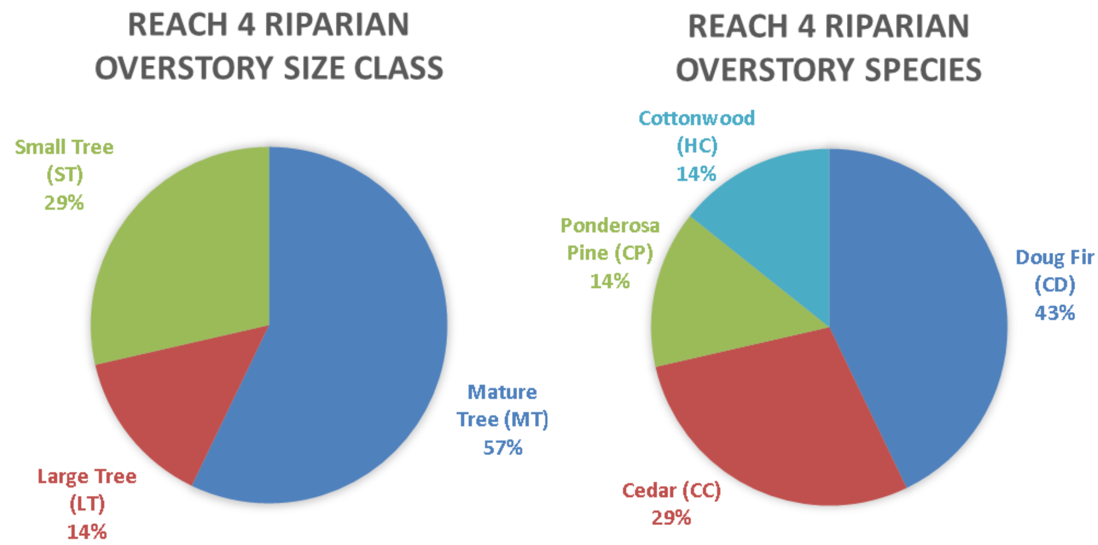


Figure 42. Dominant overstory riparian vegetation size and species identified within 100 feet of Mad River based on n^{th} unit ocular estimates.

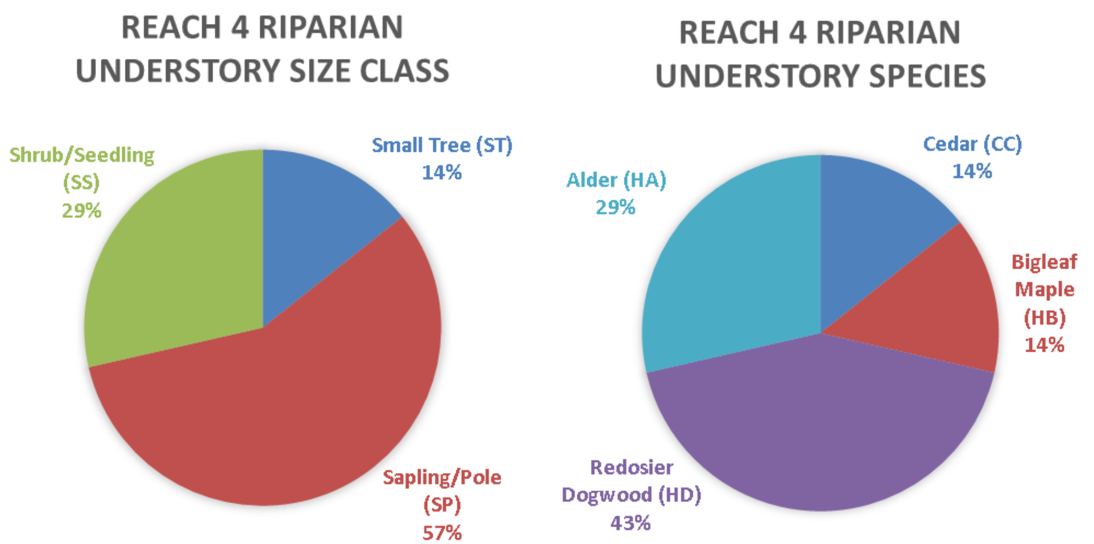


Figure 43. Dominant understory riparian vegetation size and species identified within 100 feet of Mad River based on n^{th} unit ocular estimates.

4.5 SUMMARY DATA

Table 14 provides a list of the data and metrics presented in this habitat assessment for the Mad River (RM 0 – 4.3).

Table 14. Summary of all data collected for Reaches 1-4 of the Mad River Habitat Assessment.

Reach	***1***	***2***	***3***	***4***	***All Reaches***
Reach Mileage boundaries	0 – 0.86	0.86 – 1.93	1.93 – 2.98	2.98 – 4.3	0 – 4.3
Wetted Width (ft)					
Pool					Averages
Mean	30	28.13	25.33	29.43	28.22
Median	30	28.5	26	26	27.63
StDev	7.53	6.03	5.03	10.26	7.21
Glide					
Mean	29.1	30.20	28.22	21.50	27.26
Median	27.75	29	28	21.5	26.56
StDev	4.0	6.61	5.45	5.45	5.38
Riffle					
Mean	29.6	30.20	34.50	28.07	30.60
Median	31	30	34.5	28	30.88
StDev	4.2	7.01	8.04	7.58	6.71
Side Channel					
Mean			9.00	3.50	6.25
Median			9	3.5	6.25
StDev			4.24	0.71	2.47
Water Depth (ft)					
Pool Maximum Depth					Averages
Mean	3.2	3.4	2.7	3.17	3.11
Median	3.15	3.2	2.6	3.00	2.99
StDev	0.5	0.6	0.3	0.8	0.55

Reach	***1***	***2***	***3***	***4***	***All Reaches***
Pool Residual Depth					
Mean	2	2.2	1.3	2.00	1.88
Median	2	2.2	1.3	2.00	1.86
StDev	0.7	0.6	0.2	1.0	0.63
Riffle/Glide Average Depth					
Mean	1.2	1.3	1.2	1.1	1.2
Median	1.2	1.3	1.3	1.1	1.2
StDev	0.3	0.4	0.3	0.3	0.3
Side Channel Average Depth					
Mean			0.65	0.3	0.48
Median			0.65	0.3	0.48
StDev			0.21	0	0.11
Bankfull Characteristics					
Width (ft)					Averages
Mean	41.00	51.33	48.00	52.50	48.2
StDev	3.46	3.56	7.87	0.71	3.9
Average Depth (ft)					
Mean	2.6	2.7	3.7	3.2	3.1
StDev	0.7	1.0	0.9	0.9	0.9
Maximum Depth (ft)					
Mean	0.50	0.76	0.63	1.13	0.8
StDev	0.50	0.76	0.63	1.13	0.8
Width: Depth Ratio					
Mean	15.52	18.79	12.88	16.41	15.90
Floodprone Width					
Mean	137.50	82.50	125.00	85.00	107.50
StDev	83.32	16.66	22.73	21.21	35.98

Reach	***1***	***2***	***3***	***4***	***All Reaches***
Habitat area %					
Pool	7%	8%	1%	7%	6%
Glide	9%	13%	17%	5%	11%
Riffle	84%	79%	82%	87%	83%
Side Channel	0%	0%	1%	1%	0.4%
Pools					
Pools per mile	4.6	7.5	2.9	5.3	4.9
Residual Depth (% of pools)					Average
Pools < 3 ft	100%	88%	100%	86%	93%
Pools 3-6 ft	0%	13%	0%	14%	7%
Riffle:Pool ratio	2	1.9	4	2.1	2.3
Mean Pool Spacing (bankfull channel widths per pool)	21.9	14.2	43.4	16.0	20.3
Large Woody Material					
Total Number Pieces					Total
Total	11	49	89	137	286
Large	0	3	14	31	48
Medium	0	19	30	43	92
Large and Medium	0	22	44	74	140
Small	11	27	45	63	146
Number of Pieces/Mile					Average
Total	12.8	45.7	84.8	103.8	61.8
Large (20 in by 35 ft)	0.0	2.8	13.3	23.5	9.9
Medium (12 in by 35 ft)	0.0	17.7	28.6	32.6	19.7
Large and Medium	0.0	20.5	41.9	56.1	29.6
Small (6 in x 20 ft)	12.8	25.2	42.9	47.7	32.1
Jams					

Reach	***1***	***2***	***3***	***4***	***All Reaches***
Total jams per reach	1	0	0	3	4
Unstable Banks					
Total Unstable Banks (% of total bank)	2.7%	1.5%	4.8%	4.5%	3.4%
Substrate: at exposed bars					
Total					Average
% Sand	5%	4%	1%	0%	3%
% Gravel	45%	49%	56%	60%	52%
% Cobble	47%	45%	40%	38%	42%
% Boulder	4%	2%	4%	2%	3%
% Bedrock	0%	0%	0%	0%	0%
Vegetation (% of sampled units in 100-foot-wide zone averaged between both banks)					
Dominant Overstory Size Class					Average
Mature Tree	0%	0%	0%	57%	14%
Large Tree	50%	33%	0%	14%	24%
Small Tree	38%	67%	100%	29%	58%
Sapling/Pole	13%	0%	0%	0%	3%
Overstory Species Composition					
Doug Fir (CD)	0%	67%	33%	43%	36%
Cedar (CC)	0%	0%	0%	29%	7%
Ponderosa Pine (CP)	38%	27%	67%	14%	36%
Willow (HW)	13%	0%	0%	0%	3%
Cottonwood (HC)	38%	7%	0%	14%	15%
Alder (HA)	13%	0%	0%	0%	3%
Dominant Understory Size Class					
Small Tree (ST)	0%	13%	0%	14%	7%
Sapling/Pole (SP)	0%	80%	83%	57%	55%
Shrub/Seedling (SS)	63%	7%	17%	29%	29%

Reach	***1***	***2***	***3***	***4***	***All Reaches***
Grassland/Forb (GF)	38%	0%	0%	0%	9%
Dominant Understory Species					
Cedar (CC)	0%	0%	0%	14%	4%
Bigleaf Maple (HB)	0%	0%	17%	14%	8%
Willow (HW)	13%	0%	0%	0%	3%
Redosier Dogwood (HD)	13%	13%	17%	43%	21%
Alder (HA)	38%	87%	67%	29%	55%
Grassland/Forb (GF)	38%	0%	0%	0%	9%

5 References

Fox, Martin, and Susan Bolton. 2007. "A Regional and Geomorphic Reference for Quantities and Volumes of Instream Wood in Unmanaged Forested Basins of Washington State." *North American Journal of Fisheries Management* 27 (1): 342–59. doi:10.1577/M05-024.1.

Hamstreet, Charles O. 2010. "SPRING AND SUMMER CHINOOK SALMON SPAWNING GROUND SURVEYS ON THE ENTIAT RIVER." Leavenworth, WA.

Hamstreet, Charles O. 2012. "SPRING AND SUMMER CHINOOK SALMON SPAWNING GROUND SURVEYS ON THE ENTIAT RIVER, 2011." Leavenworth, WA.

Johnsen, Andy, Tom Desgroseillier, Cal Yonce, Brett Kokes, and R.D. Nelle. 2013. "Integrated Status and Effectiveness Monitoring Program-Entiat River Intensively Monitored Watershed Study, 2013." Leavenworth, WA.

Nelson, Mark C. 2013. "Spawning Migrations of Adult Fluvial Bull Trout in the Entiat River 2007 -2013." Leavenworth, WA.

Nelson, Mark C., Barbara Kelly-Ringel, and R. D. Nelle. 2008. "Review of Bull Trout Redd Observations in the Entiat River." Leavenworth, WA.

Peven, Chuck, Bob Rose, Woody Trihey, and Sarah M. Walker. 2004. "Entiat Subbasin Plan."

Potter, Hayley, Tom Desgroseillier, Dan Sulak, and R.D. Nelle. 2015. "Integrated Status and Effectiveness Monitoring Program - Entiat River Intensively Monitored Watershed Study, 2014." Leavenworth, WA.

Potter, Hayley, Tom Desgroseillier, Cal Yonce, Jordan Sanford, and R.D. Nelle. 2013. "Integrated Status and Effectiveness Monitoring Program-Entiat River Intensively Monitored Watershed Study, 2012." Leavenworth, WA.

Rich, Cameron, and Ringel Jayson. 1995. "Mad River 1995 Hankin-Reeves Stream Habitat Survey Report."

Terraqua, Inc. 2017. "Geomorphic Assessment of the Entiat River Watershed."

USBR. 2009. "Entiat Tributary Assessment." Denver, CO.

USBR. 2012. "Lower Entiat Reach Assessment." Boise, ID.

USFS (US Forest Service). 2015. "Stream Inventory Handbook: Level I & II, Pacific Northwest Region. Version 2.15." https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3854765.pdf.

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