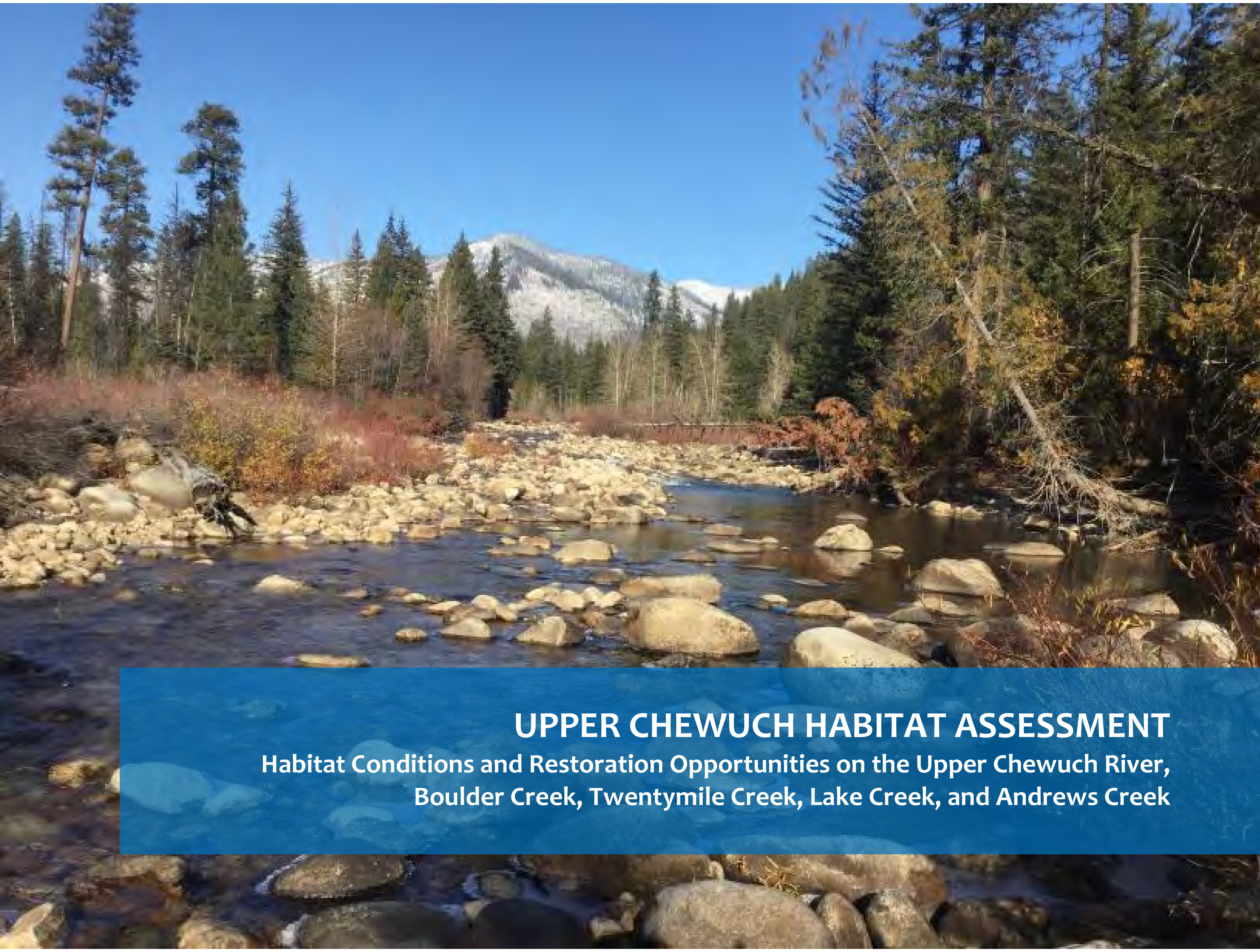

UPPER CHEWUCH HABITAT ASSESSMENT

Habitat Conditions and Restoration Opportunities on the Upper Chewuch River, Boulder Creek, Twentymile Creek, Lake Creek, and Andrews Creek

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1. INTRODUCTION

This report summarizes the evaluation of 11.4 miles of mainstem and tributary habitat in the Upper Chewuch Basin, including information on habitat surveys, a geomorphic assessment, hydrology and hydraulic modeling, and recommendations for additional habitat restoration work. This project is being conducted by the Yakama Nation Fisheries Upper Columbia Habitat Restoration Project (YN UCHRP) to help objectively identify and prioritize targeted riverine restoration projects to benefit federal Endangered Species Act (ESA) listed salmonids, including Chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*O. mykiss*) and bull trout (*Salvelinus confluentus*).

This habitat assessment of the Upper Chewuch River and tributaries continues the work of the Chewuch River Reach assessment on the lower 20 miles of the Chewuch River (Inter-Fluve 2010). The 2010 reach assessment identified restoration projects up to RM 19 that have been implemented over the last nine years in the Chewuch Basin or order to address habitat degradation and ecological concerns. The assessment area of this current report begins upstream of previous habitat assessment from RM 19.0 up to the confluence with Andrews Creek at approximately RM 26. The lower segments of four tributaries are also included in the assessment area: Andrews Creek, Lake Creek, Twentymile Creek and Boulder Creek (which is a tributary to the Lower Chewuch) (Table 1). This assessment area is identified as a priority area for salmon habitat restoration actions in the Regional Technical Team's Upper Columbia Revised Biological Strategy (UCRTT 2017) and the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (UCSRB 2007).

The restoration strategy presented in this report includes a project ranking and evaluation process for potential project areas. This strategy evaluates potential habitat restoration actions based on current habitat conditions, geomorphic restoration potential, feasibility, infrastructure, and social constraints. Current habitat conditions for reach-based ecosystem indicators (REI) are compared with targets to determine the level of function in each reach. To address areas that are not currently functional, potential restoration project areas within reaches are identified, described in detail, and their locations mapped, where possible. Future site-specific analyses will build upon this information to refine potential project areas, evaluate alternatives, and develop detailed designs for implementation.

Table 1. Mileage assessed in the mainstem Chewuch River and Tributaries.

STREAM	RIVERMILES
Andrews Creek	0 – 0.5
Boulder Creek	0 – 1.05
Chewuch River	19.1 – 25.9
Lake Creek	0 – 2.83
Twentymile Creek	0 – 0.69

1.1 Purpose

For the Upper Chewuch River and tributary habitat assessment, the goal was consistent with a previous downstream assessment which included evaluation of current riverine conditions, investigation of ecological concerns limiting salmonid population viability, identification of key habitat restoration and protection opportunities, and evaluation of project alternatives to maximize potential for salmon recovery. A combination of channel unit-level habitat surveys, field geomorphic assessment, and evaluation of hydrologic process forms the basis of information for this restoration strategy. Evaluating existing physical conditions and biological limitations is critical to effective restoration planning and prioritization.

Specific objectives for the assessment include:

1. Evaluate and quantify existing habitat conditions, geomorphic conditions, and anthropogenic degradations throughout the study reach with a focus on the needs of threatened and endangered salmonids.
2. Identify, prioritize, and conceptually develop restoration projects in the study reach that benefit threatened and endangered salmonids.

1.2 Ecological Concerns

This reach is identified in the Regional Technical Team's Biological Strategy (RTT 2017) and the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (UCSRB 2007). The ecological concerns identified for the Upper Chewuch include sediment conditions, riparian conditions (riparian vegetation and LWD recruitment), peripheral and transitional habitat (side channel and wetland construction), and channel structure and form (bed and channel form). The 2007 Recovery Plan identified priorities in the Upper Chewuch assessment unit that include increasing habitat diversity by restoring riparian habitat and reducing sediment input by improving road maintenance. Lower Chewuch ecological concerns include the above as well as water quantity (decreased), food (altered primary productivity or prey species composition and diversity), species interactions (introduced predators and competitors), and habitat quantity (anthropogenic barriers). These concerns are relevant for Boulder Creek and also may affect conditions in upstream reaches.

1.3 Project Organization

This project includes three primary components:

1. **Reach Assessment:** Habitat and geomorphic evaluation based on field surveys and USFS Level II stream inventory (USFS 2012).
2. **REI Analysis**: Analysis of ecological condition of the Upper Chewuch study area using Reach-Based Ecosystem Indicators (REI).
3. **Restoration Strategy:** Science-based restoration opportunity identification targeting recovery of ESA-listed salmonids.

2. STUDY AREA CHARACTERIZATION

The Chewuch River flows on the east side of the Cascade Mountains and is a tributary to the Methow River, entering at RM 51.5. The study area for this assessment includes the Chewuch River from the confluence with Twentymile Creek (RM 19.1) to the confluence with Andrews Creek (RM 25.9), as well as four Chewuch River tributaries: Andrews Creek (RM 0.0 to RM 0.5), Boulder Creek (RM 0.0 to RM 1.05), Lake Creek (RM 0.0 to RM 2.83), and Twentymile Creek (RM 0.0 to RM 0.69). The upper extent of all the tributary surveys is defined by the location of anadromous fish barriers, except for on Lake Creek (on which surveyed reaches extend to the confluence with Disaster Creek) (Figure 1 and Figure 2). The study area was divided into reaches to allow for data organization and to separate sections of streams and rivers that are different in basic habitat characteristics (e.g. gradient, confinement, flow, velocity). Reach breaks for the study area are shown in Figure 3.

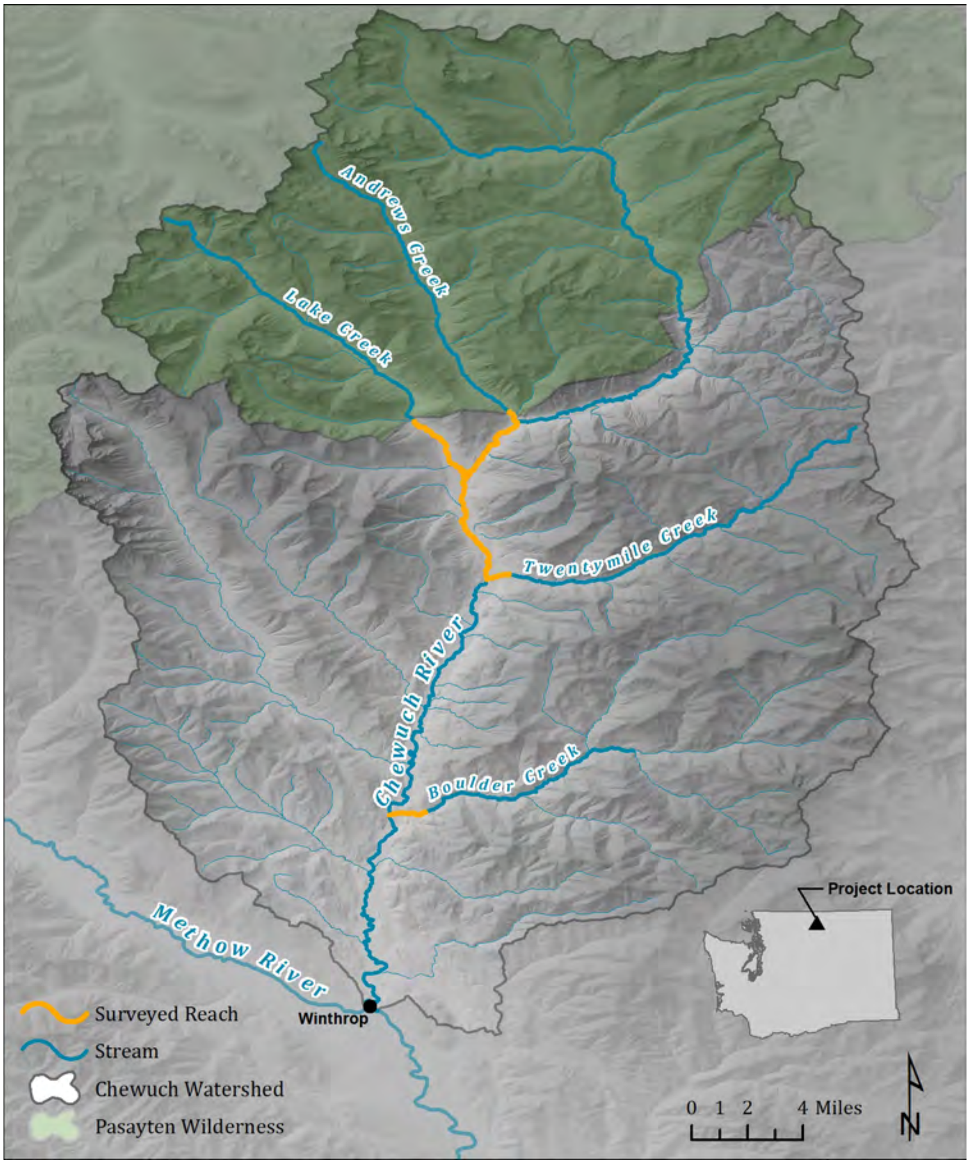

Figure 1. Assessment extent map.

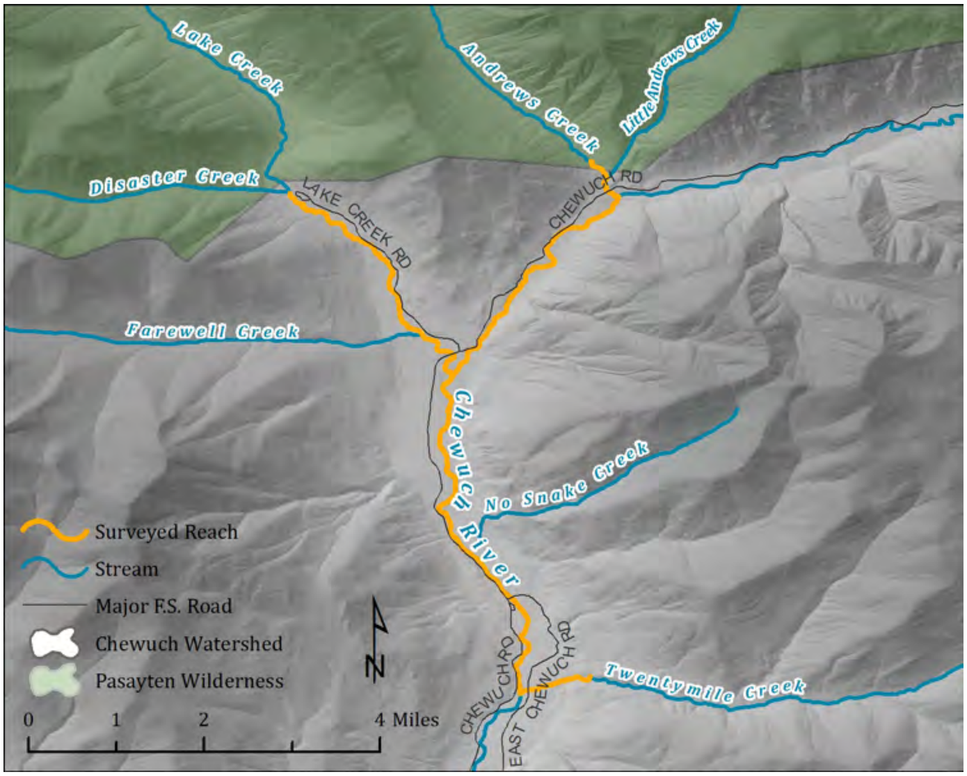

Figure 2. Zoomed in assessment extent map of main assessment area without Boulder Cr.

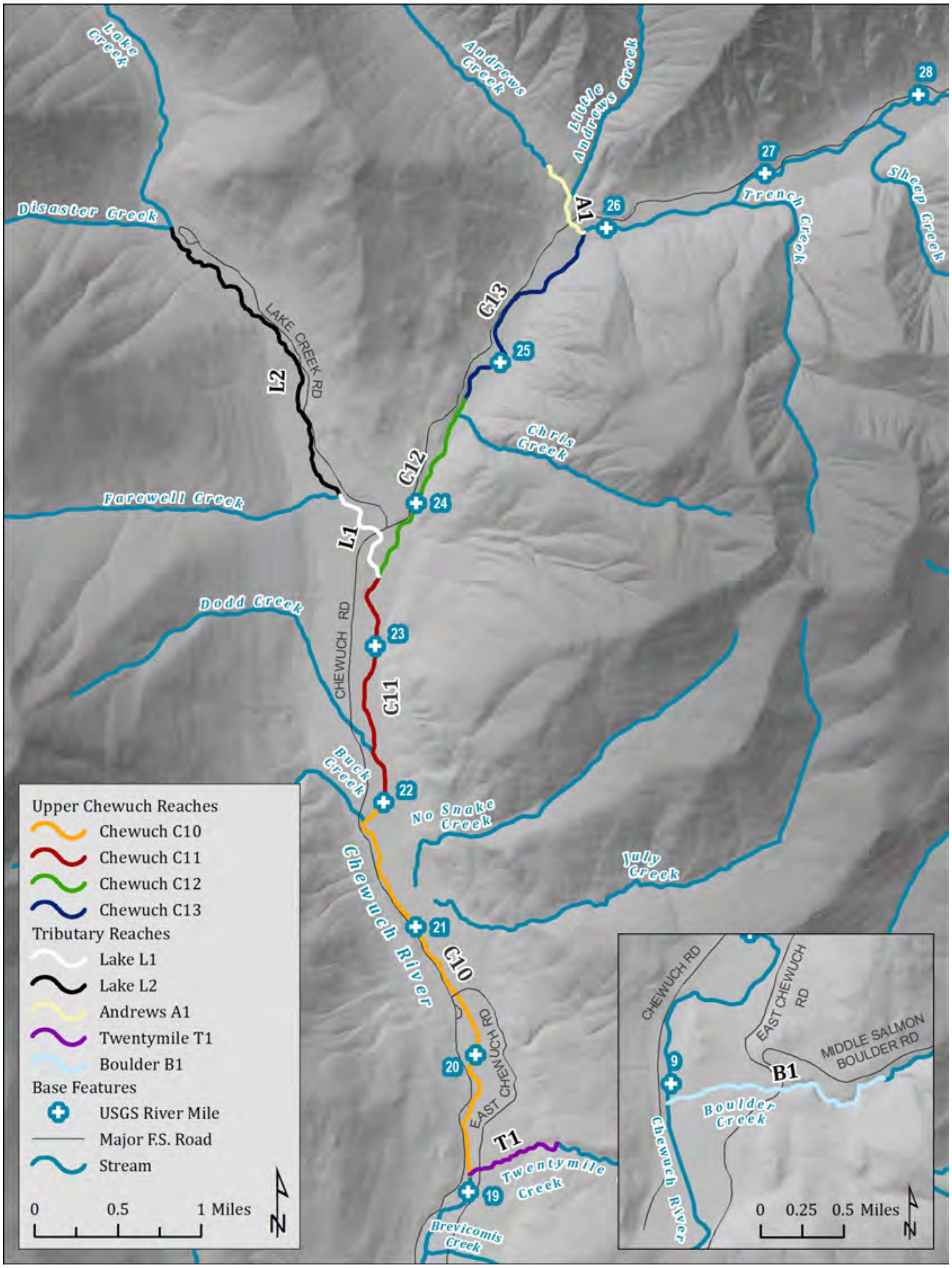

Figure 3. Map of reach breaks used in Habitat Assessment.

This assessment included detailed field evaluation of current riverine habitat and geomorphic conditions throughout the study area. Relevant data, scientific literature, and technical reports were compiled and reviewed to inform this assessment.

The following contains a partial list of previous assessments and reports reviewed for this project:

- Twentymile Creek Fish and Riparian Habitat Assessment Report (IWW 1992)

- Washington State Salmon and Steelhead Stock Inventory (WDFW 1993)
- Andrews Creek Stream Survey Report (USFS 1998a)
- Boulder Creek Stream Survey Report (USFS 1998b)
- Salmon, Steelhead and Bull Trout Habitat Limiting Factors: WRIA 48 (Andonaegui 2000)
- Monitoring Protocols: Effectiveness Monitoring of Physical/Environmental Indicators in Tributary Habitats (Hillman and Giorgi 2002)
- Lake Creek Stream Survey Report (USFS 2003)
- Methow Subbasin Plan (NPCC 2004)
- Chewuch River Stream Survey Report (USFS 2008)
- Methow Subbasin Geomorphic Assessment (USBR 2008)
- Chewuch River Reach Assessment (Inter-Fluve 2010)
- A Biological Strategy to Protect and Restore Salmonid Habitat in the Upper Columbia Region (UCRTT 2017)
- Chewuch River Recreation and Large Wood Assessment (MIG Inc. 2014)
- Chewuch River Mile 9.56 to 13 Recreational Use Assessments (Jonason 2012)
- USFS Chewuch Transportation Plan Map (2018)

The study area characterization includes information on setting and climate, geology and glacial history, human disturbance history, wildfires, water quantity and quality, fish use population status, and ecological concerns.

2.1 Project Setting

The Chewuch River runs southerly through a glacially-carved valley from the eastern Cascade Mountains to its confluence with the Methow River in Winthrop, Washington. The Chewuch River watershed (including hydrologic unit code [HUC] 1702000804: Lower Chewuch River and HUC 1702000803: Upper Chewuch River) occupies 525 square miles within the Methow River Basin (HUC 17020008) and water resource inventory area (WRIA) 48. It is the largest watershed within the Methow River Basin (NPCC 2004). The United States Forest Service (USFS) manages about 95% of the watershed, and 34% of the watershed is within the Pasayten Wilderness (USBR 2008) (Figure 4). USFS management begins at river mile (RM) 9.1; lands downstream of RM 13.5 along the Chewuch River are mostly privately owned except for five WDFW parcels between RM 2 and 14.2. This habitat assessment was conducted exclusively on USFS lands, including the mainstem Chewuch River from RM 19.1 to RM 25.7, major tributaries feeding into that section of the mainstem, and Boulder Creek (which enters the Chewuch River at RM 8.9).

The vegetative communities within the Chewuch watershed vary significantly in response to temperature, precipitation, soil characteristics, disturbance regimen and hydrology. In addition to this relatively continuous variation in plant communities as a function of environmental factors, riparian valley bottoms vary systematically from the rest of the watershed. The riparian zone in the lowest extent of the watershed is highly modified by private land ownership, but is generally characterized by associations from the black cottonwood *(Populus trichocarpa)* series as described by Kovalchik and Clausnitzer (2004) with a significant component of ponderosa pine *(Pinus ponderosa)*. As valley width diminishes and stream gradient increases moving upstream, the cottonwood community gradually gives way to a Douglas-fir *(Pseudotsuga menziesii)*/ common snowberry *(Symphoricarpus albus)* association with an abundance of red osier dogwood (*Cornus sericea*) in the understory and continued presence of ponderosa pine in the canopy (Kovalchik and Clausnitzer, 2004). This general community type dominates all of the reaches surveyed in this assessment.

Upstream of the surveyed reaches, the alluvial floodplain becomes drastically reduced and the riparian forests can be more appropriately characterized by the hillslope community associations described by Lillybridge et al. (1995). These hillslope community associations also characterize all of the upland forests of the watershed.

The elevational range of the Chewuch watershed encompasses nearly the entire range of elevation found within the greater Okanogan National Forest. As a result, nearly all of the coniferous tree diversity of the National Forest can likely be found within the watershed (Lillybridge et al., 1995). At the lowest and warmest elevations in the watershed, conditions are too warm and dry for trees and a scrub-shrub community dominates uplands. Upon reaching elevations of ~2,500 – 3,000 ft., ponderosa pine becomes dominant followed by a transition through Douglas-Fir, western larch (*Larix occidentalis*), subalpine fir (*Abies lasiocarpa*), Engleman spruce (*Picea engelmannii*) which reaches timberline where whitebark pine (*Pinus albicaulis*) and mountain hemlock (*Tsuga mertensiana*) can be found (Gaines et al. 2010). Within this general trend, significant variability can be expected based on available soil moisture, soil composition, aspect, slope angle, slope position, frost frequency, disturbance history and interspecific biological interaction.

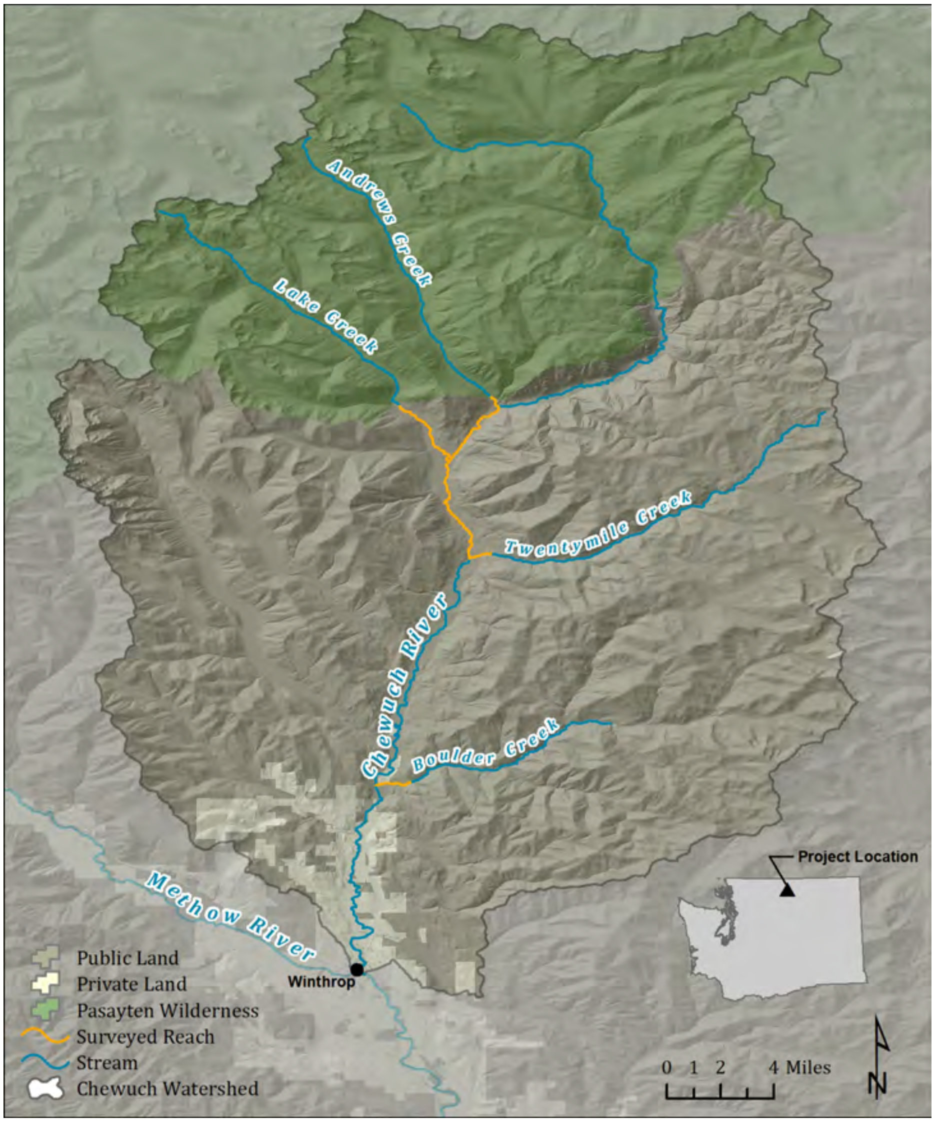

Figure 4. Landownership in the Chewuch Watershed.

2.2 Climate

Annual precipitation in the Chewuch River drainage ranges from about 35 inches in the upper reaches of the watershed and about 15 inches at the confluence with the Methow River (Andonaegui 2000). Annual Chewuch River flows are characteristic of a snowmelt-dominated hydrologic system. Streamflow is typically low at the beginning of the water year (October 1) and remains low through the winter as cold temperatures force precipitation to fall as snow. Flows are maintained at a consistent rate over the winter by groundwater and limited snowmelt. Streamflow begins to increase dramatically as temperatures rise in April and snowpack begins to melt, with a peak in late May and early June. Then flows slowly descend over the summer due to loss of snowpack, seasonal drought, and higher air temperatures. It is expected that global climate change will spur several shifts in Chewuch River hydrology due to warmer annual average temperatures and reduced snowpack, including lower summer flows, more winter high flow events, and earlier peak flows in the spring (Beechie 2013).

Stream temperatures are projected to rise in the Chewuch Watershed, which will degrade water quality for temperature sensitive fishes including salmonids and lamprey (Gaines et al 2012, Mantua et al 2010). Snowpack is also anticipated to decrease, which will fundamentally alter the hydrology of the watershed, shifting it from a snowmelt driven hydrologic regime towards a rain driven regime. With less available snow pack, summer stream temperatures will rise and there will be less available water to support summer flows, degrading both water quality and quantity.

Additionally, restoration planners should consider the impacts of anthropogenic climate change on restoration needs and effectiveness. Beechie et al. (2013) estimated that summer base flows will decrease, winter flood events will become more common, and stream temperatures will increase between 2 and 6°C across the Pacific Northwest by 2070-2099. Anthropogenic climate change is likely to decrease water quantity and quality across the east slope of the Cascade Mountains, especially in the hot summer season (Beechie et al. 2013). Hydrologic regimes across the Columbia River Basin will increasingly be dominated by rainfall rather than snowmelt (Figure 5). This will place extreme challenges on Chinook and steelhead populations already limited by altered hydrology and degraded water quality. Beechie et al. (2013) also found that restoring floodplain connectivity, restoring stream flow regimes, and re-aggrading incised channels will most likely ameliorate climate change and increase salmonid population resilience over the long term. In contrast, restoration actions focused solely on instream habitat rehabilitation are less likely to ameliorate for climate change effects. Thermal refugia and high flow refugia, which are characteristic of dynamic river systems with high floodplain connectivity, will likely become especially important habitat features in the face of climate change.

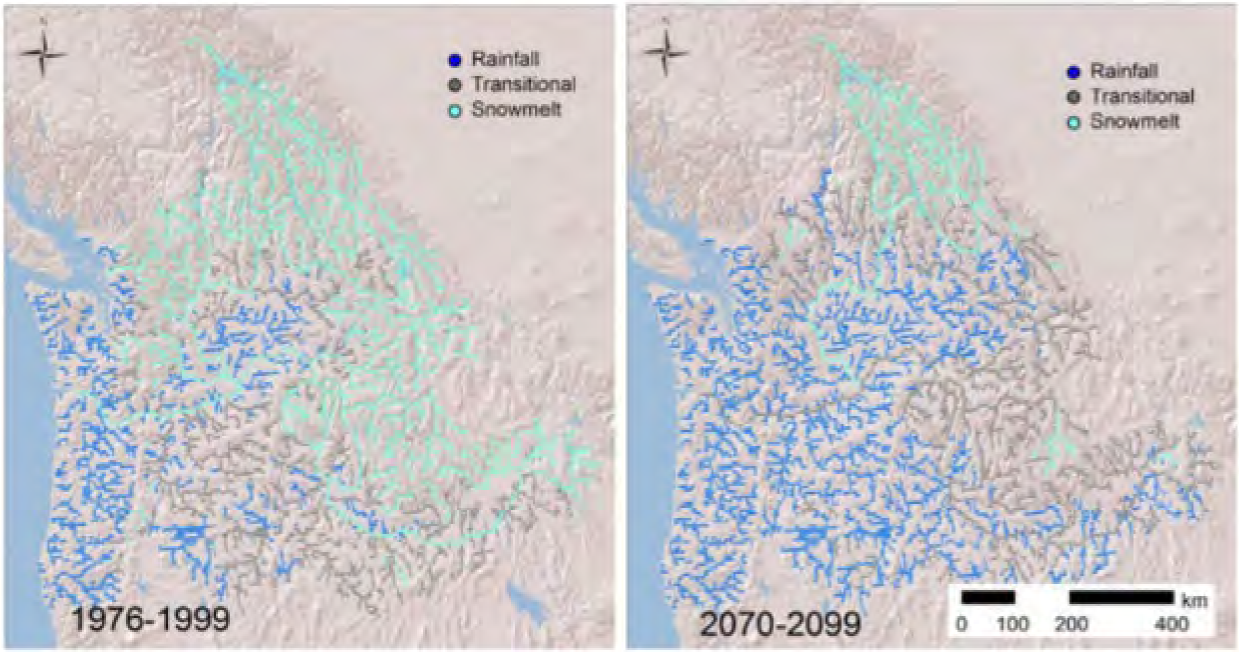

Figure 5. Modeled hydrologic regimes of the Columbia River Basin over time (from Beechie et. al 2013). The transition from snowmelt-dominated to rainfall-dominated hydrologic regimes across the region will have significant impacts on the long-term viability of salmonid populations.

2.3 Geology

The Chewuch River watershed is geographically diverse, with elevations ranging from nearly 8,700 feet in the Pasayten Wilderness down to about 1,700 feet at the confluence with the Methow River in Winthrop. The mainstem Chewuch River flows through a U-shaped, glacially-carved valley surrounded by rugged, mountainous terrain. Intensely steep slopes are common, often with grades above 60-70% (Andonaegui 2000, NPCC 2004). Major peaks in the Chewuch River drainage include Remmel Mountain (8,685 feet), Cathedral Peak (8,601 feet), Windy Peak (8,331 feet), and Andrew Peak (8,301 feet). Fish passage is blocked at varying points on many tributaries of the Chewuch River by steep chutes and waterfalls.

The bedrock geology of the upper Chewuch River is included in the Okanogan Complex primarily composed of Cretaceous and Jurassic intrusive granites, with a highly metamorphosed unit trending northwest-southeast across the upper limits of the project reach (Stoffel and McGroder 1990). The Tiffany Mountain gneiss extends from North Twentymile Peak across the Chewuch River between RM 26 – 32, and extends toward the northwest forming the ridge between Andrews Creek and the Upper Chewuch River. This same unit extends southwest of North Twentymile Peak crossing the Twentymile and Boulder Creek watersheds (Stoffel and McGroder 1990). Channels crossing this geologic unit are preferentially oriented to the folding axis of the gneiss, trending northeast-southwest. The intrusive Cathedral Batholith (Geologic Units Kiqmc and Kigdc, Figure 6) underlies the northeastern upper watershed, consisting of varying mineralogy of granites that are upstream of the project reach (Stoffel and McGroder 1990). Much of the bedrock underlying the project reach is the Trondhjemite of Doe Mountain (Geologic Unit KJitd, Figure 6), an intrusive tonalite forming 2 domes centered in the upper Lake Creek watershed and west of the Chewuch River/Twentymile Creek confluence. This same unit outcrops on the eastern side of the Chewuch valley between Junior and Spring Creeks (Chewuch RM 14 and 17).

Quaternary alluvium (Qa) overlies the Chewuch valley bottom downstream of RM 31, and extends approximately 1.4 miles up Lake Creek valley (Stoffel and McGroder 1990) (Figure 6). Older alluvial deposits differentiated by relative height above the valley floor are present along the valley margins downstream of Dodd Creek, primarily on the western side of the valley. The lower portion of Boulder Creek through the alluvial fan is mapped as Older alluvium (Qoa) (Stoffel and McGroder 1990). Remnant Pleistocene glacial drift deposits are found in tributaries draining the valley walls downstream of Twentymile Creek, and 2 mass wasting deposits are identified in Honeymoon Creek (tributary to Twentymile Creek).

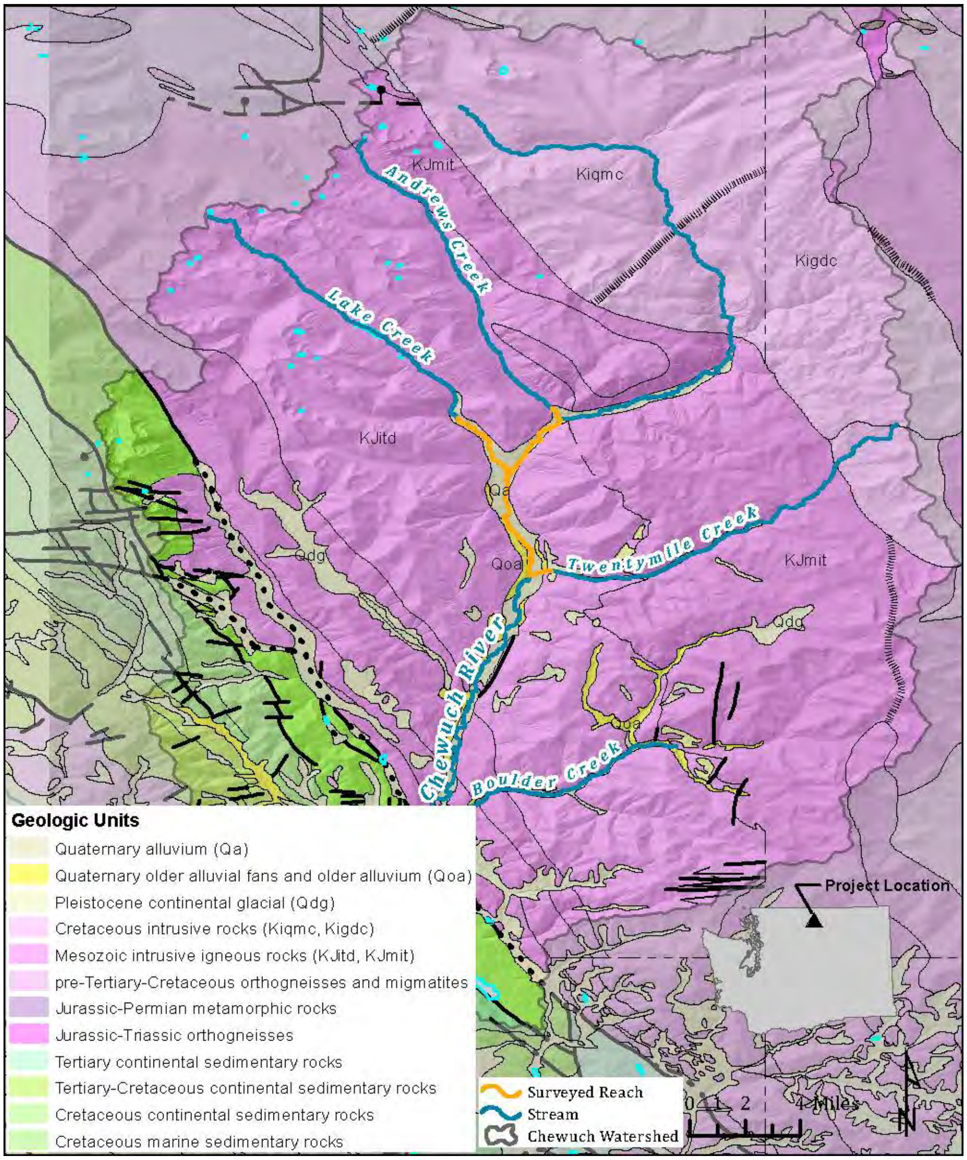

Figure 6. Surficial geology of the Upper Chewuch Basin

Due to the scale of the geologic mapping completed for the watershed, alluvial fans emanating from the tributary creeks as they enter the Chewuch valley are not shown. Alluvial fans were observed at the confluence of all the major tributaries within the project reach, typically varying in size relative to the contributing drainage area size. These fans deliver large volumes of sediment locally to the Chewuch, exceeding transport capacity and resulting in the accumulation of sediment over time building up the fan. A dynamic equilibrium has been reached where the Chewuch has steepened sufficiently to maximize transport capacity around the fan, adjusting to periodic pulses of sediment during flood events. The tributary creeks are typically unstable as they flow across the alluvial fans, with the potential of dramatically altering course during flood events.

2.4 Human Disturbance History

Though the Chewuch River and its tributaries appear relatively untouched in many areas, there is still a significant history of anthropogenic impacts in the area. Ancestors of current members of the Confederated Tribes and Bands of the Yakama Nation and the Confederated Tribes of the Colville Indian Reservation lived in and around the Methow Valley for at least 7,500 years. However, human activities have only significantly altered the landscape over the last 200 years of European occupation (NPCC 2004). The majority of human impacts in the Chewuch River watershed have occurred outside the Pasayten Wilderness and below Chewuch RM 25.0, and human activities limit salmonid production in this area (Andonaegui 2000).

2.4.1 Pre-European Settlement

Prior to the arrival of the first European trappers in 1811, the Methow valley was inhabited by the Methow Indians, with at least ten villages stretching from the mouth of the Methow River up to the confluence with the Chewuch River (NPCC 2004). The Methow Indian relied heavily on Pacific salmon including Chinook, sockeye, coho salmon and steelhead for subsistence, additionally hunting big game and collecting local roots, berries, and nuts (NPCC 2004). The seasonal movement between villages following food sources across the landscape would have minimized disturbance and impacts to the local environment.

2.4.2 Mining

Hard rock mining in the upper Chewuch River watershed occurred primarily in the early 1900's, leaving several abandoned mine sites scattered along valley hillsides. Extraction of copper, silver, gold, tungsten, manganese, and silica occurred in the upper portions of the Eightmile, Twentymile, Tungsten, and Andrews Creeks (USGS 2018a). The larger clusters of activity occurred near Billy Goat Mountain in the Eightmile Creek headwaters, and Apex and Wolframite Mountain in the Tungsten Creek headwaters. These abandoned mine sites have historically contributed sediment to creeks, negatively impacting aquatic habitats (NPCC 2004).

Two gravel and sand pits were identified in the upper Chewuch, the Bud Creek, and an unnamed pit on the alluvial fan of July Creek on the eastern side of the Chewuch valley. The Bud Creek Pit is located to the east of the Bud Creek confluence with Falls Creek (USGS 2018a). The unnamed gravel pit first appears on historic air photos in 1975, however is currently not in use. Sometime between 2011 and 2013 July Creek avulsed across the alluvial fan toward the north, flowing through the abandoned parking and material staging area associated with the pit. Prior to the avulsion July Creek flowed directly into the Chewuch River near RM 20.2, following the avulsion the creek now flows into the No Snake Side Channel near RM 21.1. At the confluence with the No Snake Side Channel there is a significant deposit of sand contributing fines to the side channel complex (Figure 7).

Figure 7. Confluence of July Creek with the No Snake Side Channel (foreground), with significant amount of sand entering the side channel from July Creek.

2.4.3 Grazing

Livestock grazing on federal lands in the Methow high county began in the late 1800's with the introduction of cattle and later sheep (McLean 2011). Sheep grazing in particular increased dramatically due to high wool demand during WWI, later decreasing in the 1940's and 1950's. The impacts from both cattle and sheep grazing on the landscape have contributed to accelerated soil erosion and compaction, displaced native plant species, and loss of understory vegetation (NPCC 2004, UCRTT 2017).

2.4.4 Timber Harvest and Channel Clearing

The historic impacts from timber harvest and clearing of the channel of wood have degraded a variety of wildlife habitats in the Upper Chewuch (NPCC 2004). Accelerated soil erosion across the watershed and the delivery of excess sediment to the channel in some areas has been exacerbated due to historic logging practices and associated road construction (USFS 2000). Clearing of riparian areas resulted in destabilized channel banks, loss of riparian cover and shade, and the removal of trees for potential future recruitment into the channel (UCRTT 2017).

Large scale clearing of wood from the channel occurred following the floods of 1948 and 1972 in an effort to improve flood conveyance (USBR 2008). This removal of wood from the river reduced instream complexity, limiting habitat availability for instream wildlife (UCRTT 2017). Historic logging of the riparian forest significantly diminished the number of large trees available for recruitment into the channel, reducing the ability of wood to accumulate into larger logjams. The smaller trees available for recruitment are more readily transported downstream, reducing their ability to provide functional instream habitat and elicit natural geomorphic processes.

2.4.5 Roads

Over 650 miles of roads have been constructed in the Chewuch drainage, which confine numerous reaches, limit riparian ecosystem health, and increase riverine sediment supplies (Figure 8). About 160 miles of these roads are within 200 feet of streams, and roads cross streams over 1,000 times in the watershed (NPCC 2004, USFS 2008). Major roads include USFS Road 51 (which becomes USFS Road 5160 after the bridge over the Chewuch at RM 20.4) that runs along the west bank of the Chewuch River and is paved until the bridge over Andrews Creek, and unpaved USFS Road 5010 that runs along the east bank of the Chewuch River up to the bridge over the Chewuch River at RM 20.4. There are also several bridges within the study area, including a bridge over Boulder Creek at RM 0.5, a bridge over Lake Creek at RM 0.3, a bridge over Andrews Creek at RM 0.1, and a bridge over the Chewuch River at RM 20.4 (Figure 9). There was also a road ford over Twentymile Creek at RM 0.1, although that was damaged in recent high flows.

2.4.6 Recreation

Recreation in the Upper Chewuch River watershed is widespread across the landscape, including camping, hiking, hunting, fishing, mountain biking, horseback riding, snowmobiling, and other outdoor pursuits. Much of the area is within the Okanogan-Wenatchee National Forest, providing public access to a variety of recreational opportunities year-round via a network of roads (Figure 10). Camp Four campground is the only established campground in the Upper Chewuch, with several dispersed camping areas primarily between USFS Road 5160 and the Chewuch River (5 were observed along the channel during surveys). The Chewuch River is the most heavily used area of the Methow Valley Ranger District for dispersed camping (USFS 2008). Abandoned skid roads throughout the historically logged floodplain have provided easier access for dispersed camping along the river (UCRTT 2017). Impacts along the riparian corridor from increased use include soil compaction, increasing bank erosion and reducing large woody debris recruitment (Andonaegui, 2000).

2.4.7 Wildlife Management

The Methow Subbasin Plan outlines a wildlife management plan that focuses on three key wildlife habitats; Eastside (Interior) riparian wetlands, shrub-steppe and Ponderosa pine habitats (NPCC 2004). To support a range of wildlife, sufficient quantity and quality of each of these identified habitats are needed. The plan suggests developing these habitats through improved silviculture and livestock grazing practices, fire management, weed control, and road management (NPCC 2004).

The arrival of the first fur trappers into the Methow watershed in the early 1800's severely reduced beaver populations across the landscape, reducing water storage capacity and habitat complexity (USFS 1994; in USFWS 2010 Buck Forest). These impacts directly limited the abundance and function of riparian wetlands throughout the watershed. Following the first wave of trappers came sheep and cattle herds in the late 1800's. There is no livestock grazing along the upper Chewuch River, but cattle continue to cause damage to some tributary riparian areas, including on Twentymile Creek above the anadromous fish barrier (USFS 2008).

Figure 8. USFS Road 5160 limits river migration and riparian function along some stretches of the upper Chewuch River.

Figure 9. Bridge over the Chewuch River at RM 20.4.

Figure 10. There are many drive-up dispersed campgrounds on USFS land in the upper Chewuch drainage, like this example on lower Lake Creek.

2.5 Wildfires

Wildfires are a natural part of Methow Valley ecology, including in the upper Chewuch watershed. However, human activities have changed the nature and impact of wildfires in the region. Beginning in the early 1900s, constant suppression of wildfires led to an accumulation of combustible fuels in forested areas (NPCC 2004). Wildfire suppression has shifted the dominant fire regime from frequent, low intensity burns to less frequent, more severe burns. For example, in 2003, the Farewell fire burned in the Upper Chewuch drainage and has affected wood loading in Lake Creek by adding substantial downed wood. This shift has changed forest communities and their capacity to store and transport water, as open stands of fire-resistant trees have been replaced by dense stands of more vulnerable species (NPCC 2004). Anthropogenic climate change will likely increase future wildfire frequency and intensity as average snowpack decreases and summer water resources diminish.

Wildfires can negatively impact fish-bearing streams by eliminating riparian vegetation, increasing surface water runoff, and spurring excessive sediment delivery. However, fires also provide ecological benefits in the long term, including increased large wood delivery, recruitment of spawning gravel, and rejuvenation of plant communities (Andonaegui 2000).

Several major wildfires have burned in the upper Chewuch drainage since the year 2000 (NWCG 2018), including the Thirtymile Fire (2001, 10,330 ac), Farewell Fire (2003, 80,864 ac), the Tripod Complex Fire (2006, 173,429 ac), the Diamond Creek Fire (2017), and the McCloud Peak Fire (2018) (Figure 11). Collectively, more than 80 percent of the upper watershed has likely burned since 2001. These fires have resulted in several large landslides on Andrews Creek and Lake Creek. Large areas of riparian forest were burned along reach L2 of Lake Creek (Figure 12Figure 12), and the resulting effects to large wood transport is evident on both Lake Creek and Andrews Creek.

Due to the expanse of recently burned area in the upper Chewuch, it is anticipated that the delivery of sediment, water, and wood to the river will be altered for the short-term. Following these recent fires, the delivery of sediment and water to the channel has likely increased, due primarily to the removal of forest cover and altered soils (Walstad et al 1990). The loss of vegetation on hillsides results in accelerated soil erosion from both sheet flow (distributed overland flow) and from a loss of root cohesion. The increased soil erosion rates produce excess sediment that is delivered down to the channel, primarily fine sediment. The rate of delivery of this sediment is exacerbated by increased runoff rates resulting from the loss of vegetative cover and reduced infiltration rates. Similarly, large wood in the form of burned trees along the channel banks and floodplain increases the potential for wood recruitment following fire. This wood is recruited into the channel through natural processes like bank erosion and blow-downs during storms. Examples of the direct impacts of these fires on instream processes and habitat availability are described in more detail in the following reach descriptions where applicable (Section 4.4).

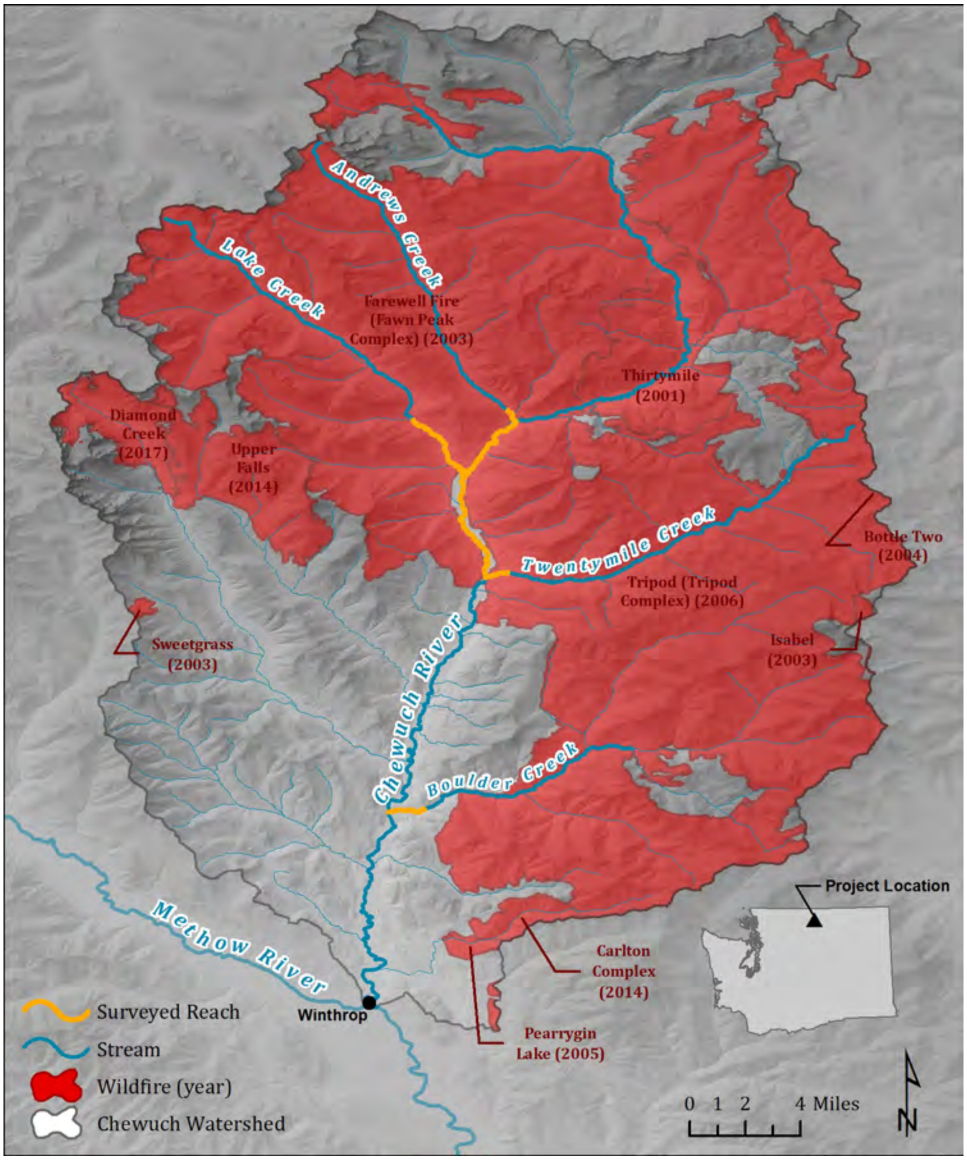

Figure 11. Large wildfires that have occurred in the Chewuch Watershed from 1973-2017. Source: WA DNR 2018.

Figure 12. The 2003 Farewell Fire burned large sections of riparian forest along Lake Creek, which has led to an influx of riverine large wood and natural creation of numerous logjams.

2.6 Fish Use and Population Status

The Chewuch River and its tributaries provide important habitat for both salmonid and non-salmonid fish species. Salmonids in the Chewuch River include spring-run Chinook, steelhead/rainbow trout, bull trout, westslope cutthroat trout (*O. clarki lewisi*), brook trout (*S. fontinalis*), and mountain whitefish (*Prosopium williamsoni*). Coho salmon (*O. kisutch*) were extirpated from the entire Methow River Basin, including the Chewuch River, in the early 1900s, but reintroduction efforts are underway (Andonaegui 2000, CRITFC 2012, Stamper 2017). The Chewuch River is also used by non-salmonid fishes, including pacific lamprey (*Entosphenus tridentatus*) which are a species of interest and managed for recovery in the Methow Basin, as well as various species of dace, sculpin, and suckers.

2.6.1 Salmonids

Salmonids are present year-round in the Chewuch River drainage, and use the Chewuch River and its tributaries for spawning, rearing, and migration. Three of the salmonid species are listed under the ESA: spring Chinook are listed as endangered, while steelhead and bull trout are listed as threatened. Fish use varies spatially and temporally among different ESA-listed species (Figure 13, Figure 17, Table 2, Table 3).

Spring Chinook, steelhead and bull trout are generally found throughout the mainstem Chewuch in the assessment area, as well as Lake Creek. The lower sections of Andrews Creek and Twentymile Creek are also thought to provide some habitat for these species. Boulder Creek in the lower reaches shows use by steelhead and spring Chinook, but not by bull trout. Restoration work targeted at the mainstem and lower sections of the tributaries is likely to have a greater benefit to multiple listed species. Coho salmon are not listed under the Endangered Species Act since the original population was extirpated (Andonaegui 2000). Westslope cutthroat trout are most prevalent in headwater tributaries, and are less common in the mainstem Chewuch River (NPCC 2004, USFS 2008). Brook trout are not native and can hybridize with and out-compete ESA-listed bull trout (USFWS 2010). Additional salmonid species present in the drainage include resident rainbow trout and mountain whitefish.

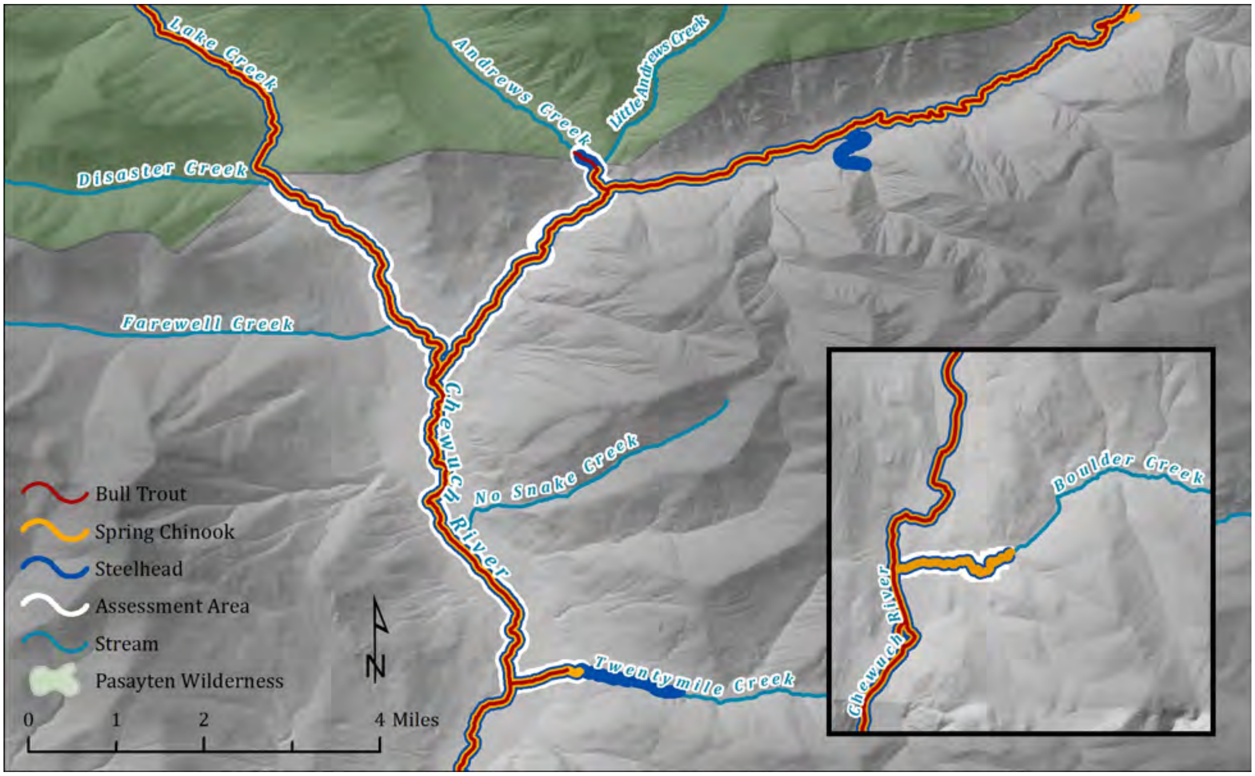

Figure 13. ESA-listed fish distribution in the Upper Chewuch Reach Assessment area. Source: Streamnet 2012.

Table 2. ESA-listed salmonid use of the Chewuch River and surveyed tributaries. Adapted from USBR 2008 and Andonaegui 2000.

RIVER	SPRING CHINOOK	STEELHEAD	BULL TROUT
Chewuch River	spawning, rearing, migration	spawning, rearing, migration	rearing, migration, foraging, overwintering
Andrews Creek	rearing	spawning, rearing, migration	spawning, rearing
Lake Creek	spawning, rearing, migration	spawning, rearing, migration	spawning, rearing, migration
Twentymile Creek	rearing	spawning, rearing	spawning, rearing
Boulder Creek	rearing	spawning, rearing	minimal use

Table 3. Generalized fish use timing for ESA-listed salmonids in the greater Methow River watershed. Adapted from WDFW 2011.

SPECIES	LIFESTAGE	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEPT	OCT	NOV	DEC
Spring Chinook	Adult migration												
	Spawning												
	Incubation												
	Rearing												
	Outmigration												
Steelhead	Adult migration												
	Spawning												
	Incubation												
	Rearing												
	Outmigration												
Bull trout	Adult migration												
	Spawning												
	Incubation												
	Foraging												

Indicates periods of peak use and high certainty that the species is present at the given life stage.

Indicates periods of less frequent use and less certainty that the species is present at the given life stage.

Indicates periods of rare use or no use.

Chinook Salmon

The Chewuch River drainage is a major spawning and rearing area for ESA-listed spring Chinook salmon (Andonaegui 2000, UCRTT 2017). Spring Chinook typically spawn in Lake Creek and in the mainstem Chewuch River (up to the confluence with Thirtymile Creek) in August and September each year (NPCC 2004, WDFW 1993). Chinook rear year-round in Lake Creek up to the confluence with Disaster Creek, the Chewuch River up to Chewuch Falls at RM 36.4, and in the lower reaches of multiple additional tributaries, including Andrews, Twentymile, and Boulder Creeks (NPCC 2004) (Figure 14). The USFS has observed Chinook salmon during snorkel surveys from the mouth of the Chewuch River up to about RM 36.0, about a half mile below the anadromous fish barrier at Chewuch Falls (USFS 2008).

There are four distinct spring Chinook populations in the Methow River Basin: Twisp River, Chewuch River, Lost River, and upper Methow mainstem spring Chinook (WDFW 1993). Genetic analysis of Chinook salmon across the Methow River Basin has shown that the Chewuch River and Twisp River stocks are mostly wild and self-recruiting, with minimal genetic influence from hatchery-origin fish (NPCC 2004, WDFW 1993). The Chewuch River provides about a third of the natural spring Chinook production in the Methow River Basin (USBR 2008).

Spawning data collected from 2005 through 2016 on the Chewuch River show distinct areas that are more heavily used by current spawners, and where restoration efforts should be managed to support spawning habitat. Specific areas in Figure 11 at RM 19.2, 20.1, 20.9, 21.8, 24.0 24.3, 25.2, and above RM 26 have been repeatedly used by spring Chinook for spawning through the years and should be managed as functional spawning habitat.

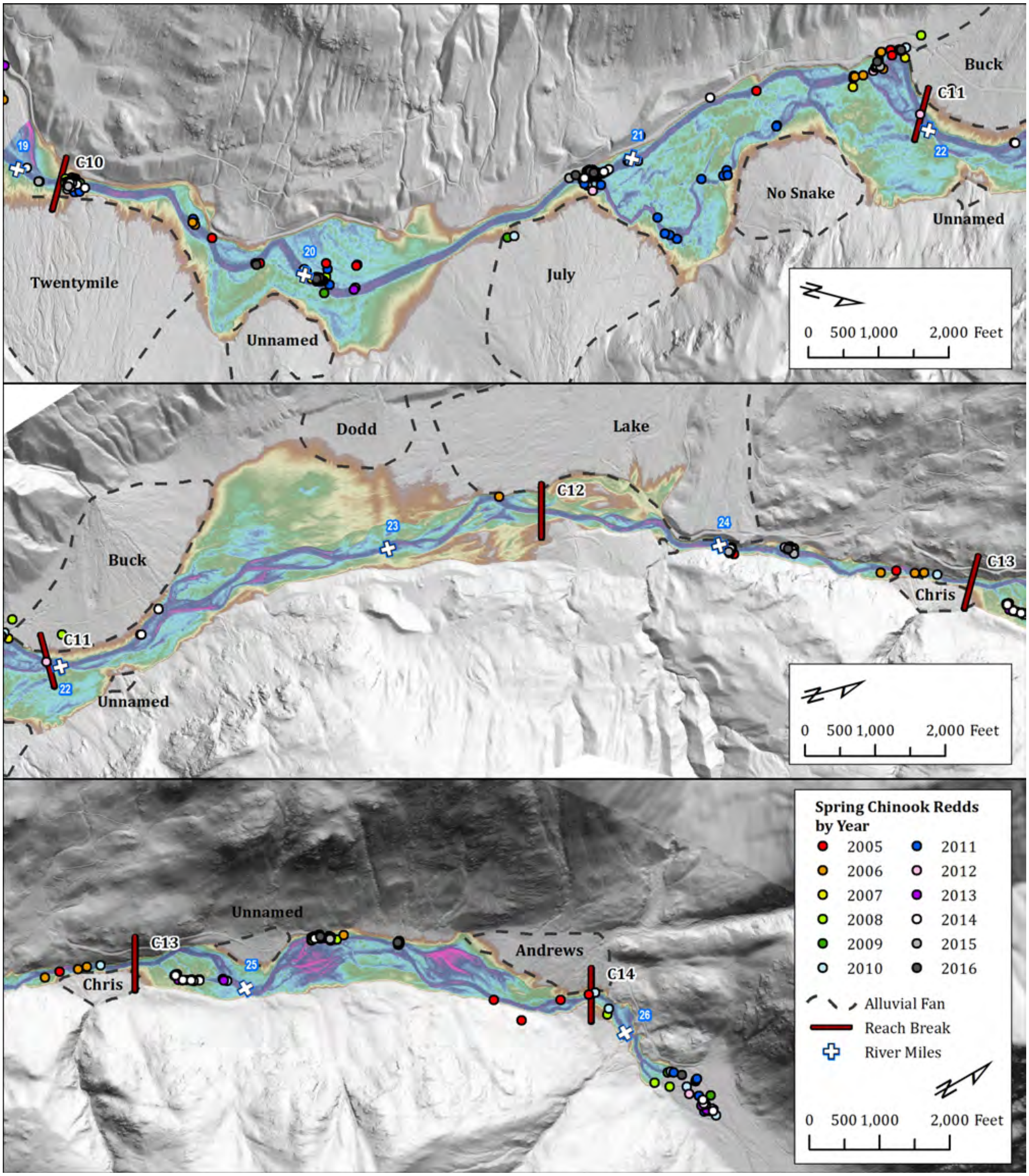

Figure 14. Spring Chinook redds in the Chewuch River from 2005 to 2016 with stream names for alluvial fans labeled.

Figure 15. Juvenile Chinook and *O. mykiss* observed in Twentymile Creek just upstream of the partial fish passage barrier at the USFS Road 5010 ford (July 2016).

Steelhead / Rainbow Trout (*O. mykiss*)

O. mykiss spawn and rear plentifully in the mainstem Chewuch River and all four surveyed tributaries (USFS 2008, NPCC 2004, Andonaegui 2000), and the upper Chewuch drainage is listed as a major spawning area for ESA-listed steelhead by the UCRTT (2014). Steelhead typically spawn in Lake Creek and in the mainstem Chewuch River from March through June each year, and rear throughout the upper Chewuch drainage all year (NPCC 2004, WDFW 2011) (Figure 15 and Figure 16).

The USFS has observed steelhead and rainbow trout from the mouth of the Chewuch River up to Chewuch Falls at RM 36.4 during stream assessment surveys. *O. mykiss* and cutthroat trout are the only salmonid species present above Chewuch Falls and several other complete passage barriers on Chewuch River tributaries (USFS 2008). Additionally, *O. mykiss* was the most common fish species observed (totaling 58% of observed fish) by the USFS in snorkel surveys from the mouth to Chewuch Falls at RM 36.4 (USFS 2008).

Though the tendency towards anadromy is genetically linked in *O. mykiss*, the offspring of anadromous steelhead can display a resident trout life history and the offspring of resident rainbow trout can display an anadromous steelhead life history. It is possible that steelhead were not extirpated from the Methow River Basin, unlike coho salmon in the early 1900s, because resident individuals were able to sustain the anadromous run once impassable dams and excessive harvest pressures were removed (NPCC 2004). Still, wild steelhead production in the Methow River Basin has declined significantly since the early 1900s (NPCC 2004).

Figure 16. Juvenile *O. mykiss* in the Chewuch River during a snorkel survey.

Bull Trout

The mainstem upper Chewuch River and Lake Creek are both productive spawning and rearing habitats for ESA-listed bull trout (NPCC 2004, UCRTT 2017). The USFS has observed bull trout on the Chewuch River from the mouth to Chewuch Falls at RM 36.4, and on Lake Creek from the mouth to the waterfall fish barrier at RM 9.3 during stream assessment surveys (USFS 2003, USFS 2008). Fluvial, and potentially resident, populations of bull trout inhabit the Chewuch River and Lake Creek (NPCC 2004). There is also an adfluvial bull trout population that spawns above Black Lake, and an average of 11 bull trout redds were counted annually from 1995 to 2003 in a mile-long survey reach above Black Lake (USFS 2003). Fluvial adult bull trout typically migrate from the Columbia River (or lower mainstem Methow River) to the upper Methow River Basin each year in May and June, and return to the Columbia River in October and November (NPCC 2004). Juvenile bull trout generally remain in their natal streams for one to four years before undertaking any migration (NPCC 2004).

Bull trout also use Andrews Creek, Twentymile Creek, and Boulder Creek for spawning and rearing, though populations in Boulder Creek and Twentymile Creek are competing with and potentially hybridizing with non-native brook trout (USFWS 2010, WDFW 2011) (Figure 17). Brook trout mature earlier, have a higher reproductive rate, are more aggressive, and are more tolerant of degraded habitat conditions than bull trout, which can lead to replacement of bull trout with brook trout in certain areas (NPCC 2004).

Bull trout have more specific habitat requirements than other salmonids in the Methow River Basin. They are one of the most temperature sensitive fish species in western North America, and are limited by water temperatures over 15°C. Bull trout distribution, abundance, and habitat quality have declined across their range in response to human impacts (NPCC 2004).

Coho Salmon

Coho salmon were once the dominant anadromous species in the Methow River Basin, and the Basin was the most abundant coho producer of all the upper Columbia tributary systems (NPCC 2004). However, populations were decimated in the early 20th century (Andonaegui 2000, Stamper 2017). Overfishing in the lower Columbia River, excessive logging, livestock grazing, unscreened irrigation diversions, and habitat destruction all contributed to the decline of Methow River coho beginning in the late 1800s. A hydroelectric dam was constructed on the Methow River at RM 6.4 near Pateros in 1915, which blocked all fish passage to the upper Methow Basin. By the time the Pateros dam was removed in 1929, coho salmon had been extirpated from the Methow River Basin (Andonaegui 2000).

The Yakama Nation began spearheading coho salmon reintroduction efforts in the Methow River Basin in 1997, which included naturalization of lower Columbia River coho through selective hatchery programs. These efforts have reestablished natural coho spawning in the Methow River and sufficient returns in some years for a limited coho fishery (CRITFC 2012). In 2019, the Yakama Nation will release 260,000 juvenile coho at two locations on the Chewuch River (C. Butler, pers. comm.). If successful, the Chewuch drainage will once again be home to coho salmon.

Westslope Cutthroat Trout

Westslope cutthroat trout are known to exhibit fluvial, adfluvial, and non-migratory life histories, but typical Methow River Basin cutthroat life histories are not well documented (NPCC 2004). In the Chewuch River drainage, cutthroat trout are often relatively more abundant above natural fish barriers on the mainstem Chewuch River and in some tributaries, including Andrews Creek, Twentymile Creek, and Boulder Creek. Cutthroat trout and *O. mykiss* are the only salmonid species present above Chewuch Falls (USFS 2008). The U.S. Forest Service observed cutthroat trout from the mouth of the Chewuch River up to Chewuch Falls at RM 36.4 during stream assessment surveys in 2008, though they only accounted for about 1% of fish observed in the mainstem (USFS 2008). In general, restoration of natural geofluvial processes and riparian areas of cutthroat-bearing streams within the Methow River Basin will have positive effects on westslope cutthroat populations (NPCC 2004).

Mountain Whitefish

Mountain whitefish are widely distributed in western North America, and are generally common in the upper Columbia River tributaries, including the Methow River (Wydoski and Whitney 2003). The USFS reports that mountain whitefish are abundant in the Chewuch River below RM 23, and have been observed up to RM 26.3. The exact upper limit of their distribution in the Chewuch River is unknown (USFS 2008).

Brook Trout

Brook trout are non-native and were intentionally introduced to the Chewuch River drainage as a game species. Brook trout have been observed in the mainstem Chewuch River at least up to RM 22.7 (USFS 2008), and have confirmed presence in Lake Creek and all the fish-bearing tributaries from Twentymile Creek downstream from Twentymile Creek (Figure 17). They also have presumed but not documented presence in the Chewuch River up to river mile 34 and Andrews Creek up to the anadromous barrier (NPCC 2004) (WDFW 2017). Brook trout can hybridize with and out-compete ESA-listed bull trout, and robust populations of brook trout in Boulder Creek and Eightmile Creek are thought to be linked with the decline of bull trout in these tributaries (USFWS 2010). Brook trout mature earlier, have a higher reproductive rate, are more aggressive, and are more tolerant of degraded habitat conditions than bull trout (NPCC 2004).

Figure 17. Brook Trout observed in Twentymile Creek just upstream of the partial fish passage barrier at the USFS Road 5010 ford (July 2016).

2.6.2 Non-Salmonid Species of Interest

Multiple non-salmonid species are present within the Chewuch River drainage, including various species of sculpin, suckers, and dace. The USFS observed sculpin (*Cottus* spp.) from the mouth of the Chewuch to RM 31.0, bridgelip sucker (*Catostomus columbianus*) at RM 12.6, and longnose dace (*Rhinichthys cataractae*) at RM 12.5 and RM 12.6 during stream inventory surveys (USFS 2008). The exact upper limits of these species in the Chewuch River are unknown. Pacific lamprey (*Lampetra tridentata*) are of particular interest due to their ecological role, anadromous nature, and importance in tribal customs and fisheries.

Pacific Lamprey

It is likely that Pacific lamprey used to occur throughout the Methow River Basin wherever anadromous salmonids were also present. Pacific lamprey have many similar habitat needs as salmon, but they spawn in sandy substrates, often on the margins of mainstem habitats (Tetra Tech 2017a). Evidence suggests that lamprey populations have declined across the Columbia River Basin, but there is a lack of information on the current abundance and distribution of Pacific lamprey in the region (NPCC 2004). Lamprey have lost an estimated 40 percent of their former habitat in the Columbia River Basin due to dams alone (MSRF 2015). Still, the lower Chewuch River is known to currently provide important habitat for spawning and rearing lamprey (Nelle et al. 2017, USBR 2008). The USFS has observed Pacific lamprey in the Chewuch River up to RM 32.0, and it is likely that their potential range in the river extends up to Chewuch Falls at RM 36.4 (USFS 2008). Pacific lamprey may be found in the river year-round. Larval lamprey rear in freshwater for up to seven years, and adults migrate and hold from summer through late spring before spawning in early summer (MSRF 2015) (Table 4).

Table 4. Pacific lamprey life history timing for the Upper Columbia River Basin above Rock Island Dam (MSRF 2015).

LIFESTAGE	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEPT	OCT	NOV	DEC
Adult migration into Tributary Mainstems												
Winter Holding and Migration to Spawning Areas												
Spawning												
Larval Rearing												
Juvenile Out Migration												

Since 2008, the Yakama Nation has been working to restore natural production of Pacific lamprey to a level "that will provide robust species abundance, significant ecological contributions and meaningful harvest within the Yakama Nations Ceded Lands and in the Usual and Accustomed areas" (YNF 2018). The Yakama Nation program includes investigation of historic and current lamprey distribution, identifying limiting factors for Pacific lamprey by watershed, and lamprey habitat restoration. Additionally, the Yakama Nation has released Pacific lamprey at various points in the Methow River, including at the confluence with the Chewuch River (Crandall 2016, Stamper 2015, YNF 2018). The Pacific Lamprey Habitat Restoration Guide was published in 2015 to provide current information on population status and needs of Pacific lamprey and to encourage lamprey recovery efforts across the Columbia River Basin (MSRF 2015).

2.7 Ecological Concerns

Targeted tributary habitat restoration depends on an understanding of local environmental factors that are limiting the recovery of salmonid populations. These ecological concerns, also known as limiting factors, are the "biological, physical, or chemical conditions and associated processes and interactions that limit a species' viability" (NOAA NMFS 2016) and are directly tied to specific life stages that are most limiting the production of the population (i.e. where survival is the lowest). The Upper Columbia Revised Biological Strategy (UCRTT 2017) contains the most recent information on ecological concerns for the Chewuch River and its tributaries, and is consistent with the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (UCSRB 2007) and the Washington Statewide Steelhead Management Plan (WDFW 2008). It identifies key threats to salmonid population viability that should be considered in protecting quality habitat and restoring degraded habitat.

The Revised Biological Strategy (2017) divides the Chewuch River into two assessment units (AUs): Lower Chewuch River and Upper Chewuch River. The Lower Chewuch AU includes river miles 0-20 of the mainstem Chewuch, as well as Twentymile, Eightmile, Boulder, and Cub Creeks. The Upper Chewuch AU includes river miles 20-35 of the mainstem Chewuch, as well as Thirtymile, Andrews, and Lake Creeks. Both assessment units are listed as a major spawning area (MaSA) for spring Chinook and steelhead.

The Revised Biological Strategy identified eight ecological concerns, listed in priority order, for the Lower Chewuch AU (UCRTT 2017):

1. **Sediment Conditions** (Increased Sediment Quantity)
2. **Peripheral and Transitional Habitat** (Floodplain Condition)
3. **Channel Structure and Form** (Instream Structural Complexity)
4. **Riparian Condition** (Riparian Condition and Large Wood Recruitment)
5. **Water Quantity** (Decreased Water Quantity)
6. **Food** (Altered Primary Productivity or Prey Species Composition & Diversity)
7. **Species Interactions** (Introduced Competitors and Predators)
8. **Habitat Quantity** (Anthropogenic Barriers)

The Revised Biological Strategy identified four ecological concerns, listed in priority order, for the Upper Chewuch AU (UCRTT 2017):

1. **Sediment Conditions** (Increased Sediment Quantity)
2. **Riparian Condition** (Riparian Condition and Large Wood Recruitment)
3. **Peripheral and Transitional Habitat** (Floodplain Condition)
4. **Channel Structure and Form** (Instream Structural Complexity)

Each ecological concern is tied to specific changes in riverine habitat and processes (UCRTT 2017):

- **Channel Structure and Form:** Includes loss of instream structures (wood, boulders, etc.); poor hydrologic function; inadequate quantity or depth of pools; inadequate spawning substrate; and loss of instream roughness, channel morphology, and habitat complexity.
- **Food:** Includes alteration of ecological dynamics affecting the quantity, quality, and/or species composition of phytoplankton or detritus; addition of competing salmonid stocks, species, or hatchery-produced fish; and alteration of ecological dynamics affecting the species composition, distribution, or nutritional quality of zooplankton, macroinvertebrates, forage fish, or other prey.
- **Habitat Quantity:** Includes total or partial human-caused blockage to previously accessible fish habitat that eliminates or decreases migration ability or alters the range of conditions under which migration is possible. Barriers include dams, culverts, thermal barriers, seasonal push-up dams, unscreened diversions, and entrainment in irrigation diversions.
- **Peripheral and Transitional Habitats:** Includes impaired access to floodplain habitats (seasonal wetlands, off-channel habitat, and side channels); loss of floodplain and hyporheic flow connectivity; degradation of floodplain habitats; and reduced overwintering and refuge habitats.
- **Riparian Condition:** Includes loss, degradation, or impairment of riparian conditions important for shading, bank stabilization, nutrient and chemical mediation, control of surface erosion, production of large woody material for stream recruitment, and production of food organisms and organic material.
- **Sediment Conditions:** Includes streambed sedimentation, high levels of suspended sediment, high turbidity, increased fine sediments in spawning gravel, and embedded substrate.
- **Species Interactions:** Includes competition with or predation by introduced species or native species that benefit from anthropogenic changes in river conditions.

- **Water Quantity:** Changes in the hydrograph that alter the natural pattern of flows over the seasons, causing inadequate flow or other flow conditions that inhibit the development and survival of salmonids.

The Ecological Concerns identified for the Chewuch Watershed were identified and updated with the Upper Columbia Revised Biological Strategy (USRTT 2017). However, findings in this assessment indicate that some of the Concerns may be affecting this section of the Upper Chewuch for only short periods of time. For example, fine sediment loading to the Chewuch River is higher than the natural condition due to road construction, and further exacerbated by recent fires, however, the storage of that sediment input in the project area is limited in extent and duration. Much of the erosion which generates excess sediment occurs on hillslopes during summer rainstorms, where infiltration rates of the soil are rapidly exceeded (Wondzell and King 2003). During these short duration, high intensity events, overland flow is conveyed to tributary drainages carrying high sediment loads eroded from the hillsides. This fine sediment is transported down the tributary drainages along with the floodwaters, impacting road crossings and culverts. At the confluence of the tributaries with the main stem channel, the larger portion of the fine sediment (sands) typically begins to fall out of suspension as it enters the low summertime flows of the main stem channel. This fine sediment will remain in the channel until flows increase at the onset of fall and winter rains, or during peak runoff in the spring. The timing, rainfall intensity, and proximity to recent burn areas can alter the magnitude of fine sediment entering the channel, and the subsequent potential impacts to aquatic habitat (spawning areas), however most of the spawning locations for spring Chinook are located outside of the depositional areas for alluvial fans (Figure 14). The fine sediment contributed to tributaries is largely transported downstream with peak flows in the spring, leaving behind relatively coarse sediment in many reaches in the survey area, indicating that the priority of this Ecological Concern in this reach may need to be revisited.

3. METHODS

The Upper Chewuch Habitat Assessment included the collection of field data and the synthesis of existing and new information to evaluate current conditions and identify restoration opportunities. Field surveys included a geomorphic survey, a habitat survey utilizing USFS Stream Inventory Handbook Level II Methods, and identification of restoration opportunities. Field work was conducted by a team from NSD during November 3-15, 2017. The team surveyed 6.8 miles of the Chewuch River between river miles 19.1 and 25.9, and 5.1 miles in the four tributaries of Boulder Creek, Andrews Creek, Lake Creek, and Twentymile Creek from the mouth of each stream to the anadromous barrier, except in Lake Creek. In Lake Creek surveys ended at Disaster Creek, which is still below the anadromous barrier, but was the upstream limit of the scope of this assessment.

Methods are described in subsections below for field surveys including geomorphic surveys (3.1), USFS stream inventory (3.2), field identification of restoration opportunities (3.3). In addition, analysis methods to evaluate hydrology, hydraulics, channel morphology, LiDAR and REM mapping and habitat are included in 3.4, along with reach ecosystem indicators (REI) analysis in section 3.5.

3.1 Geomorphic Surveys

Baseline geomorphic data and observations were collected during field surveys to document active and impaired geomorphic processes and to characterize existing conditions. The data collected supported the characterization of channel morphology, connection to the adjacent floodplain (degree of incision), controls and patters of sediment transport, presence and influence of instream wood, active bank erosion, and impediments to natural processes. All information was collected digitally in the field, providing georeferenced locations for all data and observations. Twenty-nine pebble counts (Wolman 1954) were taken at strategic locations to better understand the role of channel confinement (due to alluvial fans at the confluence with larger tributaries, bedrock reaches, and channel incision confining the inset floodplains) on sediment transport characteristics and the resultant distribution of sediment sizes throughout the reach.

3.2 USFS Stream Inventory

U.S. Forest Service Level I and Level II stream survey protocols, which are detailed in the USFS Stream Inventory Handbook (USFS 2012), were applied on the mainstem Chewuch River, Andrews Creek, Lake Creek, Twentymile Creek, and Boulder Creek. The purpose of the USFS stream inventory procedure is to identify existing stream channel, riparian, and aquatic ecosystem conditions on a watershed scale (USFS 2012). Prior to field surveys, Level I data were collected in the office using satellite imagery, USGS maps, and Google Earth/ArcGIS software. Level II data were collected in the field by NSD personnel Roby Ventres-Pake and Robert Dohrn on from November 3-13th 2017. Data were recorded on an iPad with custom data forms that allowed for all habitat data to be spatially georeferenced. Additional notes were recorded throughout each reach, and a draft reach summary was written upon completion of each reach.

A key element of the Level II stream survey was the delineation of channel units along the entire length of the study area. Channel units included various types of fast-turbulent water (e.g. riffles and rapids), fast-nonturbulent water (e.g. glides), slow water (e.g. pools), and side channels. Most field data—including bankfull and floodprone widths, vegetation assessments, substrate estimation, water temperature, large woody debris census, and more—was collected at the channel unit level. Additionally, Wolman pebble counts and stream discharge were collected on the reach level. The upper extents of stream inventory surveys were bounded by anadromous fish barriers on Boulder Creek, Twentymile Creek, and Andrews Creek, and were bounded by pre-determined tributary confluences on the mainstem Chewuch River and Lake Creek.

3.3 Field Identification of Restoration Opportunities

Field surveys were used to identify preliminary restoration and habitat enhancement opportunities across the upper Chewuch study area. Surveyors made note of local geomorphology; anthropogenic features, human impacts, and infrastructure risks; impaired instream habitats, disconnected floodplain areas, and disturbed riparian zones that could benefit from restoration; and high-functioning habitat features that should be preserved. Project concepts were developed from these observations, and these concepts were refined using data from the USFS stream inventory and LiDAR-based geomorphic analysis. Restoration opportunities were selected to address specific ecological concerns and reach-scale restoration targets within a watershed context. Potential restoration actions are discussed in Section 5.2.

3.4 Hydraulic, Geomorphic and Habitat Analyses

3.4.1 Hydrology

The climate of the Chewuch River watershed has a seasonal variability characterized by cold winters and hot, dry summers. Precipitation is highest through the fall and winter when precipitation falls as snow and accumulates. As temperatures rise through spring and into summer, flows ramp up as a result of increased snowmelt in the upper watershed with peak snowmelt and peak flows typically occurring in May and June. The hydrograph for the Chewuch River at USGS 12448000 (Chewuch River at Winthrop, WA) is shown in Figure 18 with mean, median, minimum and maximum flows by month from 1991 through 2018. Fall rain events produce localized high flow events, but these events typically occur prior to significant snow accumulation reducing the magnitude of these flood events. There are two irrigation withdrawals at RM 9.2

and RM 8.5 that impact flows within the Chewuch River during the summer months (Inter-Fluve 2010) but these occur outside of the study area.

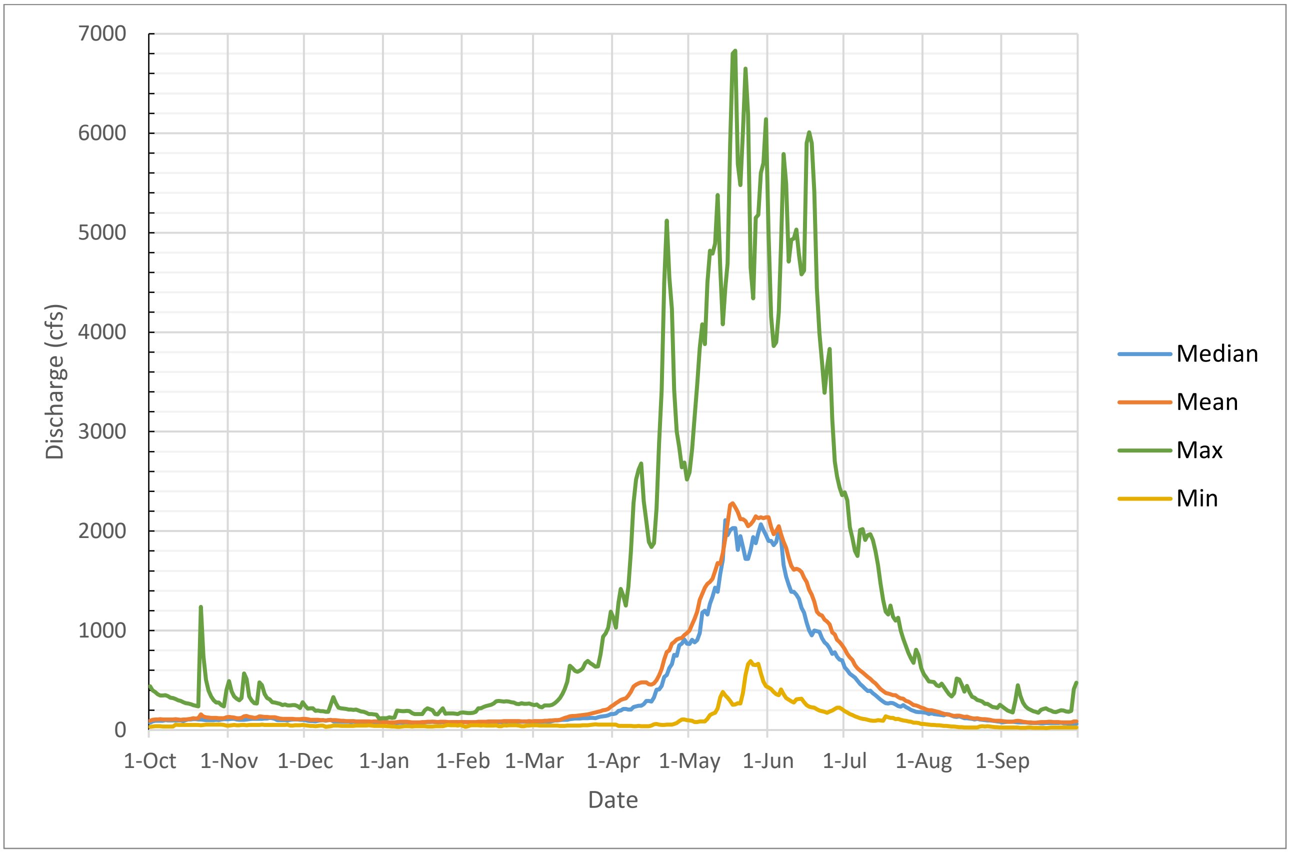

Figure 18. Median, Mean, Minimum and Maximum Daily Discharge at USGS 12448000: Chewuch River at Winthrop, WA (1991-2018).

3.4.2 Hydraulic modeling

The primary objective of NSD's hydraulic analysis was to evaluate existing flow patterns, hydraulic parameters, and inundation extents to characterize current riverine conditions within the Project Reach. Establishing baseline hydraulic conditions also enables quantitative comparison with the proposed condition modeling representing restoration actions in later phases of design. This comparison is critical to ensuring that the design elements are meeting the intended habitat uplift without increasing risk to existing habitat, property, and infrastructure.

Hydraulic conditions were modeled using the U.S Army Corps of Engineer's one-dimensional (1D) HEC-RAS V5.0.5 models. The 1-dimensional (1D) model was conducted for the 100-year event, 2-year event, and 38 cfs for the existing conditions. These flows were selected to identify risks to infrastructure and flooding (100 year), conditions and effects of the channel forming flow (2-year) and habitat conditions under low flow conditions (38 cfs) (Figure 18). This modeling system is intended for calculating water surface profiles for steady gradually varied flow, and the basic computation procedure is based on the solution of the one-dimensional energy equation. Although useful at the planning level, the 1D model does not represent some flow characteristics, such as areas with multiple channels, at the highest levels of accuracy, so future design efforts should include a 2-dimensional (2D) model.

Hydraulic Cross-Sections and Topography

The full length of the model reach is 7 miles (RM 19 – RM 26). The geometry for this analysis was delineated in RAS Mapper, and the cross-sectional spacing ranges from 50ft-500ft. The 2015 Okanogan LIDAR data was incorporated as the model topography. Expansion and contraction coefficients were included for two existing bridges.

Roughness

Hydraulic analyses require an assessment of the resistance (drag force) that the ground surface and other physical features exert against the movement of water to calculate energy losses. This drag force is commonly referred to as roughness. The most accepted method to assess roughness uses the Manning's n resistance factor (Chow, 1959). Common factors that affect roughness values include: channel sediment size, gradation, and shape; channel shape, channel meandering, bank and floodplain vegetation, obstructions to flow, flow depth, and flow rate. Manning's n values for this project were assigned to the channel bottom and floodplain in accordance with standard hydraulic reference manuals (Chow, 1959; Barnes, 1967; Hicks and Mason, 1998). The same model roughness values were used for all flows under existing conditions and are shown in Table 5 below.

Table 5. Existing conditions model roughness values.

ROUGHNESS TYPE	MANNING'S N VALUE
Floodplain	0.10
Channel	0.046
Road	0.016

Boundary Conditions

Hydraulic models require the user to input a known boundary condition at the upstream and downstream extents to begin the computational routine. The inflow conditions for all model runs include flow from the Chewuch River set to the corresponding peak flow rates for the 100-year, 2-year, and a base flow of 38 cfs, which was measured during the November 5, 2017 field visit. Flow change locations were included for Lake Creek and Twentymile Creek. The downstream boundary conditions for all flows were assigned to normal depth using a slope of 0.01 ft/ft, which was determined by calculating the slope of the channel bed at the downstream end of the model.

3.4.3 Channel Morphology

Channel morphology along the project reaches was classified using Montgomery and Buffington (1997) and Rosgen (1996) channel classification systems. These classification methods identify channels based on a number of characteristics, including absolute and relative dimensions, gradient, planform, relative stability, valley and channel confinement, substrate character, and floodplain condition. The channel morphology can provide insight about larger scale geomorphic features controlling form, as well as identify historic disturbances that have altered the channel form from its pre-disturbance condition.

3.4.4 LiDAR and REM mapping

As part of the geomorphic assessment a terrain analysis was performed to evaluate the elevations of the floodplains and side channels relative to the main stem channel. The methods used for this analysis were adapted from Jones (2006) and utilize the LiDAR terrain surface (bare-earth digital elevation model) collected in June and July 2015 (Quantum Spatial 2015). Cross sections along the project reach are digitized across the valley bottom perpendicular to the valley axis. Each of the cross sections are attributed with the elevation of the water surface in the channel where the cross section crosses the channel. A Triangulated Irregular Network (TIN) surface is created from the digitized cross sections using the water surface elevation in the channel, creating a new datum from which the relative elevation of the adjacent floodplains can be evaluated. Simply subtracting the water surface TIN elevations from the LiDAR elevations results in a relative elevation map (REM) depicting elevations of the floodplain and instream features relative to the water surface elevation of the channel at the time of the 2015 LiDAR survey. The relative elevation results were verified during field surveys and were found to be accurate to within one foot. The REM is useful in identifying floodplain side channels, potential avulsion (new channel) pathways, presence of terraces and inset floodplains, and relic channel scars on the floodplain.

3.5 Reach-based Ecosystem Indicators

Reach-based Ecosystem Indicators (REI) provide a consistent framework to evaluate habitat impairments and compare the geomorphic and ecological function across reaches. Each metric in the analysis is summarized for a given reach and compared to the REI criteria to determine the rating as adequate, at risk, or unacceptable for that metric condition. REI indicators can be evaluated at the drainage basin and reach scales, but are likely more meaningful at the reach scale for restoration project development. The reach-based ecosystem indicators (REI) analysis for the Upper Chewuch Reach Assessment builds upon previous reach assessments and REI analyses in the Chewuch Watershed, including an assessment of the Chewuch River from RM 2.2 to 20 (Inter-Fluve 2010) and the Methow Sub-basin Geomorphic Assessment (USBR 2008). The indicators used in the analysis match those used in previous assessments, which were originally developed by U.S. Fish and Wildlife Service in 1998, as published in Hillman and Giorgi (2002) but are also supplemented with additional references (e.g. Fox and Bolton 2007).

4. ASSESSMENT RESULTS

4.1 Hydrology

4.1.1 Peak Flows

Peak flow estimates for each reach break were approximated using two different methodologies. For Andrews Creek, a set of regression equations developed for the Methow-Chelan (WRIA 48 and 47) regions were used to estimate peak flows for the 2-, 25-, and 100-year recurrence interval flows (Orsborn, 2002). These regression equations were developed by utilizing data from seven regional gauged systems, including Andrews Creek (USGS 12447390) which has been active since 1968. The regression equations are used to estimate a relationship between drainage area and mean annual precipitation to peak flow discharges. Since Andrews Creek gauge data was utilized to develop this regression equation, it was determined to be an appropriate method for estimating peak flow values within Andrews Creek. The WSDOT regression equations only provide peak flow estimates for the 2-, 25-, and 100-year recurrence intervals, so a logarithmic relationship between these values was developed to calculate 5-, 10- and 50-year recurrence interval flows following the formula below:

$Q = 223.18*\ln(R)+101.08$

Where Q = recurrence interval flow in cfs

R = recurrence interval in years

For Boulder, Lake, and Twentymile Creeks and Chewuch River, 2-, 5-, 10-, 25-, 50-, and 100-year recurrence interval flow estimates were calculated using regression equations for Region 2 of Mastin et al. (2016). These regression equations utilize local stream gauge data (including data from 89 gauges in Region 2) to develop relationships between drainage area, mean annual precipitation, and area-weighted forest canopy cover to estimate peak flow discharge values. Due to the Mastin et al. regression equation utilizing stream gauge data through 2014 and the additional gauge locations used to develop the regression equation, it was determined to be more suitable for all reaches except for Andrews Creek.

At the downstream limit of each reach, regression equation input variables were computed using StreamStats (USGS 2018b). Chewuch River peak flow estimates did not utilize USGS 12448000 (Chewuch River at Winthrop, WA) because it is located much further downstream in the drainage (just upstream of the confluence with the Methow River) and likely does not provide a good estimate of discharge in the upper drainage. The results of this analysis are summarized in Table 6 and Table 7 below. Reach breaks correspond to reaches shown in Figure 22.

Table 6. Peak flow discharge estimates in tributaries (cfs).

STREAM	REACH	Q2	Q5	Q10	Q25	Q50	Q100
Andrews Creek	A-1	263	460	615	800	974	1141
Boulder Creek	B-1	250	414	544	722	877	1030
Lake Creek	L-1	197	339	454	616	759	903
Lake Creek	L-2	183	320	432	593	735	880
Twentymile Creek	T-1	144	219	277	352	416	478

Table 7. Peak flow discharge estimates in Chewuch River (cfs).

STREAM	REACH	Q2	Q5	Q10	Q25	Q50	Q100
Chewuch River	C-10	821	1275	1612	2054	2431	2789
Chewuch River	C-11	808	1254	1584	2019	2389	2741
Chewuch River	C-12	663	1010	1266	1600	1884	2153
Chewuch River	C-13	658	1005	1261	1596	1881	2150

4.1.2 Survey Flows

Discharge was measured once on each stream in the upper Chewuch assessment area using an electromagnetic portable flow meter and top setting depth rod, based on USFS stream inventory protocols (USFS 2012) (Table 8).

Table 8. Measured discharge on each stream within the upper Chewuch assessment area.

STREAM	DATE	DISCHARGE (CFS)	LOCATION NOTES
Upper Chewuch River	11/5/2017	38.47	Measured just below the confluence with Twentymile Creek
Andrews Creek	11/3/2017	4.44	Measured under the bridge, at RM 0.1
Lake Creek	10/31/2017	16.36	Measured downstream of the bridge, at RM 0.2
Twentymile Creek	11/4/2017	3.24	Measured at the mouth
Boulder Creek	11/3/2017	8.77	Measured just downstream of the bridge, at RM 0.5

During the course of the 10-day survey period, flows continually receded from a recent peak flow of 144 cfs measured on October 22, 2017. USGS gauge 12448000 (Chewuch River at Winthrop, WA) flow records ranged from 106 cfs to 78.6 cfs during the survey period (October 31 – November 9, 2017). Flows recorded at USGS gauge 12447390 (Andrews Creek near Mazama, WA) varied between 4.75 and 9.25 cfs over the course of the 10-day survey period. The gauge measurement at the time of the survey was recorded as 4.76 cfs.

4.2 Hydraulic Model

The hydraulic depth, velocity, and shear maps from the existing conditions model simulations for 38 cfs, the 2-year flow and the 100-year flow are shown in Appendix E. Hydraulic modeling at the 38 cfs flow was completed to assess low flow habitat conditions and shear stress. The 2-year flow represents the channel forming flows that have the highest effect on geomorphology and channel unit formation. Habitat unit diversity can be observed by reviewing the depth and velocity maps under current conditions. The level of connection of off-channel and side channel habitat can also be observed from modeling both at low flow and channel forming flows. Increasing the capacity for off-channel habitat connection between the low flow and the 2-year flow would likely provide some of the greatest benefits to juvenile Chinook for rearing and overwintering. The 100-year flow was modeled to assess any risks to infrastructure or flooding of property. Completed model runs were initially reviewed in HEC-RAS to verify accuracy of results and then exported to a GIS compatible data file. GIS files include data raster grids representing the model depth results. Summary statistics for the Chewuch River thalweg are included in Table 9.

Table 9. Hydraulic Summary Statistics for Chewuch River Channel Thalweg

SIMULATION	DEPTH (FT)			VELOCITY (FT/S)			SHEAR STRESS (LBS/ SQ FT)		
	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX
100-year	1.38	2.8	5.4	4.52	9.4	15.2	1.5	6.2	13.1
2-year	0.89	1.8	3.4	1.47	5.7	9.1	0.1	1.8	9.1
Base Flow 38 cfs	0.49	1.3	3.1	0.05	0.3	7.7	0.01	0.4	8.3

4.3 Watershed Geomorphic Description

4.3.1 Historic Aerial Photograph Assessment

The earliest available historic aerial photographs from 1953 post-date human disturbance in the watershed, however they were used to characterize the change in conditions over time, natural and impaired geomorphic processes, and historic disturbances that have impacted processes and available habitat within the reach (Appendix D). By 1953 most of the road network that exists today was already constructed, including Forest Service and logging roads. Roads running along the Chewuch River are primarily at the valley margin or on alluvial fans emanating from larger tributaries. USFS Road 5160 road runs along the western valley margin along the entire main stem channel through the project reach. USFS Road 5010 runs along the eastern valley margin from the downstream end of the project reach up to the bridge over the Chewuch River at RM 20.4.

Reviewing the historic air photos reveals that the main stem Chewuch has remained relatively stable laterally over time (Appendix D). Significant bank erosion was limited to a few locations, with much of the channel remaining in the same location over the past 64 years. Where floodplains are present, there is evidence of historic side channels in the photos and the LiDAR, however, most of the side channels are currently perched above the channel. Much of this disconnection is also present in the 1953 aerial photo, however, some side channels were active in 1953 that have subsequently become disconnected (Appendix D). The lack of floodplain activation where the valley widens at the 2-year (Appendix E, page 2) and 100-year floods (Appendix E, page 3) further suggests that the main stem channel has lowered or incised over time. The relative lack of lateral channel migration, perched side channel inlets, and lack of floodplain activation dating as far back as 1953 indicates that disturbances leading to the current, incised nature of the channel occurred prior to 1953. Further incision and associated disconnection of floodplain and side channel continued to propagate upstream through the reach following 1953, as is evident upon review of the historic air photos.

Specific side channels have become less connected since the 1953 photo. No Snake Side Channel in the 1953 photo appears to have conveyed more flow based on the wider channel form with more unvegetated bars. At RM 22.3-22.5, upstream of July Creek, there is a side channel that is currently 8 feet above the current channel. Looking at the 1953 photo, the channel was an active anabranch channel of the mainstem (Appendix D). The side channel at RM 22.8 on the left bank is currently 3 feet above the mainstem, where in the 1953 photo, the same side channel is wider and appears to be more active. Between RM 25 and 25.4 the mainstem channel was flowing on the left bank in 1953 and is now flowing in a side channel adjacent to USFS Road 5160. The left bank channel that had served as the mainstem is now at a higher elevation than the current mainstem, indicating that downcutting has occurred in this area. These disconnected side channels are key areas where restoration to provide additional off-channel rearing habitat and overwintering habitat is likely to be successful.

4.3.2 Channel Substrate Characterization

The large-scale controls on reach scale geomorphology from alluvial fans emanating from larger tributaries directly impact sediment transport character within the reach. Further, confined reaches of the mainstem exhibit different sediment characteristics than unconfined reaches, and those of tributaries. The confinement of the channel is due to the alluvial fans constricting and accelerating flow around the fan, increasing transport capacity. Confined reach sediment characteristics can also be observed in incised reaches, where floodplains are disconnected and stream power is increased. Figure 19 shows median grain size (D50) distribution in confined and unconfined reaches of the mainstem, and in tributaries. The median grain size distribution in unconfined reaches covers a larger range of sizes than in either the tributaries or the confined reaches, which indicates a better potential for floodplain restoration, based on the capacity to provide a mosaic of habitat types and velocities. Confined reaches are more likely to have more consistent high velocity flows, and tributaries are generally steeper than the mainstem Chewuch River.

In areas upstream of alluvial fans, flows are generally constricted and slowed due to backwatering effects during large floods, decreasing transport capacity and reducing median grain size as shown in Figure 20. The exception to this can be observed in incised areas where even though the valley is not affected by alluvial fans, the confined inset floodplain still results in higher shear stress and sediment transport (Figure 22, upstream of RM 22). Similarly, in general, multithread channels have a lower distribution of median grain size than single thread channels, due to lower velocities (Figure 21 and Figure 20 and Appendix E). Side channels also have much lower velocities and median grain size. The exception to this concept is an area that may have multiple channels, but is also incised (see Appendix E upstream from RM 22 for more detail), which due to the confinement of the inset floodplain may also have higher shear stress.

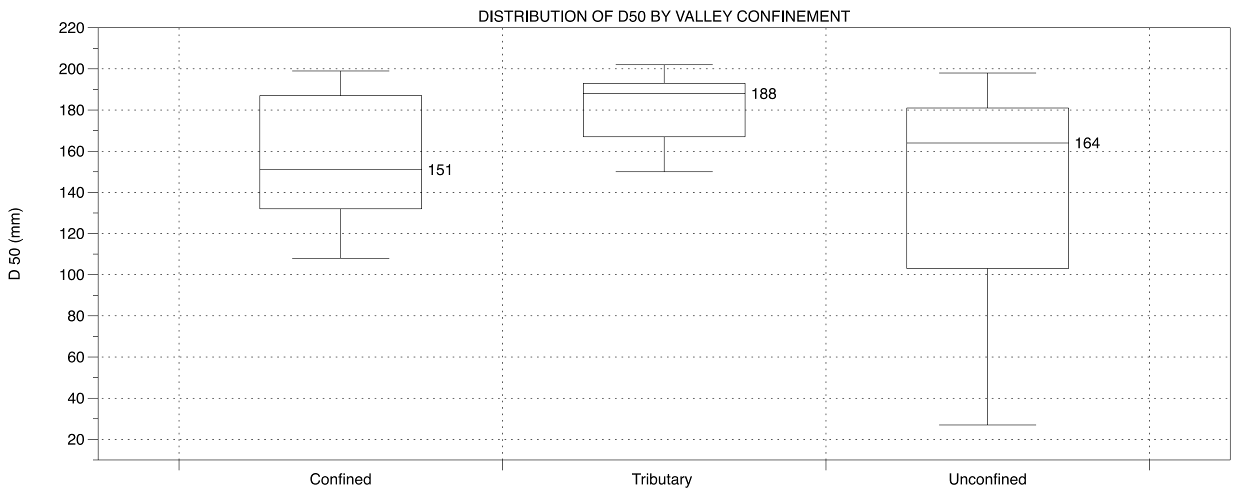

Figure 19. Distribution of surface D50 by valley confinement (main stem channel) and tributaries.

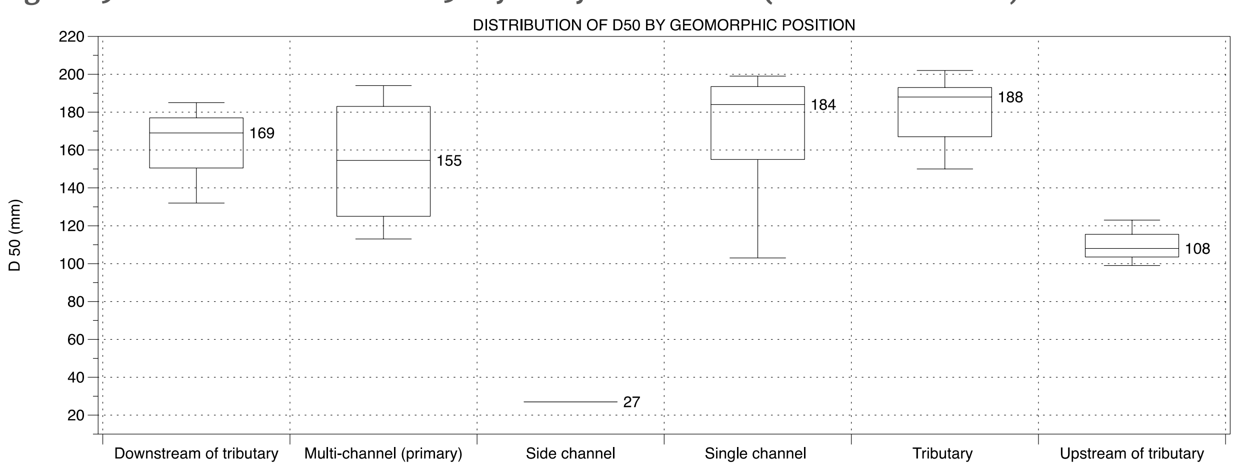

Figure 20. Distribution of surface D50 by geomorphic position.

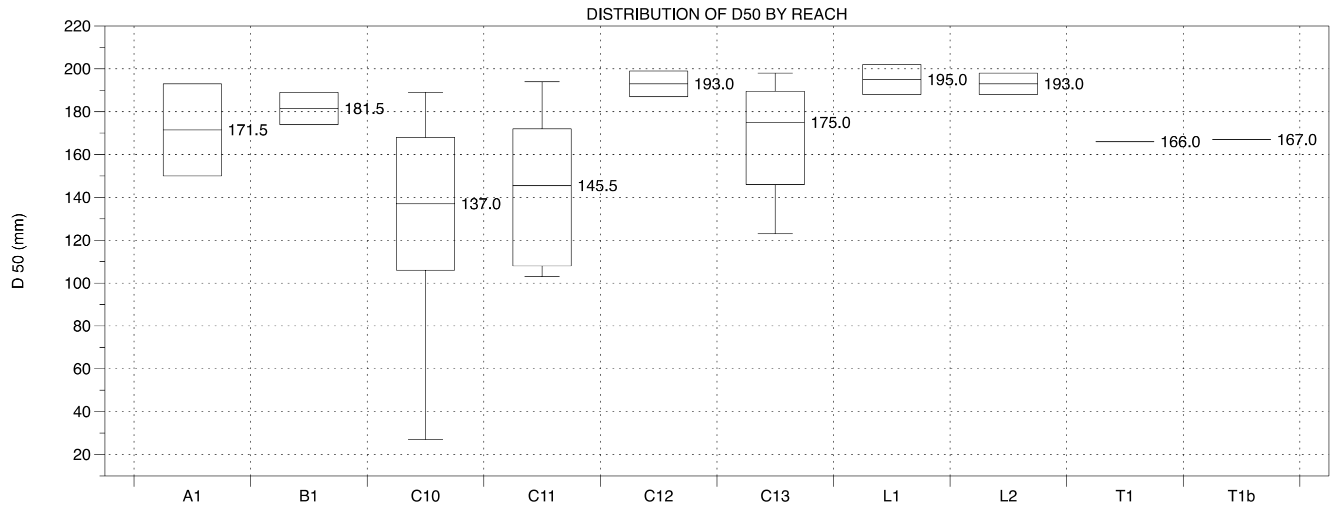

Figure 21. Distribution of surface D50 by reach.

Information on substrate characteristics by project reach can also help to inform decisions about restoration actions. The mean and distribution of grain sizes in a reach can convey information about the potential sediment transport in that reach and the potential for habitat diversity. The reach -specific distributions of the D50 are shown in Figure 21, and identify that specific reaches (e.g. C10, C11) may be better candidates for restoration work than some of the other areas. D50 is influenced by stream gradient, shear stress, sediment sources and stability, and habitat diversity (which are largely driven by depth and velocity). A larger distribution of grain sizes across the D50 is an indication that there is potential in the reach for a higher diversity of habitats, given the current sediment transport conditions.

4.4 Chewuch River Reach Descriptions

In the following sections, reach descriptions provide further detail on habitat conditions. Table 10 summarizes the habitat metrics for each reach and relates to each description below. A map of sampled reaches is provided in Figure 22.

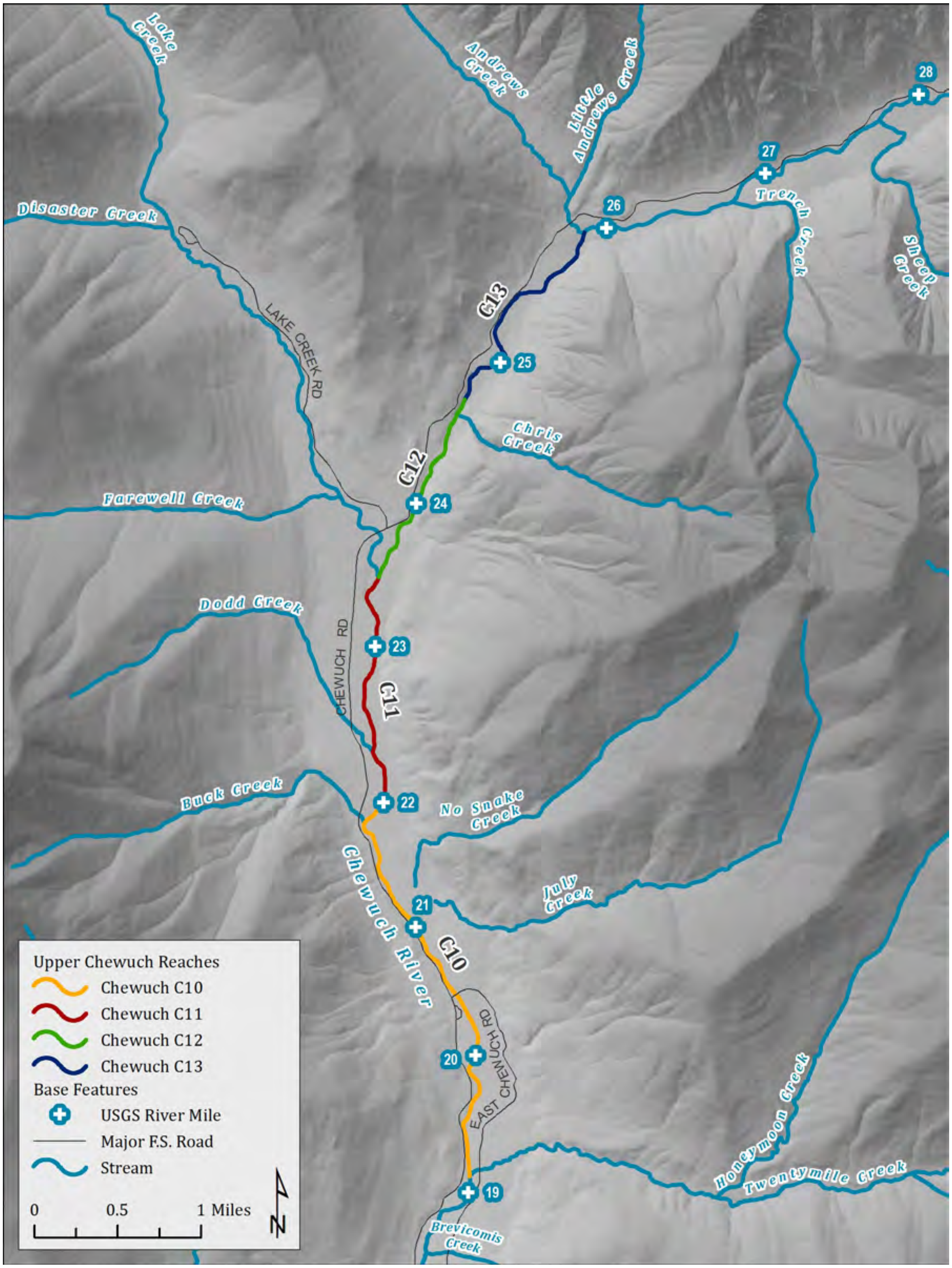

Figure 22. Reach map showing reach breaks in Upper Chewuch and tributaries.

4.4.1 Chewuch C10

Reach Overview

Reach C10 (Figure 23) is moderately confined between alluvial fans on the east and high hillslopes on both the east and west. The reach is located between the confluence with Twentymile Creek at RM 19.1 and the top of No Snake side channel at RM 22.0. Though the reach lacks sinuosity and complex habitat in the mainstem, it has ample high-quality salmonid rearing habitat in several side channels, including No Snake side channel (Figure 24). Two small tributaries (July Creek and No Snake Creek) flow into the No Snake side channel, with minimal contribution to flow. There is a significant influx of hyporheic flow through the No Snake side channel.

Anthropogenic features in the reach include USFS Road 51/5160 along river right, three dispersed campsites in the lower half mile of the reach, Camp Four Campground, the bridge over the Chewuch River at RM 20.4, and the quarry along river left near the downstream end of the No Snake side channel. The downstream section of July Creek runs through the parking area of the quarry and fine sediments and sand are transported to No Snake Side Channel at the mouth of July Creek.

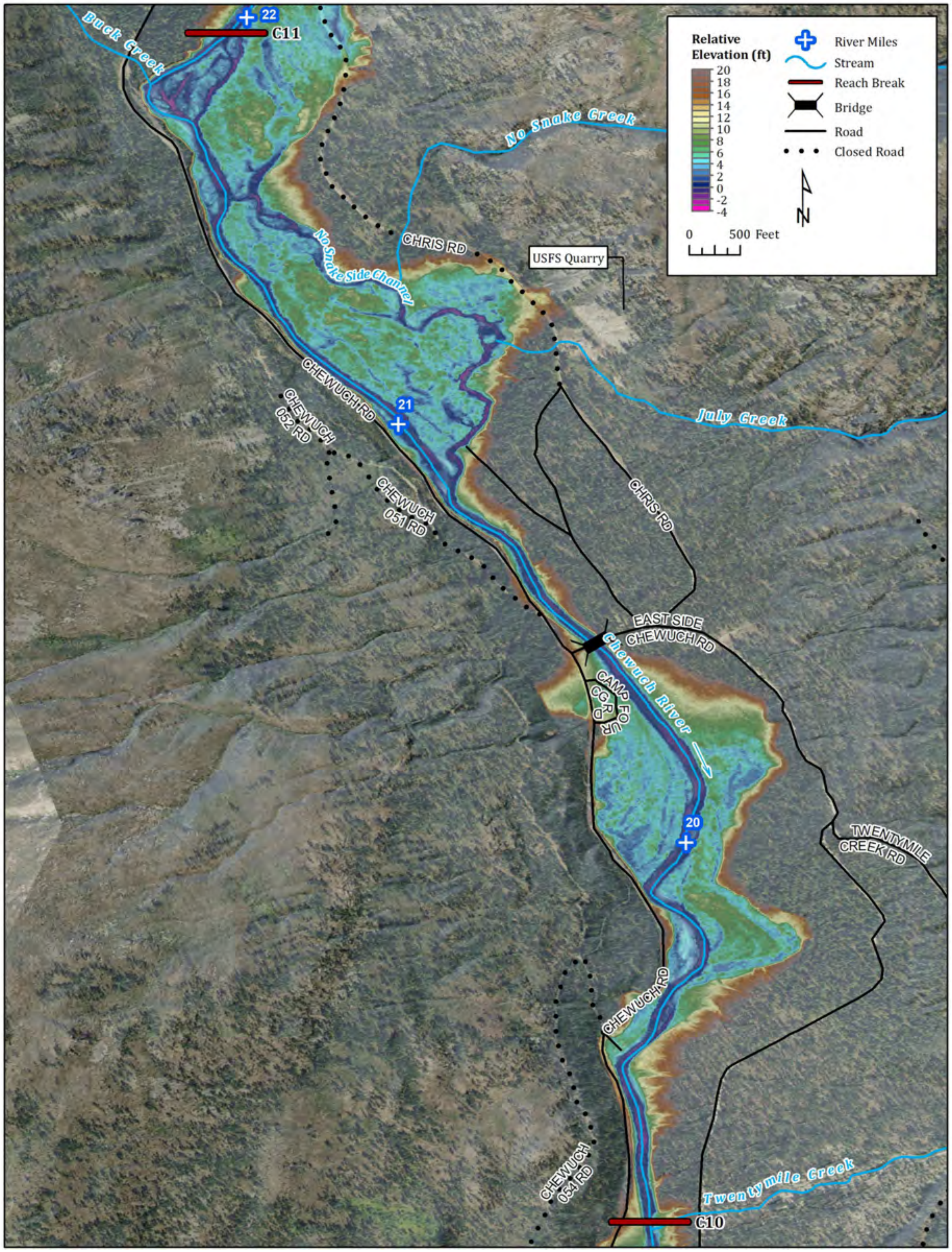

Figure 23. C-10 Reach Map.

Figure 24. High quality juvenile salmonid rearing habitat in the No Snake Side Channel.

Habitat Conditions

Average gradient over the course of Reach C10 is 1.0 percent. According to the USFS (2008), "substrate is too large in many areas of the reach for steelhead or spring Chinook spawning, although anadromous fish (mainly Chinook) do spawn in the lower gradient areas in the reach" (Figure 25). There are several sections of extended fastwater habitat in the lower half of reach C10, especially around the bridge over the Chewuch River at RM 20.4. Spring Chinook spawning density is the highest in this reach compared to other sections of the mainstem within the study area (Figure 14). Much of the spawning occurs at the inlets and outlets of currently active, or potential side channel habitat. Reconnection of additional side channel habitat in this reach would provide rearing areas near emergence sites for fry and early juveniles that generally experience high levels of mortality.

Large trees dominate the riparian canopy. Ponderosa pine (*Pinus ponderosa*) was the dominant canopy species and red alder (*Alnus rubra*) was the most common understory species. Instream wood resources were deficient through much of the reach, with only 84 pieces per mile of qualifying large woody debris (LWD). Much of this LWD was recorded in the No Snake Side Channel, meaning the mainstem had especially low LWD densities.

Figure 25. Boulder-dominated substrate and uninterrupted riffle habitat in Reach C10.

There is substantial side channel habitat in reach C10 as compared to other reaches in the study area. The largest side channel, known as the No Snake side channel for the tributary that flows into it, is 1.2 miles long and has significant amounts of high-quality salmonid rearing habitat. The lower 4,500 feet of the side channel are meandering and exhibit pool-riffle morphology with abundant fish cover and LWD resources. The upper 1,800 feet of the side channel are a complex network of hyporheic-fed, exclusively slow-water channels through mature forested floodplain. Upstream of this section the side channel runs through mature forested floodplain habitat. Four active beaver dams were found in the upper portion (Figure 26). The top end of the No Snake side channel was dry at the time of survey, and, with the exception of negligible inflow from No Snake Creek and potentially July Creek, the entire side channel complex was fed by hyporheic flow at the time of survey. Average water temperature was 2 degrees Celsius higher in the side channel (3 °C) than in the mainstem (1 °C) at the time of survey.

Two smaller side channel complexes were also identified in reach C10 downstream from the bridge from RM 20.4 to 19.7 on both banks. These areas are not connected during low flow, and are marginally connected at the 2-year flow based on hydraulic model results (Appendix E, page 2). Reconnection of these areas through large wood placement and excavation of pilot channels could provide additional off-channel rearing area in this lower gradient reach.

Figure 26. Several large beaver dams and associated ponds were present in the No Snake Side Channel complex.

Geomorphology

Several confining features are intermittently present throughout the reach, including USFS Road 5160 and high hillslopes along the eastern edge of the valley. There are also high hillslopes/alluvial fans along the western edge of the valley in the bottom half mile of the reach and from Camp Four up to the downstream end of the No Snake side channel. The geomorphology of reach C10 is heavily influenced by the large, active alluvial fans formed by several tributaries draining the eastern valley margin. These alluvial fans confine the floodplain and channel, creating a marked change in channel planform and floodplain function. This natural process creates sub-reaches along the channel where the floodplain is broad and there are multiple channels between confining alluvial fans (Figure 23). The rapid confinement of the floodplain and channel forces hyporheic flow upward immediately upstream of the alluvial fans, commonly expressed by groundwater presence and/or wetland vegetation alongside channels and off-channel floodplain wetlands. These locations are prime rearing for salmonids as there is significant temperature buffering during both the winter and summer months.

There are two distinct valley segments within reach C10 that are separated by the July Creek alluvial fan. The downstream valley extends from Twentymile Creek to July Creek alluvial fans. Floodplains are present on both sides of the main channel and have relic side channels, however the inlets to the longest of these features are perched above the channel 8 – 10 feet. A 0.6 mile long side channel on the left bank (east) floodplain flows around an unnamed tributary alluvial fan, with groundwater influence both up and downstream of the fan (open water and wetland vegetation). The inlet to this side channel complex is currently perched above the channel, limiting overbank flow to large flood events – two-year flow modeling shows marginal connection. The right bank floodplain (west) has several relic side channel features at the upstream end that have similar perched inlets and some wetland vegetation present. At the downstream end of the right bank floodplain there is an active side channel with groundwater influence between RM 19.7 – 19.8.

The upstream valley segment extends from the July Creek alluvial fan up to the inlet of the No Snake side channel near RM 22 (Figure 23). The main stem channel flows along the western side of the valley upstream of the July Creek alluvial fan, with the 1.2 mile-long No Snake side channel on the left bank (eastern) floodplain. The side channel flows around the No Snake alluvial fan, and is groundwater influenced along the lower 1.05 miles with multiple beaver dams. The lower 0.8 miles of the side channel has perennial flow with abundant large wood as groundwater and tributary contributions are sufficient to maintain surface flow. The upstream inlet (RM 22) to this side channel complex is currently perched above the main stem channel 6 – 8 feet, limiting overbank activation at the inlets to large flood events, although connection at the two-year flow is supported by the model (Appendix E, page 2).

The main stem channel is characterized by a plane-bed, incised channel with an average bankfull width of 81.7 feet width:depth ratio of 25.8. The reach is dominated by riffle habitat (57%), with several extremely long riffle units found near the bridge at RM 20.4, and near the top of the reach adjacent to the No Snake side channel. The stream channel averages 1% gradient over the reach, though maximum gradients of up to 3% were observed near the RM 20.4 bridge. Both pool and large wood counts were below the average for the entire project reach, indicating available habitat is lacking relative to upstream reaches of the river. A total of 4.67 pools/mile were measured, with over 90% of the pools shallow (less than 2 feet deep). The channel is classified as a Rosgen type C3 and B3 channel, with the type present being a function of position relative to confining alluvial fans (Table 10).

Figure 27. Significant active bank erosion at RM 21.8 threatens USFS Road 5160.

Active bank erosion exists in sections of the channel between large alluvial fans. Bank erosion is typified by undercut banks at most locations along the main stem channel. There is significant active bank erosion near RM 21.8 on the right bank of the channel for approximately 600 feet as it approaches USFS Road 5160 (Figure 27). Bank protection has been placed along the road for approximately 160 feet at the downstream end of active erosion where the channel impinges on the road. The resultant cut-bank is between 20 and 30 feet high and is composed of fine grained, easily erodible sediments. This site has been identified as a chronic source of fine sediment to the channel.

The channel substrate is characterized by a wide range in average (D50) grain size between 27 and 189 mm, with an average D50 of 137 mm (Table 10). The large range in average grain size is attributed to the variation of valley and channel confinement from multiple alluvial fans, and samples from the No Snake side channel that are finer relative to the main stem channel. Locations where the main stem channel is confined by fans have a larger average D50 than locations where the valley is unconfined. Sediment samples in the No Snake side channel were 80% finer than those in the main stem channel. The percent sand in the main stem channel is between 0-4%, and 7% in the No Snake side channel. The sample in the No Snake tributary was taken at the confluence with July Creek, where significant fine sediment was observed entering the side channel (Figure 7). Subsurface sediment sampling at this location had 29% sand, considerably more than subsurface samples in the main stem channel which had between 0-7% sand, indicating that July Creek is contributing fines to the side channel.

4.4.2 Chewuch C11

Reach Overview

Reach C11, located between the top of the No Snake Side Channel (RM 22.0) and the confluence with Lake Creek (RM 23.5), is confined between high hillslopes and roads on both sides of the valley (Figure 28). The channel has low sinuousity and low habitat complexity. However, there are numerous high-flow channels and fastwater side channels throughout the reach and both velocity and shear stress are higher throughout the reach than in c10. Two tributaries are present in the reach: Bear Creek and Lake Creek. Bear Creek, which enters the Chewuch near the bottom of Reach C11, was dry at the time of survey. Lake Creek, which enters the Chewuch at the top of Reach C11, was contributing approximately 30% of flow at the time of survey. Aside from road grades along each side of the valley, there is very little human disturbance in the reach. Anthropogenic features in the reach include USFS Road 5160 along the west valley hillslope, USFS Road 800 (currently closed) along the east valley hillslope, and one dispersed campsite complex on river right.

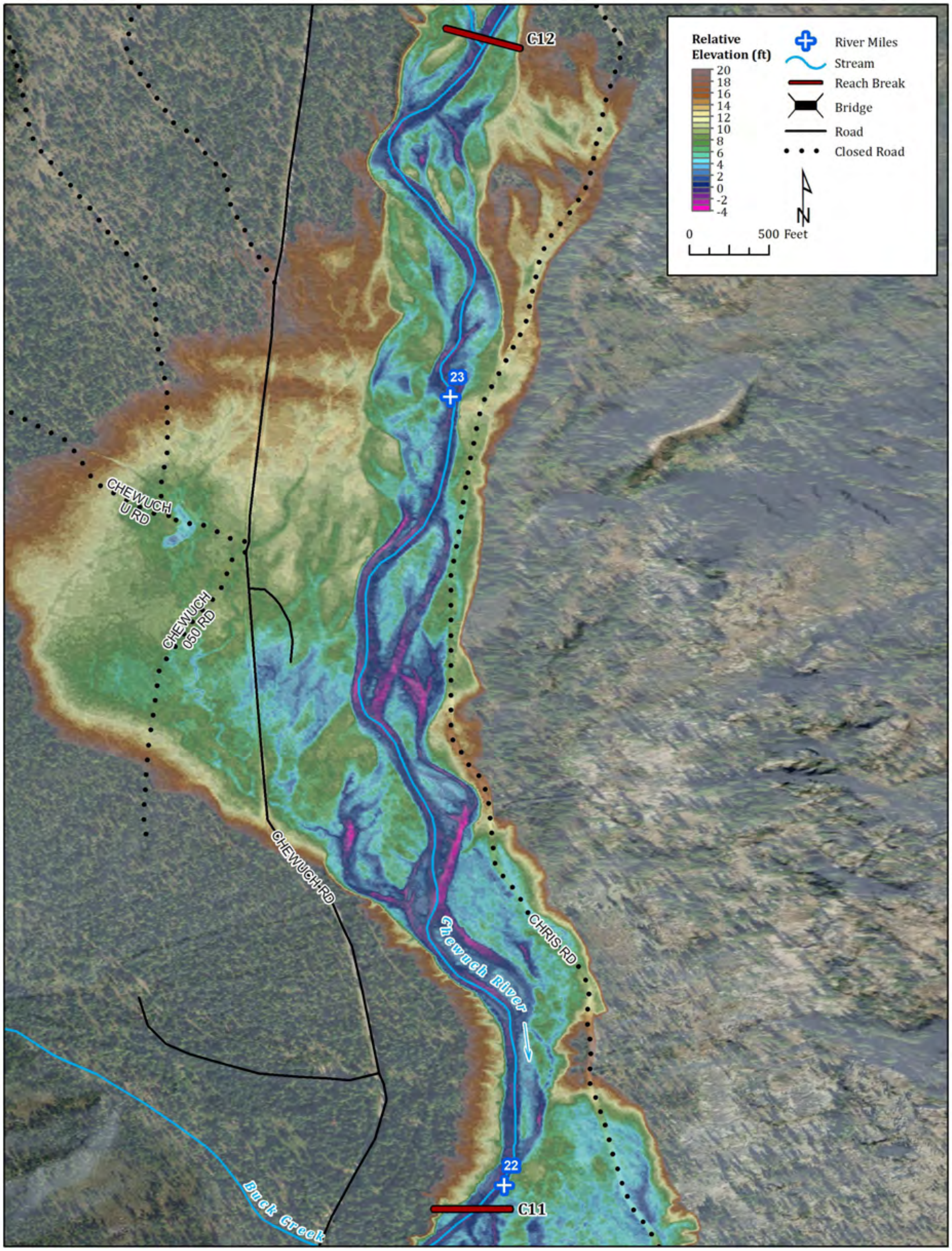

Figure 28. C11 Reach Map.

Habitat Conditions

Average gradient over the course of Reach C11 is 2.12%. Reach C11 had 3.36 pools per mile, and pools comprised 5.5% of total habitat area. This was the lowest pool proportion of any reach on the mainstem Chewuch River. There are sections of extended fastwater habitat throughout reach C11 (Figure 29), including many fastwater high flow channels that were dry at the time of the survey (Figure 30).

Small trees dominated the riparian canopy. Ponderosa pine (*Pinus ponderosa*) was most commonly the dominant canopy species and black cottonwood (*Populus trichocarpa*) was most commonly the dominant understory species. Instream wood resources were deficient through much of the reach, although there were 75 pieces per mile of qualifying large woody debris (LWD), there were only 25.5 pieces per mile for pieces > 12 in diameter and 35 ft long, which is well below the target condition of 42.5 pieces/mile of that size range (Fox and Bolton 2007).

Figure 29. Extended riffle habitat typical of Reach C11.

Geomorphology

Reach C11 is highly confined by the Buck Creek alluvial fan at the downstream end of the reach from RM 21.8 to 22.4. The Lake Creek alluvial fan confines the channel at the upper end of the reach, with the only unconfined section of channel in the reach between RM 22.4 and 22.7 (Figure 28). The large alluvial fan of Lake Creek extends ¾ mile downstream of the confluence with the main stem channel, coalescing with the

Dodd Creek alluvial fan at the downstream end. Groundwater influenced side channels are limited in reach C11, owing to the overall confinement of the valley and channel. There are multiple side channels present on either side of the channel through this reach, however there is only 1 groundwater influenced side channel between RM 22.9 – 23.0 on the right bank floodplain. There is flow deflection of the main stem channel at the inlet to the side channel at RM 23, with flow increasing in the side channel in the downstream direction, indicating additional groundwater contribution to flow (Figure 28). Active side channels with no connection to groundwater are present on the left bank floodplain between RM 22.2 – 22.8 and 23.2 – 23.3 that convey bankfull and greater flows. Several potential flow pathways for side channels were noted, but clear indication of connection with these relict channels was lacking in the low flow and two-year flow model results (Appendix E, pages 1 and 2).

The main stem channel is characterized by a steep (>2%) riffle dominate channel lacking pools and instream wood. The channel is a Rosgen type B3, with some C3 sections where confinement is less pronounced. The average bankfull width is 78 feet, with a width:depth ratio of 20.3. The channel has very low sinuosity (1.09) and low geomorphic complexity (near 75% fast turbulent channel types). At 2.12%, the overall gradient in Reach C11 is over twice that of Reach C10 (1%) (Table 10). Reach C11 is dominated by riffle habitats, and two rapids are present with gradients of up to 10%. There are multiple extremely long fastwater (riffle) channel units with minimal LWD and little habitat complexity (Figure 29). Some large sections of active erosion and channel incision are present in the reach, along with numerous fastwater side channels and other high-flow channels. Some side channel features are activated by island/bar apex LWD jams. Both pool and wood counts were below the average for the project reach, indicating available habitat is lacking relative to upstream reaches of the river.

Active bank erosion is found throughout the reach on both sides of the channel as the river creates and inset floodplain along this reach. Recent bank erosion was observed at riffles and on the outside of meander bends. Reach C11 has the highest measured active bank erosion of all the reaches included in the assessment, with just over 22% of stream banks eroding by length (Table 10). This is more than double the amount of any of the other reaches. Most of the eroding banks are more than 10 feet high and composed of readily erodible recent alluvium and alluvial fan deposits. Connection of high flow side channels in this reach would likely require excavation to form pilot channels, as well as placement of large wood to direct flows due to the difference in elevation between the channel bed and the floodplain above. Erosion into the alluvial fan deposits along the right bank loads the channel with large boulders and cobble (Figure 31), increasing the average channel substrate size cumulatively in the downstream direction. Shear stress and velocity are higher in this reach than in C10 (Appendix E, pages 5 and 8) and there is very limited evidence of spawning in the spawning data (Figure 14).

Figure 30. One of numerous fastwater side channels in Reach C11 that were dry under low flow survey conditions.

Figure 31. Wetted side channel area in Reach C11.

4.4.3 Chewuch C12

Reach Overview

Reach C12 is located between the confluence with Lake Creek at RM 23.5 and the top of the gorge at RM 24.7 (0.1 miles upstream of the confluence with Chris Creek) (Figure 32). The reach is highly confined by alluvial fan deposits, high hillslopes, and a bedrock gorge running from RM 23.9 to RM 24.7 (Figure 33) and has and average gradient of 3.3%. Due to the natural confinement of the reach, there is limited floodplain habitat. This reach carries much less water than reaches C11 and below since it is upstream of the confluence with Lake Creek. One unnamed tributary flows into Reach C12 at RM 23.9, and Chris Creek flows into the Chewuch at RM 24.6. Each tributary contributes about 1% to the total flow of the Chewuch in Reach C12.There is little human disturbance in Reach C12. Anthropogenic features include USFS Road 5160 along river right and a single dispersed campsite complex on right bank at RM 23.7. The Chewuch River Road is almost entirely set back from the river corridor or high above the river corridor, except for one small section with some bank armoring between RM 23.8 and RM 23.9.

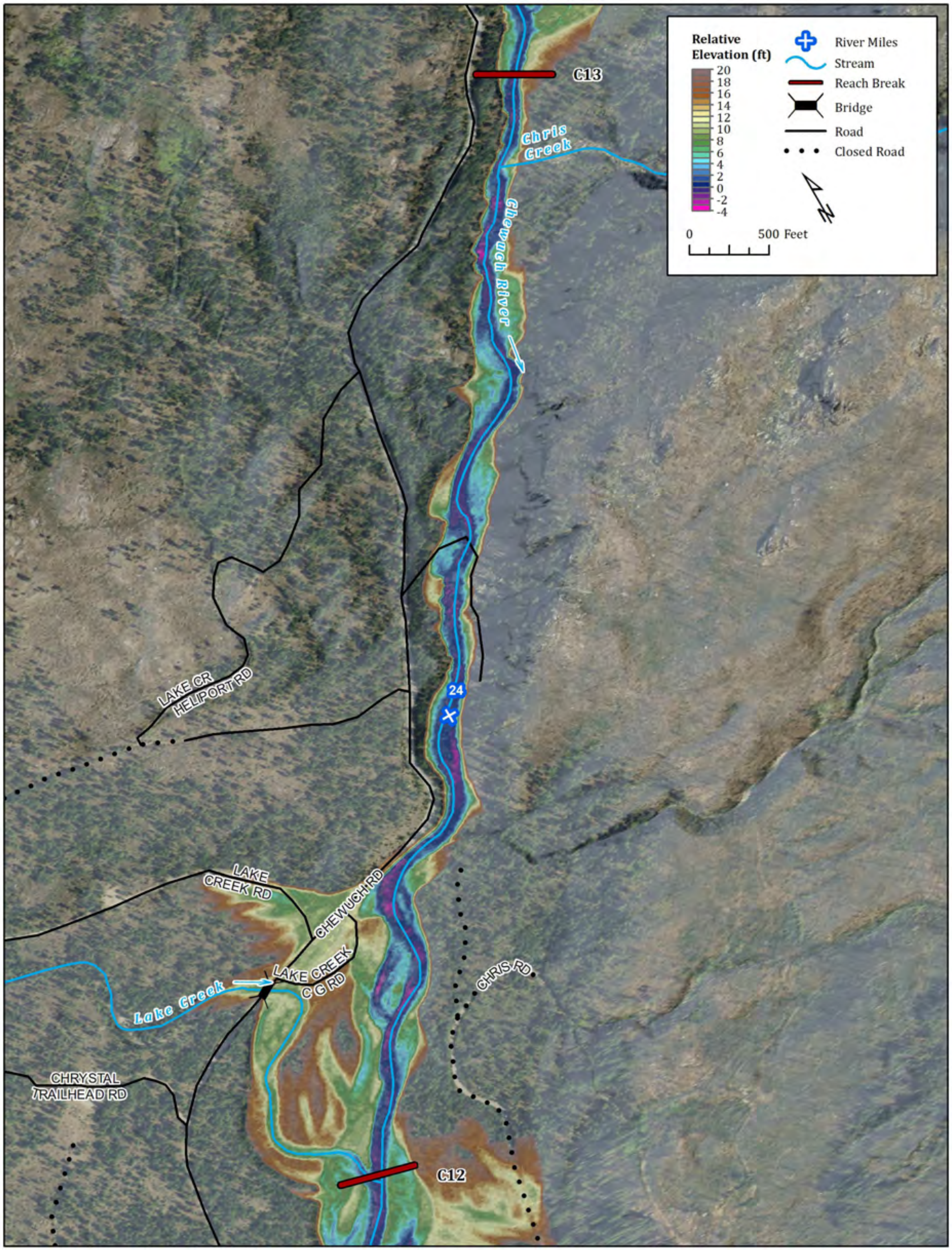

Figure 32. C12 Reach Map.

Figure 33. The Chewuch River runs through a deep gorge in Reach C12, confined by high hillslopes and rock cliffs.

Habitat Conditions

There are increased large wood resources in Reach C12 compared to C11, but there are few stable LWD jams. Reach C12 has an increased frequency of pools, of generally smaller size and with greater maximum depths, compared to downstream reaches. This reach has deeper pools on average with 43 percent of pools having greater that 3 ft. residual depth, which could provide thermal and velocity refuge for juvenile Chinook salmon, although the gradient in the reach may preclude active use by fish from downstream spawning areas. Due to the bedrock in the reach, bank erosion is limited at just 6.2 percent, and percent fines are 11.4 percent.

Geomorphology

Reach C12 is highly confined by the Lake Creek alluvial fan at the downstream end (RM 23.5 – 24.1) and the Chris Creek alluvial fan at the upstream end (RM 24.4 – 24.7). There is a narrow, 200-foot wide bedrock valley between the bounding alluvial fans defining reach C12 (RM 24.1 – 24.4). The Chewuch River valley begins to widen near RM 24 at the Lake Creek alluvial fan and downstream of the bedrock gorge. Additional confining features include a campground on the right bank near RM 23.7, and bank protection installed along USFS Road 5160 between RM 23.8 and 23.9.

The mainstem channel has the highest average slope (3.33%) of all the reaches assessed, and lowest average width:depth ratio. The low sinuosity (1.06) is a result of valley and alluvial fan confinement. There is essentially no floodplain development and there is only one small side channel in Reach C12 at RM 23.7 where the valley opens up downstream of the gorge. The channel is dominated by riffle and rapids with a large cobble and boulder substrate. The average bankfull width is 71.4 feet and is classified as a Rosgen type B2 and F2b channel. Reach C12 had the highest measured pools/mile (11.02), lowest mean pool spacing (479 feet), and highest percentage of pools greater than 2 feet deep (63.3%), relative to the other reaches assessed. All pools measured were greater than 1 foot deep, with an average residual depth of 2.8 feet (Table 10).

Wood loading is average compared to the project reach averages. Small pieces of wood comprise 2/3 of the wood present in the reach, with 84.3 pieces/mile, although 47.2 pieces/mile fall into the target size range for Fox and Bolton (2007) (Table 10 and Appendix A). The three of the four logjams in the reach are located in the narrow bedrock canyon section of the reach, where large pieces have become entangled on large boulders, creating stable accumulations of wood. Local wood recruitment is low throughout most of the reach, as the channel is highly confined with little available space for channel migration. Wood present in the channel is likely in transport, recruited into the channel upstream in reach C13.

Reach C12 has the lowest measured active bank erosion (6.2% of streambanks eroding), with sites occurring on the outside of meander bends as the channel flows around the Lake Creek alluvial fan (Table 8). The lack of active bank erosion is attributed to the high confinement of the channel (Figure 34), and lack of space for channel migration processes to occur. There is an actively eroding section of highly fractured bedrock in the gorge section of the reach near RM 24.4, recruiting a number of large boulders to the river.

The channel substrate is characterized by coarse cobble and boulders, with an average D50 of 147.5 mm (Table 10). Samples taken in the highly confined gorge section of the reach averaged 193 mm, while those downstream averaged 105.5 mm. This dramatic shift in the channel substrate is attributed to the widening of the valley and channel downstream of the gorge, decreasing flow velocities and transport capacity of the channel and resulting in fining of the bed due to deposition of finer substrate.

Figure 34. The Chewuch River confined by steep hillslopes in Reach C12.

4.4.4 Chewuch C13

Reach Overview

Reach C13 is located between the top of the gorge at RM 24.7 and the confluence with Andrews Creek at RM 25.9 (Figure 35). There is significant floodplain and side channel development in lower portions of the reach, but the upstream section of reach is moderately confined by an alluvial fan and high hillslope from RM 25.7 to the top of the reach. Andrews Creek, which joins the Chewuch at the top of Reach 13, is the only tributary within the reach. Andrews Creek contributes approximately 25% of the total flow of reach C13. There is very little human disturbance, and anthropogenic features include USFS Road 5160 along river right and a single dispersed campsite complex on right bank that appears to be used by horse packers (some plastic irrigation piping was found near the camp area). For the most part, the Chewuch River Road is set back from the river corridor, and throughout the reach it does not cut off any potential floodplain habitats.

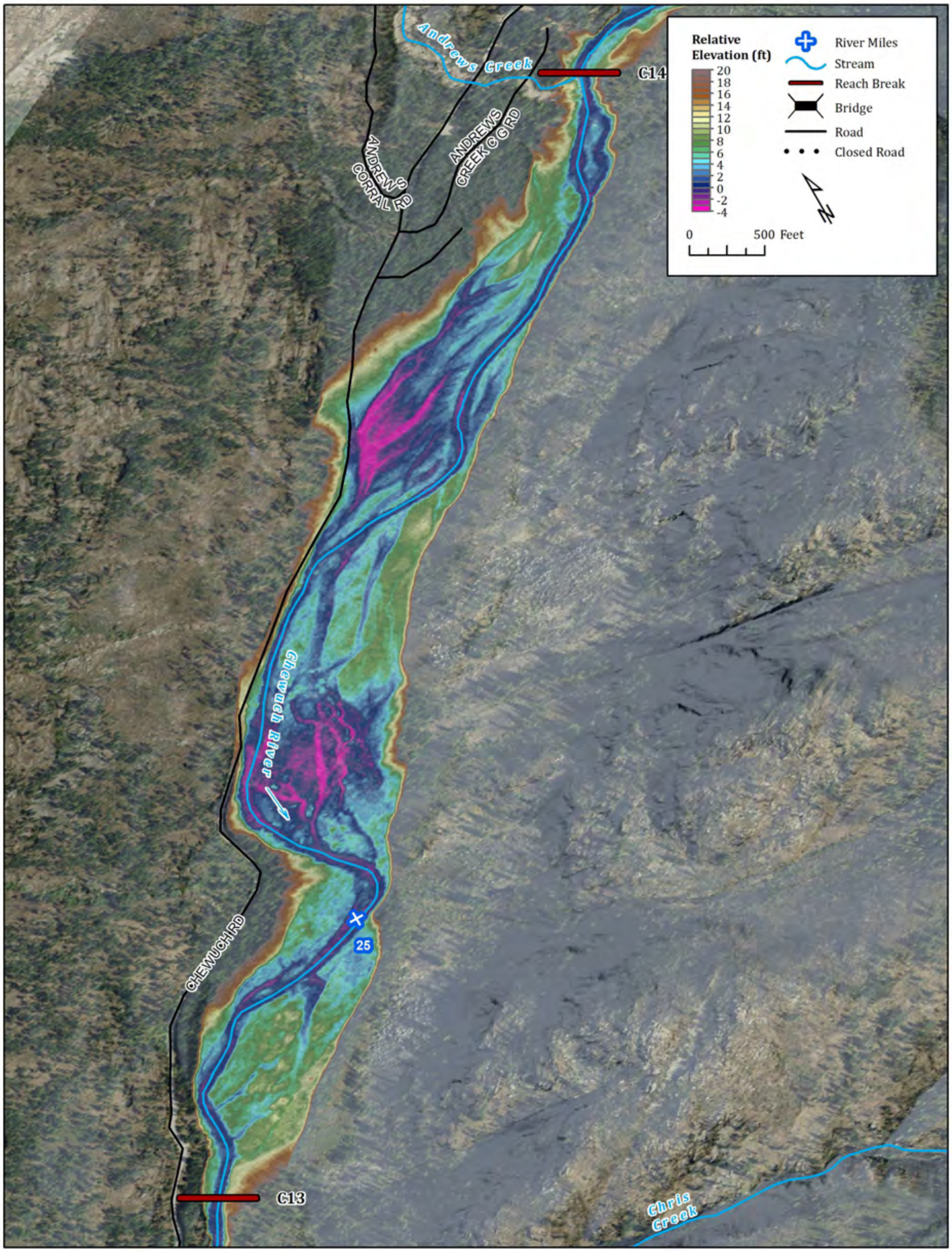

Figure 35. C13 Reach Map.

Habitat Conditions

Reach C13 is far less confined than C12 and has numerous side channels from RM 24.7 to RM 25.7. Many of the side channels, especially the two long side channels near the bottom of the reach, have significant amounts of quality salmonid rearing habitat and pool-riffle morphology. Spawning records show high levels of spawning in the downstream side channel on river left at RM 24.8, and in the mainstem at RM 25.2 against river right. Hydraulic model results show moderate connection at low flow in the side channel complexes and some increase in connection at the two-year flow. Velocity and shear stress are similar to C10 at the two-year flow (Appendix E, page 8). There are ample LWD resources within the side channels, including several massive jams. Forested floodplain is present on both sides of the river for much of the reach, and there is abundant channel-spanning wood in places (though much of this LWD is above bankfull).

Geomorphology

There are several valley confining alluvial fans throughout reach C13, with the Andrews Creek fan bounding the upstream end of the reach, and the Chris Creek fan at the downstream end. These alluvial fans confine the floodplain and channel, creating marked changes in channel planform and floodplain function. Between the alluvial fans, the floodplain is broad with multiple active side channels, and the channel is more sinuous and connected to the floodplain (Figure 35). An additional unnamed tributary flowing from the western side of the valley forms an alluvial fan that confines the channel between RM 24.8 and 25.1. The rapid confinement of the valley at the Chris Creek alluvial fan forces hyporheic flow upward upstream of the constriction, improving groundwater connection in upstream side channels. Side channels on the left bank (eastern) floodplain where flowing during field surveys in late fall during base-flow conditions, indicating groundwater is supporting flow in these critical habitat features. The left bank side channels between RM 24.7 and 24.9 upstream of the Chris Creek alluvial fan, and between RM 25.1 and 25.5 upstream of the unnamed tributary alluvial fan, both had flowing water present during base-flow conditions. These locations are prime rearing for salmonids as there is significant temperature buffering during both the winter and summer months. These two areas are also used by spawning spring Chinook year after year. Side channels in the reach become progressively dryer and less connected to the main channel with perched inlets further upstream toward the Andrews Creek alluvial fan.

The channel is characterized by pool riffle morphology where unconfined, with a well-connected floodplain with side channels that are active over a range of flows. The channel is more simplified where confined by alluvial fans, with more plane bed morphology and lack of side channels and floodplain. The river is classified as a Rosgen type B3, C3 and C4 channel in reach C13, with the type being a function of position relative to confining alluvial fans.

Reach C13 had the highest wood loading of all the reaches assessed, with more than double the number of pieces relative to the project reach averages. Small wood dominates the distribution of wood sizes (66% of all pieces), with 240 pieces/mile throughout the reach (Figure 36). Individual large wood pieces and logjams are found primarily in the unconfined sections of the reach between the alluvial fans. There was more than double the amount of large size class wood measured in reach C13 (12.9 pieces/mile) relative to the other reaches assessed (Table 10). The abundance of large wood in the reach is attributed to the recent fire that burned a significant portion of the left bank floodplain between RM 25.7 – 25.1. There are numerous down trees on the floodplain and side channels where the fires occurred, readily available for transport during high flow events. Much of the large wood observed in the reach is within and downstream of the burn area, indicating transport of this material has been initiated.

Active erosion locations are found primarily in the unconfined sections of the reach between the alluvial fans. Much of the observed bank erosion is associated with instream wood and logjams as flow is deflected in the channel to adjacent banks. Where erosion is occurring adjacent riparian forest and downed trees are recruited into the channel.

There is a general trend of coarsening in the downstream direction from the upstream end of the reach to the unnamed tributary alluvial fan near RM 24.8. The channel bed typically ranges from boulder to gravel with cobble as the predominate substrate, and over half the channel is classified as riffle (54.3% of channel length). The high sediment loads from Andrews Creek at the upstream end of the reach contribute the full range of grain sizes to the creek (Figure 37). As the channel and floodplain flow around the alluvial fan, the valley is less confined and finer sediment begins to deposit in the channel. The furthest upstream sediment sample (D50 169 mm) in the reach is immediately downstream of where the valley begins to be less confined from the alluvial fan, and where deposition would initiate. Samples taken progressively downstream continue to coarsen (D50 181 to 198 mm) through the reach, downstream to the unnamed tributary alluvial fan. This pattern indicates that the reach is transport limited, as the supply of sediment from Andrews Creek is sufficient to exceed capacity. The overall connectedness of the floodplain between the alluvial fans also indicates that transport through the reach does not exceed supply.

Figure 36. Abundant large wood resources in a Reach C13 side channel.

Figure 37. Reach C13 showing higher diversity of substrate than other reaches.

4.4.5 Geomorphic and Habitat Data Summary

The geomorphic and habitat characteristics for the Chewuch River reaches from RM 19.1 to 25.9 surveyed for the upper Chewuch Assessment are presented in Table 10. The metrics are summarized from field data collected for the geomorphic assessment and USFS Region 6 Level II stream habitat protocol in October 2017.

Table 10. Geomorphic and habitat metrics for Chewuch River mainstem reaches.

Metric	Chewuch C10	Chewuch C11	Chewuch C12	Chewuch C13	Chewuch Average
Rivermiles	19.1 – 22.0	22.0 – 23.5	23.5 – 24.7	24.7 – 25.9	19.1 – 25.9
Measured reach length (mi)	2.57	1.49	1.27	1.4	6.73
Beginning elevation (ft)	2334	2470	2637	2860	2334
Ending elevation (ft)	2470	2637	2860	2991	2991
Change in elevation (ft)	136	167	223	131	657

Metric	Chewuch C10	Chewuch C11	Chewuch C12	Chewuch C13	Chewuch Average
Channel Characteristics					
Rosgen type	C3, B3	B3, C3	B2, F2	B3, C3, C4	B3, C3, B2, F2, C4
Sinuousity	1.10	1.09	1.06	1.16	1.10
Average slope (%)	1.0	2.12	3.33	1.77	1.85
Average bankfull width (ft)	81.7	78	71.4	68.0	75.3
Width:Depth ratio	25.8	20.3	19.8	23.1	22.5
Floodprone width (ft)	154.5	169.4	99.5	163.8	147.4
Average valley width (ft)	800	1000	150	500	613
Average D50 (mm)	137	165.5	147.5	175	148.7
Habitat Summary					
% Pool	8.4	5.5	9.8	10.3	8.2
% Riffle	57.5	68.0	62.6	54.3	60.4
% Rapid	0	3.4	23.5	10.5	6.3
% Cascade	0	0	1.2	0	0.2
% Braided	0	2.6	0	0	0.7
% Fast non-turbulent	17.1	2.8	0.7	14.2	10.5
% Side channel	17	17.6	2.2	10.7	13.8
Pool Characteristics					
Pools per mile	4.67	3.36	11.02	7.86	6.24
Average Max pool depth (ft)	2.8	3.0	4.3	3	3.4
Average residual depth (ft)	1.3	1.6	2.8	1.8	2.0
Average residual depth < 1 ft (% of pools)	16.7	20	0	9.1	9.5
Average residual depth 1-2 ft (% of pools)	75	60	35.7	72.7	59.5
Average residual depth 2-3 ft (% of pools)	8.3	0	21.7	9.1	11.9
Average residual depth > 3 ft (% of pools)	0	20	42.9	9.1	19
Large Wood					
Small (6” x 20’) count	152	73	107	336	167
Medium (12” x 35’) count	60	30	53	155	75
Large (20” x 35”) count	6	8	7	18	10
Small pieces/mile	59.1	49	84.3	240	99.3
Medium pieces/mile	23.3	20.1	41.7	110.7	44.3
Large pieces/mile	2.3	5.4	5.5	12.9	5.8

Metric	Chewuch C10	Chewuch C11	Chewuch C12	Chewuch C13	Chewuch Average
Erosion and Substrate					
% Streambank Eroding	10.8	22.1	6.2	7	11.7
% Fines	15	6.6	11.4	13.8	12.2
% Gravel	21.9	15.3	14.2	16.2	17.2
% Cobble	48.9	38.4	30.2	43.8	40.6
% Boulder	14.3	39.7	42.8	26.2	29.7
% Bedrock	0	0	1.4	0	0.4
Riparian Canopy Proportions					
% Small Trees	18.5	62.5	68	66.7	51.7
% Large Trees	77.8	37.5	32	33.3	47.2

4.5 Tributary Reach Descriptions

4.5.1 Andrews Creek

Reach Overview

Reach A1, located from the mouth of Andrews Creek to the waterfall at RM 0.53, is a very steep, unconfined, low sinuosity reach flowing out from a confined gorge and V-shaped valley into an alluvial fan (Figure 38). The reach is dominated by rapid and cascade habitats and includes several braided sections. The gorge at the top of the reach includes a series of waterfalls that form the fish migration barrier. There is only one tributary in Reach A1 (Little Andrews Creek), located at the upper end of the reach. Little Andrews Creek contributes about 15% of the total flow present in Reach A1. There is very little human disturbance in Reach A1. The only significant anthropogenic feature in the reach is the USFS Road 5160 bridge over Andrews Creek at RM 0.1. There is also a USGS stream gage located upstream of the sample reach on Andrews Creek.

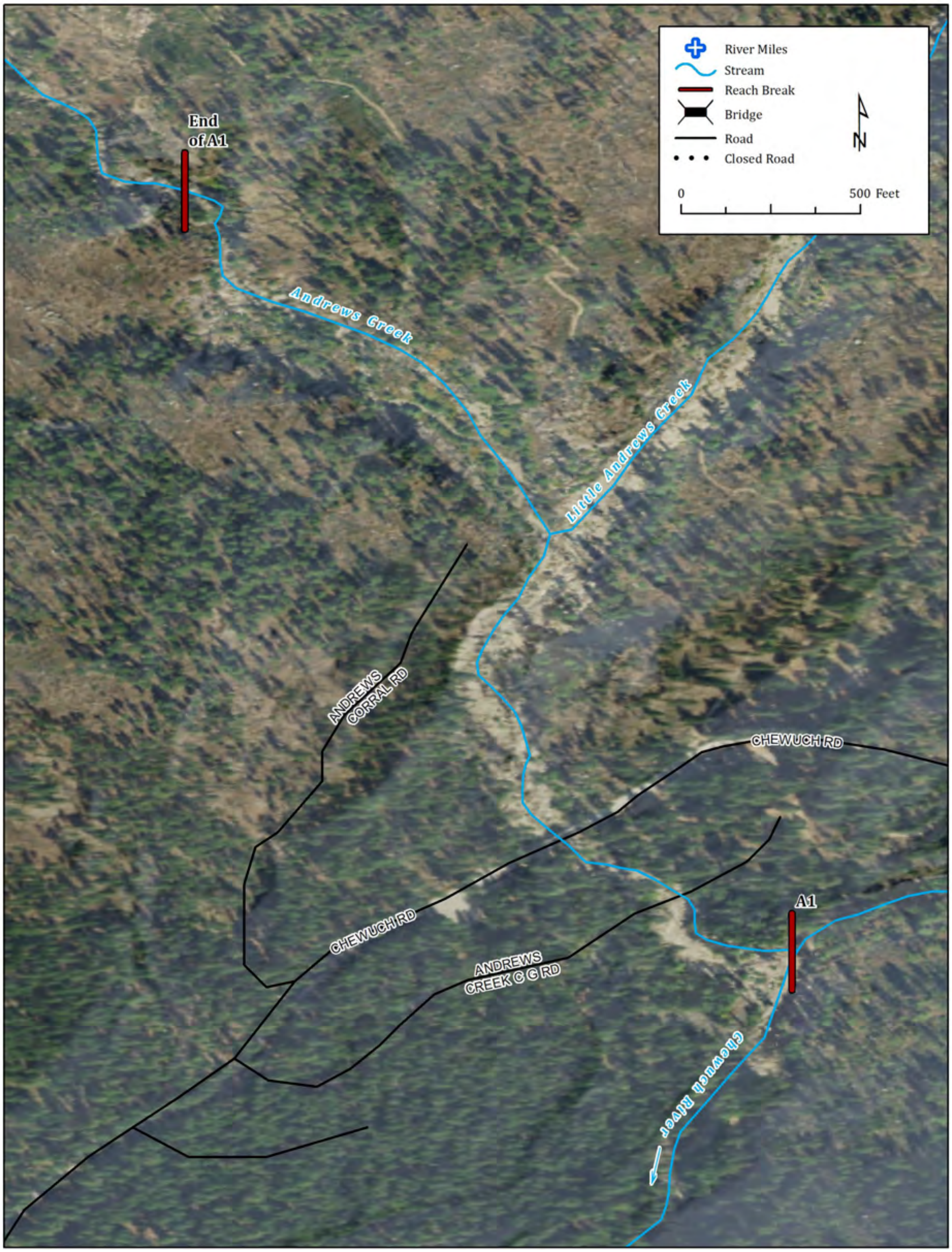

Figure 38. A1 Reach Map.

Habitat Conditions

Andrews Creek is very steep (11.54 %) with over 50 percent of the habitat area in rapid and cascade units. Deep pools occur in the reach (greater than 3 feet deep) but there is little side channel habitat. Over half of the substrate is boulder and percent fines are relatively low at 5.6 percent. LWD is more abundant above the confluence with Little Andrews Creek. Due to the gradient and dominant substrate in this reach, habitat is likely suitable for cutthroat or potentially steelhead with limited opportunities to restore Chinook habitat.

Geomorphology

Reach A1 on Andrews Creek extends from the confluence with the Chewuch River upstream to near RM 0.5. The channel is incised into the alluvial fan at the downstream end of the reach from RM 0.0 – 0.18, upstream of which the channel is confined within a narrow bedrock canyon. The canyon is only 130 – 150 feet wide at the head of the alluvial fan, widening to near 230 feet before narrowing again at the upstream end, terminating at the fish barrier falls at RM 0.5 (Figure 39). Little Andrews Creek joins Andrews Creek near RM 0.3. The channel is braided upstream of the fan, extending from valley wall to valley wall in most locations, with some minor floodplain and side channel habitat present between Little Andrews Creek and the fish barrier falls. Recent fires in the watershed greatly impacted the riparian forest upstream of reach A1 and adjacent hillslopes within the reach. These fires left abundant downed trees and standing snags, resulting in high wood loading in the reach, although the potential for wood recruitment is low.

The channel is classified as a Rosgen type B2 and B3 channel (Figure 40) with a bankfull width of 66.3 feet, with a width:depth ratio of 19.5. Cascades and braids comprise 90.1% of the channel length, with pools present in 3.4% of the channel. Pools density is 9.43 pools/mile and pool depths are typically 1-3 feet deep (80% of total), with 20% of pools greater than 3 feet deep (Table 11).

Wood loading was high in reach A1, although the majority of wood is small (67% of all wood). The high wood loading is attributed to the recent fires in the reach, bringing down numerous trees directly into the channel, and destabilizing hillslopes contributing to additional recruitment into the channel. Wood loading is evenly distributed along the reach, with 3 logjams observed that are effective in trapping mobile wood of varying sizes. Instream wood and logjams deflect flow into the banks contributing to bank erosion with of 12.9% of channel banks were actively eroding.

The channel substrate is characterized as boulder and cobble, with an average D50 of 171.5 mm. Samples were measured in the channel both up and downstream of the Little Andrews Creek confluence near RM 0.3. Grain size distribution shows boulders comprise 50.3% of the channel substrate (Table 11, Figure 40). Recent fires in the upper Andrews Creek drainage have likely increased short-term sediment supply to the channel, contributing more fine sediment to the creek as hillslopes erode following the loss of forest cover. However, it does not appear that these finer sediments have migrated downstream to reach A1, or have all been transported through.

Figure 39. This series of falls form a barrier to anadromous fish migration at RM 0.5 on Andrews Creek.

Figure 40. Andrews Creek flows through an extremely steep alluvial fan with boulder-dominated substrate and ample large wood resources.

4.5.2 Lake Creek L1

Reach Overview

Reach L1, located from the mouth of Lake Creek upstream to the confluence with Farewell Creek at RM 0.7, flows through a moderate gradient alluvial fan (Figure 41). There is only one tributary in Reach L1 (Farewell Creek), located at the upper end of the reach which contributes about 10% of the total flow. Anthropogenic features include the USFS Road 5160 bridge over Lake Creek at RM 0.3, a dispersed campsite complex along river left just downstream of the bridge, and the dirt/gravel Lake Creek Road (NF-100), which only is near to the creek in the upper 0.1 mile of Reach L1.

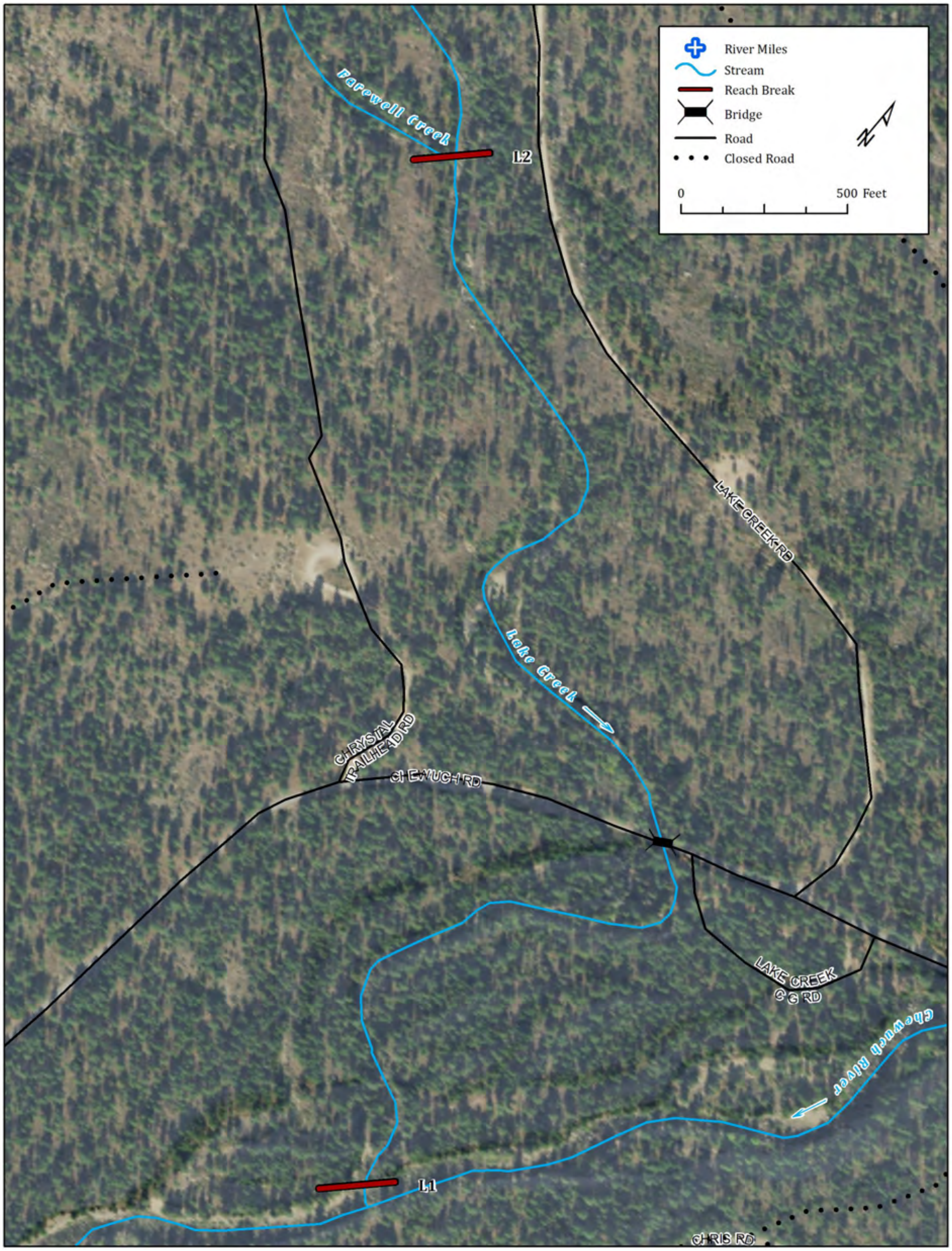

Figure 41. L1 Reach Map.

Habitat Conditions

Lake Creek habitat quality is generally rated at risk or unacceptable in the REI analysis. Spawning size gravel is limited (10%) and percent fines and erosion are both low at 1.2 percent and 5.6 percent respectively. There were 31.4 pieces per mile of wood at the time of the survey which is below the REI target (Table 11). There is only one jam in the reach, which is at an island apex and forces some flow into a fastwater side channel. There are 8.57 pools per mile but most are less than 2 feet deep and side channels are limited to an inset floodplain below the bridge.

Geomorphology

Reach L1 on Lake Creek is incised as it flows across the alluvial fan down to USFS Road 5160, below which the channel drops onto an abandoned floodplain terrace of the main stem Chewuch River down to the confluence. The disconnection of the channel within the alluvial fan surface diminishes the likelihood that the channel will avulse in the future to another distributary channel traversing the fan. An inset floodplain has developed in the center of the reach, extending 800 – 900 feet upstream of the bridge and 600 feet downstream of the bridge. There are active side channels within the inset floodplain downstream of the bridge. The channel has a reach average slope of 2.9% and is classified as a Rosgen type B3 channel.

Wood loading is low and composed primarily of small wood pieces (66% of all wood). The high gradient and confinement of the channel makes this a transport reach for wood, resulting in very low wood presence. Local wood recruitment is low as few locations of active bank erosion were observed, with most observations of erosion occurring in association with instream wood.

The channel substrate is characterized as boulder and cobble, with an average D50 of 195 mm (Figure 42). Samples were measured in confined sections of channel both up and downstream of the USFS Road 5160 bridge and have similar grain size distribution. Recent fires in the upper Lake Creek drainage have likely increased short-term sediment supply to the channel, contributing more fine sediment to the creek as hillslopes erode following the loss of forest cover. However, these finer sediments either have not migrated downstream to reach L1 or have all been transported through. It is anticipated that in the short-term future the average bed substrate size will decrease as fines work downstream and the landscape begins to recover.

Figure 42. Instream conditions at RM 0.1 in Reach L1 showing boulder and cobble substrate and shallow pools.

4.5.3 Lake Creek L2

Reach Overview

Reach L2, located from the confluence with Farewell Creek at RM 0.7 to the confluence with Disaster Creek at RM 2.83, is a rapid dominated reach with significant LWD influence and moderate floodplain connectivity (Figure 43). Between RM 2.4 and RM 2.7 there is a distinct 1,500-foot long section of extremely complex braids, side channels, high flow channels, and forested floodplain with abundant LWD and quality salmonid spawning and rearing habitat.

There is only one tributary in Reach L2 (Disaster Creek), located at the upper end of the reach. Disaster Creek contributes about 10% of the total flow. There is very little human disturbance in Reach L2. Anthropogenic features include the dirt/gravel Lake Creek Road (NF-100) along river left and the Lake Creek trailhead on river left at the top of the reach.

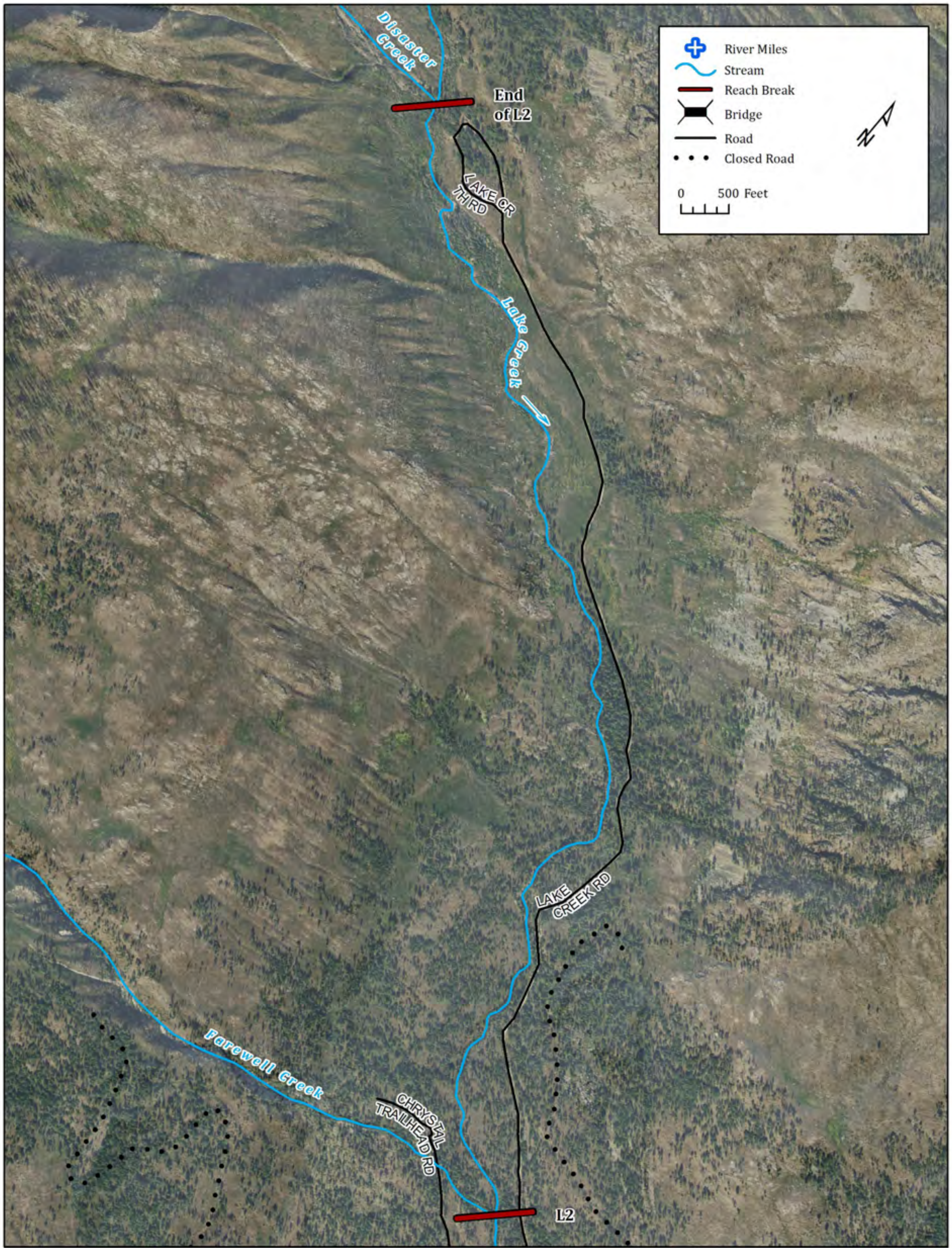

Figure 43. L2 Reach Map.

Habitat Conditions

The L2 reach is rated as at risk and unacceptable in most of the REI categories. There are abundant LWD resources in Reach L2, however the future recruitment potential is low due to the recent fires. The 2003 Farewell Fire burned the entire riparian canopy upstream of RM 2.0, and evidence of understory burning is common throughout the reach (Figure 44). Reach L2 has sections of high-quality habitat and high levels of wood as well as moderate gradient. This reach also has a higher proportion of habitat area in side channels at 7.9 percent, yet a moderate proportion of pool habitat at 7.1 percent. Most pools are 2-3 feet deep and substrate consists of mostly cobble boulder with 13 percent fines. The higher levels of fines are likely due to the recent fires.

Geomorphology

Reach L2 is incised into the alluvial fan upstream of Farewell Creek to near RM 1.9 at the head of the fan where the valley constricts to just 300 feet wide. The valley widens to 700 feet upstream of the constriction, and the channel is well connected to the adjacent floodplain up to the confluence with Disaster Creek. Recent fires in the watershed greatly impacted the riparian forest downstream of Disaster Creek to the valley constriction at RM 1.9. These fires burned much of the riparian forest, leaving abundant downed trees and standing snags but limited sources for future recruitment. The incised nature of the channel downstream of the valley constriction suggests that historic incision has lowered the channel over time. The origin of the incision is likely from the Chewuch River, propagating upstream from the confluence as the main stem lowered due to other watershed disturbances over time.

Wood loading was by far considerably higher in reach L2 than in any of the other reaches (tributary or Chewuch River) assessed. The majority of wood is small (66% of all wood) (Figure 45 and Figure 46). The remaining wood observed was primarily medium sized, occurring at 105.6 pieces/mile, and large wood pieces at 23.0 pieces/mile (Table 11). Qualifying wood for the REI analysis (>12 in diameter and >35 ft in length) occurs at 128.6 pieces/mile. The high wood loading is attributed to the recent fires in the upper end of the reach, bringing down numerous trees directly into the channel. Wood loading is greater above the channel constriction at RM 1.9 where the fires burned much of the floodplain forest, however logjams are evenly distributed throughout the reach. These logjams are very effective in trapping mobile wood moving downstream, as wood loading in the downstream L2 reach is low. Minimal areas of erosion are in association with instream wood and logjam locations, as the channel is deflected as a result of the wood in the channel.

The channel substrate is characterized as boulder cobble, with an average D50 of 193 mm. Samples were measured in the channel both up and downstream of the valley constriction at RM 1.9, and have similar grain size distribution. Recent fires in the upper Lake Creek drainage have likely increased short-term sediment supply to the channel, contributing more fine sediment to the creek as hillslopes erode following the loss of forest cover. The high fine sediment loading in reach L2 increased downstream of the valley constriction, indicating that it is working downstream from the burned area upstream. It is anticipated that in the short-term future the bed will coarsen as fines continue to work downstream and the landscape begins to recover, reducing fine sediment loading upstream.

Figure 44. Significant LW resources are present at the upstream end of Reach L2, where the Farewell Fire burned in 2003.

Figure 45. The view looking downstream (left) and upstream (right) from a channel-spanning logjam in Reach L2, showing retention of finer substrates and streambed aggradation above the jam.

Figure 46. This channel-spanning jam in Reach L2 is trapping fine sediments and creating a large dam pool.

4.5.4 Twentymile Creek

Reach Overview

Reach T1 (Figure 47) extends from the mouth of Twentymile Creek to the 37-foot waterfall at RM 0.65 (Figure 48), which is the anadromous barrier. The reach flows through two distinct sections: a highly confined, moderately sinuous V-shaped valley in its upper 0.15 miles and a minimally-sinuous channel set in high gradient, highly active alluvial fan in its lower 0.5 miles. There are no tributary confluences within reach T1. There is also moderate human disturbance, most notably a concrete-lined ford for USFS Road 5010 just 350 feet above the mouth, that washed out partially in spring of 2018 (Figure 49). The ford is a partial barrier to anadromous fish migration. The USFS Road 700 grade runs along Twentymile Creek upstream of Reach T1. The main channel has at times been straightened and intentionally confined in the alluvial fan by a levee that runs along the creek in the lower reaches.

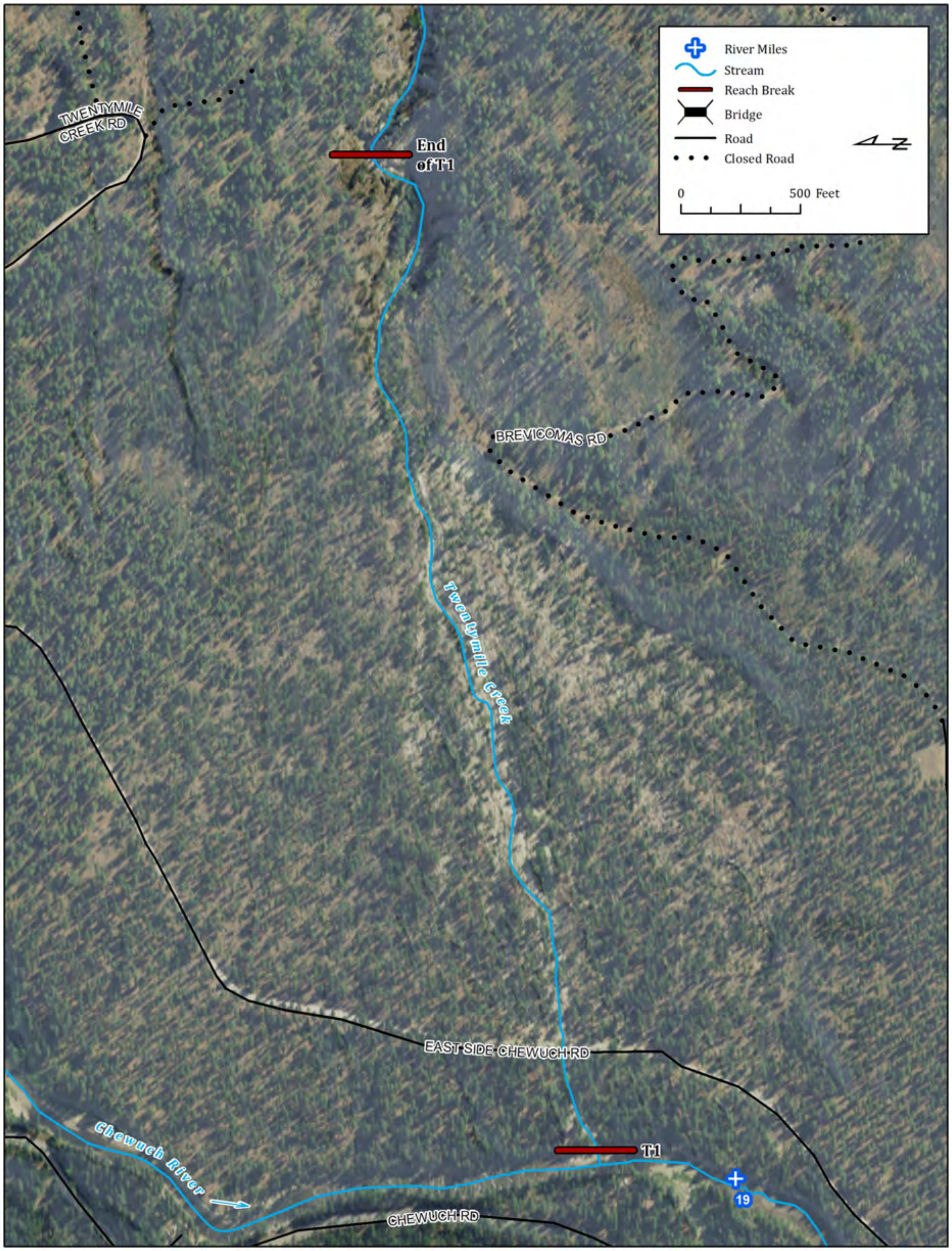

Figure 47. T1 Reach Map.

Habitat Conditions

Habitat quality in Twentymile Creek is rated as at risk or unacceptable in the REI analysis. Qualifying wood is low at 7.7 pieces/mile. Habitat area is mostly (88%) rapid and riffle with 14.6 percent pool and no side channel areas observed at low flow. Confinement of the channel by the levee at the downstream end prevents connection with distributary channels that would connect with the Chewuch. The ford on USFS Road 5010 also prevents channel migration since the flows are funneled toward the ford crossing (Figure 49). Percent fines are 6.1 percent, with over 20 percent actively eroding banks. Some incision/channelization is present in the alluvial fan.

Geomorphology

Reach T1 on Twentymile Creek is comprised of two distinct geomorphic terrains; a narrow bedrock canyon upstream and an alluvial fan at the downstream end. The transition between these landscapes occurs approximately 0.5 miles upstream from the confluence with the Chewuch River, with ¾ of the reach within the alluvial fan. The upstream bedrock canyon section is bounded by steep outcrops of Cretaceous-Jurassic tonalite, terminating at the waterfall fish barrier at RM 0.65 mile (Figure 48). The channel upstream in the canyon is dominated by cascades and rapids with numerous bedrock-forced plunge pools. At the transition to the alluvial fan the channel is incised 8-10 feet, with levee features (large boulders) built up on either bank (Figure 50). Additionally, Twentymile Creek has been intentionally channelized through the alluvial fan in the past (NPCC 2004). Downstream on the fan there are multiple active side channels on the right bank floodplain (north of the channel), all of which could develop and capture the channel during a large flood event, or if the levee were removed.

The reach has an average slope of 8.74 percent and is classified as Rosgen type B3 (on the alluvial fan) and A2 (in the canyon). The reach average bankfull width is 41.3 feet, with a width:depth ratio of 16.3. The reach is dominated by rapids, cascades, and braids comprising 78.6 percent of the total channel length. Pools make up 14.6% of the channel, giving Twentymile Creek the highest average number of pools with 29.23 pools/mile. Approximately 1/3 of the pools are greater than 2 feet deep, found primarily in the canyon section of channel (Table 11).

Wood loading is low and composed primarily of small wood pieces (86% of all wood). The high gradient and sediment loads make this section of Twentymile Creek a transport reach for wood, resulting in low wood presence. Active bank erosion was prevalent along the channel, with 21.7% of banks actively eroding primarily between the canyon section of channel and USFS Road 5010 bridge (Table 11).

The channel substrate is characterized as boulder cobble, with an average D50 of 166.5 mm (Table 11). Both sediment samples were taken in the alluvial fan section of the channel, with little variation in the distribution along the channel. The distribution of grain sizes measured shows half are boulders (53.2), with decreasing amounts of finer cobble (23.9%) and gravel (15.7%) proportions. Recent fires in the upper Twentymile Creek drainage have likely increased short-term sediment supply to the channel, contributing more fine sediment to the creek as hillslopes erode following the loss of forest cover.

Figure 48. The falls on Twentymile Creek at RM 0.65 are a barrier to anadromous fish passage.

Figure 49. Partially washed out fish barrier on Twentymile Creek at the USFS Road 5010 ford (RM 0.1).

Figure 50. Twentymile Creek flows through an extremely steep alluvial fan with boulder-dominated substrate. Note levee formation along left bank.

4.5.5 Boulder Creek

Reach Overview

Reach B1, extends from the mouth of Boulder Creek to the waterfall at RM 1.05, which is the barrier to anadromous fish migration (Figure 51 and Figure 52). The reach flows through two distinct sections: a highly confined bedrock gorge in its upper half and a moderately incised channel set in a moderate gradient alluvial fan in its lower half. There are no tributary confluences within reach B1. The lower half of the reach has some human disturbance and a high potential for restoration. Anthropogenic features include several dispersed campsites on both sides of the river below RM 0.5 and the USFS Road 37 bridge across Boulder Creek. There are additional signs of heavy use in the lower section of the creek, including trash, old concrete, and graffiti.

Figure 51. Waterfall on Boulder Creek at RM 1.05, approximately 30 feet high, is a fish passage barrier.

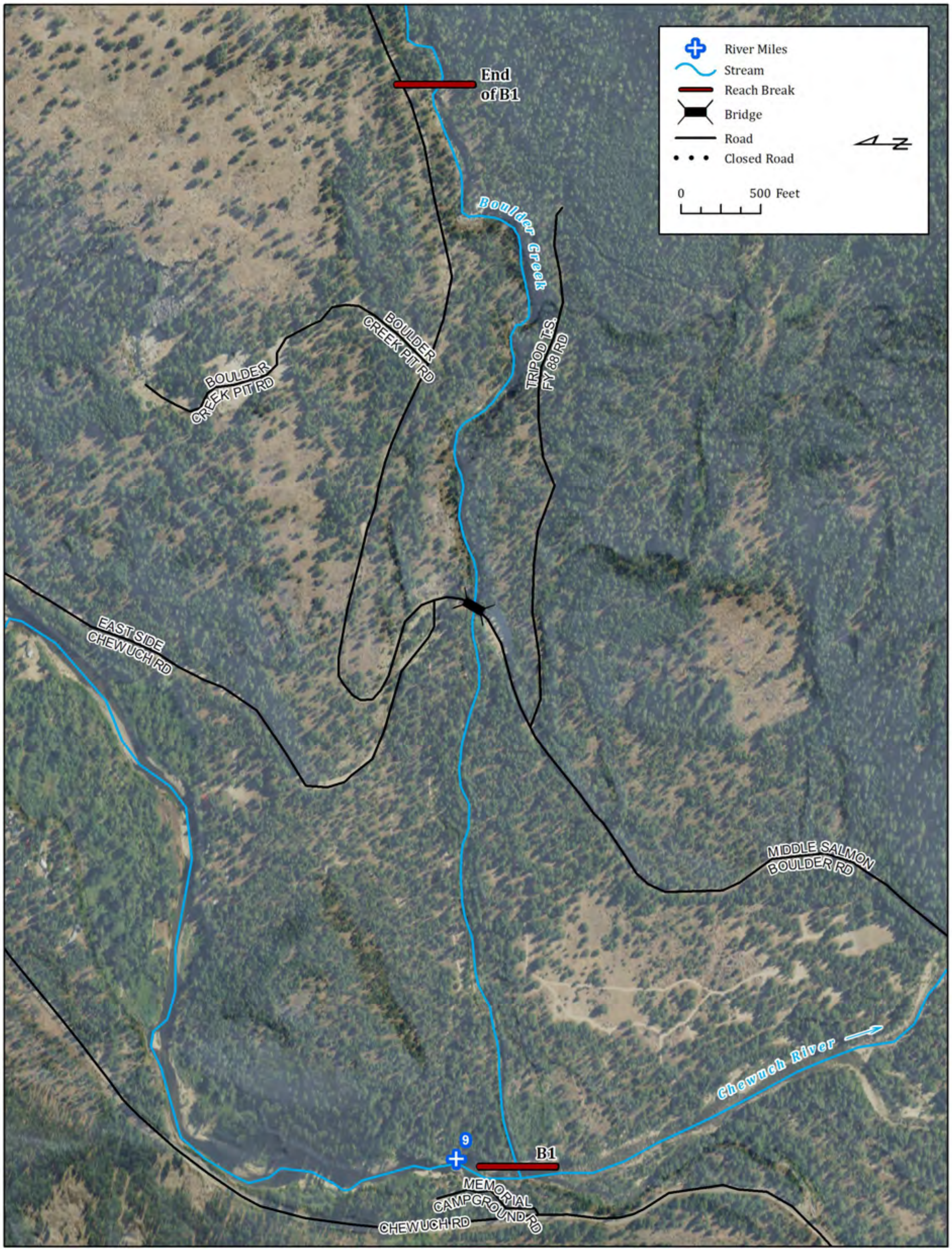

Figure 52. B1 Reach Map.

Habitat Conditions

Habitat conditions in Boulder Creek in reach B1 are degraded with just 5.7 qualifying pieces of wood per mile. Habitat area at low flow is 11 percent pool, 52 percent rapid, 30 percent riffle with no side channel area identified (Figure 53). The average slope is higher than the Chewuch at 4.18 percent and sinuosity is 1.19. Bank erosion and fines are relatively low at 6.2 percent and 10.7 percent respectively. The upper end of reach B1 is bounded by a 20-foot waterfall impassable to anadromous fish. There is also a bedrock chute 0.15 miles below the waterfall, which is at least a partial barrier to fish migration.

Geomorphology

Reach B1 is comprised of two distinct geomorphic terrains; a narrow bedrock canyon upstream and an alluvial fan at the downstream end. The transition between these landscapes occurs at the USFS Road 37 bridge, near the mid-point of the reach. The upstream bedrock canyon section is bounded by steep outcrops of Cretaceous-Jurassic metamorphic rocks, terminating at the waterfall fish barrier approximately 0.53 miles upstream of the bridge. The channel upstream of the bridge is dominated by riffles and rapids with numerous bedrock-forced pools. Downstream of the bridge the channel is incised into the alluvial fan, with an inset floodplain that has developed in some areas forming a narrow active floodplain. Boulder Creek was intentionally channelized through the alluvial fan (NPCC 2004). The deeply incised nature of the channel and formation of an inset floodplain suggest that incision has continued to lower the channel. The origin of the incision is likely from the Chewuch River, propagating upstream from the confluence as the main stem lowered due to other watershed disturbances over time.

The channel has a reach average slope of 4.18% and is classified as a Rosgen type B3 (alluvial fan) and A2 (canyon) channel. The reach average bankfull width is 33.2 feet, with a width:depth ratio of 13.3. There are 16.19 pools/mile, with over half (58.9%) shallow less than 2 feet deep, however 29.4% were deep (>3 feet) (Table 11).

Wood loading is very low and composed primarily of small wood pieces (70% of all wood). The high gradient and confinement of the channel makes this section of Boulder Creek a transport reach for wood, resulting in very low wood presence. Local wood recruitment is low as few locations of active bank erosion were observed. A total of 6.2% of channel banks were actively eroding, (Table 11) and much of the active erosion is downstream of the bridge as flows enter the alluvial fan. Very little erosion occurs upstream of the bridge in the canyon section, but there are some areas where the highly fractured bedrock is failing.

The substrate is characterized as boulder and cobble, with an average D50 of 181.5 mm (Table 11). There is little change in the channel substrate transitioning from the canyon to alluvial fan, except for the lack of bedrock in the alluvial fan section. The distribution of grain sizes present in the channel is large, with 10.7% fines and near equal proportions of gravel, cobble, and boulders (Figure 54). Recent fires in the upper Boulder Creek drainage have likely increased short-term sediment supply to the channel, contributing more fine sediment to the creek as hillslopes erode following the loss of forest cover.

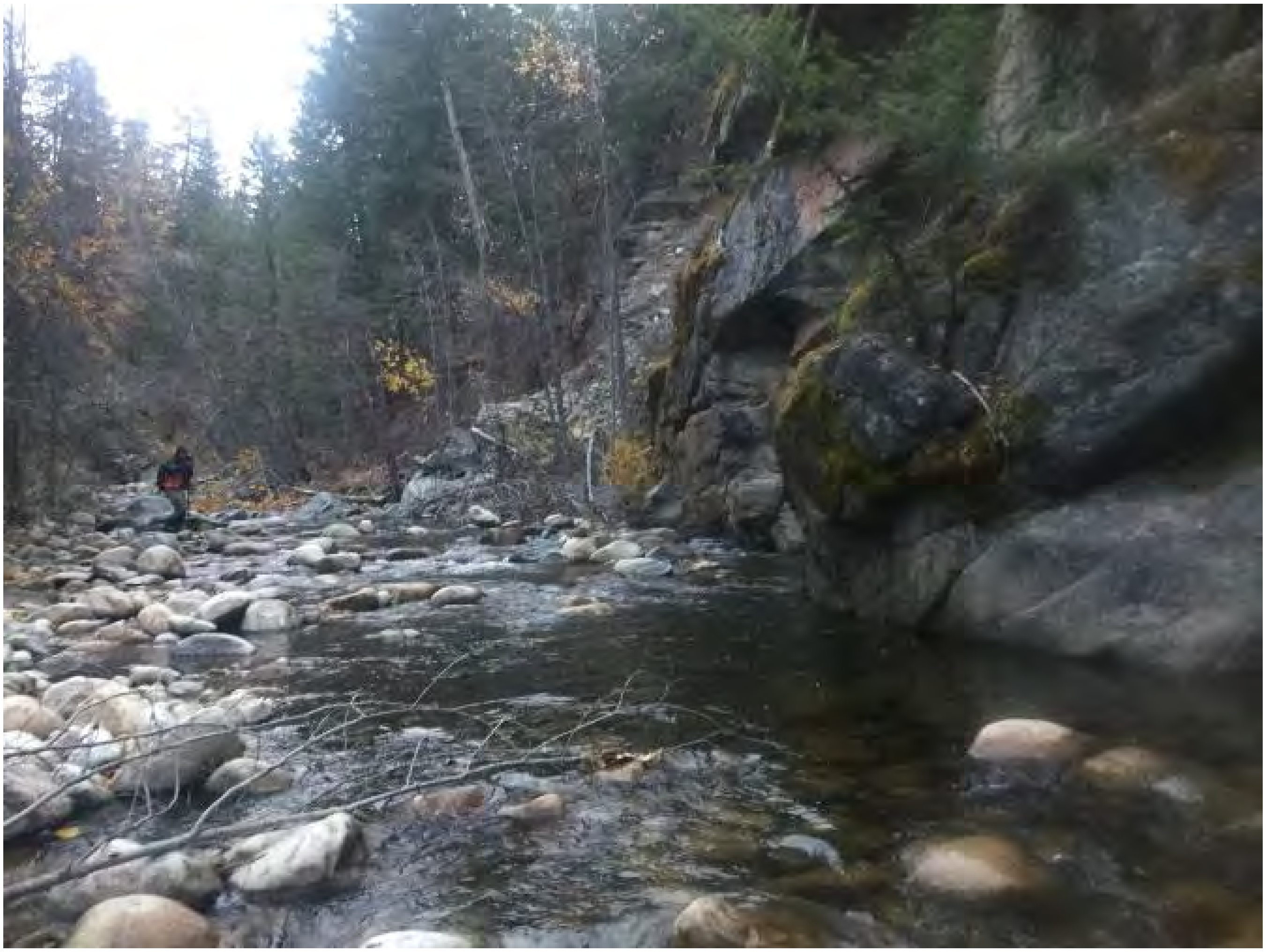
Figure 53. Boulder Creek confined by bedrock walls in the upper half of reach B1.

Figure 54. Boulder Creek main channel (left) and a partially wetted side channel (right) in the lower section of Reach B1 showing diversity of substrate.

4.5.6 Tributary Geomorphic and Habitat Data Summary

The geomorphic and habitat characteristics for the tributaries surveyed for the Upper Chewuch Habitat Assessment are presented in Table 11. The metrics are summarized from field data collected for the geomorphic assessment and USFS Region 6 Level 2 stream habitat protocol in October and November 2017.

Table 11. Geomorphic and habitat metrics for Chewuch River mainstem reaches.

Metric	Boulder Creek	Twentymile Creek	Lake Creek L1	Lake Creek L2	Andrews Creek
River miles	0.0 – 1.05	0.0 – 0.65	0.0 – 0.7	0.7 – 2.83	0.0 – 0.5
Measured reach length (mi)	1.05	0.65	0.70	2.13	0.53
Beginning elevation (ft)	2071	2330	2637	2745	2994
Ending elevation (ft)	2303	2630	2745	3178	3317
Change in elevation (ft)	232	300	108	433	323

Metric	Boulder Creek	Twentymile Creek	Lake Creek L1	Lake Creek L2	Andrews Creek
Rosgen type	B3, A2	B3	B3	B3, C3	B2, B3
Sinuousity	1.19	1.14	1.27	1.09	1.13
Average slope (%)	4.18	8.74	2.92	3.85	11.54
Average bankfull width (ft)	33.2	41.3	41.9	37.1	66.3
Width:Depth ratio	13.3	16.3	15.6	13.3	19.5
Floodprone width (ft)	71.4	84.5	116.6	102.6	113.4
Average valley width (ft)	110	200	400	350	120
Average D50 (mm)	181.5	166.5	195	193	171.5
% Pool	11	14.6	5.3	7.1	3.4
% Riffle	29.9	2.8	33.5	28.8	0
% Rapid	51.6	47.2	54.4	46.3	4
% Cascade	0.8	14.9	0	0	36.6
% Braided	0	16.5	0	7.3	53.5
% Fast non-turbulent	6	3.2	4.4	2.7	2.5
% Side channel	0	0	2.4	7.9	0
Pools per mile	16.2	29.23	8.57	9.86	9.43
Average Max pool depth (ft)	4	2.5	2.9	2.9	3.4
Average residual depth (ft)	2.7	1.6	1.3	1.8	2.6
Average residual depth < 1 ft (% of pools)	11.8	31.6	33.3	23.8	0
Average residual depth 1-2 ft (% of pools)	47.1	36.8	50	33.3	40
Average residual depth 2-3 ft (% of pools)	11.8	21.1	16.7	33.3	40
Average residual depth > 3 ft (% of pools)	29.4	10.5	0	9.5	20
Small (6” x 20’) count	14	31	43	619	129
Medium (12” x 35’) count	6	4	20	225	53
Large (20” x 35”) count	0	1	2	49	40
Small pieces/mile	13.3	47.7	61.4	209.6	243.3
Medium pieces/mile	5.7	6.2	28.6	105.6	100
Large pieces/mile	0	1.5	2.9	23	18.9
% Streambank Eroding	6.2	21.7	5.6	2.9	12.9
% Fines	10.7	6.1	1.2	13	5.6
% Gravel	22.6	15.7	10	16.4	16.2
% Cobble	30.2	23.9	27.9	27.7	27.9
% Boulder	29.3	53.2	60.9	42.7	50.3
% Bedrock	7.2	1.1	0	0.2	0

4.6 Reach-based Ecosystem Indicators

The REI analysis is used to identify the levels of function for geomorphic and ecological conditions at the watershed and reach scales within the assessment area. Metrics in the analysis were developed from the USFWS Matrix of Diagnostics/Pathways and Indicators (1998) and the NOAA Fisheries Matrix of Pathways and Indicators (1996). These source documents were supplemented with site-specific information from the

US Bureau of Reclamation and the Yakama Nation that identified the needs of target and ESA-listed species in the watershed.

Data collected as part of the geomorphic assessment and Level 2 habitat survey provided information on current habitat conditions in the Upper Chewuch and sampled tributaries to allow a condition rating to be assigned for each metric. Metrics summarized at the watershed scale include road density, disturbance, peak flows/hydrology and water quality and quantity. Road density in the Upper Chewuch watershed ranges from 0.36 mi/mi^2 from RM 19.1 to the headwaters (excludes Boulder Creek) to 0.89 mi/mi^2 if the area of the Pasayten Wilderness is removed from the calculation. Both of these densities are within the adequate rating for road density. Disturbance, including natural and anthropogenic causes, is rated at unacceptable condition in the Upper Chewuch and Boulder Creek watersheds primarily due to the increased severity of wildfires which have burned over 80% of the watershed in recent years. Additional disturbance from roads, campgrounds and dispersed camping is also present in the watershed. The watershed is rated at risk for peak flows based on an initial review of the hydrograph from 1992 to 2018. More frequent 10 and 5-year flows have been observed in the watershed since 2005 indicating a potential shift to higher and more frequent peak flows. The watershed condition rating for water quality and water quantity (low flows) is at risk. One site in the mainstem Chewuch near Boulder Creek is on the 303d list for the State of Washington (listing ID 39349) for temperature and Lake Creek has been listed as a Category 2- waters of concern- by Washington Department of Ecology for dissolved oxygen. The predicted shift from a snow dominated to rain snow mix hydrograph also contributed to the potential risk for this watershed.

Reach level metrics include substrate, large wood, pools, off-channel habitat, channel dynamics, and riparian vegetation. Analysis at this scale allows for the identification of impaired sections that may be suitable for restoration efforts. Areas identified as At Risk or Unacceptable Risk may be in need of restoration action to address degraded habitat conditions (Table 12) and this information was used to prioritize restoration actions.

Vertical channel stability was the most common indicator across reaches that was rated Unacceptable Risk with all reaches having some sort of impairment in this category. Connectivity between off-channel habitat and the main channel was also identified as a common area of degradation in the reaches, which relates to the Peripheral and Transitional Habitats Ecological Concern identified for the Upper Chewuch Basin. Only c10 and c13 had adequate ratings for off-channel habitat connectivity. Large woody debris was also below standard in most of the reaches including all of the tributary reaches due to lack of potential near- term recruitment. Pool frequency and quality was At Risk across all sampled reaches, likely tied to the low levels of wood in many of the reaches. Vegetation structure had five Adequate ratings, but vegetation disturbance and canopy cover had either At Risk or Unacceptable Risk across sampled reaches. Bank stability/Channel migration and large woody debris were also indicators that showed evidence of degradation, due to bank erosion, low levels of wood in some reaches, lack of wood recruitment potential and recent fire. Twentymile Creek had the highest number of Unacceptable Risk ratings, while C13 had the greatest number of Adequate ratings. Details on the ratings and rationale at the watershed and reach level are included in Appendix A.

Table 12. Results summary of REI Analysis.

GENERAL CHARACT-ERISTICS	GENERAL INDICATORS	SPECIFIC INDICATORS	REACH								
			C10	C11	C12	C13	Andrews	Boulder	Lake L1	Lake L2	Twenty-mile
Habitat Quality	Substrate	Dominant substrate/ Fine sediment	At risk	Adequate	At risk	At risk	Adequate	Adequate	Adequate	At risk	At risk
	Large Woody Debris	Pieces/mile at bankfull	Unacceptable risk	Unacceptable risk	Adequate	Adequate	At risk	Unacceptable risk	Unacceptable risk	Unacceptable risk	Unacceptable risk
	Pools	Pool frequency and quality	At risk	At risk	At risk	At risk	At risk	At risk	At risk	At risk	At risk
	Off-channel habitat	Connectivity with main channel	Adequate	Unacceptable risk	Unacceptable risk	Adequate	Unacceptable risk	Unacceptable risk	Unacceptable risk	At risk	Unacceptable risk
Channel Condition	Dynamics	Floodplain connectivity	At risk	At risk	Adequate	Adequate	At risk	Unacceptable risk	At risk	At risk	Unacceptable risk
		Bank stability/ Channel migration	At risk	At risk	At risk	At risk	At risk	At risk	At risk	At risk	Unacceptable risk
		Vertical channel stability	Unacceptable risk	Unacceptable risk	Unacceptable risk	Unacceptable risk	Unacceptable risk	Unacceptable risk	Unacceptable risk	Unacceptable risk	Unacceptable risk
Riparian Vegetation	Condition	Vegetation structure	Adequate	Adequate	Adequate	Adequate	At risk	At risk	Adequate	Unacceptable risk	At risk
		Vegetation disturbance	At risk	At risk	At risk	At risk	At risk	Unacceptable risk	At risk	Unacceptable risk	Unacceptable risk
		Canopy cover	At risk	At risk	At risk	At risk	Unacceptable risk	At risk	At risk	Unacceptable risk	Unacceptable risk

● (green) = Adequate ● (yellow) = At risk ● (red) = Unacceptable risk

5. RESTORATION STRATEGY

This restoration strategy is designed to provide a foundation for targeted and effective restoration in the upper Chewuch River and its tributaries, including Andrews Creek, Lake Creek, Twentymile Creek, and Boulder Creek. A solid restoration strategy begins with scientific analysis at the watershed scale, identifying key limiting factors and natural processes that drive site-specific project objectives. This strategy has been built with analyses of stream habitat characteristics, geomorphic conditions, hydrologic patterns, and reach-based ecosystem indicators (REI) to identify and prioritize specific project opportunities across the upper Chewuch study area. The restoration strategy describes existing and target conditions based on historical information, current conditions assessment, environmental needs of ESA-listed salmonid species, and an understanding of functioning ecological conditions identified by the REI analysis. Project opportunities presented here are designed specifically to create target ecological conditions through active restoration and successful integration with long-term ecological processes.

Development of the restoration strategy was guided by the habitat objectives set forth in the Upper Columbia Recovery Plan (UCSRB 2007), the ecological concerns for the Upper Chewuch and recommended restoration actions from Upper Columbia Revised Biological Strategy (2017), and by field and analytical work conducted as part of this Habitat Assessment. More analysis will still be necessary before projects are implemented; this may include topographic survey, hydraulic modeling, engineering analysis, and alternatives evaluation.

5.1 Existing and Target Habitat Conditions

An understanding of the current ecological concerns for Upper Chewuch and tributaries and a comparison of existing and target habitat conditions was used to identify action types and projects. Existing conditions were developed based directly on analyses and surveys performed as part of this Reach Assessment including habitat survey data and also the hydraulics and geomorphology assessments. Target habitat conditions have been developed based on the REI assessment in Appendix A, the Matrix of Diagnostics/Pathways and Indicators (USFWS 1998), and the NMFS Matrix of Pathways and Indicators (NMFS 1996).

Ecological concerns for the Upper Chewuch and recommended restoration actions from Upper Columbia Revised Biological Strategy (2017) in priority order:

1. Sediment Conditions (increased sediment quantity)
    - Road management, reduction, and maintenance to restore sediment and wood recruitment rates within riparian areas
2. Riparian Conditions (riparian condition and LWD recruitment)
    - Restore condition in degraded areas associated with residential development or where there are legacy effects from past riparian logging practices/stream cleaning
    - Improve wood recruitment, allow regeneration
    - Fence riparian areas and wetlands, maintain existing fences
3. Peripheral and Transitional Habitat (side channel and wetland construction)
    - Reconnect disconnected side channels or where low wood loading has changed the inundation frequency, improve hydraulic connection of side channels and wood complexity within the side channels
4. Channel Structure and Form, Instream Structural Complexity
    - Install large wood and ELJ's in geomorphically appropriate locations to provide short-term habitat benefits and intermediate-term channel form and function benefits. Scale and locations should be consistent with the biological objectives and geomorphic potential for the reach and site.

Our findings from the habitat assessment did not support the ranking of the Ecological Concerns in the above order for the Upper Chewuch. We did not find that there was increased sediment quantity in much of the Upper Watershed, outside of minor depositional areas. The overall substrate in the reach was coarse gravel to cobble or boulder in many of the sampled reaches. Low fines (below 20%) were detected in all the sampled reaches, and road density in the overall watershed is low with an adequate rating in the REI. We would not prioritize sediment projects as the number one objective in this watershed.

Restoration priorities in the region should focus on the second through fourth priority Ecological Concerns listed above. For long-term restoration, the revegetation of riparian forests will be critical in some areas to increase the potential for wood recruitment over the next decades to centuries. In the shorter-term reconnection of off-channel and side channel habitat through the placement of wood structures to direct flow into existing flow paths and some limited excavation of pilot channels will help re-engage existing areas that have been disconnected for decades. In addition, placement of wood in the channel will help to restart the wood cycle in the Upper Chewuch in terms of providing stable points for transitional wood in the basin to be retained. This, in turn will likely store more sediment and provide a wider range of sediment sizes to compliment the coarse gravel, cobble and boulders currently present.

5.2 Reach-Scale Restoration Strategies

This section provides reach scale comparisons between key habitat indicators from the REI and current conditions. Based on the finding of this assessment one of the primary limiting factors limiting habitat availability is the disconnection of the channel from the floodplain. Multiple lines of evidence including the historic air photo record, field collected sediment data and observations, REM analysis, and hydraulic modeling all suggest historic incision of the channel has resulted in the current disconnected channel. The historic air photos show side channel inlets connected in 1953 that are currently perched 6-8 feet above the channel. These same air photos show side channel inlets disconnected in 1953, indicating that the onset of incision occurred prior to 1953 (Appendix D). Channel clearing following the flood of 1948, coupled with beaver trapping and logging, may have all contributed to early channel incision. The lack of floodplain activation during moderate (Appendix E, page 2) and even larger scale floods (Appendix E, page 3) also indicates the channel is disconnected due to historic incision.

The sediment data collected in the main stem channel describes an armored channel lacking spawning suitable gravels. This is contrary to the ecologic concerns outlined in the Upper Columbia Revised Biological Strategy (2014), where increased sediment was the highest rank concern in the upper Chewuch. The contribution of fine sediment to the channel appears to correlate with locations of dense spawning activity (Figure 14), particularly at the confluence of the No Snake side channel and the main stem, and near RM 22.7 where the channel is actively migrating and recruiting sediment.

Potential restoration actions associated with addressing condition issues are identified are provided in the tables below. Appendix A includes the target conditions for each indicator.

5.2.1 Chewuch C10

INDICATOR	EXISTING CONDITION	RESTORATION ACTION TYPE
Large Woody Debris	There is very little mainstem wood, with only 60 pieces in mainstem over 2.9 mile reach. Only 26 pieces in the mainstem are greater than 12 in diameter and 30 ft long, coming out to a density 9 pieces/mile, well below the threshold for adequate or at risk conditions. The majority of the large wood is located in the No Snake side channel, where habitat quality, including LWD is good condition. The mainstem is in an unacceptable Risk condition. There is recruitment potential, but hardly any existing structure to retain recruited wood.	Install Habitat Structures
Floodplain Connectivity	Incision is reducing floodplain connectivity. Disconnected side channel complex between RM 19.7 – 20.15 on the eastern floodplain immediately upstream of the Twenty-Mile Creek alluvial fan and downstream of the July Creek alluvial fan exhibits off-channel wetlands and abundant wood. Historic incision has deactivated this side channel complex, as the inlet is current perched 6-8 feet above the current channel, limiting the frequency and magnitude of flow into the side channel complex.	Floodplain Habitat Reconnection

INDICATOR	EXISTING CONDITION	RESTORATION ACTION TYPE
Off-channel Habitat	This reach has an excellent example of potential off-channel habitat in the Upper Chewuch -No Snake Side Channel is a highly functioning long slow side channel with numerous pools and LWD. There has been some cut off of off-channel features, so while the reach is an adequate condition some restoration could re-engage more habitat and improve the quality of the off-channel habitat even more.	Floodplain Habitat Reconnection
Pools	Reach met criteria for pool frequency, but are at risk due to low number of large pools.	Install Habitat Structures

5.2.2 Chewuch C11

INDICATOR	EXISTING CONDITION	RESTORATION ACTION TYPE
Large Woody Debris	Majority of mainstem devoid of medium and large pieces, but there is recruitment potential from riparian forests. This reach is just above the threshold for adequate condition.	Install Habitat Structures
Floodplain Connectivity	This reach is dominated by riffle habitats, and two rapids are present with gradients of up to 10%. There are multiple extremely long fastwater (riffle) channel units with minimal LWD and little habitat complexity. Some large sections of active erosion and channel incision are present in the reach, along with numerous fastwater side channels and other high-flow channels. The relative lack of disturbance to the floodplain forest	Floodplain Habitat Reconnection
Off-channel Habitat	Limited off-channel habitat in C11 with only 1 slow side channel that has little wood and no cover, placing the reach in unacceptable risk.	Floodplain Habitat Reconnection
Pools	Reach met criteria for pool frequency, but are at risk due to low number of large pools.	Install Habitat Structures

5.2.3 Chewuch C12

INDICATOR	EXISTING CONDITION	RESTORATION ACTION TYPE
Large Woody Debris	High natural confinement throughout the majority of the reach as the river flows through a natural gorge formed by bedrock and talus slopes, which lower recruitment potential. However, there are currently adequate wood resources in the reach and there is good potential for recruitment from upstream reaches.	Install Habitat Structures
Floodplain Connectivity	This reach is dominated by riffle habitats, and two rapids are present with gradients of up to 10%. There are multiple extremely long fastwater (riffle) channel units with minimal LWD and little habitat complexity. Some large sections of active erosion and channel incision are present in the reach, along with numerous fastwater side channels and other high-flow channels. The relative lack of disturbance to the floodplain forest	Floodplain Habitat Reconnection
Off-channel Habitat	Limited off-channel habitat in C11 with only 1 slow side channel that has little wood and no cover, placing the reach in unacceptable risk.	Floodplain Habitat Reconnection

INDICATOR	EXISTING CONDITION	RESTORATION ACTION TYPE
Pools	Reach met criteria for pool frequency, but are at risk due to low number of large pools.	Install Habitat Structures

5.2.4 Chewuch C13

INDICATOR	EXISTING CONDITION	RESTORATION ACTION TYPE
Large Woody Debris	There is a high amount of wood in the reach, especially collected in several large side channels. Lots of short term recruitment from fire, and opportunities for long term recruitment through floodplain processes.	Install Habitat Structures
Floodplain Connectivity	The channel is characterized by pool riffle morphology where unconfined, with a well-connected floodplain and side channels active over a range of flows. The channel is more simplified where confined by alluvial fans, with more plane bed morphology and lack of side channels and floodplain, but alluvial fans are a natural process that reduces floodplain so the reach is in adequate condition.	Floodplain Habitat Reconnection
Off-channel Habitat	Several slow side channels providing good off-channel habitat, including one with abundant LWD and fish cover, so this reach is in adequate condition. Opportunities also exist to reconnect and engage additional off-channel features that would increase the quality and abundance of habitat.	Floodplain Habitat Reconnection
Pools	Reach met criteria for pool frequency, but are at risk due to low number of large pools.	Install Habitat Structures

5.2.5 Boulder Creek

INDICATOR	EXISTING CONDITION	RESTORATION ACTION TYPE
Large Woody Debris	There is little wood in the reach, and low recruitment potential due to gorge in upper portion of reach and incised conditions with little riparian forest in lower portion of reach.	Install Habitat Structures
Floodplain Connectivity	Boulder Creek has a highly confined bedrock gorge in its upper half and a moderately incised channel set in a moderate gradient alluvial fan in its lower half. Downstream of the bridge the channel is incised into the alluvial fan, with an inset floodplain that has developed in some areas forming a narrow active floodplain. Incision in the lower portion of the reach has cut off the historic floodplain, resulting in a floodplain width that is drastically reduced, resulting in an unacceptable risk condition.	Floodplain Habitat Reconnection
Off-channel Habitat	No off-channel habitat, so reach is in unacceptable risk condition.	Floodplain Habitat Reconnection
Pools	Decent number of large pools, but pool frequency is below threshold for adequate condition, so reach is at risk.	Install Habitat Structures

5.2.6 Twentymile Creek

INDICATOR	EXISTING CONDITION	RESTORATION ACTION TYPE
Large Woody Debris	Large wood frequency is well below 20 pieces/mi, and high gradient reduces potential for retaining recruited wood.	Install Habitat Structures
Floodplain Connectivity	The main channel has at times been straightened and intentionally confined in the alluvial fan by a levee that runs along the creek in the lower reaches. At the transition to the alluvial fan at the terminus of the canyon the channel is incised 8-10 feet into the alluvial fan, with levee features built up on either bank of large boulders. These features are the result of overbank flooding and the rapid fallout of large material once flow escapes the channel and are only found at the head of the fan. Additionally, Twentymile Creek has been intentionally channelized through the alluvial fan in the past (NPCC 2004).	Floodplain Habitat Reconnection
Off-channel Habitat	No off-channel habitat, so reaches are in unacceptable risk condition.	Floodplain Habitat Reconnection
Pools	Reach met criteria for pool frequency, but are at risk due to low number of large pools.	Install Habitat Structures

5.2.7 Lake Creek L1

INDICATOR	EXISTING CONDITION	RESTORATION ACTION TYPE
Large Woody Debris	This reach meets the threshold for adequate, but long-term recruitment potential is low due to fires that destroyed much of the riparian zone in these reaches.	Install Habitat Structures
Floodplain Connectivity	The channel is incised as it flows across the alluvial fan down to USFS Road 5160, below which the channel drops onto an abandoned floodplain terrace of the main stem Chewuch River down to the confluence. The deeply incised nature of the channel and formation of an inset floodplain suggests that historic incision has lowered the channel, destabilizing the adjacent banks and forming the inset floodplain. Restoration potential includes wood addition to reduce incision, provide habitat, and promote floodplain development.	Floodplain Habitat Reconnection
Off-channel Habitat	No off-channel habitat, so reaches are in unacceptable risk condition.	Floodplain Habitat Reconnection
Pools	At risk due to pool frequency and low number of large pools.	Install Habitat Structures

5.2.8 Lake Creek L2

INDICATOR	EXISTING CONDITION	RESTORATION ACTION TYPE
Large Woody Debris	This reach meets the threshold for adequate, but long-term recruitment potential is low due to fires that destroyed much of the riparian zone.	Install Habitat Structures
Floodplain Connectivity	Several large logjams were observed downstream of the valley constriction as well, forming as a result of high upstream loads from the recently burned section of channel, and local wood recruitment from banks as the channel responds to the instream wood with increased bank erosion. The incised nature of the channel downstream of the valley constriction suggests that historic incision has lowered the channel over time.	Floodplain Habitat Reconnection
Off-channel Habitat	Some slow side channels are present, but not abundant so the reach is at risk.	Floodplain Habitat Reconnection
Pools	Decent number of large pools, but pool frequency is below threshold for adequate condition, so reach is at risk.	Install Habitat Structures

5.2.9 Andrews Creek

INDICATOR	EXISTING CONDITION	RESTORATION ACTION TYPE
Large Woody Debris	This reach meets the threshold for adequate, but long-term recruitment potential is low due to fires that destroyed much of the riparian zone.	Install Habitat Structures
Floodplain Connectivity	The channel is incised into the alluvial fan at the downstream end of the reach from RM 0.0 – 0.18, upstream of which the channel is confined within a narrow bedrock canyon. The incised nature of the channel through the alluvial fan suggests that historic incision has lowered the channel over time. The origin of the incision is likely from the Chewuch River, propagating upstream from the confluence as the main stem lowered due to other watershed disturbances over time.	Floodplain Habitat Reconnection
Off-channel Habitat	No off-channel habitat, so reaches are in unacceptable risk condition.	Floodplain Habitat Reconnection
Pools	Reach meets criteria for pool frequency, but at risk due to low number of large pools	Install Habitat Structures

5.3 Restoration Action Types and Project Areas

This section provides a description of the overall actions types and the site-specific project opportunities identified during field surveys and further advanced based on the reach assessment results. A total of 12 specific project opportunities were identified and are presented in Table 13 - Table 20 below. All of the project opportunities are presented in maps located in Appendix B.

5.3.1 Floodplain Habitat Reconnection

The purpose of this action is to improve hydraulic connectivity between the main channel flows and those floodplain areas that include side-channels, off-channel habitat, and riparian wetlands. Prior to alteration of reach scale processes by removal of wood, bank armoring, and clearing of riparian forests, the channel was more frequently connected with these floodplain habitats that provide important ecological functions. The proposed actions increase floodplain capacity and provide access for aquatic organisms to move between floodplain and channel features. Site specific actions include the installation of large wood structures to deflect flows and targeted grading or excavation to increase connectivity with off channel areas. There is also an opportunity to remove a levee in Twentymile Creek to reduce confinement and reconnect with the alluvial fan.

5.3.2 Install Habitat Structures

Stable accumulations or "key" pieces of large woody material act as hard points in the floodplain that create backwater, promote sediment deposition and pool formation, decrease potential for channel incision, and provide essential cover habitat. Wood loading targets typically use reference reaches of "natural and unmanaged" forests in comparison to existing reach conditions. Fox and Bolton (2007) recommend a restoration target of >20 key pieces per mile for channels similar in size to the Upper Chewuch River. Current wood loading in Upper Chewuch Basin and tributaries sampled under this assessment ranges from 0 to 110.7 pieces per mile.

The addition of key pieces in the main channel and the stabilization of existing wood is recommended to increase wood stability and function in the main stem. The formation of stable wood jams in the channel relies upon recruitment or placement of key pieces that are large enough to resist hydraulic forces of flood flows. These key pieces are essential to the restoration of habitat-forming processes in Upper Chewuch River and its tributaries. Without key pieces, any wood recruited to the channel is likely to be quickly transported through the system and provide little, if any, geomorphic function.

Table 13. Restoration Opportunities in Chewuch C10.

PROJECT LOCATION	NAME	POTENTIAL RESTORATION ACTIONS	DESCRIPTION AND RATIONALE	RANK	PHOTO/IMAGERY
RM 19.5-20.3	Project Area 1	o Split flow and island formation o Pool formation and thermal refuge development o Excavation to connect hyporheic flow to side channel and low flow channels o Deflector ELSs to divert flow into existing side channels o Enhance lateral movement and provide instream cover and variation in thalweg	o Reach is generally incised with a plane-bed channel form o Lack of large wood limits connectivity with potential side channel habitat. o Re-engage side channels to increase peripheral and transitional habitats. o Increase diversity of channel bed by adding wood to increase pool habitat and contribute to island formation	High	
RM 20.9-21.9	Project Area 2	o ELS's to divert flow into side channels and away from eroding banks o ELS's to provide pool habitat and increase hydraulic complexity o ELS's to promote lateral movement and enhance edge habitat o Loosely anchored wood loading in side channels o Excavation to increase flow to No Snake and other side channels	o Increase diversity of channel bed by adding wood to increase pool habitat o Re-engage side channels to increase peripheral and transitional habitats. Lack of large wood limits connectivity with potential side channel habitat.	Med	

Table 14. Restoration Opportunities in Chewuch C11.

PROJECT LOCATION	NAME	POTENTIAL RESTORATION ACTIONS	DESCRIPTION AND RATIONALE	RANK	PHOTO/IMAGERY
RM 22.0 to 22.8	Project Area 3	o Bar apex ELS's to for island formation o ELS's to divert flow into side channels o Excavate entrances to side channels o ELS's to promote pools and lateral movement o Decommission road and dispersed camping area	o Increase diversity of channel bed by adding wood to increase pool habitat and contribute to island formation o Re-engage side channels to increase peripheral and transitional habitats. Lack of large wood limits connectivity with potential side channel habitat. o Remove human disturbance from reach	Med	
RM 22.8-23.5	Project Area 4	o ELS to create backwater and deflect flow into side channel o Divert flow into existing side channel habitat o Excavate openings to side channels to encourage flow o Enhance mainstem habitat complexity and edge habitat.	o Backwater and lower velocity habitat is limited in this reach o Placement of wood structures and excavation at side channel openings will help to increase channel length and reduce shear stress	Med	

Table 15. Restoration Opportunities in Chewuch C12.

PROJECT LOCATION	NAME	POTENTIAL RESTORATION ACTIONS	DESCRIPTION AND RATIONALE	RANK	PHOTO/IMAGERY
RM 23.5-23.8	Project Area 5	o ELS's to improve connection to high flow side channel o Remove road crossing and build natural channel	o Focus restoration efforts in small section of reach with less confined floodplain o Encourage floodplain development and reduce human disturbance.	Med	

Table 16. Restoration Opportunities in Chewuch C13.

PROJECT LOCATION	NAME	POTENTIAL RESTORATION ACTIONS	DESCRIPTION AND RATIONALE	RANK	PHOTO/IMAGERY
RM 24.7-25	Project Area 6	o Bar apex jam to drive island formation o ELS's to increase floodplain connection o ELS's and excavation to divert flow into existing side channels.	o Re-engage side channels to increase peripheral and transitional habitats. Lack of large wood limits connectivity with potential side channel habitat. o Increase diversity of channel bed by adding wood to increase pool habitat and contribute to island formation	Med	
RM 25.0 - 25.8	Project Area 7	o ELS's to divert flow into existing side channels o ELS's to encourage lateral movement and improve edge habitat o ELS's to dissipate shear stress and form pools at cool water confluence	o Re-engage side channels to increase peripheral and transitional habitats. o Improve edge habitat quality and quantity to benefit juvenile Chinook o Connect and create additional thermal refuge in mainstem and off-channel habitat for juvenile rearing	High	

Table 17. Restoration Opportunities in Chewuch L1.

PROJECT LOCATION	NAME	POTENTIAL RESTORATION ACTIONS	DESCRIPTION AND RATIONALE	RANK	PHOTO/IMAGERY
RM 0.0 – 0.5	Project Area 8	o Deflector ELS's and excavation to divert flow into distributary channels o ELS's to increase hydraulic complexity and enhance habitat	o Increasing channel length at the confluence with Lake Creek will provide more edge habitat and off-channel habitat o Increase channel complexity	Med	

Table 18. Restoration Opportunities in Chewuch L2.

PROJECT LOCATION	NAME	POTENTIAL RESTORATION ACTIONS	DESCRIPTION AND RATIONALE	RANK	PHOTO/IMAGERY
RM 1.0 - 1.5	Project Area 9	o Large channel spanning ELS's to aggrade incised channel and promote braided and off-channel habitat	o Incised channel area prevents connection with off-channel areas o Jams could retain wood from upstream	Med	
RM 2.1 – 2.5	Project Area 10	o Pile arrays to recruit natural wood from recent fires and promote channel braids	o Although there is considerable wood in L2 upstream of RM 1.9, the lower reach could increase in complexity if some of the fire recruited wood was captured.	Med	

Table 19. Restoration Opportunities in Twentymile Creek.

PROJECT LOCATION	NAME	POTENTIAL RESTORATION ACTIONS	DESCRIPTION AND RATIONALE	RANK	PHOTO/IMAGERY
RM 0-1.2	Project Area 11	o Replace or install roughened channel to provide fish passage o Remove remaining sections of levee, place material back in channel to restore grade and improve distributary channel connection o ELS's to deflect flow into distributary channels o Excavations to enhance distributary connection; place material back in main channel to restore grade	o The lower sections of Twentymile Creek are affected by levees that confine the channel and prevent connection to the alluvial fan. o Reconnection with the alluvial fan will increase channel length and provide additional off-channel habitat for juvenile rearing	High	

Table 20. Restoration Opportunities in Boulder Creek

		0	0		
RM 0 to 0.7	Project Area 12	o Channel spanning ELS's to promote aggradation of incised channel o ELS's to deflect flow into floodplain channels o Excavation of high flow channels to increase connectivity o Enhance side channels with additional wood	o The incised channel would benefit from aggradation to reconnect with existing floodplain channel network o Adding wood to mainstem and side channels will increase the availability of pool habitat and cover for juvenile rearing	Med	

5.4 Project Prioritization and Scoring

Project prioritization is useful in directing funding and effort to the highest priority areas. Prioritization was completed using a scoring matrix to rank the project groupings within and across reaches. The primary driver in the ranking is the benefit score for each project, followed by the benefit to cost score, and the feasibility designation. The basis for each of the scores and designations includes the following criteria:

- Benefit Score: Projects are scored according to 4 benefit categories, which include a "recovery gap" category, fish use, root causes and ecological concerns. Climate Change is also included in the benefit score. Scores for each category are summed to obtain the Benefit Score.
- Cost Score: Projects are given a Cost Score, which reflects the overall relative cost for the project based on techniques, access, and construction feasibility.
- Benefit-to-Cost Score: Total benefit score is divided by the cost score to obtain the Benefit-to-Cost Score.
- Feasibility Designation: Projects are given a Feasibility Designation based on the overall likely feasibility of being able to implement the project within a 10-year timeframe.

Table 21 provides a summary of the project prioritization and ranking. Full details on the scoring criterion, scores, and rationale are provided in Appendix C.

Table 21. Project prioritization scores and ranking.

PROJECT NAME	BENEFIT SCORE	BENEFIT/COST SCORE	FEASABILITY DESIGNATION	CLIMATE CHANGE IMPACT	RANK
C13-RM 25.0-25.8	13	6.5	High	High	1
C10- RM 19.5-20.3	12	6	High	Moderate	2
T1- RM 0-1.2	12	6	Moderate	Moderate	3
C11-RM 22.8-23.5	11	5.5	High	Moderate	4
C10-RM20.9 -21.9	11	5.5	Moderate	Moderate	5
C11-RM 22.0-22.8	11	5.5	Moderate	Moderate	6
B1-RM 0-0.7	10	5	High	Moderate	7
L2-RM 1.0-1.5	10	5	High	Moderate	8
L2-RM 2.1-2.5	10	5	High	Moderate	9
C13-RM 24.7-25.0	10	5	High	Moderate	10
C12-RM 23.5-23.8	10	5	High	Moderate	11
L1-RM 0.0-0.5	10	5	Moderate	Moderate	12

The first component of the benefit score, the recovery gap, is defined as the difference in ecological conditions between the current habitat and the target condition that could be addressed with restoration measures (i.e. the intrinsic potential of the habitat would support that level of improvement if habitat conditions were restored). The benefit to cost score provides a measure of cost-effectiveness to compare across projects. The cost score is a ranking of relative cost by category based on the construction technique, potential for excavation, and level of complexity in potential structures or channel forms. Benefit score was the initial indicator of rank followed by the benefit to cost score.

Construction feasibility can affect the cost and ability to implement projects within a basin. Factors that affected the feasibility score included distance from roads for equipment access, number of land owners, and any regulatory or permitting limitations that may affect project cost or schedule. Initial feasibility was included in the overall project ranking as a minor indicator.

Climate change is likely to affect the Upper Chewuch River basin at some point as modeled by Beechie et al. (2013). Planning for the effects of climate change is a forward-looking approach that is included in the prioritization of projects at a qualitative level. Most projects provided a moderate benefit to climate change except those in areas where connection to ground water sources could be documented.

5.5 Restoration Strategy Summary

The restoration strategy for the Upper Chewuch Habitat Assessment provides an integration of a thorough understanding of the current conditions including fish presence and spawner use, Ecological Concerns as identified by the Upper Columbia Revised Biological Strategy, hydraulic modeling output (depth, velocity and shear stress), and restoration potential by project reach to provide restoration opportunities, their locations and associated project actions. The strategy includes a prioritization of project opportunities (Appendix C) that synthesizes input from biological and physical habitat data, objectives specific to species needs in the study area, as well as construction cost effectiveness, feasibility and the relative level of resilience to climate change provided by each project. The strategy presented in this document provides context to the selection process for project implementation by clarifying potential project effects.

6. CONCLUSION

The Upper Chewuch Habitat Assessment can be used as a planning tool to develop restoration strategies to benefit adult and juvenile salmonids and other aquatic species in the Chewuch Basin. This assessment identifies specific project locations and actions that are selected to address the historical changes and habitat degradation, work with the natural geomorphic processes rather than against them, and improve habitat conditions specifically for ESA listed salmonids and other aquatic species of concern. The data presented provide a background and rationale for restoration efforts and a clear prioritization method that can be used as a communication tool with funders and stakeholders.

Project concept maps, hydraulic model output, project descriptions and photos, and the historical aerial photo series are also valuable tools that can be used to convey project plans and ideas to secure funding and talk with landowners about potential project effects. These tools are also the building blocks for the next series of steps in design and implementation of identified projects, in terms of providing baseline topography, ecological conditions and project ideas. However, additional work will be needed to advance these ideas to the concept level of design, and new ideas may emerge during that more detailed analysis. Proposed condition hydraulic models based on more specific topographic data in the project area would be included in the evaluation of project alternatives at the concept level.

Additional information on habitat conditions is currently being collected (e.g. Methow Subbasin Water Quality Restoration and Monitoring Program) that may provide additional insight into the relative contribution of project areas for climate change resiliency, as well as the need to include water quality or quantity concerns in future assessments. This framework provides an opportunity to incorporate that data into an established planning process. In addition, the clear identification of intended habitat outcomes for each of the project ideas helps establish monitoring objectives that can be used for future project effectiveness monitoring and adaptive management.

The Upper Chewuch Habitat Assessment provides clear identification of priorities and actions for project implementation that can be used for funding applications and stakeholder outreach, and can also be updated as new data become available.

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Appendix A

REI Analysis Details

Natural Systems Design

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1. INTRODUCTION

REI analysis assists in evaluating the health of the stream ecosystem and in identifying areas where management or restoration actions are needed. The reach-based ecosystem indicators (REI) analysis for the Upper Chewuch Reach Assessment builds upon previous reach assessments and REI analyses in the Chewuch Watershed, including an assessment of the Chewuch River from RM 2.2 to 20 (Interfluve 2010) and the Methow Sub-basin Geomorphic Assessment (USBR 2008). The analysis uses a set of indicators that provide a standardized and convenient way to evaluate ecosystem parameters. The analysis begins with a selection of indicators that are appropriately assessed at the watershed scale including drainage network and roads, disturbance regime, hydrology, and water quality and quantity. The bulk of the analysis focuses on indicators evaluated at the reach scale which span numerous habitat parameters that are important to salmonids. The reach scale indicators are broken down into three categories with subcategories of indicators within each:

1. Habitat quality – substrate, large wood, pools, off-channel habitat
2. Channel condition – floodplain connectivity, bank stability/channel migration, vertical channel stability
3. Riparian vegetation – vegetation structure, vegetation disturbance, canopy cover

The condition of each indicator is evaluated using defined criteria and placed into one of three condition ratings: adequate, at risk, or unacceptable condition.

The indicators and criteria used in this analysis match those used in previous assessments in the Chewuch River unless otherwise noted. Criteria and indicators (also known as pathways and indicators) were originally developed by U.S. Fish and Wildlife Service in 1998, as published in Hillman and Giorgi (2002) and are also derived from NOAA Fisheries Matrix of Pathways and Indicators (1996). The data used herein come chiefly from a USFS Level II Stream Inventory and geomorphic assessment conducted in November 2017 by Natural Systems Design to support the Upper Chewuch Habitat Assessment project. Additional materials and data from other sources were also used when appropriate and are cited as such throughout this analysis.

2. WATERSHED CONDITION

2.1 Effective Drainage Network and Watershed Road Density

Roads can cause watershed scale habitat degradation; the primary threat being altered sediment delivery and dynamics. In the Upper Chewuch, the vast majority of roads are unpaved, so the road surfaces are a potential source for fine sediment during run-off periods. Road building can destabilize steep slopes when the hillside is cut and the fill is used to form the road bed, leading to increased risk for landslides which can deliver large amount of sediment to streams. Unpaved roads can also directly contribute to an increase in sediment delivery from erosion of side cast and hillslope cuts, direct runoff from the road surfaces, and erosion of drainage ditches (Reid et al 1981).

Criteria

GENERAL INDICATORS	ADEQUATE CONDITION	AT RISK CONDITION	UNACCEPTABLE CONDITION
Effective drainage network and watershed road density	Zero or minimum increases in active channel length correlated with human caused disturbance. Road density < 1 mi/mi^2	Low to moderate increase in active channel length correlated with human caused disturbances. Road density 1-2.5 mi/mi^2	Greater than moderate increase in active channel length correlated with human caused disturbances. Road density >2.4 mi/mi^2

Road density was calculated using USFS road data and watershed area from USGS stream stats.

Chewuch Watershed Condition: Adequate

Road density from the downstream extent of the reach assessment at RM 19.1 to the headwaters of the Upper Chewuch watershed is 0.36 mi/mi^2, indicating an adequate condition for road density. This analysis includes the Twentymile, Lake and Andrews Creek drainage areas, but does not include Boulder Creek since it is not continuous with that drainage area. Sixty percent of the Upper Chewuch watershed is within the Pasayten Wilderness, which is a roadless area, and therefore significantly reduces the overall watershed road density. In the portion of the watershed that is not in Wilderness road density is 0.89 mi/mi^2, which is still within adequate condition.

Boulder Creek Watershed Condition: At risk

Road density for the Boulder Creek Watershed is 1.8 mi/mi^2 road density, indicating an at risk condition.

2.2 Disturbance Regime

Disturbances are a natural part of ecosystems, and a defining characteristic of a functioning ecosystem is resiliency to disturbance as well as the ability to recover. As humans affect landscapes and ecosystems, we can alter the nature and severity of disturbances, and also create new ones. Disturbances can degrade the health of a watershed ecosystem, including the fish and other organisms that inhabit it, particularly if the ecosystem or disturbance regime is already altered, out of balance, or severely degraded.

Criteria

GENERAL INDICATORS	ADEQUATE CONDITION	AT RISK CONDITION	UNACCEPTABLE CONDITION
Disturbance Regime	Environmental disturbance is short lived; predictable hydrograph, high quality habitat and watershed complexity providing refuge and rearing space for all life stages or multiple life-history forms. Natural processes are stable.	Scour events, debris torrents, or catastrophic fires are localized events that occur in several minor parts of the watershed. Resiliency of habitat to recover from environmental disturbances is moderate.	Frequent flood or drought producing highly variable and unpredictable flows, scour events, debris torrents, or high probability of catastrophic fire exists throughout a major part of the watershed. The channel is simplified, providing little hydraulic complexity in the form of pools or side channels. Natural processes are unstable.

Watershed Condition: Unacceptable condition

Disturbances in the Upper Chewuch and Boulder Creek watersheds come from both natural and anthropogenic causes. Wildfires are one of the major sources of disturbance and are a natural part of the landscape in the Chewuch. However, forest practices and fire suppression since the early 1900's have led to an increase in combustible fuels, which have worsened the severity and intensity of wildfires (NPCC 2004). Since 2001, 80 percent of the Upper Chewuch Watershed has burned in several wildfires, along with a large portion of the Boulder Creek Watershed burning in the Tripod Fire (2006). This level of disturbance has resulted in significant impacts to vegetation. Additionally, climate change is predicted to increase the occurrence and severity of forest fires in the Okanogan National Forest, including the Chewuch Watershed (Gaines et al 2012).

Roads can also pose a significant concern, as mentioned in Section 2.1. Roads can affect sediment dynamics in a watershed by significantly increasing sediment delivery from upland areas (Reid et al 1981). In the Chewuch Watershed, increased sediment delivery is a top ecological concern (UCRTT 2017), although the relative density of roads in the Upper Chewuch is low. The increased delivery of sediment associated with road networks represents a significant source of disturbance and may be contributing towards reducing the resiliency of the watershed in Boulder Creek.

In addition to roads and wildfires, numerous small-scale disturbances from recreation including campgrounds and dispersed campsites in the riparian corridor have cleared vegetation, further impacting streams in the Upper Chewuch and Boulder Creek watersheds and also reducing ecological resiliency.

The combination of wildfires, roads, and recreation impacts put both the Upper Chewuch and Boulder Creek watersheds in unacceptable condition. Wildfires are the most significant concern and primary driver of the unacceptable condition in both places. Large portions of both watersheds have burned in recent years, and large fires have continued to occur almost annually in the Upper Chewuch indicating a dramatic shift from a natural disturbance regime.

2.3 Flow/Hydrology

The hydrologic regime of a watershed is a defining trait for stream ecosystems, shaping physical and biological characteristics. One of the primary attributes of the hydrologic regime is the magnitude, timing, and duration of peak flows, which have significant implications for instream habitat. Altered hydrology can cause peak flows to be larger than would naturally occur, or to occur during times of year that fish populations may not be adapted to withstand. Increased high flows can increase scour and incision, degrade habitat, and destroy redds.

Hydrology and peak flow data from the USGS stream gauge 12448000 near the mouth of the Chewuch River in Winthorp, WA, and flow recurrence data from USGS StreamStats was used to evaluate peak flow conditions.

Criteria

GENERAL INDICATORS	ADEQUATE CONDITION	AT RISK CONDITION	UNACCEPTABLE CONDITION
Flow/hydrology	Magnitude, timing, duration, and frequency of peak flows within a watershed are not altered relative to natural conditions of an undisturbed watershed of similar size, geology, and geography.	Some evidence of altered magnitude, timing, duration, and/or frequency of peak flows relative to natural conditions or an undisturbed watershed of similar size, geology, and geography.	Pronounced changes in magnitude, timing, duration, and/or frequency of peak flows relative to natural conditions or an undisturbed watershed of similar size, geology, and geography.

Watershed Condition: At risk

A large portion of the Chewuch Watershed has burned in fires since 2001. The loss of vegetation from these widespread fires has the potential to affect the hydrology of the watershed, leading to more intense and frequent peak flow events (Shakesby and Doerr 2006). In the Chewuch, there is some evidence of a potential sift in peak flow magnitude since the mid 2000's. In a 12-year span since 2005 there have been 3 peak flows in exceedance of the 10-year flow recurrence, and five peak flows in exceedance of the 5-year flow recurrence (Figure 1). Given the short period of record for the gage data and variability of peak flows in the period of record (1992-2017), this trend does not appear to be statistically significant but does point towards a potential trend and merits being tracked into the future. With large fires continuing to occur on a nearly annual basis in the Chewuch watershed, there is a chance that fire effects on hydrology will become more pronounced or at least continue to the point where there is a statistically significant shift. However, vegetation recovery from fires may offset the future impacts depending on the rate of recovery and the scale of new fires. Recovery time from fire effects to peak flows varies, but can take up to several decades (Shakesby and Doerr 2006).

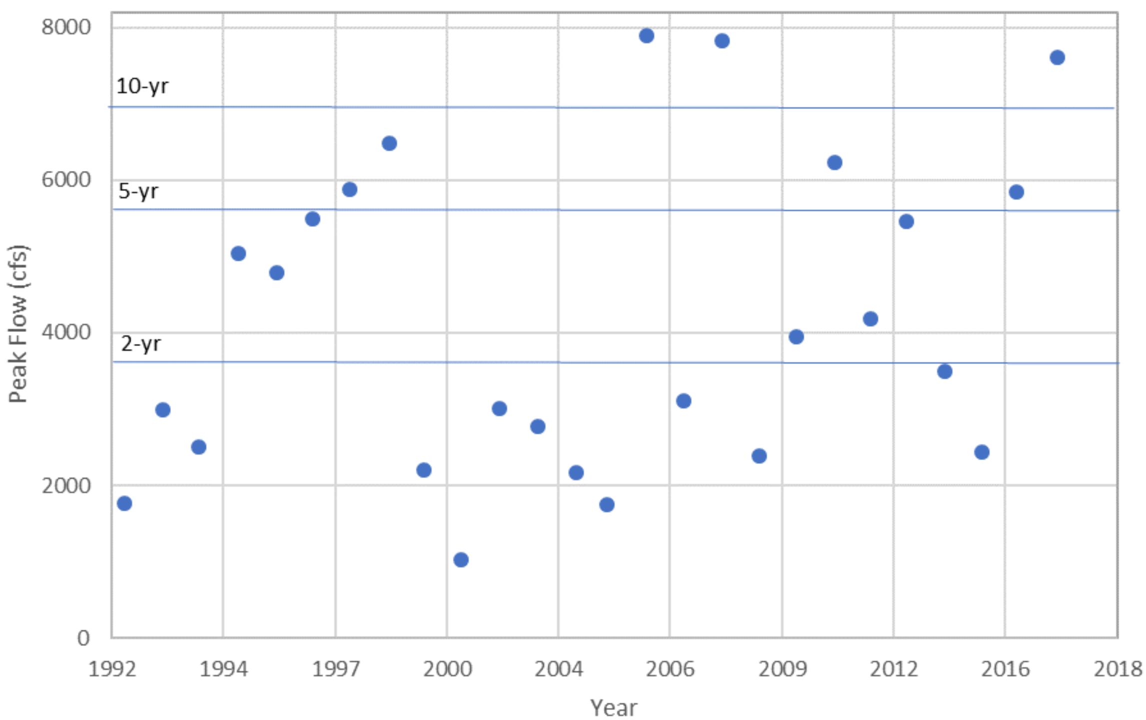

Figure 1. Peak flows for the Chewuch River from USGS gage 12448000 with 2, 5, and 10 year flows indicated in solid blue lines.

A shifting hydrologic regime due to climate change puts the Chewuch Watershed at risk to potential adverse effects from changing flow patterns, combined with the reduced capacity for moisture on the landscape due to recent widespread fire activity (Beechie et al. 2013). Open ground and areas where fire has removed vegetation have higher run-off rates than heavily vegetated soils. As the climate changes we expect earlier peak flows, reduced summer flows, higher peak flows from decreased snow pack and more precipitation falling as rain rather than snow (Gaines et al 2012). While the Chewuch Watershed currently has a snowmelt driven hydrograph and peak flows, it is expected that it will become a transition, mixture of rain and snowmelt driven, watershed by 2100 (Mantua et al 2010). These conditions will lead to high flow occurring in different times of year than historically, and potentially larger flow events that cause more redd scour, bank erosion, and habitat degradation.

2.4 Water Quantity and Quality

Salmonids are cold water fishes that are sensitive to water quality degradation and require clean, clear, cold water to survive and flourish. If stream temperatures are too warm, they can be lethal to salmonids during all life stages. To protect salmonids and other aquatic species from stream temperature degradation, the Washington Department of Ecology (WA DOE) has developed water temperature standards (Table 1) and identified assessment categories for areas that require additional work to meet standards. Other water quality parameters are also important to salmonids and regulated by WA DOE, including dissolved oxygen, turbidity, pH, and biological and chemical contaminants.

Water quantity, as it pertains to this evaluation, refers to the amount of water in the stream during low flow. If summer flows are too low, quantity of available habitat is reduced and low flows contribute to warm water temperatures particularly if streamside shading is not adequate.

Criteria

GENERAL INDICATORS	ADEQUATE CONDITION	AT RISK CONDITION	UNACCEPTABLE CONDITION
Quantity/ Temperature/ Chemical Contamination/ Nutrients	Adequate instream flows for habitat, low levels of water quality impairments from land use sources, no excessive nutrients, no CWA 303d designated reaches or exceedances of Washington State Department of Ecology standards – 173-201A-200.	Inadequate instream flows for habitat, moderate levels of water quality impairments from land use sources, some excess nutrients, CWA 303d designated reaches.	Inadequate instream flows for habitat, high levels of water quality impairments from land use sources, high levels of excess nutrients, CWA 303d designated reaches.

Water quality assessment categories (https://ecology.wa.gov/Water-Shorelines/Water-quality/Water-improvement/Assessment-of-state-waters-303d/Assessment-categories)

- Category 1 – meets tested standards for clean waters.
- Category 2 – waters of concern.
- Category 3 – Insufficient data.
- Category 4 – Polluted waters that do not require a TMDL.
  - Category 4a – has a TMDL
  - Category 4b – has a pollution control program
  - Category 4c – is impaired by a non-pollutant
- Category 5 – polluted waters that require a TMDL.

Watershed Condition: At risk

The Upper Chewuch as a whole has no water quality designation. Additionally, this portion of the watershed is above any irrigation diversions, so instream water withdrawals that can contribute to inadequate water quantity during low flow periods is not a concern. One location on Lake Creek, near the mouth, is listed as a Category 2 waterbody for dissolved oxygen, based off of one sample in 2001 (WA DOE 2014).

To protect incubation of salmonids that spawn from late spring to early fall, additional temperature criteria have been developed by WA DOE. Chewuch River and Lake Creek have additional spawning/incubation criteria of 13°C from August 15-July 1, and the lower 1 mi of Boulder Creek also has additional spawning/incubation criteria of 13°C from October 1-June 15 (WA DOE 2011).

The lower Chewuch in the vicinity of Boulder Creek (river mile 8), below the assessment area, is listed on the State of Washington's 303d list (listing ID 39349) for temperature impairment due to water temperatures exceeding 16°C 7-DADMAX during July and August. Above river mile 15, which includes the Upper Chewuch Assessment area that begins near river mile 19, temperature data from USFS (unpublished) shows no impairment as of 2007 (USFS 2007). A more recent temperature study of the Methow Watershed led by the Methow Salmon Recovery Foundation began in 2010, funded by WA DOE – Methow Subbasin Water Quality Restoration and Monitoring Program (Study ID G1000282) - will provide a more current picture of temperature conditions. The study monitored temperature across six sites in the Upper Chewuch and one site at RM 0.5 in Boulder Cr. Field data collection finished in November 2017, but as of December 2018 there has not been a report presenting the findings or any new DOE listings.

Water temperatures are predicted to increase in the face of climate change (Gaines et al 2012). Additionally, snowpack is projected to decrease in the coming decades as the watershed shifts from a snowmelt driven hydrology towards a rain driven hydrology, which will also impact summer water temperatures and flows (Metua et al. 2010). With less snowpack available, summer water temperatures will increase and the flows will likely decrease further putting the watershed in an at risk condition for degradation.

Table 1. Washington Department of Ecology 173-201A-200 7-day average of daily maximum (7-DADMax) water temperature standards (WA DOE 2016).

CATEGORY	HIGHEST 7-DADMAX
Char Spawning and Rearing	12°C
Core Summer Salmonid Habitat	16°C
Salmonid Spawning, Rearing, and Migration	17.5°C
Salmonid Rearing and Migration **Only**	17.5°C
Non-anadromous Interior Redband Trout	18°C
Indigenous Warm Water Species	20°C

3. HABITAT QUALITY- REACH SCALE METRICS

3.1 Substrate

Spawning habitat is the focus of the substrate habitat quality indicator. The availability of appropriately sized substrate is critical for successful salmon spawning. Salmon spawn in gravel and small cobble with sizes most commonly ranging from 10 mm to 50 mm for bull trout, steelhead and Chinook (Kondolf and Wolman, 1993). In general, substrate size preferences vary by species, and larger fish will typically spawn in coarser (larger) substrate. Additionally, fine sediments can degrade spawning habitat. Fines can embed larger substrate and make them more difficult to mobilize by spawning salmon during red creation, and can also smother incubating eggs by reducing the flow of oxygenated water through redds (Quinn 2005).

Criteria

SPECIFIC INDICATOR	ADEQUATE CONDITION	AT RISK CONDITION	UNACCEPTABLE CONDITION
Dominant substrate/fine sediment	Gravels or small cobbles make-up >50% of bed materials in spawning areas. Reach Embeddedness in rearing areas <20%. ≤12% fines (<0.85 mm) in spawning gravel or 12% surface fines of ≤6 mm.	Gravels or small cobbles make-up 30-50% of bed materials in spawning areas. Reach embeddedness in rearing areas 20-30%. 12-17% fines (<0.85 mm) in spawning gravel or 12-20% surface fines of ≤6 mm.	Gravels or small cobbles make-up <30% of bed materials in spawning areas. Reach embeddedness in rearing areas >30%. >17% fines (0.85 mm) in spawning gravel or > 20% surface fines of ≤6 mm.

Reach Condition

CHEWUCH C10	CHEWUCH C11	CHEWUCH C12	CHEWUCH C13	ANDREWS	BOULDER	LAKE L1	LAKE L2	TWENTY-MILE
At Risk	Adequate	At Risk	At Risk	Adequate	Adequate	At Risk	At Risk	At Risk

Substrate composition results in percent

SUBST-RATE SIZE	CHEWUCH C10	CHEWUCH C11	CHEWUCH C12	CHEWUCH C13	ANDREWS (NR)	BOULDER (NR)	LAKE L1 (NR)	LAKE L2 (NR)	TWENTY-MILE (NR)
Sand and Fines ≤2 mm	15.0	6.6	11.4	13.8	5.6	10.7	1.2	13.0	6.1
Gravel 2–63 mm	21.9	15.3	14.2	16.2	16.2	22.6	10.0	16.4	15.7
Cobble 64–256 mm	48.9	38.4	30.2	43.8	27.9	30.2	27.9	27.7	23.9
Boulder >256 mm	14.3	39.7	42.8	26.2	50.3	29.3	60.9	42.7	53.2
Bedrock	0.0	0.0	1.4	0.0	0.0	7.2	0.0	0.2	1.1

NR= No redd data, so counts were not specific to spawning areas

Spawning ground survey data from WDFW from 2005-2015 were used to establish where spawning areas were located on the mainstem Chewuch River, and select sediment data for analysis from those areas. Andrews, Boulder, Lake, and Twentymile did not have redd data, so in these reaches all sediment data from the reach were used, not only those data from channel units with spawning. Only sediment data from channel units with identified spawning activity were used to calculate the substrate composition for the reaches in the mainstem Chewuch. Since there were no redd data available for the tributaries, all sediment samples were used for composition calculations.

Chewuch C10 and C13 have >50% gravel and cobble in spawning areas, but levels of fine sediment in spawning areas were too high so both reaches were rated at risk. Chewuch C12 has 45% cobble and gravel, just under the 50% threshold, and also has fine sediment levels very close to the at risk condition, so the reach is in at risk condition.

In Chewuch C11, spawning only occurred in side channels where substrate data is not collected under the USFS Level II Protocol, so substrate in spawning areas cannot be evaluated. No spawning in the mainstem over the 10-year period of redd data indicates the mainstem is likely not in good condition for spawning, although the substrate conditions meet the adequate condition rating criteria. Since the spawning populations are limited, there may be areas for spawning in c11 along the mainstem or other side channels that are not being used, so the reach is rated adequate.

Andrews Creek had less than 50% gravels and cobbles, so was rated as at risk. The fine substrate in Andrews Creek is low at 5.6% but the gradient of the reach results in more than 50% of the substrate being in the boulder size class.

Boulder Creek had gravels or small cobbles accounting for > 50% of substrate and had less than <12% fines, so this reach is rated as adequate with a caveat that all the tributary reaches did not have redd data, so the substrate across the entire reach was used instead of substrate in channel units with documented spawning.

Lake Creek L1 and L2 reaches both have substrate comprised of between 30-50% gravel and cobbles, which is in the at risk condition. Fine sediment in L1 is low at only 1.2%, but fines are more of a concern in L2 where they make up 13.0% of the substrate likely due to loading from the large burned areas in L2. Both reaches are considered at risk due to the quantity of available spawning sized substrates falling into the at risk condition.

Twentymile Cr scores within the adequate condition for fines with only 6.1% fines, but had 39.6% cobble and gravel, under the 50% threshold. Due to the coarse size of sediment in Twentymile Cr with over 50% boulders and the low amount of gravel and cobble, the amount of spawning habitat available is not adequate so the reach is in at risk condition.

3.2 Large Woody Debris

Large wood is an integral component of forested streams. It provides numerous functions and habitat benefits including providing a food resource for macroinvertebrates, cover for fish, trapping sediment and organic matter, and limiting long-term incision by promoting connection with side channel and off-channel habitat. Additionally, it creates hydraulic and geomorphic complexity by interrupting the flow of moving water and creating eddies and localized scour that can form pools (USBOR and USACE 2015).

Large wood levels can be evaluated using a frequency metric of the number of pieces above a defined size per mile of stream. Previous reach assessments in the Chewuch River used a frequency of 20 pieces per mile, which is based on guidance for evaluating stream habitat set forth in Hillman and Gorgi (2002). Fox and Bolton (2007) studied large wood abundance in unmanaged systems across Washington State, and found 20 pieces per mile to be too low for natural conditions. For Eastern Washington streams with a channel width between 16 to 164 feet they found an average of 42.5 pieces per mile, which is the criteria that is used for this assessment.

Criteria

SPECIFIC INDICATOR	ADEQUATE CONDITION	AT RISK CONDITION	UNACCEPTABLE CONDITION
Pieces per mile at bankfull	> 42.5 pieces/mile with > 12 in diameter and > 35 ft length; and adequate sources of wood available for both long and short-term recruitment.	Current wood frequency is being maintained at the minimum levels for adequate condition, but potential sources for long-term wood recruitment are lacking in order to maintain the minimum frequency for adequate condition.	< 42.5 pieces/mile with > 12 in diameter and > 35 ft length, and potential sources for both short and/or long-term recruitment are lacking.

Reach Condition

CHEWUCH C10	CHEWUCH C11	CHEWUCH C12	CHEWUCH C13	ANDREWS	BOULDER	LAKE L1	LAKE L2	TWENTY-MILE
Unaccept-able	Unaccept-able	Adequate	Adequate	At Risk	Unaccept-able	Unaccept-able	At Risk	Unaccept-able

Large wood frequency

REACH	CHEWUCH C10	CHEWUCH C11	CHEWUCH C12	CHEWUCH C13	ANDREWS	BOULDER	LAKE L1	LAKE L2	TWENTY-MILE
Pieces /Mile	25.7	25.5	47.2	123.6	118.9	5.7	31.4	128.6	7.7

Large wood condition in Chewuch C10 is unacceptable. Overall the wood density in this reach at 25.7 pieces/mile is well below the adequately functioning threshold, and the majority of that wood is in the side channel. Moreover, there is very little mainstem wood, with only 60 pieces in mainstem over the 2.9 mile reach. Only 26 pieces in the mainstem are greater than 12 in diameter and 35 ft long, coming out to a density 9 pieces/mile, well below the threshold for adequate or at risk conditions. The majority of the large wood is located in the No Snake side channel, where habitat quality, including large wood is good condition. The mainstem is in an unacceptable condition. There is recruitment potential, but limited existing structure to retain recruited wood.

In Chewuch C11 large wood condition is also unacceptable. The majority of the mainstem is devoid of pieces greater than 12 in diameter and 35 ft long, leading to a wood frequency well below the criteria for adequate condition. There is recruitment potential from riparian forests where large trees are present along the banks, but the reach is in unacceptable condition due to low wood frequency.

Unlike C10 and C11, large wood in reaches C12 and C13 is in adequate condition. C12 has high natural confinement throughout the majority of the reach as the river flows through a natural gorge formed by bedrock and talus slopes, which lowers recruitment potential. However, there are currently adequate wood resources in the reach with a wood frequency of 47.2 pieces/mi which is above the criteria set forth by Fox and Bolton (2007). Additionally, with an adequate amount of wood currently in the reach, there is good potential for retention of new wood being recruited via transport from upstream reaches. C13 has a high amount of wood in the reach, especially collected in several large side channels. Short-term recruitment is good due to mortality from fires, and there are also opportunities for long term recruitment through floodplain processes. The reach is in adequate condition.

In the tributaries, none of the reaches are in adequate condition for large wood. Lake L2 and Andrews reaches meet the threshold for adequate condition, with woody frequency approximately triple the criteria, but long-term recruitment potential is low due to fires that destroyed much of the riparian zone. Due to the low long-term recruitment potential both reaches are at risk.

In Lake L1 the riparian vegetation has been affected by fires but to a lesser degree. Trees are present along the banks in large stretches of the reach, but overall, the current wood frequency is below the threshold for adequate condition, especially downstream of the Chewuch Rd. bridge. From the bridge to the confluence with the Chewuch River there are only six pieces of large wood greater than 12 in diameter and 35 ft long. Due to the current low wood frequency, Lake 1 is in unacceptable condition.

In Twentymile Creek and Boulder Creek large wood condition is also unacceptable. Large wood frequency in Twentymile Creek is well below 42.5 pieces/mi, and high gradient reduces potential for retaining recruited wood. Large wood frequency in the Boulder Creek reach is very low, at 5.7 pieces/mile. Recruitment potential is also low due to the gorge in upper portion of reach and incised conditions with a degraded riparian forest in lower portion of reach.

3.3 Pools

Pools are critical habitat for salmonids. Adults use pools for holding while migrating and spawning, and juveniles use them for rearing to provide velocity refuge, feeding areas next to eddies, and thermal refugia. Pools can be evaluated by a number of metrics, including pool frequency and maximum depth which are used here. Pool frequency (spacing) is a function of large wood loading, channel type, slope, and width (Montgomery et al 1995). As channel width increases average pool frequency decreases, which is reflected in the condition criteria for pools, where larger channels need fewer pools per mile to be in adequate condition.

Pool metrics include channel width for calibration of targets, pools/mile, number of pools > 1m deep, average fish cover, and average percent sand and fines. The percent sand and fines metric was calculated using only sediment data from within pool habitats within the reaches. These data are not comparable to the substrate data which were specific to areas with spawning activity present.

Criteria

SPECIFIC INDICATOR	ADEQUATE CONDITION	AT RISK CONDITION	UNACCEPTABLE RISK CONDITION
Pool frequency and quality	Channel width (ft) pools/mile 0-5 39 5-10 60 10-15 48 15-20 39 20-30 23 30-35 18 35-40 10 40-65 9 65-100 4 Pools have good cover and cool water, and only minor reduction of pool volume by fine sediment	Pool frequency is similar to adequate condition, but pools have inadequate cover/temperature, and/or there has been a moderate reduction of pool volume by fine sediment	Pool frequency is considerably lower than values for adequate condition, also cover/temperature is inadequate, and there has been a major reduction of pool volume by fine sediment
Large pools	Reach has many large pools >1 m deep	Reach has few large pools >1 m deep	Reach has no pools >1 m deep

Reach Condition

CHEWUCH C10	CHEWUCH C11	CHEWUCH C12	CHEWUCH C13	ANDREWS	BOULDER	LAKE L1	LAKE L2	TWENTY-MILE
At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk

Pool frequency and number of deep pools

METRIC	CHEWUCH C10	CHEWUCH C11	CHEWUCH C12	CHEWUCH C13	ANDREWS	BOULDER	LAKE L1	LAKE L2	TWENTY-MILE
Channel width (ft)	81.7	78.0	71.4	68.0	66.3	33.2	41.9	37.1	41.3
Pools/mile	4.67	3.36	11.02	7.86	9.43	16.19	8.57	9.86	29.23

METRIC	CHEWUCH C10	CHEWUCH C11	CHEWUCH C12	CHEWUCH C13	ANDREWS	BOULDER	LAKE L1	LAKE L2	TWENTY-MILE
# pools >1 m deep	1	2	10	3	1	8	1	7	5
Avg fish cover	1%	1%	1%	7%	0%	2%	2%	11%	3%
Avg % sand and fines	18%	13%	16%	21%	10%	15%	3%	21%	8%

Pool condition in all Chewuch reaches is at risk. In C10 pool frequency is slightly above the adequate threshold, but the quality of the pools puts the reach in the at risk condition. Only one of 12 pools is greater than 1 meter deep, and fish cover is also very poor with nine of the 12 pools having no cover and the remaining three only have 5 percent cover. Fine sediment is also a moderate concern due to substrate in the pools consisting of 18 percent sand and fines on average. In Chewuch C11 pool frequency is slightly below adequate threshold and fish cover is very low. In C12 pool frequency and the number of deep pools are both well above the adequate threshold, however average fish cover is very low so pool condition is at risk. Pool metrics in C13 meet adequate criteria for frequency and is the highest of the Chewuch reaches. Fish cover for several pools was over 20%, but several other pools had no cover so on the reach level cover is deficient. There are also few deep pools in C13 and also had the highest level of fine sediments in pools for mainstem reaches, so the reach is in at risk condition as well.

In the tributaries pool condition is also at risk in all reaches. In Andrews and Twentymile the reaches meet criteria for pool frequency and fine sediment in pools is low, but pool condition is at risk due to low number of large pools and low fish cover. In Lake Creek, pool frequency is slightly below the adequate criteria in both L1 and L2. Both Lake Creek reaches also have a low number of deep pools. Although L2 has seven deep pools, the reach is also over 2 miles long so proportionally the number of deep pools is small. Fine sediment is also a concern in L2, with the reach having the highest percentage of fines in pools, which is probably attributable at least in part to the sediment loading from the Farewell Fire that burned a large portion of the reach. Fish cover in L1 and L2 is deficient, with L1 pools having very low cover and L2 having mixed pool cover, with over 30% in half the pools, but the remaining pools with little or no cover. Boulder Creek has a moderate number of deep pools, but pool frequency and fish cover are both not adequate so the reach is also at risk.

3.4 Off-channel habitat

Off-channel habitat provides low energy areas for flow refugia, hyporheic upwelling and thermal refuge, and productive foraging for rearing salmonids (Sommer et al 2001, Roni et al 2002). These types of habitats are sensitive to changes in channel elevation, and can become lost, disconnected, or degraded as a result of human activities that disrupt geomorphic river processes (Roni et al 2002).

Criteria

SPECIFIC INDICATOR	ADEQUATE CONDITION	AT RISK CONDITION	UNACCEPTABLE CONDITION
Connectivity with main channel	Reach has many ponds, oxbows, backwaters, and other off-channel areas with cover, and side channels are low energy areas. No manmade barriers present along the	Reach has some ponds, oxbows, backwaters, and other off-channel areas with cover, and side channels are generally high energy areas. Manmade barriers present that prevent access to off-channel	Reach has few or no ponds, oxbows, backwaters, and other off-channel areas. Manmade barriers present that prevent access to off-

SPECIFIC INDICATOR	ADEQUATE CONDITION	AT RISK CONDITION	UNACCEPTABLE CONDITION
	mainstem that prevent access to off-channel areas.	habitat at some flows that are biologically significant.	channel habitat at multiple or all flows.

Reach Condition

CHEWUCH C10	CHEWUCH C11	CHEWUCH C12	CHEWUCH C13	ANDREWS	BOULDER	LAKE L1	LAKE L2	TWENTY-MILE
Adequate	Unaccept-able	Unaccept-able	Adequate	Unaccept-able	Unaccept-able	Unaccept-able	At Risk	Unaccept-able

Chewuch C10 has substantial off channel habitat, and is rated in adequate condition. Slow side channels make up 17% of the total wetted area, and the reach also hosts an excellent example of potential off-channel habitat in the Upper Chewuch. The No Snake Side Channe in C10l is a highly functioning long slow side channel with numerous pools and LWD. Additionally, roads or other manmade features are out of the floodplain and do not impact off-channel connectivity aside from a small portion of the decommissioned Chris Rd which crosses the left bank floodplain near the top of the reach.

In Chewuch C11 off-channel habitat is severely limited. There are a small number of side channels in C 11, but all but one of them are fast side channels with minimal flow refugia. The one slow side channel has little wood and no cover. Chewuch Road also crosses low lying floodplain near river mile 22.5 cutting off a portion of floodplain area. The lack of low energy off-channel habitat on its own places the reach in unacceptable condition, and the road through the floodplain adds to the impairment.

Chewuch C12 has no slow side channels or off-channel features, placing the reach in unacceptable condition. The river flows through a canyon that naturally limits availability off-channel habitat for most of the reach. Roads and other manmade features are out of the floodplain aside from where the road cross Lake Creek, so manmade features are not a major driver in the lack of off-channel habitat. Upstream of the Lake Creek confluence there is some available floodplain, but no low energy areas or slow velocity features currently exist.

Chewuch C13 has several slow side channels providing good off-channel habitat, including one with abundant LWD and fish cover. Additionally, Chewuch Road runs along the valley wall and no other manmade features are present that block off channel habitat, so this reach is in adequate condition.

In the tributary reaches, off-channel habitat is overall not in good condition. Andrews, Boulder, Lake L1, and Twentymile all have no off-channel habitat, so these reaches are in unacceptable condition. Manmade features have varying degrees of impact on off-channel areas in these reaches. In Lake L1, Andrews, and Twentymile roads cut across the alluvial fans, thereby constraining side channel and distributary development. The Twentymile Cr alluvial fan is probably the most impacted with additional levees and other manmade features that also cut off side channels and distributaries. In Boulder Creek official Forest Service roads are all out of the floodplain, but there are several unimproved roads in the right bank floodplain which have some impact on off-channel development. Lake L 2 has some slow side channels, but they not abundant so the reach is at risk.

4. CHANNEL CONDITION

4.1 Floodplain Connectivity

The connection of a stream to its floodplain is critically important to maintain ecological processes that form and support habitat for not only salmonids and other aquatic species, but also terrestrial species. A properly functioning and connected floodplain supports numerous processes including large wood recruitment, dissipation of high flow energy, sources of sediment, and development and maintenance of off-channel habitat features.

Criteria

SPECIFIC INDICATOR	ADEQUATE CONDITION	AT RISK CONDITION	UNACCEPTABLE CONDITION
Floodplain Connectivity	Floodplain areas are frequently hydraulically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation, and succession	Reduced linkage of wetland, floodplains, and riparian areas to main channel; overbank flows are reduced relative to historic frequency, as evidenced by moderate degradation of wetland function, riparian vegetation/succession.	Severe reduction in hydrologic connectivity between off-channel, wetland, floodplain, and riparian areas; wetland extent drastically reduced and riparian vegetation/succession altered significantly.

Reach Condition

CHEWUCH C10	CHEWUCH C11	CHEWUCH C12	CHEWUCH C13	ANDREWS	BOULDER	LAKE L1	LAKE L2	TWENTY-MILE
At Risk	At Risk	Adequate	Adequate	At Risk	Unacceptable	At Risk	At Risk	Unaccept-able

Floodplain connectivity in Chewuch C10 is moderately reduced due to incision placing the reach in an at risk condition. Between RM 19.7 – 20.15, there is a disconnected side channel complex on the eastern floodplain immediately upstream of the Twenty-Mile Creek alluvial fan. Additionally, downstream of the July Creek alluvial fan there is a side channel complex with off-channel wetlands and abundant large wood. Historic incision has deactivated this side channel complex, and the inlet is currently perched 6-8 feet above the channel, limiting the frequency and magnitude of flow into the side channel complex.

C11 is a high energy reach with little moderate floodplain degradation. The reach is dominated by riffle habitats, and there are two rapids with gradients of up to 10%. There are multiple extremely long fast water (riffle) channel units with minimal LWD and little habitat complexity. Some large sections of active erosion and channel incision are present in the reach, along with numerous fast water side channels and other high-flow channels. There are disconnected side channels throughout the reach – near river mile 22.2, 22.5, and 23.1. Due to the presence of some high energy side channels but the disconnection of most side channels, the reach is in at risk condition.

C12 has very high natural confinement due bedrock canyon and alluvial fan from Lake Cr at bottom of reach. There is essentially no floodplain development and there is only one small side channel at RM 23.7. Due to natural confinement that limits the intrinsic floodplain connectivity, the reach has an adequate rating condition.

The channel in C13 is characterized by pool riffle morphology where the reach is naturally unconfined, with a well-connected floodplain and side channels active over a range of flows. The channel is more simplified where confined by alluvial fans, with more plane bed morphology and lack of side channels and floodplain, but alluvial fans are a natural process that reduces floodplain area, so the reach is in adequate condition.

None of the tributary reaches have adequate floodplain connectivity. Boulder Creek has a highly confined bedrock gorge in its upper half and a moderately incised channel set in a moderate gradient alluvial fan in its lower half. Downstream of the bridge, the channel is incised into the alluvial fan with an inset floodplain that has developed in some areas, forming a narrow active floodplain. Incision in the lower portion of the reach has cut off the historic floodplain, resulting in a floodplain width that is drastically reduced. There were also active efforts to channelize the creek in the alluvial fan, perhaps to protect infrastructure upstream (historic bridge crossing). These conditions combined result in an unacceptable rating.

In Twentymile Creek the main channel has at times been straightened and intentionally confined in the alluvial fan by a levee that runs along the creek in the lower reaches. At the transition to the alluvial fan at the terminus of the canyon the channel is incised 8-10 feet into the alluvial fan, with levee features built up on either bank of large boulders. These features are the result of overbank flooding and the rapid fallout of large material once flow escapes the channel and are only found at the head of the fan. Additionally, Twentymile Creek has been intentionally channelized through the alluvial fan in the past (NPCC 2004). The reach is rated in unacceptable condition.

In Lake L1 the channel is incised as it flows across the alluvial fan down to USFS Road 5160, below which the channel drops onto an abandoned floodplain terrace of the main stem Chewuch River down to the confluence. The disconnection of the channel with the alluvial fan surface diminishes the likelihood that the channel will avulse in the future to another distributary channel traversing the fan. An inset floodplain has developed in the center of the reach, extending 800 – 900 feet upstream of the bridge and 600 feet downstream of the bridge. There are active side channels within the inset floodplain downstream of the bridge. Downstream of the inset floodplain the channel is deeply incised into the adjacent floodplain, and upstream the channel is less incised. The deeply incised nature of the channel and formation of an inset floodplain suggests that historic incision has lowered the channel, destabilizing the adjacent banks and forming the inset floodplain. The origin of the incision is likely from the Chewuch River, propagating upstream from the confluence as the main stem lowered due to other watershed disturbances over time. Reach is rated at risk.

Lake L2 has several large logjams downstream of the valley constriction, formed as a result of high upstream wood loads from the recently burned section of channel. The incised nature of the channel downstream of the valley constriction suggests that historic incision has lowered the channel over time. Reach is rated at risk.

In Andrews Creek the channel is incised into the alluvial fan at the downstream end of the reach from RM 0.0 – 0.18, upstream of which the channel is confined within a narrow bedrock canyon. The incised nature of the channel through the alluvial fan suggests that historic incision has lowered the channel over time. The origin of the incision is likely from the Chewuch River, propagating upstream from the confluence as the main stem lowered due to other watershed disturbances over time. The reach is rated at risk.

4.2 Bank Stability/Channel Migration

Bank erosion is a natural fluvial process, but can become modified by human impacts. Humans can both accelerate and slow natural bank erosion and channel migration rates, both of which can result in effects that negatively impact aquatic habitat. Bank stability and channel migration that is occurring at slower than natural rates will reduce large wood and sediment recruitment, and potentially lead to incision and simplification of habitat. Accelerated channel migration and reduced bank stability can lead to its own suite of negative habitat effects including causing too much sedimentation in the channel degrading spawning habitat and riparian vegetation. Excess sedimentation can also prevent the formation and stability of deep pool habitat.

Criteria

SPECIFIC INDICATOR	ADEQUATE CONDITION	AT RISK CONDITION	UNACCEPTABLE CONDITION
Bank stability/channel migration	Channel is migrating at or near natural rates	Limited amount of channel migration is occurring at a faster/slower rate relative to natural rates, but significant change in channel width or planform is not detectable.	Little or no channel migration is occurring because of human actions preventing reworking of the floodplain; or channel migration is occurring at an accelerated rate such that channel width has at least doubled, possibly resulting in a channel planform change, and sediment supply has been noticeably increased from bank erosion.

Reach Condition

CHEWUCH C10	CHEWUCH C11	CHEWUCH C12	CHEWUCH C13	ANDREWS	BOULDER	LAKE L1	LAKE L2	TWENTY-MILE
At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	Unacceptable

Analysis of historical photos of the Chewuch River covering all mainstem reaches from 1950's to current show very limited channel migration. The lack of migration is mostly due to incision that has occurred prior to the 1950's photoset. The limited migration in all four reaches place them in the at risk category.

Like the Chewuch reaches, bank stability/channel migration in the tributaries is not in adequate condition. In Twentymile Creek channel constraints (levees) have disrupted natural alluvial fan processes, resulting in incision and have greatly reduced the natural function and migration of the channel in this reach. Constriction of flow results in a channel that is higher energy compared to reference condition due to flow not being able to spread out into multiple channels across the fan. This reach is rated at unacceptable risk.

In Lake L1 and Andrews Creek incision into the alluvial fans has reduced the width of the channel and active floodplain, thereby cutting off many of the distributary channels and limiting channel migration in the lower portions of both reaches. Above the alluvial fans in these reaches the channel is less confined and has some room to migrate. These reaches are rated as at risk.

Lake L2 has increased bank erosion due to wood loading from forest fires. Additionally, in lower end of reach channel is incised, reducing the potential for channel migration. This reach is rated at risk.

In Boulder Creek incision into the alluvial fan in the lower portion of this reach has greatly reduced the channel width and floodplain connectivity, resulting in an inset floodplain that has a much narrower migration potential and channel corridor. This reach is rated at risk.

4.3 Vertical Channel Stability

Undisturbed stream channels tend to be dynamically stable, where both erosion and deposition occur but generally balance each other out and the general planform of a channel remains unchanged. When channel dynamics are altered by human impacts, the channel will fall out of equilibrium, leading to increased rates of erosion or deposition that act in lateral (stream banks) and vertical (stream bed) directions. Vertical instability can cause a stream to aggrade or incise as the channel attempts to again reach equilibrium. Both of these trends can degrade stream habitat in several ways. Channels with excessive aggradation will become shallower, where pools fill in and the channel becomes flatter, less complex, and potentially destabilized. Conversely, an incising channel will lead to increased stream power, hydraulic and geomorphic simplification, and a disconnected floodplain.

Criteria

SPECIFIC INDICATOR	ADEQUATE CONDITION	AT RISK CONDITION	UNACCEPTABLE CONDITION
Vertical Channel Stability	No measurable or observable trend of aggradation or incision and no visible change in channel planform.	Measurable or observable trend of aggradation or incision that has the potential to, but has not yet caused, disconnect of the floodplain or a visible change in channel planform.	Enough incision that the floodplain and off-channel habitat areas have been disconnected; or enough aggradation that a visible change in channel planform as occurred.

Reach Condition

CHEWUCH C10	CHEWUCH C11	CHEWUCH C12	CHEWUCH C13	ANDREWS	BOULDER	LAKE L1	LAKE L2	TWENTY-MILE
Unaccept-able	Unaccept-able	Unaccept-able	Unaccept-able	Unaccept-able	Unaccept-able	Unaccept-able	Unaccept-able	Unaccept-able

All reaches in the Upper Chewuch assessment area have incision that has caused varying degrees of disconnection of floodplains and loss of off-channel areas, leading to an unacceptable condition for all reaches. In the Chewuch River reaches, there are multiple lines of evidence for incision including disconnection of side channel and floodplain features from historical air photo analysis, relative elevation model analysis, and hydraulic modeling results showing a lack of floodplain activation during moderate and larger scale floods.

In the tributary reaches, there is evidence of all the alluvial fan reaches – Andrews, Boulder, Twentymile, and Lake L1 being incised into the fans leading to at least some disconnection of historic distributary channels and channel simplification. In Lake L2, the channel is cut down relative to the floodplain downstream of the valley constriction at RM 1.9 indicating incision.

Additional discussion of incision and floodplain connectivity can be found in the geomorphic assessments for each reach in the main Upper Chewuch Report, Section 5.2 of the main report, and in the Floodplain Connectivity (Section 4.1) assessment of this appendix.

5. RIPARIAN VEGETATION

5.1 Vegetation Structure

Riparian zones are linkages between aquatic and terrestrial ecosystems and provide critical habitat for animals that inhabit both. They perform numerous ecosystem services such as providing source trees for large wood recruitment, shading streams, controlling sediment transport, and contributing organic matter and nutrients to aquatic food webs. Healthy riparian communities, including those found in the Columbia Basin are comprised of a diverse array of plant species with varying age and seral stages (R. Crawford 2003).

Criteria

SPECIFIC INDICATOR	ADEQUATE CONDITION	AT RISK CONDITION	UNACCEPTABLE CONDITION
Vegetation structure	>80% of species composition, seral stage, and structural complexity are consistent with potential native community	50-80% species composition, seral stage, and structural complexity are consistent with potential native community.	<50% species composition, seral stage, and structural complexity are consistent with potential native community.

Reach Condition

CHEWUCH C10	CHEWUCH C11	CHEWUCH C12	CHEWUCH C13	ANDREWS	BOULDER	LAKE L1	LAKE L2	TWENTY-MILE
Acceptable	Acceptable	Acceptable	Acceptable	At Risk	At Risk	Acceptable	Unaccept-able	At Risk

Much of the Upper Chewuch River hosts healthy riparian vegetation communities that are not severely impacted by human activities. Chewuch reaches C10, C11, C12, and C13, as well as Lake Creek reach L1, all have acceptable vegetation condition, including large stands of relatively mature trees and diverse understory vegetation. While most of these reaches have been affected by fires, the damage is fairly minimal and riparian vegetation remains robust and diverse.

The Andrews Creek, Twentymile Creek, and Boulder Creek reaches all are at risk due to seral stage conditions where there are very few or no large trees as a result of fire, natural disturbance, and human disturbance, respectively.

Lake Creek reach L2 is in a state of unacceptable condition since much of the riparian forest was entirely eliminated by fire.

5.2 Vegetation Disturbance

Disturbances to floodplains and riparian vegetation from humans can take many forms. Mature trees may be harvested from riparian forests, vegetation cleared to make roads or campsites, or fluvial floodplain processes disrupted that are integral to development and maintenance of healthy riparian forests. Bank armoring, road and levee building, and incision all disrupt fluvial floodplain function and degrade riparian plant communities.

Criteria

SPECIFIC INDICATOR	ADEQUATE CONDITION	AT RISK CONDITION	UNACCEPTABLE CONDITION
Vegetation disturbance (natural/human)	>80% mature trees (medium-large) in the riparian buffer zone that are available for recruitment by the river via channel migration; <20% human disturbance in the floodplain; <2 mi/mi² road density in the floodplain	50-80% mature trees in the riparian buffer zone that are available for recruitment by the river via channel migration; 20-50% human disturbance in the floodplain; 2-3 mi/mi² road density in the floodplain.	<50% mature trees in the riparian buffer zone that are available for recruitment by the river via channel migration, >50% human disturbance in the floodplain; >3 mi/mi² road density in the floodplain.

Reach Condition

CHEWUCH C10	CHEWUCH C11	CHEWUCH C12	CHEWUCH C13	ANDREWS	BOULDER	LAKE L1	LAKE L2	TWENTY-MILE
At Risk	At Risk	Adequate	At Risk	At Risk	Unaccept-able	At Risk	Unaccept-able	Unaccept-able

Human disturbance in the upper Chewuch River and surveyed tributaries is generally minor, though some key pieces of infrastructure limit riparian communities and wood recruitment potential. Of all the reaches, Chewuch River reaches C10 and C11 have the highest proportions of large trees in the riparian area (defined as a 30m belt along each river bank), but are still classified as at risk due to roads on both banks of the river (at times immediately adjacent to the active channel), as well as several smaller dirt roads and dispersed and official campsites in the riparian area.

Chewuch River reach C12 has almost no human disturbance in the floodplain (the river runs through a gorge in reach C12 and the Chewuch River Road is high above the river on right bank), but naturally steep slopes and rock slides that have limited riparian development. Since the lack of riparian vegetation is chiefly due to natural processes, this reach is in adequate condition despite not meeting the 80% mature trees criteria.

Chewuch River reach C13 is classified as at risk due to the presence of Chewuch River Road on river right and several campsites in the riparian area. Mature trees make up only 33% of the canopy layer.

In the tributary reaches, Andrews Creek is at risk due to lack of mature trees in the floodplain and natural disturbance. Lake Creek reach L1 is at risk due to the road and bank modification along left bank.

Boulder Creek, Lake Creek reach L2, and Twentymile Creek have been classified as unacceptable due to lack of mature vegetation for recruitment in all reaches. Additional evidence for unacceptable condition includes excessive channel incision in Boulder Creek and Twentymile Creek which reduces vegetation recruitment and also lowers the alluvial water table, reducing available water for tree growth. In Lower Boulder Cr there are campsites and extensive human disturbance further degrading vegetation condition. In Lake Creek L2 and Twentymile Creek natural disturbance from fires and alluvial processes have impaired riparian vegetation.

5.3 Canopy Cover

Shade via canopy cover is an integral ecosystem service riparian vegetation provides. Canopy cover reduces the input of solar radiation to a stream, thereby helping to keep water temperature cool especially during summer months. In addition to blocking solar radiation, an intact riparian canopy can also reduce air temperatures in and around the stream channel by several degrees (Moore et al 2005). Salmonids being cold water fishes are particularly sensitive to water temperature, and need shaded stream corridors to keep water temperatures from getting lethally warm when ambient air temperatures are high.

Criteria

SPECIFIC INDICATOR	ADEQUATE CONDITION	AT RISK CONDITION	UNACCEPTABLE CONDITION
Canopy Cover	Trees and shrubs within one site potential tree height distance have >80% canopy cover that provides thermal shading to the river.	Trees and shrubs within one site potential tree height distance have 50-80% canopy cover that provides thermal shading to the river.	Trees and shrubs within one site potential tree height distance have <50% canopy cover that provides thermal shading to the river.

Reach Condition

CHEWUCH C10	CHEWUCH C11	CHEWUCH C12	CHEWUCH C13	ANDREWS	BOULDER	LAKE L1	LAKE L2	TWENTY-MILE
At Risk	At Risk	At Risk	At Risk	Unacceptable	At Risk	At Risk	Unacceptable	Unacceptable

Percentage of canopy cover as measured from 100 ft buffer with vegetation ≥ 15 ft tall.

CHEWUCH C10	CHEWUCH C11	CHEWUCH C12	CHEWUCH C13	ANDREWS	BOULDER	LAKE L1	LAKE L2	TWENTY-MILE
64%	52%	54%	59%	38%	63%*	61%	43%*	43%

* Only partial coverage of LiDAR in reach

Canopy cover was assessed by using vegetation height as a surrogate. Vegetation height was calculated using the difference between the highest hit and bare earth points from 2015 LiDAR. Maps of vegetation height are available in Appendix F. All vegetation within a one potential tree height of the active channel 15 ft or taller was counted as a tree. A 100-ft buffer around the active channel was the measure for one potential tree height.

There are some areas along the Chewuch River where vegetation is greater than 100 feet tall, but these are limited. Along the tributaries, much of the vegetation is less than 80 feet and in some areas most of the vegetation is less than 60 feet tall. This is likely due to the extensive fires that have occurred in the watershed, but limits the recruitment potential for many areas.

No reach attained the adequate condition of > 80% canopy cover. The mainstem Chewuch reaches all had between 50-80 % canopy cover, indicating an at risk condition for the Chewuch reaches. In the tributaries, Boulder and Lake L1 also had between 50-80 % canopy cover, placing them in the at risk category. Andrews, Lake L2, and Twentymile reaches had < 50% canopy cover, indicating an unacceptable condition.

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Appendix B

Project Concepts Map – LiDAR

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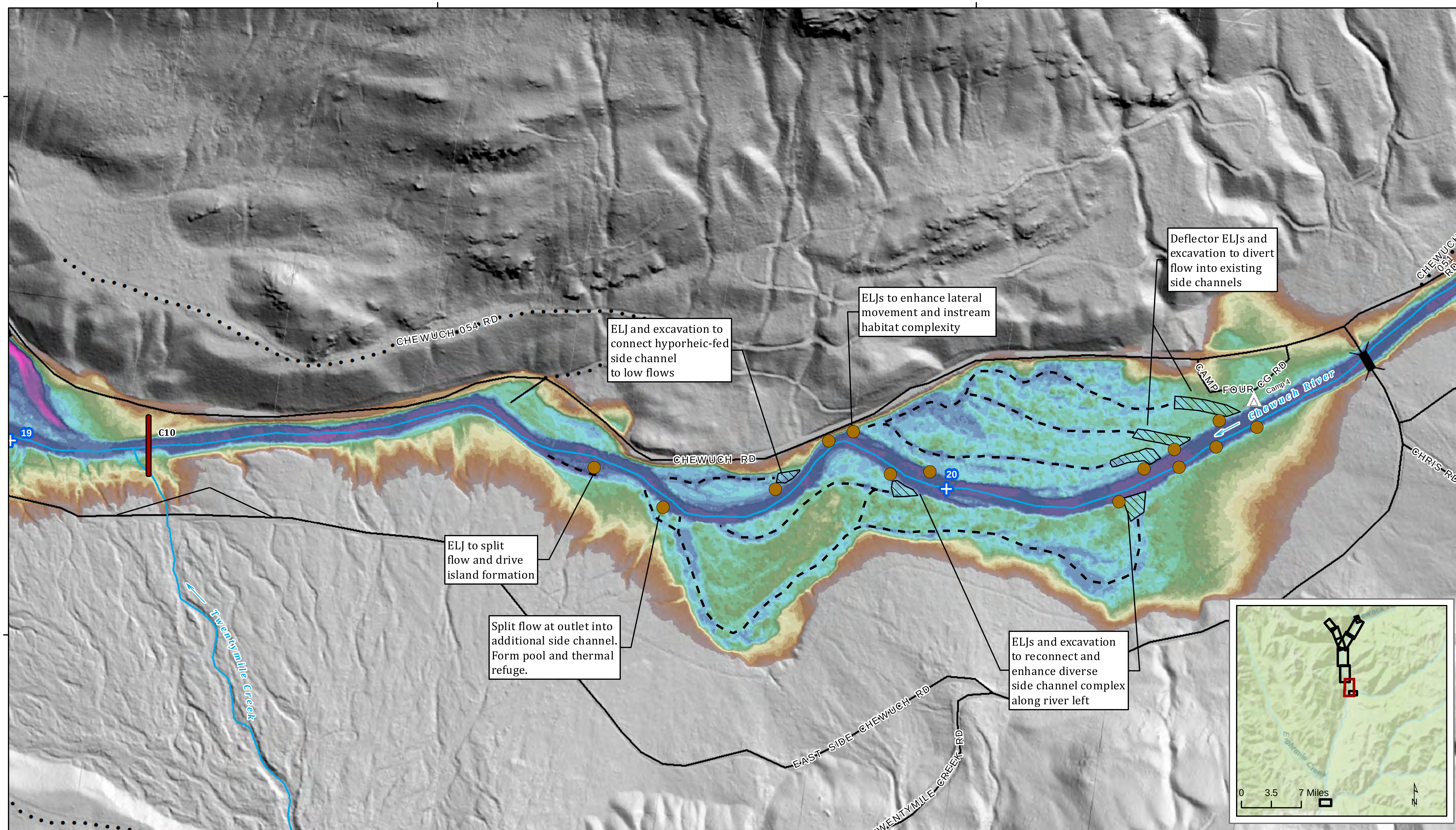

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Upper Chewuch Habitat Assessment

Restoration Concepts - Map 1, Chewuch Reach 10a

Relative elevation is derived as the difference between bare earth elevations and a reference plane representing the low flow water surface. Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).

0 250 500 Feet

Lambert conformal conic projection, NAD 1983 State Plane Coordinate System (WA North Zone)

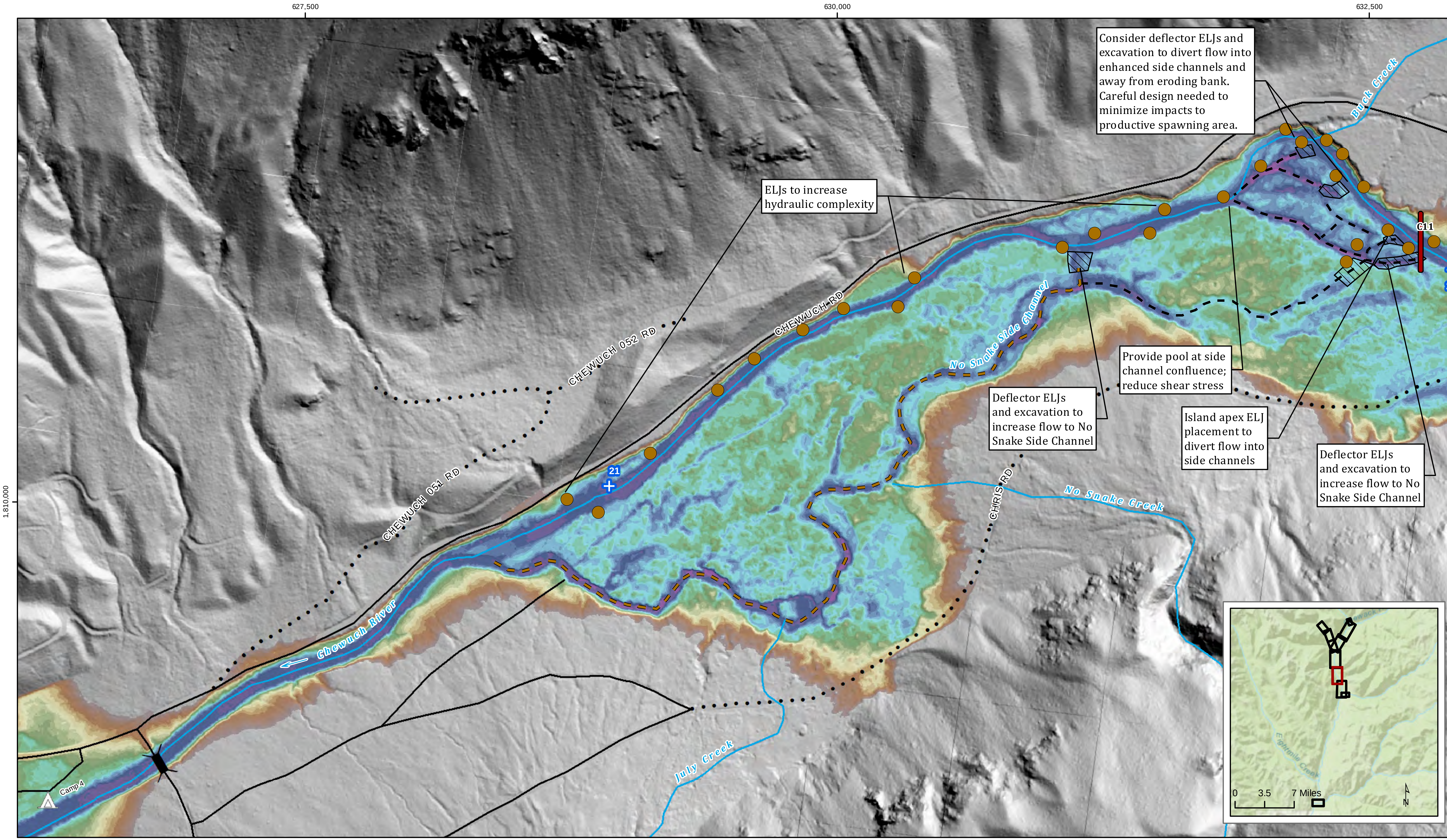
Relative Elevation (ft)

-4 -2 0 2 4 6 8 10 12 14 16 18 20

Machine Placed ELJ
Pile Array
Enhanced Side Channel
Loosely Anchored Wood Loading
Channel Excavation
Levee Removal
Reach Break
River Miles
Stream
Road
Closed Road
Unimproved Road
Bridge

Yakama Nation Fisheries

Natural Systems Design



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Upper Chewuch Habitat Assessment

Restoration Concepts - Map 2, Chewuch Reach 10b

Relative elevation is derived as the difference between bare earth elevations and a reference plane representing the low flow water surface. Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).

0 250 500 Feet

Lambert conformal conic projection, NAD 1983 State Plane Coordinate System (WA North Zone)

Relative Elevation (ft)

-4 -2 0 2 4 6 8 10 12 14 16 18 20

Machine Placed ELJ

Pile Array

Enhanced Side Channel

Loosely Anchored Wood Loading

Channel Excavation

Levee Removal

Reach Break

River Miles

Stream

Road

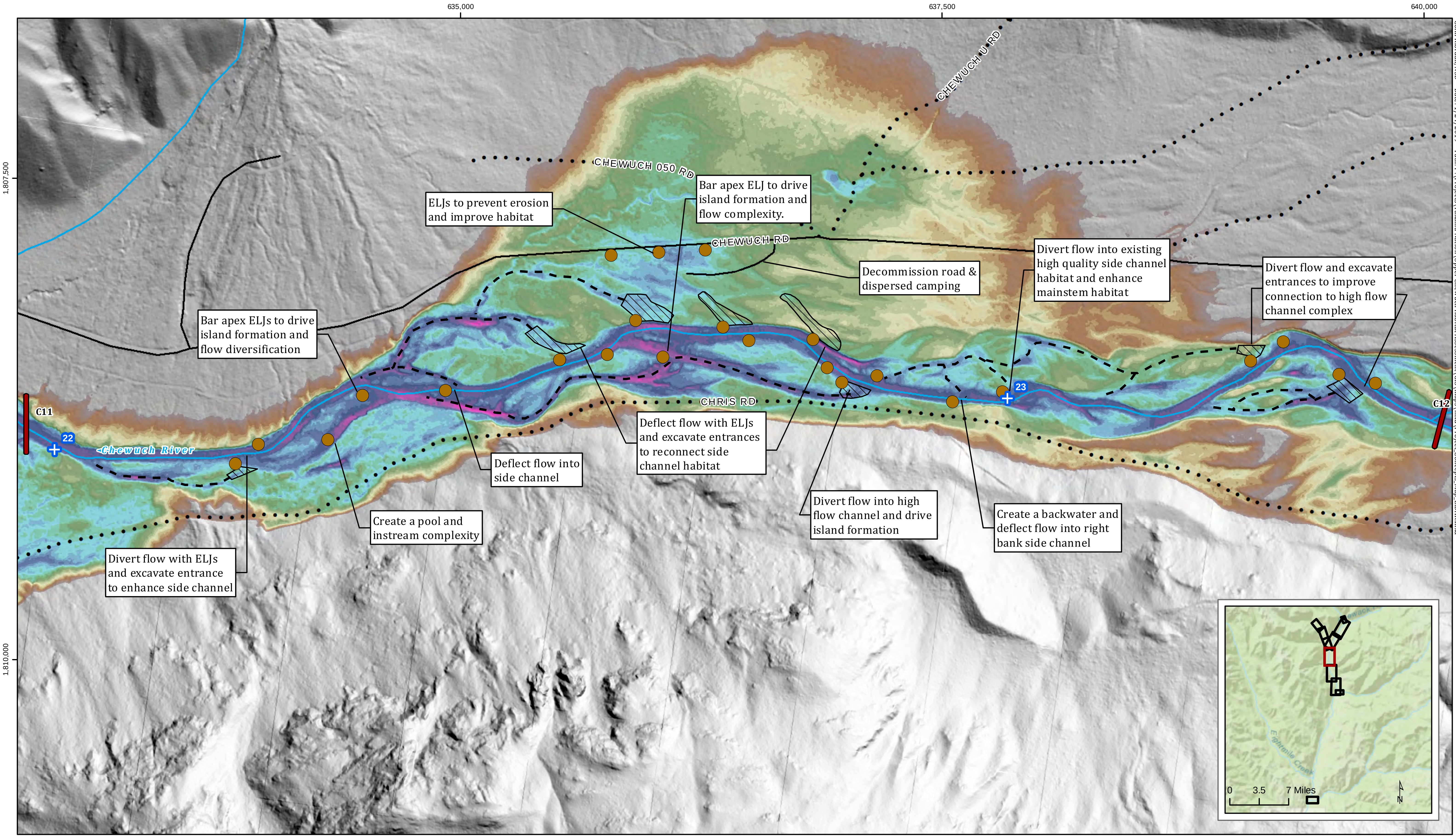
Closed Road

Unimproved Road

Bridge

Yakama Nation Fisheries

Natural Systems Design



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Upper Chewuch Habitat Assessment

Restoration Concepts - Map 3, Chewuch Reach 11

Relative elevation is derived as the difference between bare earth elevations and a reference plane representing the low flow water surface. Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).

0 250 500 Feet

Lambert conformal conic projection, NAD 1983 State Plane Coordinate System (WA North Zone)

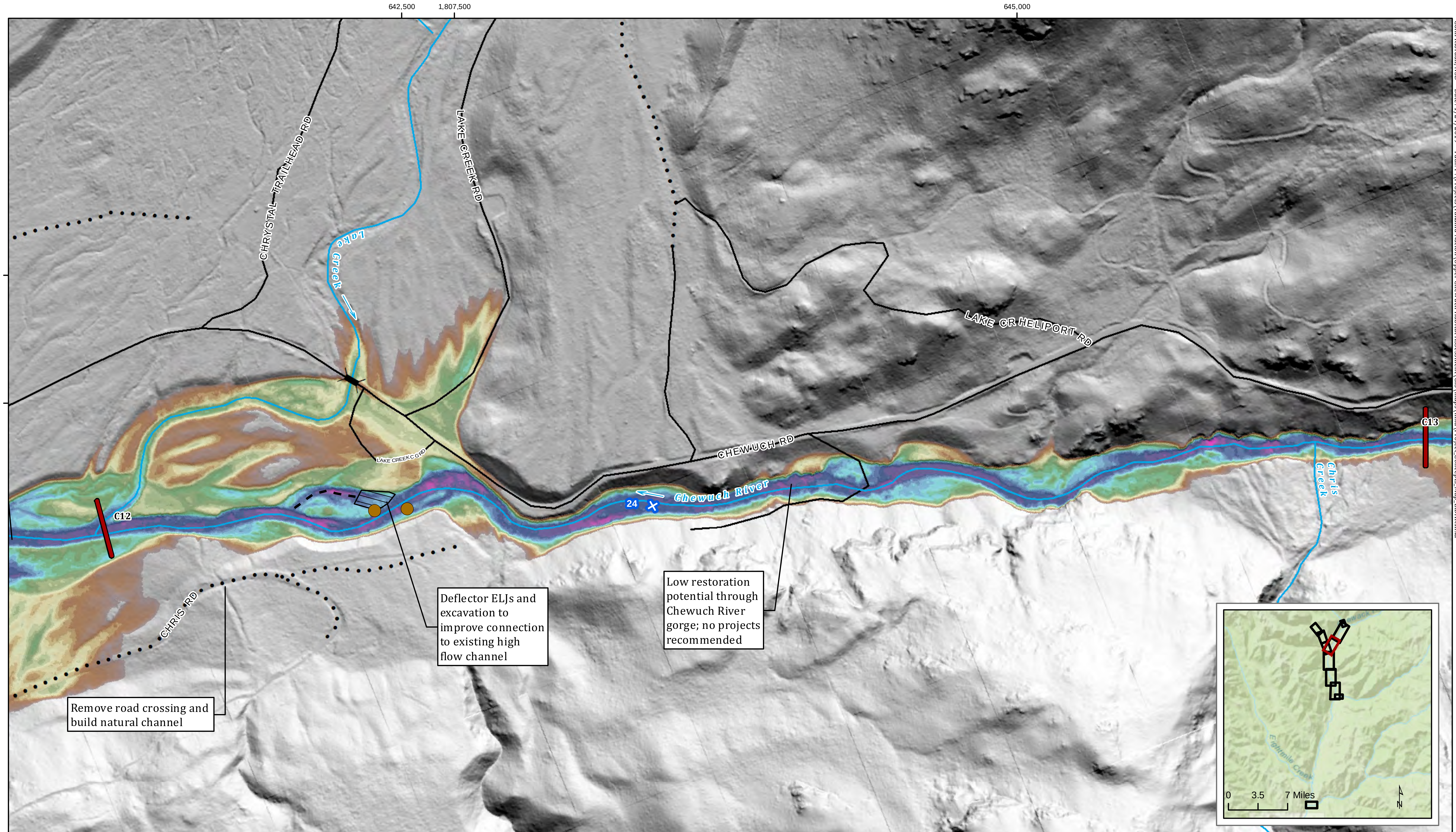
Relative Elevation (ft)

-4 -2 0 2 4 6 8 10 12 14 16 18 20

Machine Placed ELJ
Pile Array
Enhanced Side Channel
Loosely Anchored Wood Loading
Channel Excavation
Levee Removal
Reach Break
River Miles
Stream
Road
Closed Road
Unimproved Road
Bridge

Yakama Nation Fisheries

Natural Systems Design



Upper Chewuch Habitat Assessment

Restoration Concepts - Map 4, Chewuch Reach 12

Relative elevation is derived as the difference between bare earth elevations and a reference plane representing the low flow water surface. Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).

0 250 500 Feet

Lambert conformal conic projection, NAD 1983 State Plane Coordinate System (WA North Zone)

Relative Elevation (ft)

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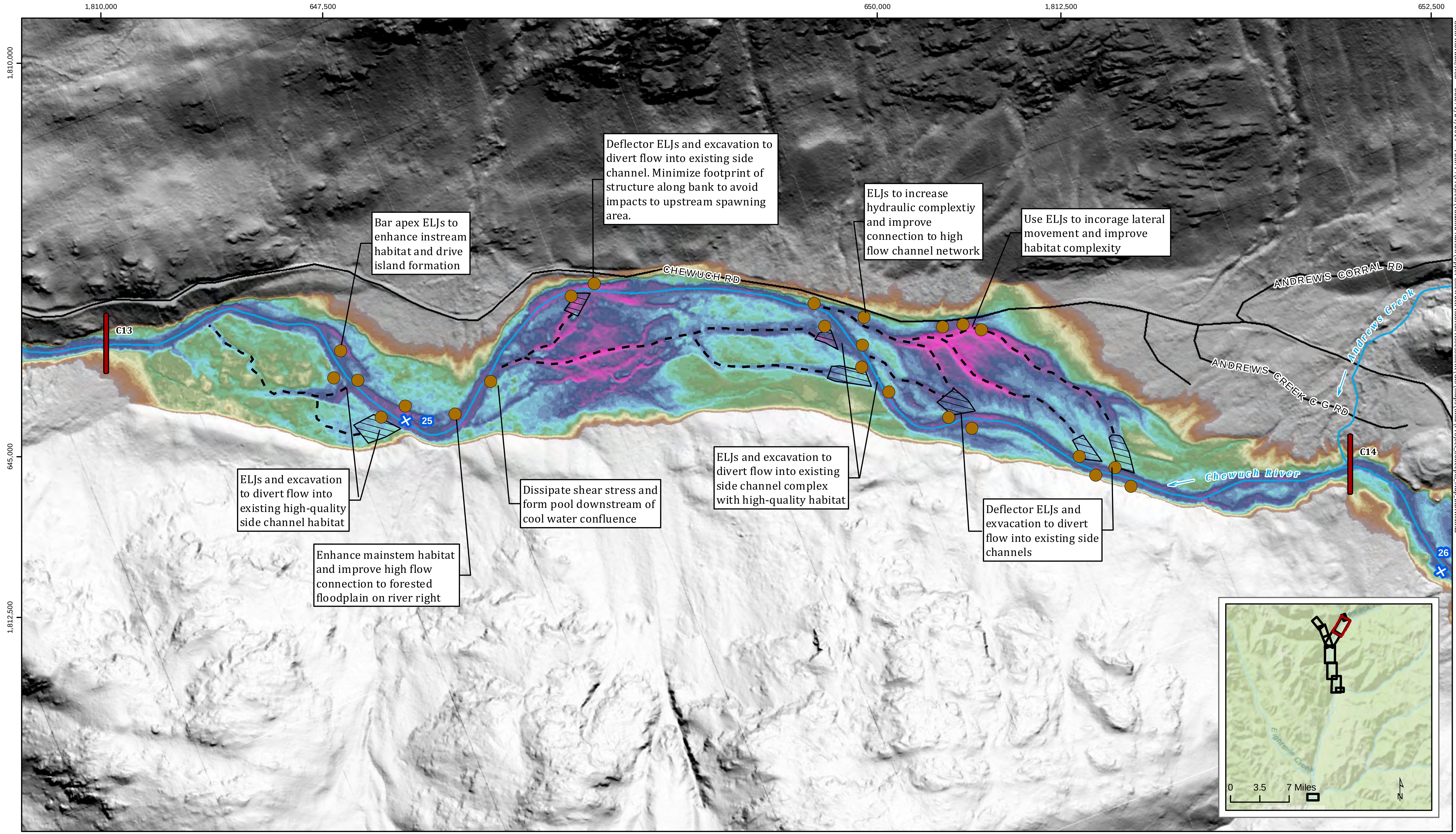
- Machine Placed ELJ
- Pile Array
- Enhanced Side Channel
- Loosely Anchored Wood Loading
- Channel Excavation
- Levee Removal
- Reach Break
- River Miles
- Stream
- Road
- Closed Road
- Unimproved Road
- Bridge

Yakama Nation Fisheries

Natural Systems Design



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Upper Chewuch Habitat Assessment

Restoration Concepts - Map 5, Chewuch Reach 13

Relative elevation is derived as the difference between bare earth elevations and a reference plane representing the low flow water surface. Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).

0 250 500 Feet

Lambert conformal conic projection, NAD 1983 State Plane Coordinate System (WA North Zone)

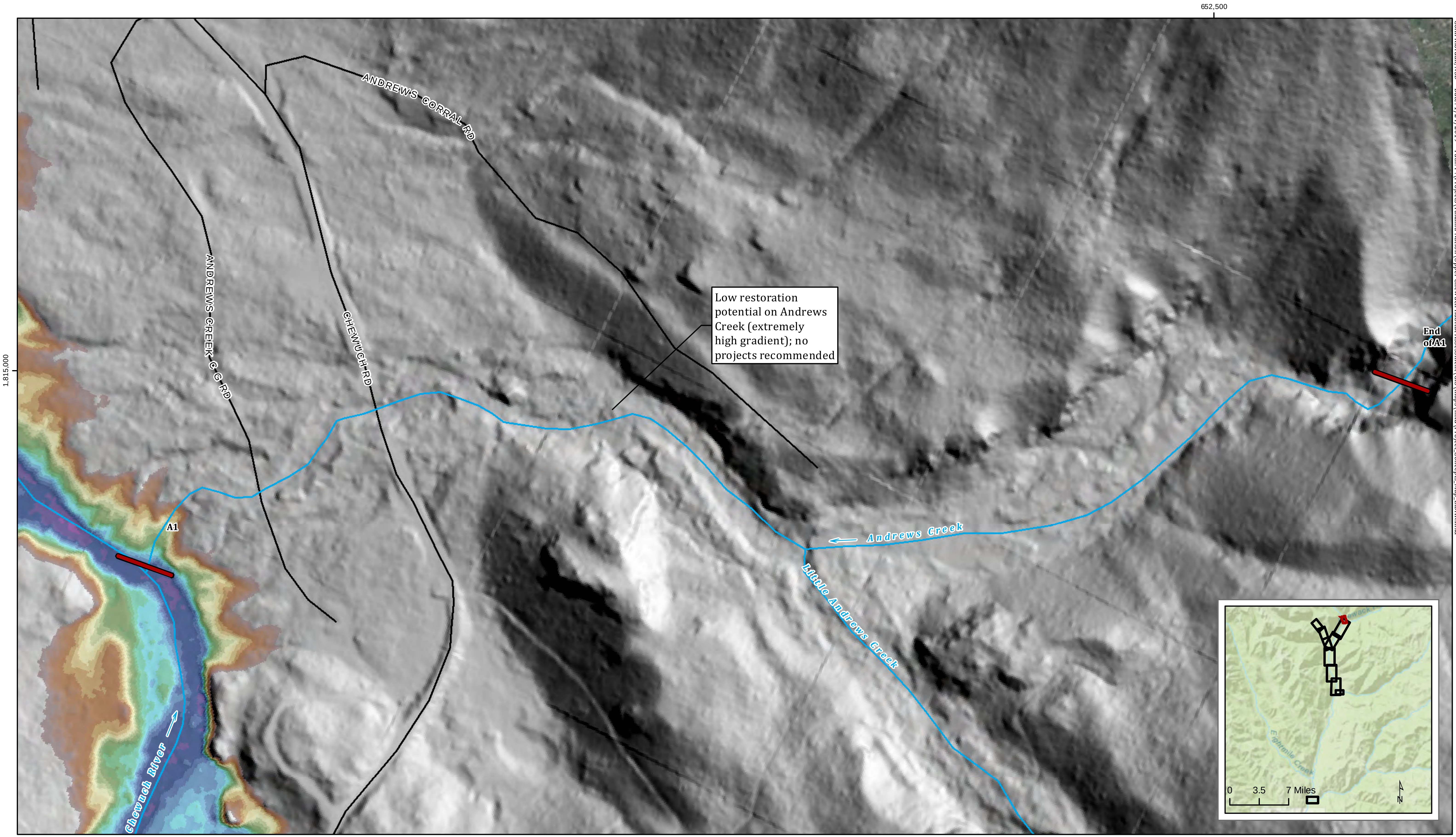
Relative Elevation (ft)

-4 -2 0 2 4 6 8 10 12 14 16 18 20

Machine Placed ELJ
Pile Array
Enhanced Side Channel
Loosely Anchored Wood Loading
Channel Excavation
Levee Removal
Reach Break
River Miles
Stream
Road
Closed Road
Unimproved Road
Bridge

Yakama Nation Fisheries

Natural Systems Design



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Upper Chewuch Habitat Assessment

Restoration Concepts - Map 6, Andrews Creek

Relative elevation is derived as the difference between bare earth elevations and a reference plane representing the low flow water surface. Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).

0 250 500 Feet

Lambert conformal conic projection, NAD 1983 State Plane Coordinate System (WA North Zone)

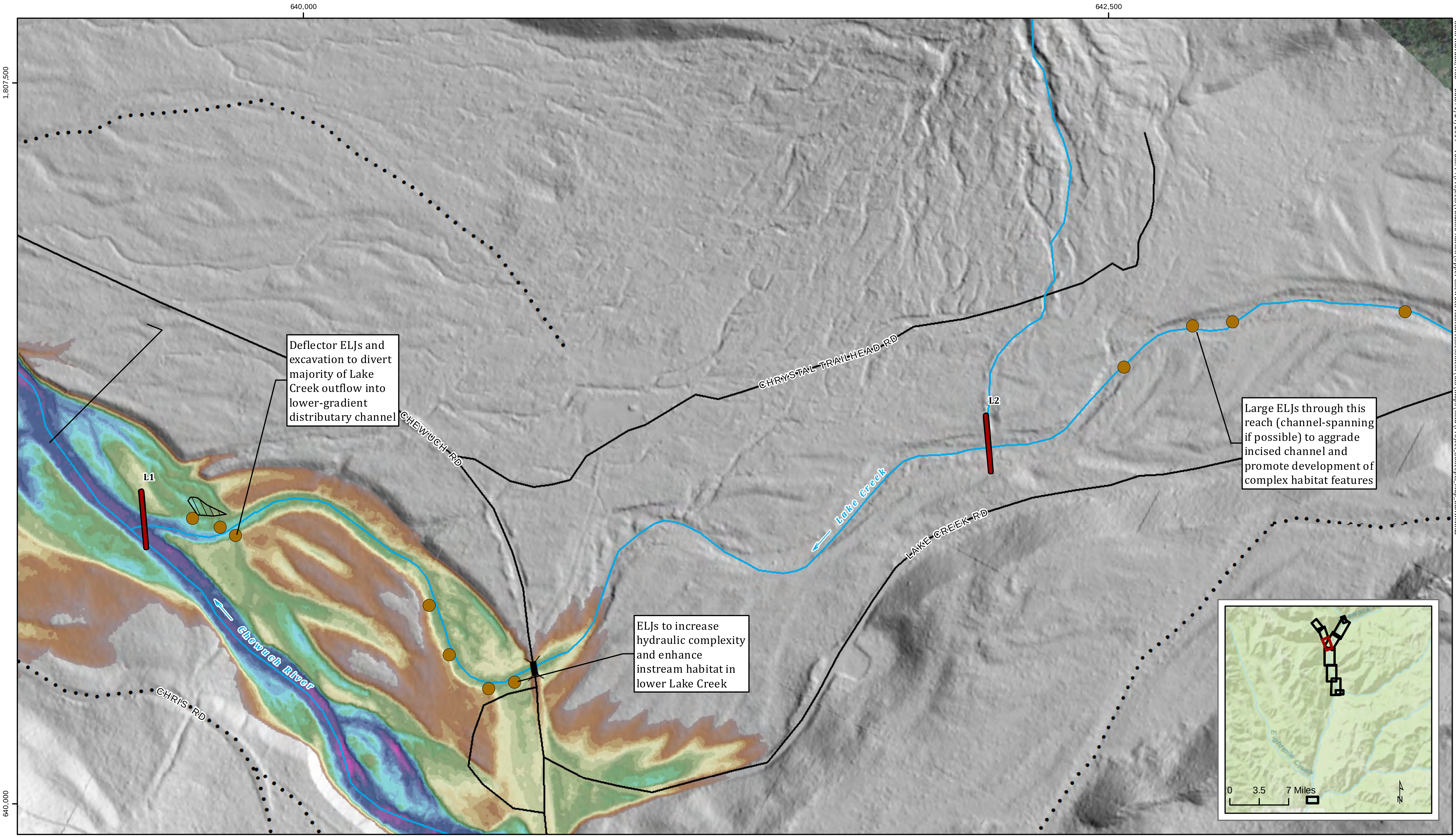
Relative Elevation (ft)

-4 -2 0 2 4 6 8 10 12 14 16 18 20

Machine Placed ELJ
Pile Array
Enhanced Side Channel
Loosely Anchored Wood Loading
Channel Excavation
Levee Removal
Reach Break
River Miles
Stream
Road
Closed Road
Unimproved Road
Bridge

Yakama Nation Fisheries

Natural Systems Design



Upper Chewuch Habitat Assessment

Restoration Concepts - Map 7, Lake Creek Reach 1 & 2a

Relative elevation is derived as the difference between bare earth elevations and a reference plane representing the low flow water surface. Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).

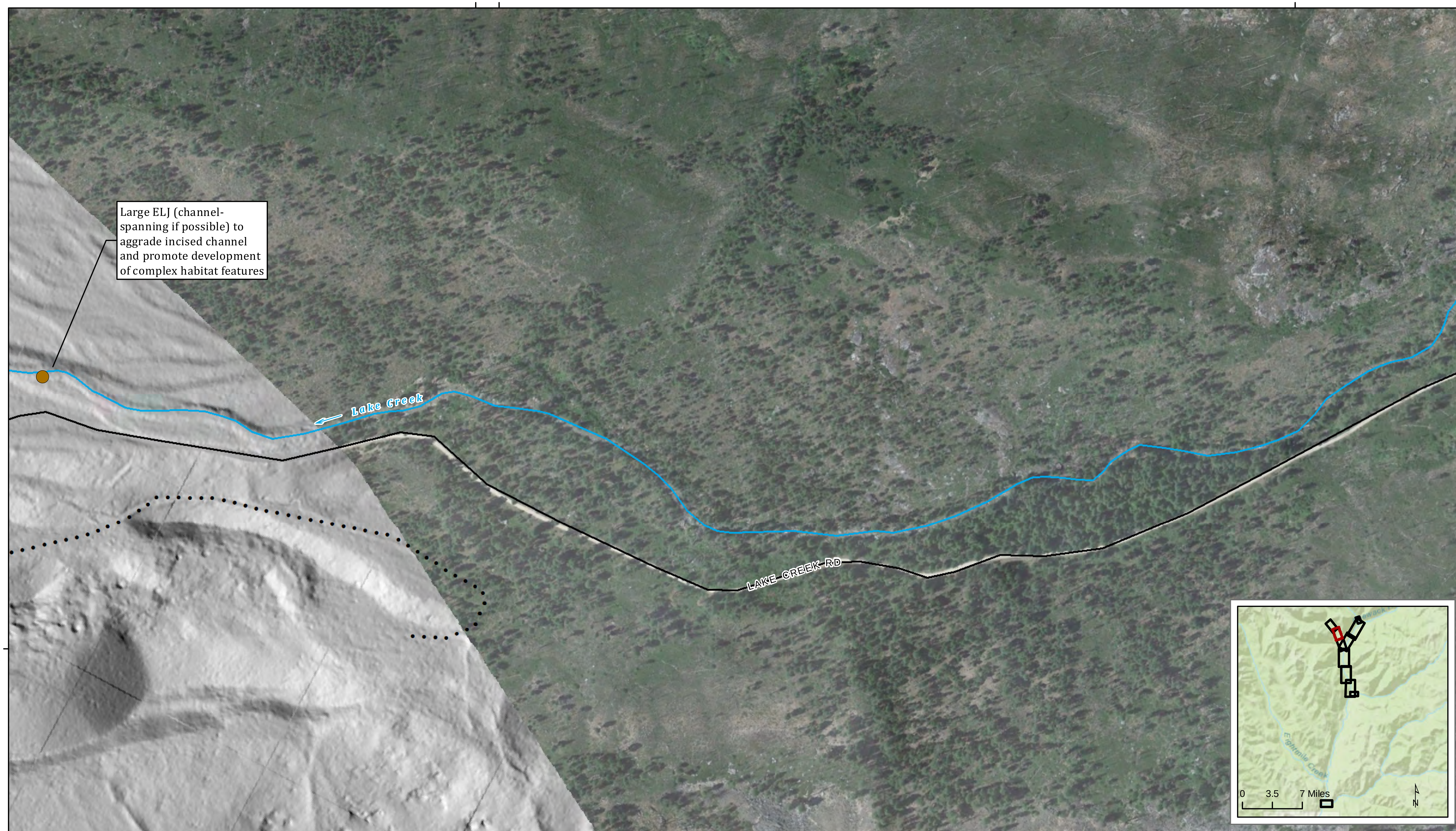
0 250 500 Feet

Lambert conformal conic projection, NAD 1983 State Plane Coordinate System (WA North Zone)

Relative Elevation (ft)

-4 -2 0 2 4 6 8 10 12 14 16 18 20

Machine Placed ELJ
Pile Array
Enhanced Side Channel
Loosely Anchored Wood Loading
Channel Excavation
Levee Removal
Reach Break
River Miles
Stream
Road
Closed Road
Unimproved Road
Bridge



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Upper Chewuch Habitat Assessment

Restoration Concepts - Map 8, Lake Creek Reach 2b

Relative elevation is derived as the difference between bare earth elevations and a reference plane representing the low flow water surface. Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).

0 250 500 Feet

Lambert conformal conic projection, NAD 1983 State Plane Coordinate System (WA North Zone)

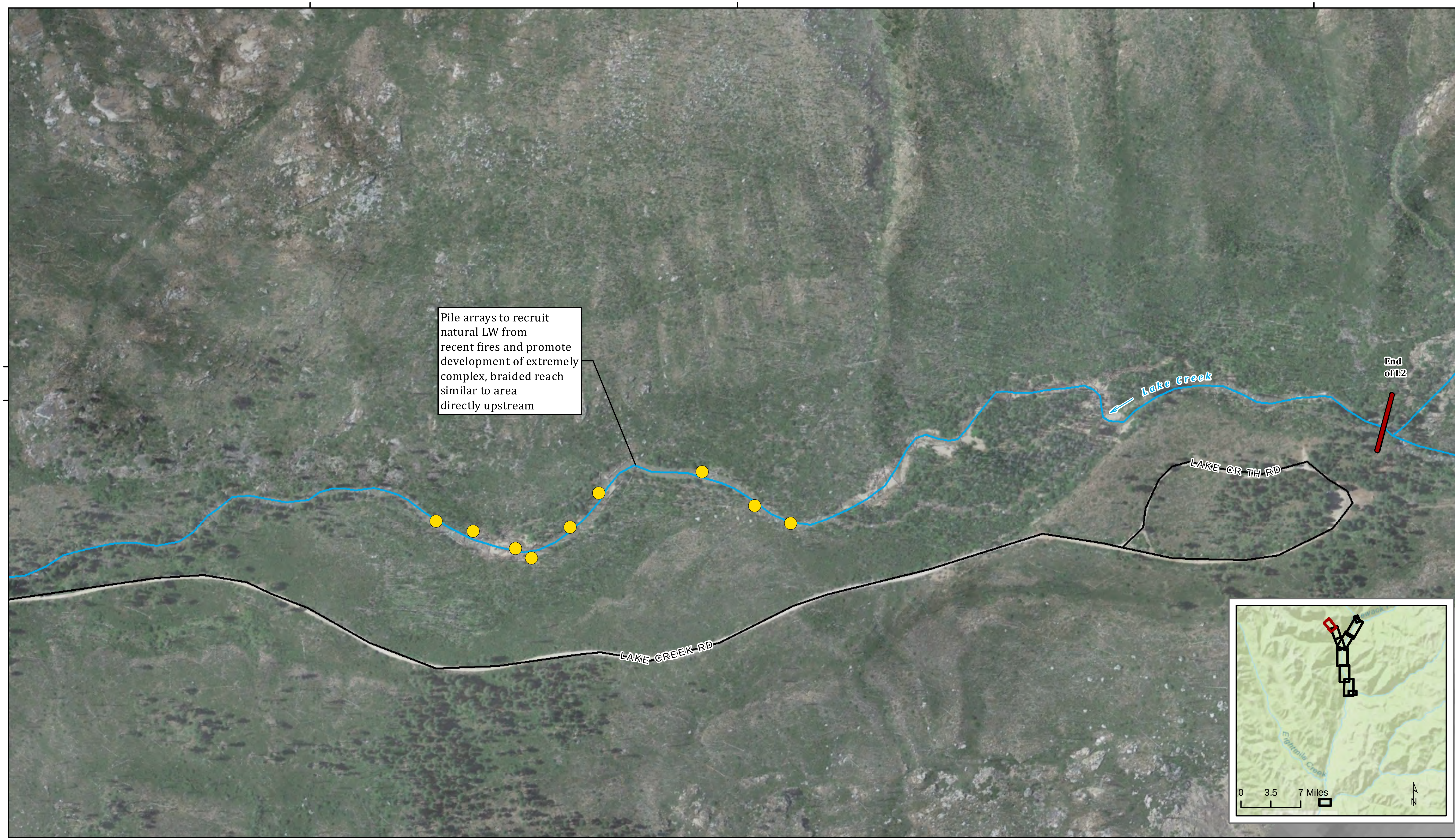
Relative Elevation (ft)

-4 -2 0 2 4 6 8 10 12 14 16 18 20

Machine Placed ELJ
Pile Array
Enhanced Side Channel
Loosely Anchored Wood Loading
Channel Excavation
Levee Removal
Reach Break
River Miles
Stream
Road
Closed Road
Unimproved Road
Bridge

Yakama Nation Fisheries

Natural Systems Design



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Upper Chewuch Habitat Assessment

Restoration Concepts - Map 9, Lake Creek Reach 2c

Relative elevation is derived as the difference between bare earth elevations and a reference plane representing the low flow water surface. Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).

0 250 500 Feet

Lambert conformal conic projection, NAD 1983 State Plane Coordinate System (WA North Zone)

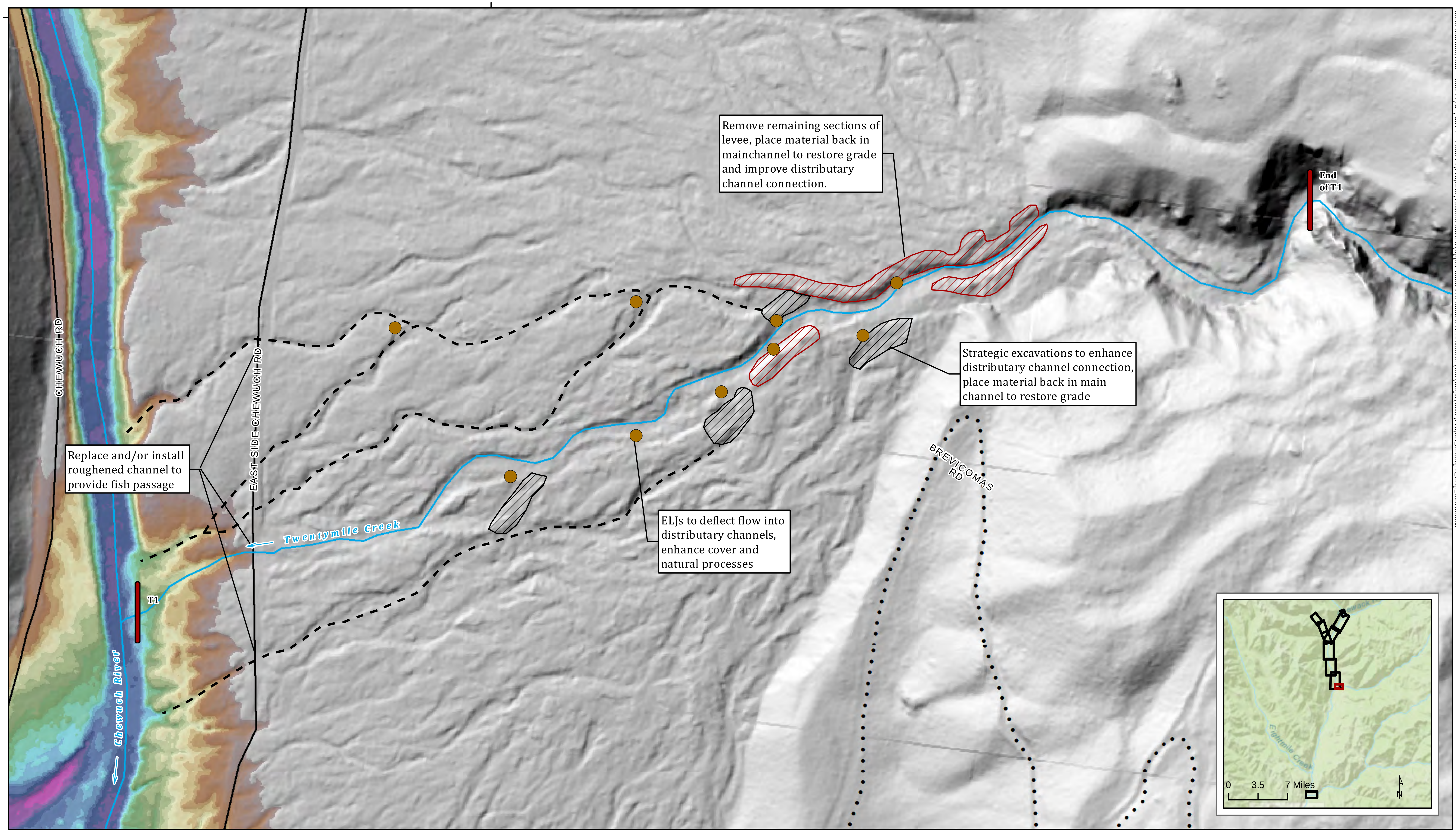
Relative Elevation (ft)

-4 -2 0 2 4 6 8 10 12 14 16 18 20

Machine Placed ELJ
Pile Array
Enhanced Side Channel
Loosely Anchored Wood Loading
Channel Excavation
Levee Removal
Reach Break
River Miles
Stream
Road
Closed Road
Unimproved Road
Bridge

Yakama Nation Fisheries

Natural Systems Design



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Upper Chewuch Habitat Assessment

Restoration Concepts - Map 10, Twentymile Creek

Relative elevation is derived as the difference between bare earth elevations and a reference plane representing the low flow water surface. Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).

0 250 500 Feet

Lambert conformal conic projection, NAD 1983 State Plane Coordinate System (WA North Zone)

Relative Elevation (ft)

-4 -2 0 2 4 6 8 10 12 14 16 18 20

Machine Placed ELJ

Pile Array

Enhanced Side Channel

Loosely Anchored Wood Loading

Channel Excavation

Levee Removal

Reach Break

River Miles

Stream

Road

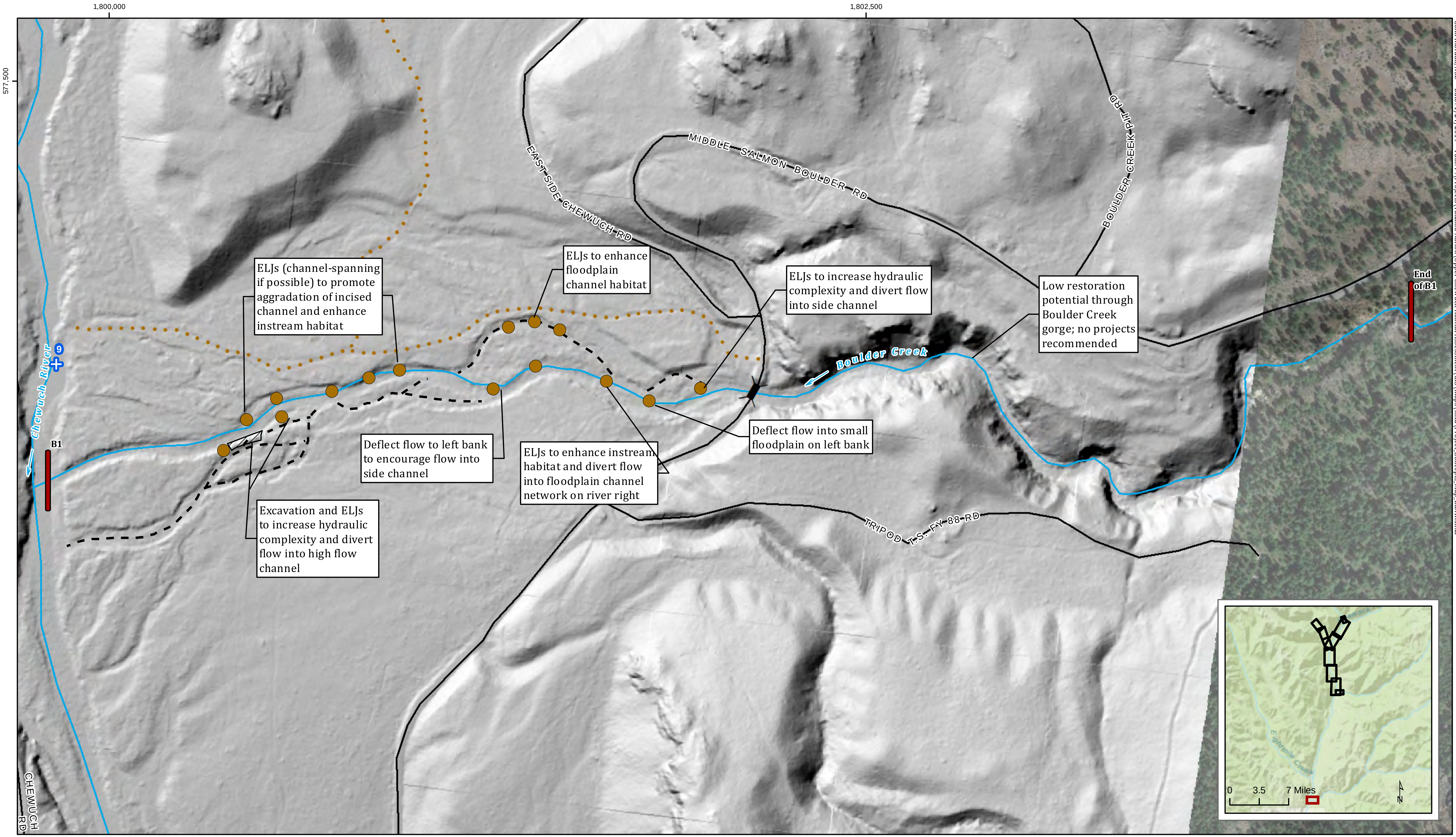
Closed Road

Unimproved Road

Bridge

Yakama Nation Fisheries

Natural Systems Design



Upper Chewuch Habitat Assessment

Restoration Concepts - Map 11, Boulder Creek

Relative elevation is derived as the difference between bare earth elevations and a reference plane representing the low flow water surface. Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).

Appendix B

Project Concepts Map – Aerial

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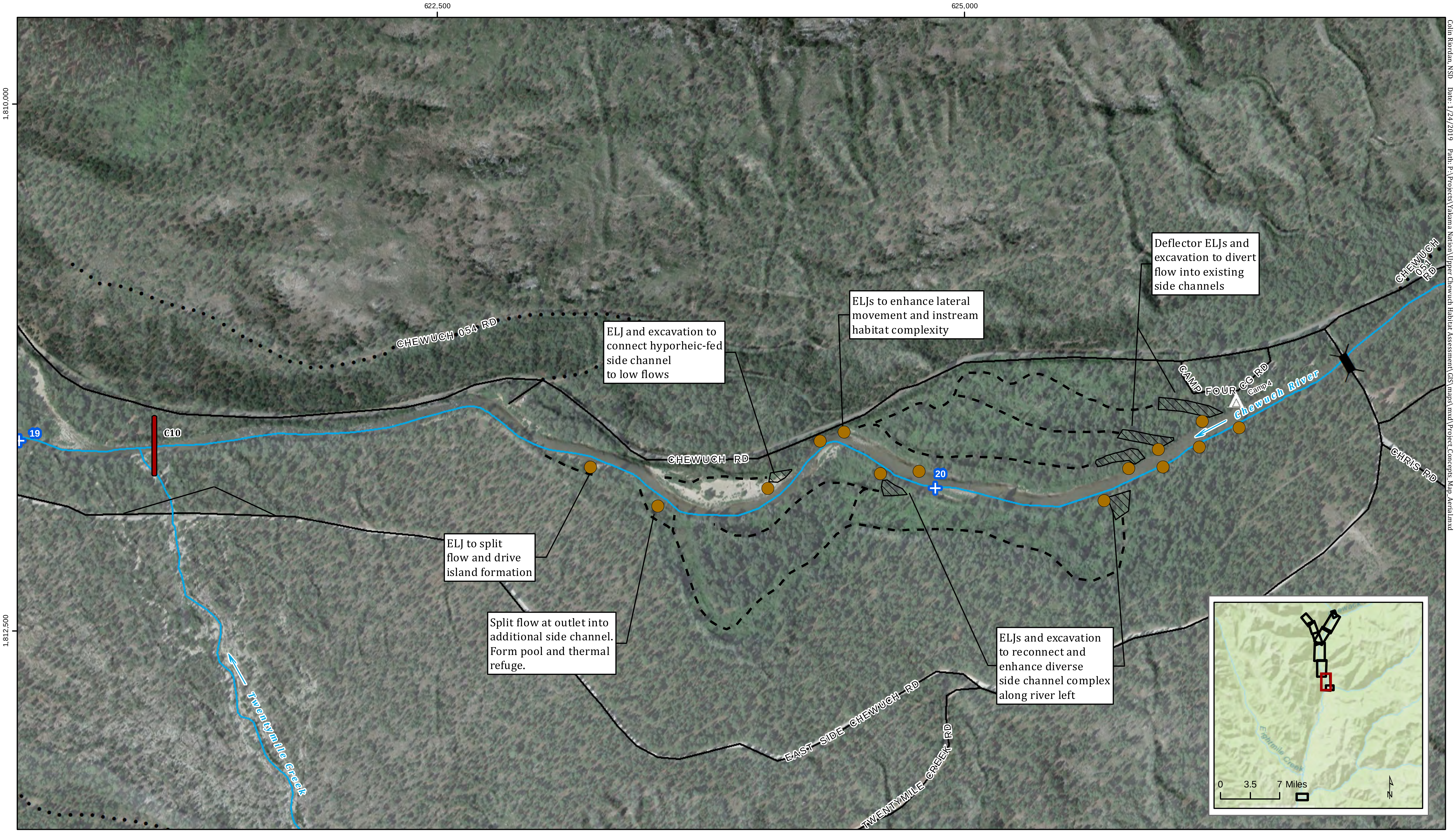


Upper Chewuch Habitat Assessment

Restoration Concepts - Map 1, Chewuch Reach 10a

Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).

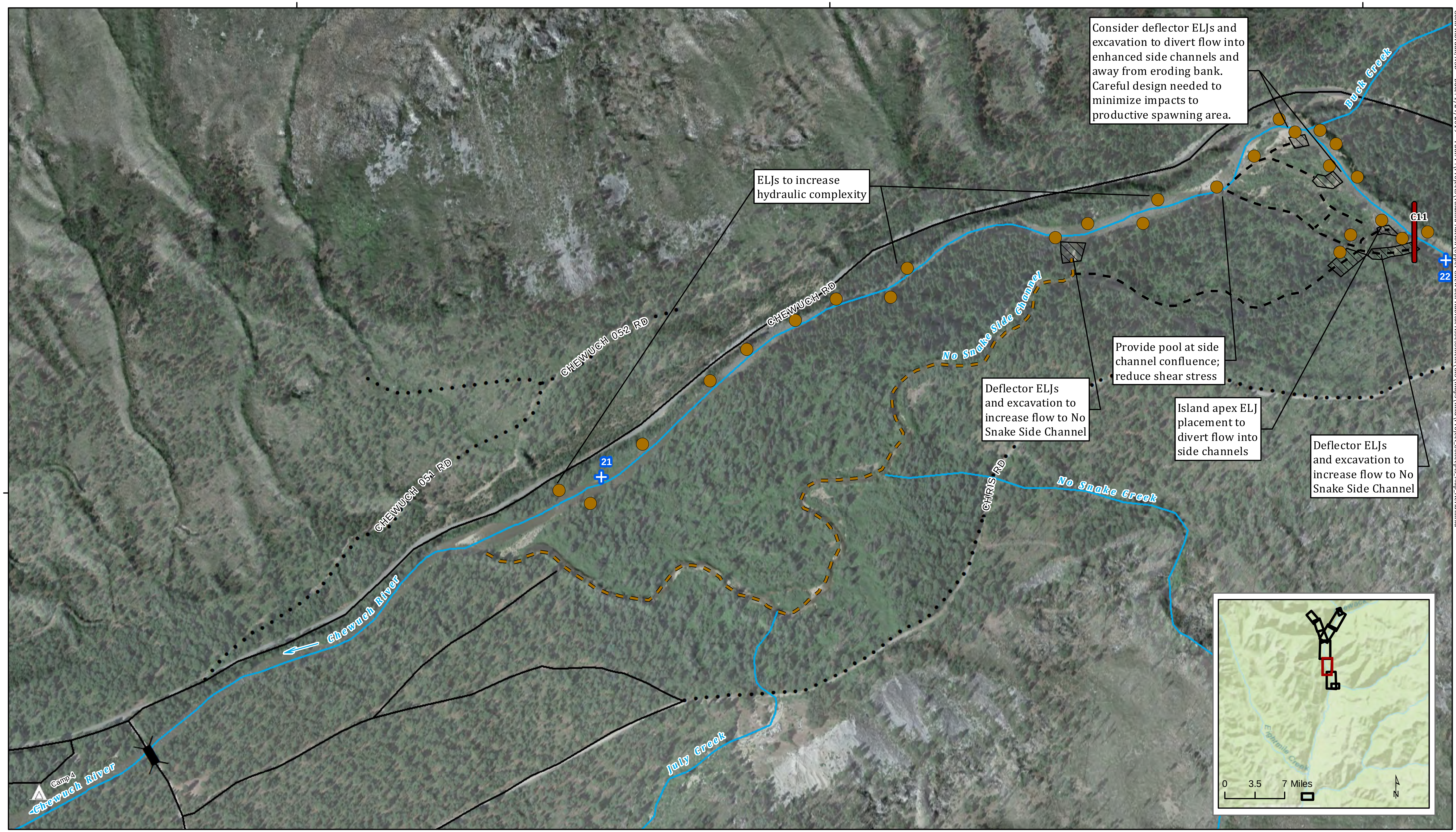
0 250 500 Feet

Lambert conformal conic projection, NAD 1983 State Plane Coordinate System (WA North Zone)

- Machine Placed ELJ
- Pile Array
- Enhanced Side Channel
- Loosely Anchored Wood Loading
- Channel Excavation
- Levee Removal
- Reach Break
- River Miles
- Stream
- Road
- Closed Road
- Unimproved Road
- Bridge

Yakama Nation Fisheries

Natural Systems Design



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Upper Chewuch Habitat Assessment

Restoration Concepts - Map 2, Chewuch Reach 10b

Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).

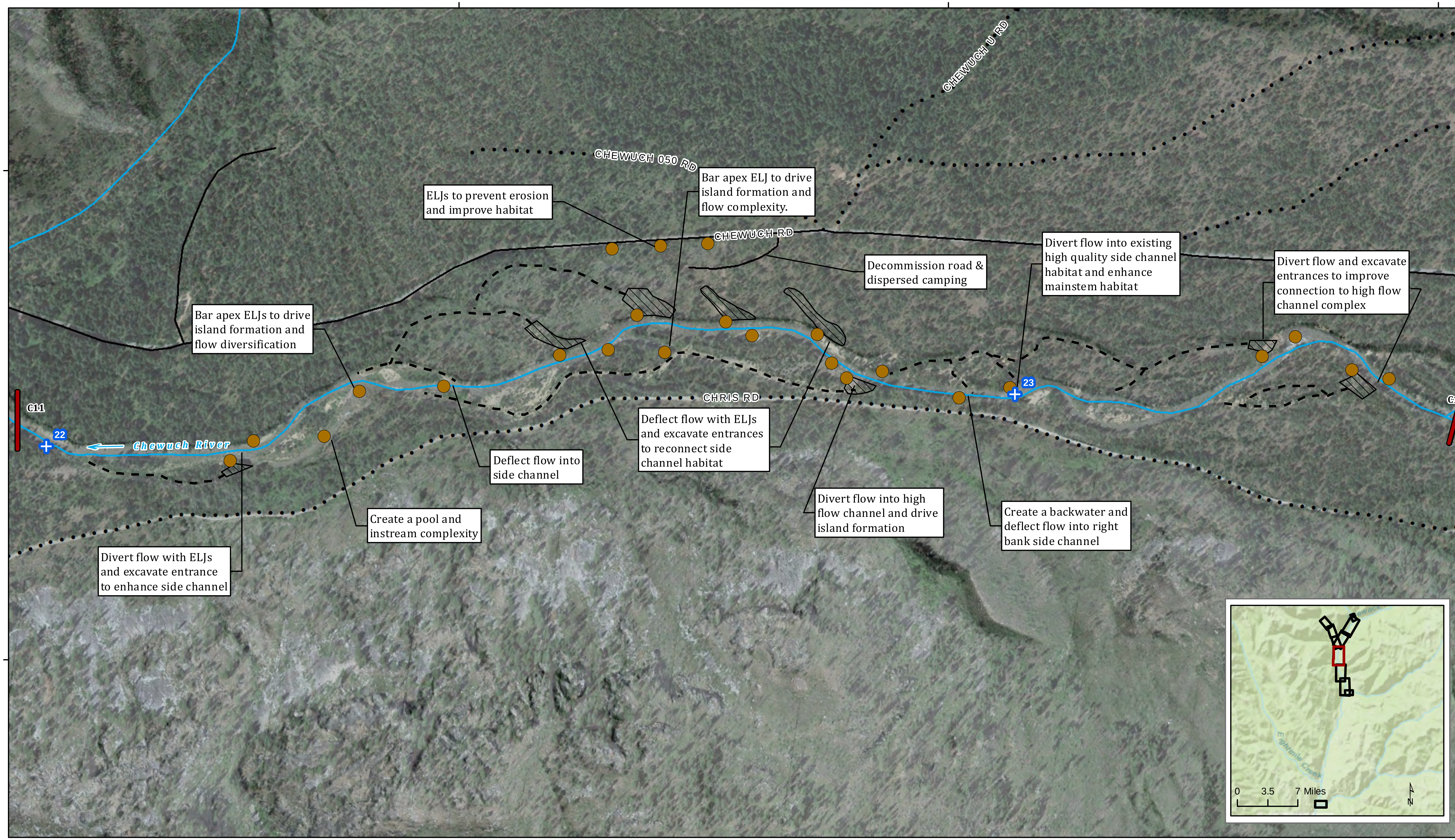
0 250 500 Feet

Lambert conformal conic projection, NAD 1983 State Plane Coordinate System (WA North Zone)

- Machine Placed ELJ
- Pile Array
- Enhanced Side Channel
- Loosely Anchored Wood Loading
- Channel Excavation
- Levee Removal
- Reach Break
- River Miles
- Stream
- Road
- Closed Road
- Unimproved Road
- Bridge

Yakama Nation Fisheries

Natural Systems Design



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Upper Chewuch Habitat Assessment

Restoration Concepts - Map 3, Chewuch Reach 11

Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).

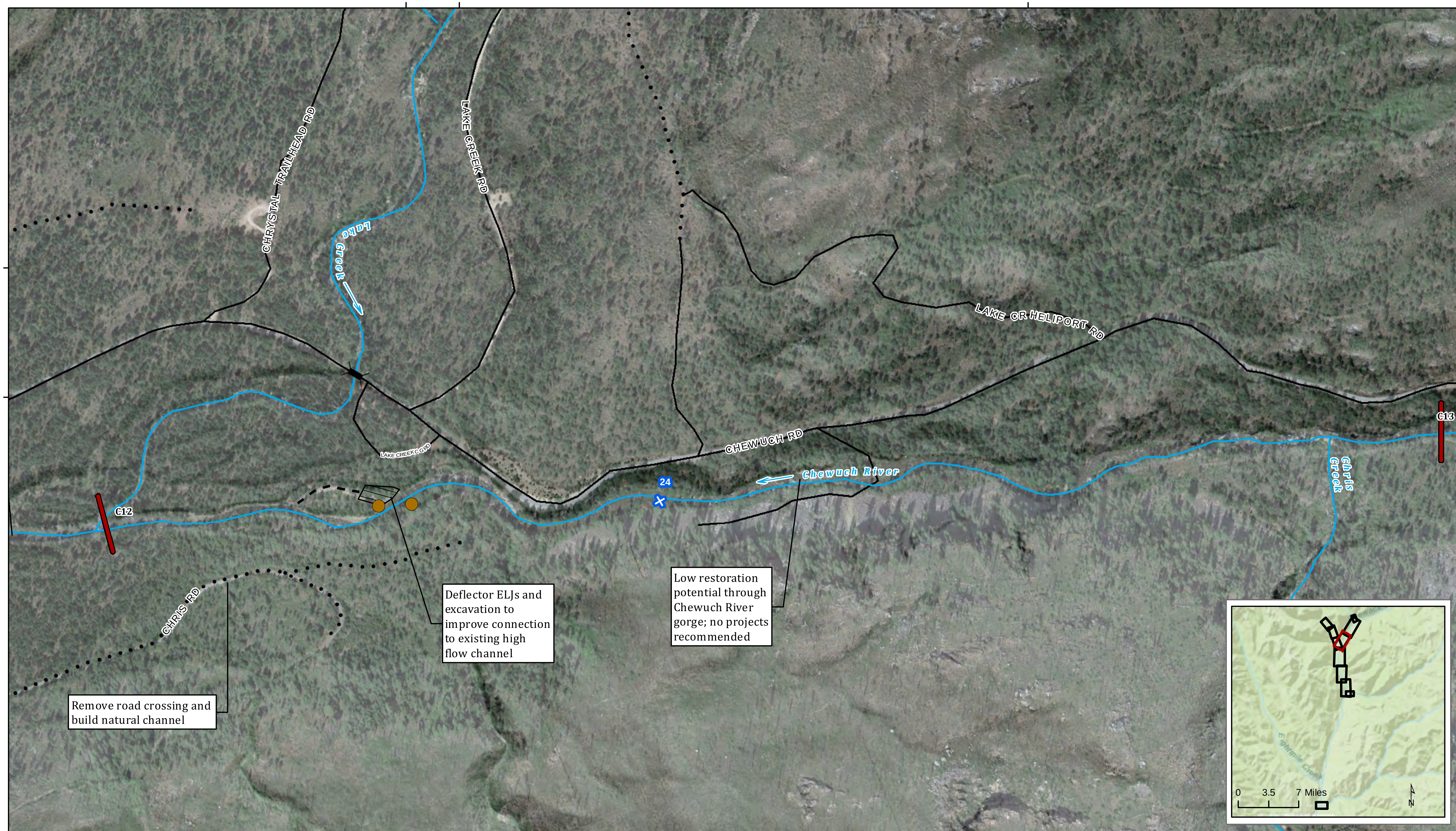
0 250 500 Feet

Lambert conformal conic projection, NAD 1983 State Plane Coordinate System (WA North Zone)

Machine Placed ELJ
Pile Array
Enhanced Side Channel
Loosely Anchored Wood Loading
Channel Excavation
Levee Removal
Reach Break
River Miles
Stream
Road
Closed Road
Unimproved Road
Bridge

Yakama Nation Fisheries

Natural Systems Design



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Upper Chewuch Habitat Assessment

Restoration Concepts - Map 4, Chewuch Reach 12

Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).

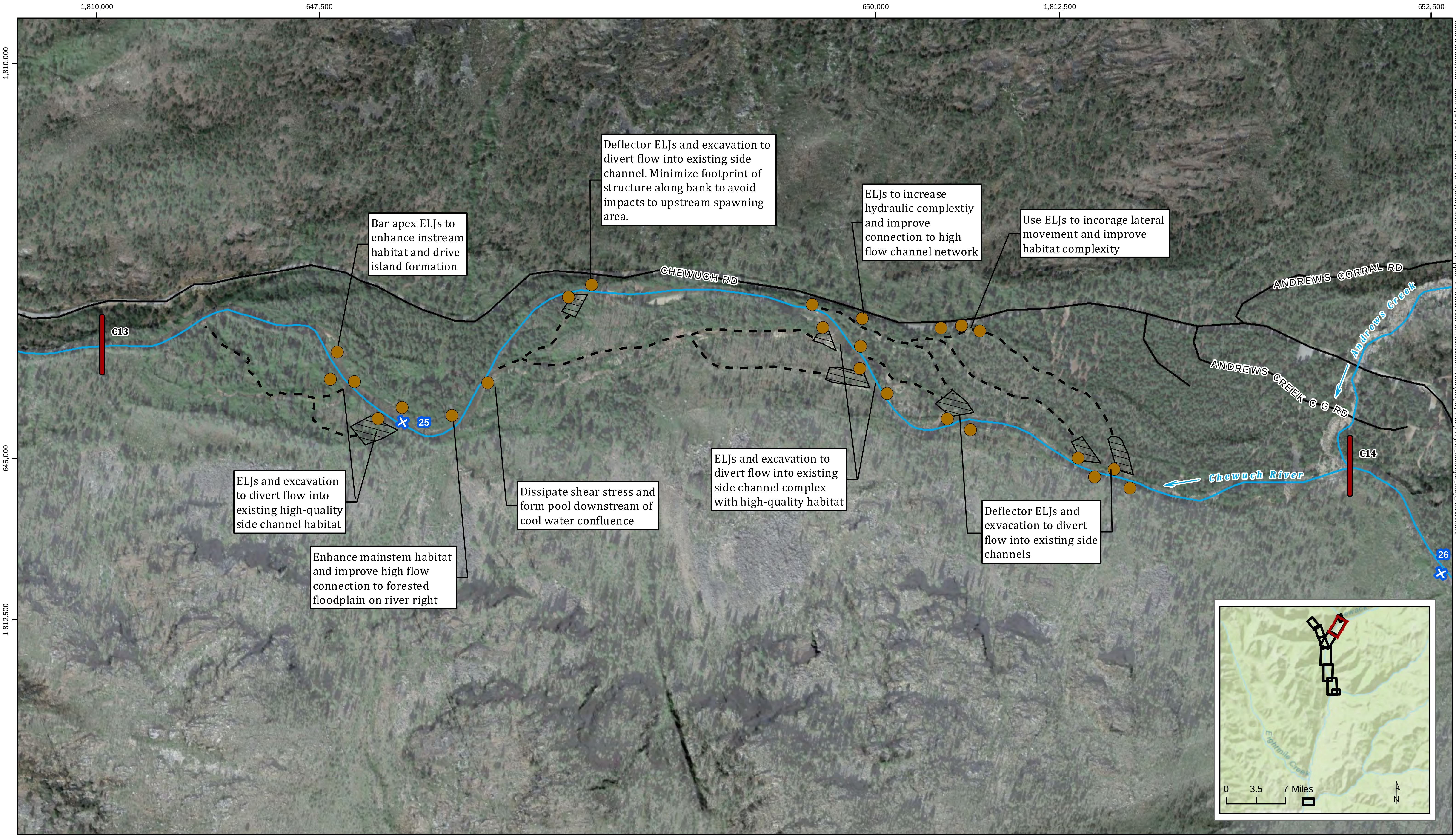
0 250 500 Feet

Lambert conformal conic projection, NAD 1983 State Plane Coordinate System (WA North Zone)

Machine Placed ELJ
Pile Array
Enhanced Side Channel
Loosely Anchored Wood Loading
Channel Excavation
Levee Removal
Reach Break
River Miles
Stream
Road
Closed Road
Unimproved Road
Bridge

Yakama Nation Fisheries

Natural Systems Design



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Upper Chewuch Habitat Assessment

Restoration Concepts - Map 5, Chewuch Reach 13

Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).

0 250 500 Feet

Lambert conformal conic projection, NAD 1983 State Plane Coordinate System (WA North Zone)

Machine Placed ELJ
Pile Array
Enhanced Side Channel
Loosely Anchored Wood Loading
Channel Excavation
Levee Removal
Reach Break
River Miles
Stream
Road
Closed Road
Unimproved Road
Bridge

Yakama Nation Fisheries

Natural Systems Design

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Upper Chewuch Habitat Assessment

Restoration Concepts - Map 6, Andrews Creek

Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).

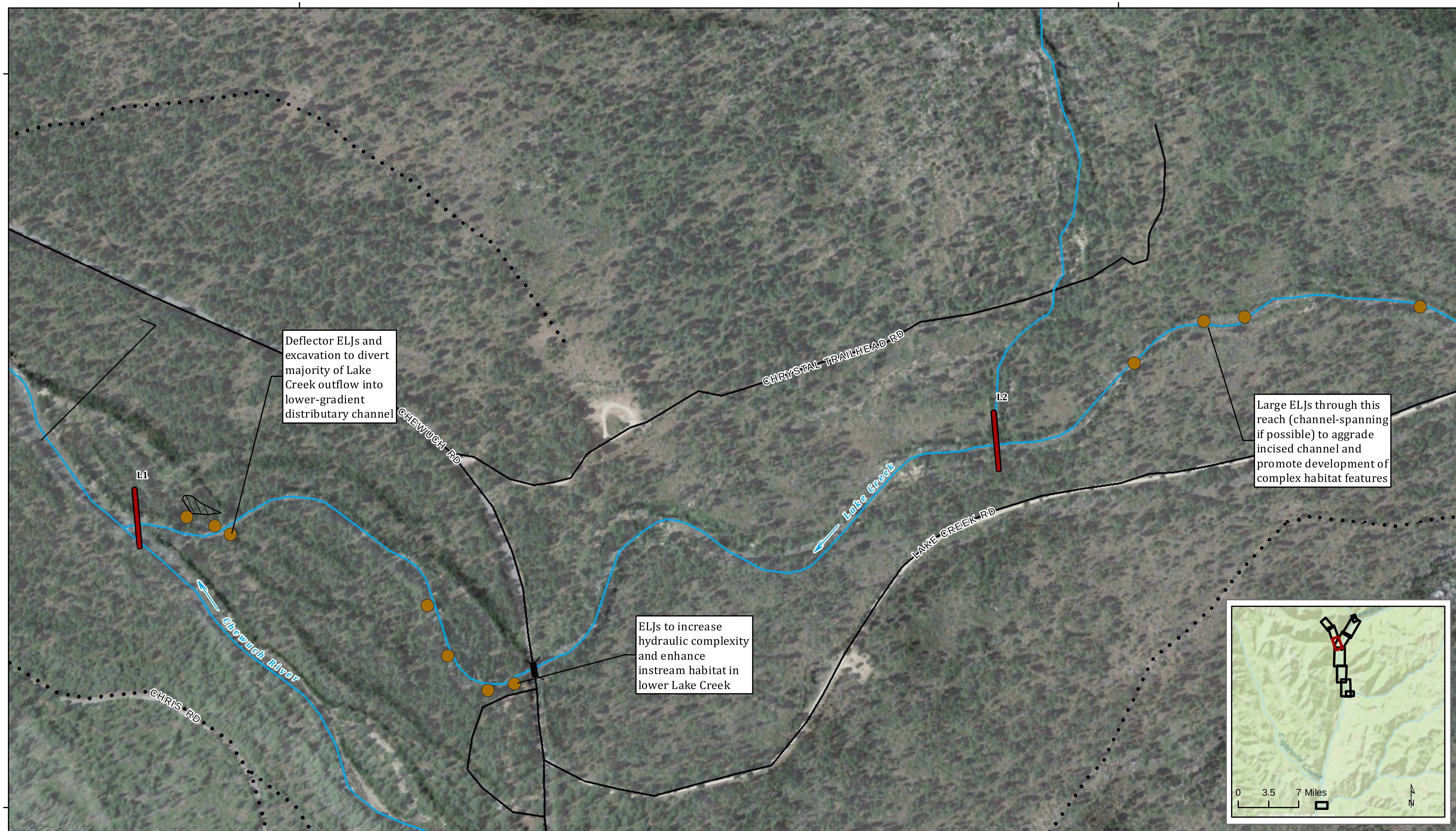
0 250 500 Feet

Lambert conformal conic projection, NAD 1983 State Plane Coordinate System (WA North Zone)

Machine Placed ELJ
Pile Array
Enhanced Side Channel
Loosely Anchored Wood Loading
Channel Excavation
Levee Removal
Reach Break
River Miles
Stream
Road
Closed Road
Unimproved Road
Bridge

Yakama Nation Fisheries

Natural Systems Design



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Upper Chewuch Habitat Assessment

Restoration Concepts - Map 7, Lake Creek Reach 1 & 2a

Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).

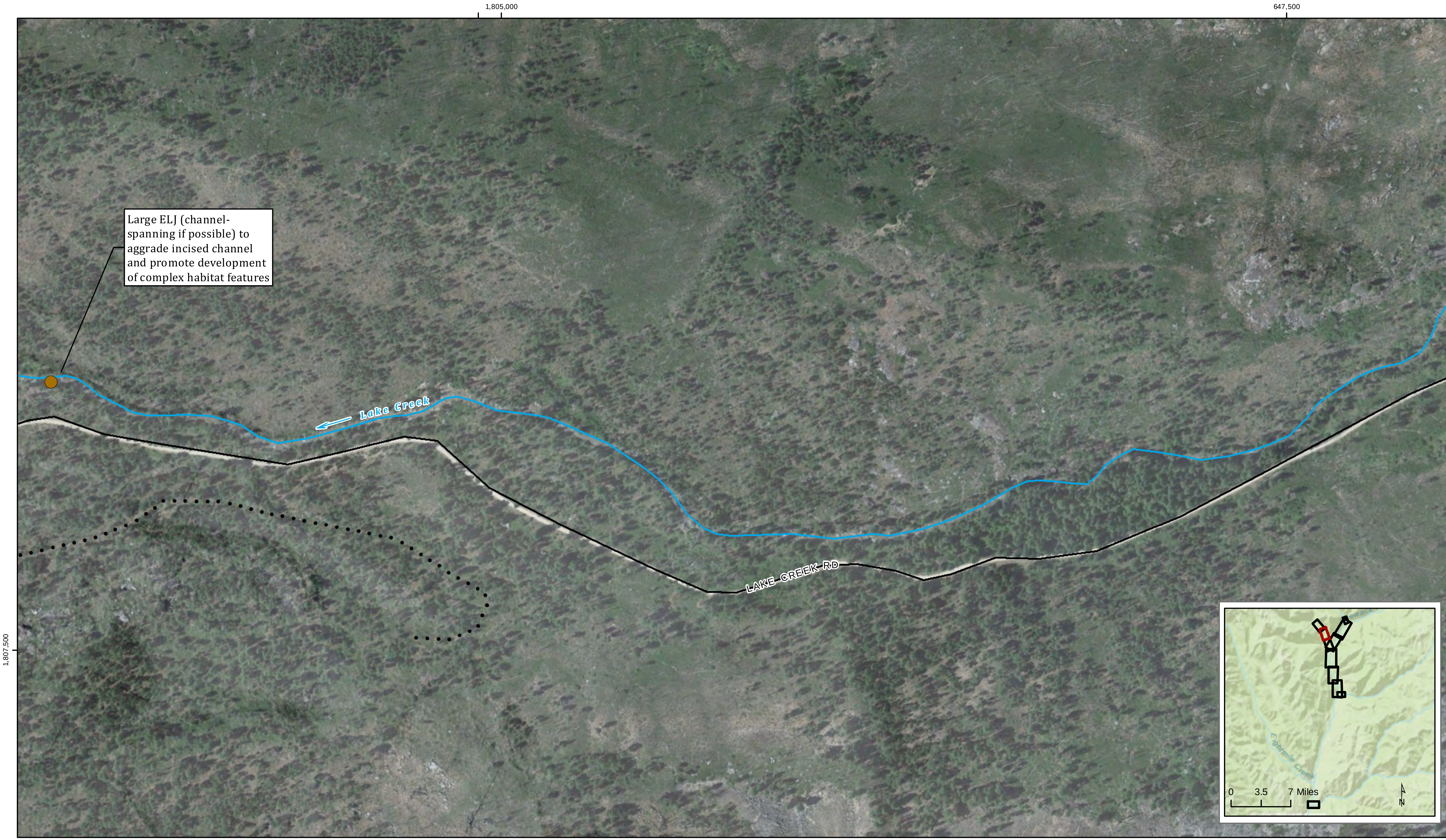
0 250 500 Feet

Lambert conformal conic projection, NAD 1983 State Plane Coordinate System (WA North Zone)

Machine Placed ELJ
Pile Array
Enhanced Side Channel
Loosely Anchored Wood Loading
Channel Excavation
Levee Removal
Reach Break
River Miles
Stream
Road
Closed Road
Unimproved Road
Bridge

Yakama Nation Fisheries

Natural Systems Design



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Upper Chewuch Habitat Assessment

Restoration Concepts - Map 8, Lake Creek Reach 2b

Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).

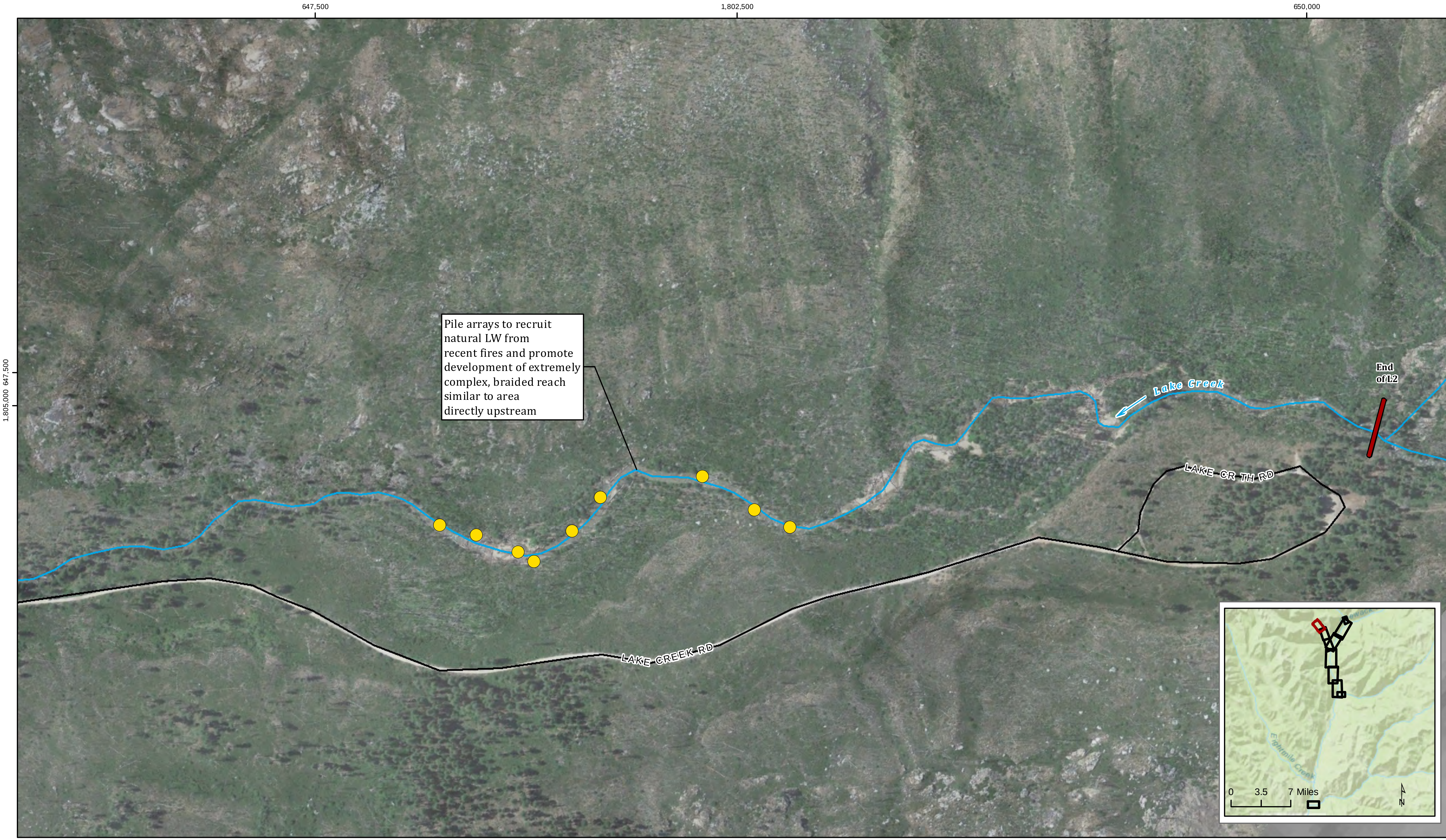
0 250 500 Feet

Lambert conformal conic projection, NAD 1983 State Plane Coordinate System (WA North Zone)

Machine Placed ELJ
Pile Array
Enhanced Side Channel
Loosely Anchored Wood Loading
Channel Excavation
Levee Removal
Reach Break
River Miles
Stream
Road
Closed Road
Unimproved Road
Bridge

Yakama Nation Fisheries

Natural Systems Design



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Upper Chewuch Habitat Assessment

Restoration Concepts - Map 9, Lake Creek Reach 2c

Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).

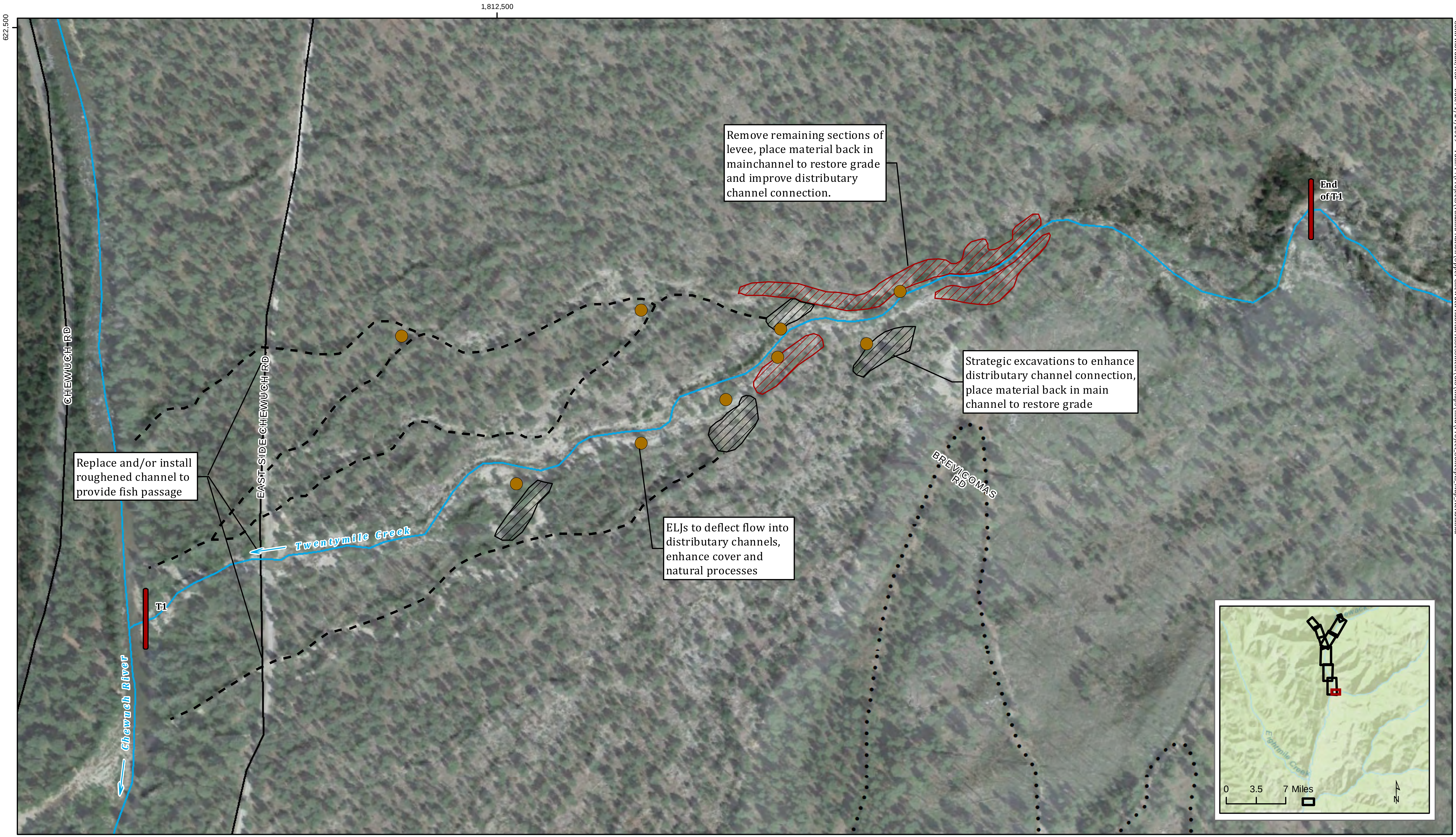
0 250 500 Feet

Lambert conformal conic projection, NAD 1983 State Plane Coordinate System (WA North Zone)

Machine Placed ELJ
Pile Array
Enhanced Side Channel
Loosely Anchored Wood Loading
Channel Excavation
Levee Removal
Reach Break
River Miles
Stream
Road
Closed Road
Unimproved Road
Bridge

Yakama Nation Fisheries

Natural Systems Design



Upper Chewuch Habitat Assessment

Restoration Concepts - Map 10, Twentymile Creek

Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).

0 250 500 Feet

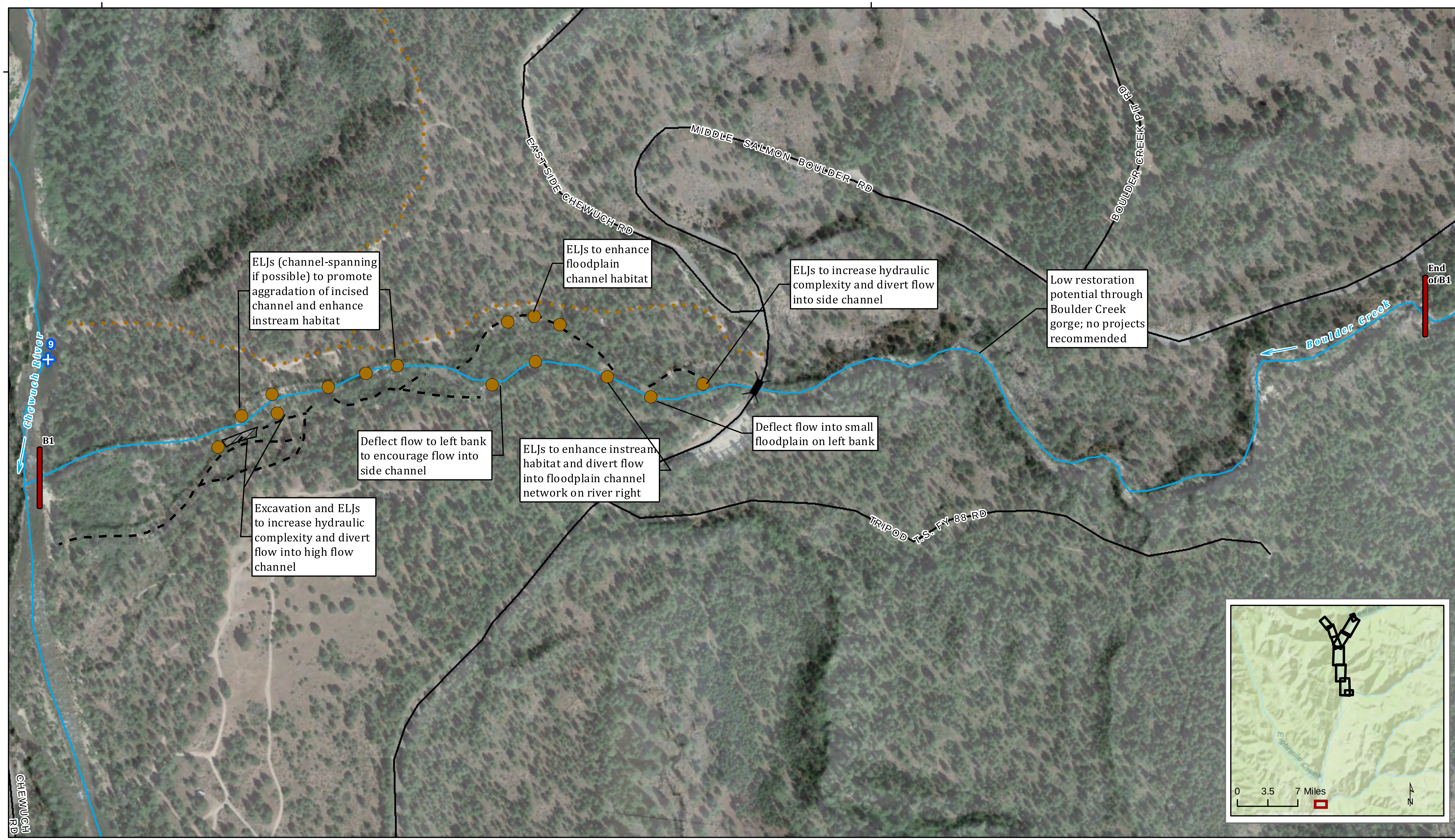
Lambert conformal conic projection, NAD 1983 State Plane Coordinate System (WA North Zone)

N

Machine Placed ELJ
Pile Array
Enhanced Side Channel
Loosely Anchored Wood Loading
Channel Excavation
Levee Removal
Reach Break
River Miles
Stream
Road
Closed Road
Unimproved Road
Bridge

Yakama Nation Fisheries

Natural Systems Design



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Upper Chewuch Habitat Assessment

Restoration Concepts - Map 11, Boulder Creek

Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).

0 250 500 Feet

Lambert conformal conic projection, NAD 1983 State Plane Coordinate System (WA North Zone)

N

Machine Placed ELJ
Pile Array
Enhanced Side Channel
Loosely Anchored Wood Loading
Channel Excavation
Levee Removal
Reach Break
River Miles
Stream
Road
Closed Road
Unimproved Road
Bridge

Yakama Nation Fisheries

Natural Systems Design

Appendix C

Project Prioritization Matrix

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Appendix D. Project Prioritization Matrix

	Project Information			Benefit Score													Cost Score		Cost Benefit	Feasibility Designation	
				Restoration Gap Analysis				Existing and Potential Fish Use		Root Causes		Ecological Concerns		Climate Change							
Reach	Project Name	Project Location (RM - RM)	Total Length (mi)	Existing Condition (1-7)	Achievable Target (1-7)	Final Gap Score Target - Existing	Rationale/Assumptions	Score (1-3)	Rationale/Assumptions	Score (1-3)	Rationale/Assumptions	Score (1-3)	Rationale/Assumptions	Score (1-3)	Rationale/Assumptions	Total Benefits Score	Score (1-3)	Rationale/Assumptions	Benefit to Cost Score	Feasibility Designation	Rationale/Assumptions
C10	Project Area 1	19.5-20.3	1.8	4	6	2	PA 1 includes multiple log jams and side channel excavation and enhancement which will increase connection with off-channel habitat and floodplain, as well as improvements in channel structure and form. However, there area still effects from human uses in terms of camp grounds and the Chewuch Rd.	3	Local reach intrinsic potential is High for both chinook and steelhead.	2	Addresses lack of wood loading and supports increased side channel hydrology.	3	Restoration actions address high priority ecological concerns associated with Peripheral and Transitional Habitat and Channel Structure and Form.	2	Wood treatment will help to aggrade the channel and treat incision to improve floodplain connectivity.	12	2	Typical log jam structures and moderate to low level of excavation.	6	High	In-channel work with adequate access; little infrastructure; USFS coordination.
C10	Project Area 2	20.9-21.9	1	5	6	1	PA 2 includes substantial wood additions in the mainstem and side channel enhancement. No Snake Side Channel currently provides high quality habitat.	3	Local reach intrinsic potential is High for both chinook and steelhead. No Snake Side Channel is known to provide high quality habitat for juvenile use based on densities.	2	Addresses lack of wood loading and supports increased side channel hydrology. Effects of sediment input from quarry still present.	3	Restoration actions address high priority ecological concerns associated with Peripheral and Transitional Habitat and Channel Structure and Form.	2	Wood treatment will help to aggrade the channel and treat incision to improve floodplain connectivity.	11	2	Typical log jam structures and moderate to low level of excavation.	5.5	Med	In-channel work with adequate access - some roads closed; little infrastructure; USFS coordination.
C11	Project Area 3	22.0-22.8	0.8	4	6	1	PA 3 provides opportunities to re-engage side channel habitat. Limitations from Chewuch Road exist in the floodplain.	3	Ground water channels would produce high quallity rearing habitat.	2	Addresses lack of wood loading and supports increased side channel hydrology.	3	Restoration actions address high priority ecological concerns associated with Peripheral and Transitional Habitat and Channel Structure and Form.	2	Wood treatment will help to aggrade the channel and treat incision to improve floodplain connectivity.	11	2	Typical log jam structures and moderate to low level of excavation.	5.5	Med	In-channel work with remote access- some closed roads; little infrastructure; USFS coordination.
C11	Project Area 4	22.8- 23.5	0.7	3	5	2	PA 4 increases available off-channel habitat and provides moderate wood loading. Limited floodplain extent limits restoration opportunities.	2	Narrower valley width limits potential use for refuge and spawning.	2	Addresses lack of wood loading and supports increased side channel hydrology.	3	Restoration actions address high priority ecological concerns associated with Peripheral and Transitional Habitat and Channel Structure and Form.	2	Wood treatment will help to aggrade the channel and treat incision to improve floodplain connectivity.	11	2	Typical log jam structures and moderate to low level of excavation.	5.5	High	In-channel work with adequate access; little infrastructure; USFS coordination.
C12	Project Area 5	23.5-23.8	0.3	3	4	1	PA 5 has minor increases to instream habitat and proposes to remove road crossing and replace with natural channel.	2	Narrower valley width limits potential use for refuge and spawning.	2	Addresses lack of wood loading and supports increased side channel hydrology.	3	Restoration actions address high priority ecological concerns associated with Peripheral and Transitional Habitat and Channel Structure and Form.	2	Wood treatment will help to aggrade the channel and treat incision to improve floodplain connectivity.	10	2	Typical log jam structures and moderate to low level of excavation.	5	High	In-channel work with remote access; little infrastructure; USFS coordination.
C13	Project Area 6	24.7-25	0.3	3	4	1	PA 6 increases local wood densities and proposes to drive island formation and increase connection to a few side channels.	2	Narrower valley width limits potential use for refuge and spawning.	2	Addresses lack of wood loading and supports increased side channel hydrology.	3	Restoration actions address high priority ecological concerns associated with Peripheral and Transitional Habitat and Channel Structure and Form.	2	Wood treatment will help to aggrade the channel and treat incision to improve floodplain connectivity.	10	2	Typical log jam structures and moderate to low level of excavation.	5	High	In-channel work with remote access; little infrastructure; USFS coordination.

C13	Project Area 7	25.0-25.8	0.8	4	6	2	PA 7 provides connection to an exstensive network of groundwater channels which could provide cool water refuge if made more accessible. Significant additions of instream wood increase channel diversity and structure. Does not address greater watershed impairment	3	Ground water channels would produce high quallity rearing habitat.	2	Addresses lack of wood loading and supports increased side channel hydrology and ground water source connection.	3	Restoration actions address high priority ecological concerns associated with Peripheral and Transitional Habitat and Channel Structure and Form.	3	Wood treatment will help to aggrade the channel and treat incision to improve floodplain connectivity and access to ground water.	13	2	Typical log jam structures and moderate to low level of excavation.	6.5	High	In-channel work with remote access; little infrastructure; USFS coordination.
L1	Project Area 8	0.0-0.5	0.5	4	5	1	PA 8 provides a local opportunity for wood placement and improving distributary hydrology.	2	Lower level of use for Chinook spawning in tributaries	2	Addresses lack of wood loading and supports increased distributary length.	3	Restoration actions address high priority ecological concerns associated with Peripheral and Transitional Habitat and Channel Structure and Form.	2	Wood treatment will help to aggrade the channel and treat incision to improve floodplain connectivity.	10	2	Typical log jam structures and moderate to low level of excavation.	5	Med	In-channel work with remote access, some distance from road to channel; little infrastructure; USFS coordination.
L2	Project Area 9	1.0-1.5	0.5	3	4	1	PA 9 provides a local opportunity to increase wood loading to aggrade channel. Still affected by recent fires.	2	Lower level of use for Chinook spawning in tributaries	2	Addresses channel incision and disconnection from floodplain. Fire effects remain.	3	Restoration actions address high priority ecological concerns associated with Peripheral and Transitional Habitat and Channel Structure and Form.	2	Wood treatment will help to aggrade the channel and treat incision to improve floodplain connectivity.	10	2	Typical log jam structures and moderate to low level of excavation.	5	High	In-channel work with remote access; little infrastructure; USFS coordination.
L2	Project Area 10	2.1-2.5	0.4	3	4	1	PA 10 provides a local opportunity to increase wood loading and capture wood from upstream. Still affected by recent fires.	2	Lower level of use for Chinook spawning in tributaries	2	Addresses capture of wood from upstream sources. Does not address long term wood recruitment.	3	Restoration actions address high priority ecological concerns associated with Peripheral and Transitional Habitat and Channel Structure and Form.	2	Wood treatment will help to aggrade the channel and treat incision to improve floodplain connectivity.	10	2	Typical log jam structures and moderate to low level of excavation.	5	High	In-channel work with remote access; little infrastructure; USFS coordination.
T1	Project Area 11	0-1.2	1.2	3	5	2	PA 11 could provide extensive reconnection to the alluvial fan and an increas in off-channel areas. However, this is dependant on extensive reworking of the road crossings to allow for distributary outlets	3	Local reach intrinsic potential is High for both chinook and steelhead.	2	Addresses lack of wood loading and supports increased side channel hydrology. Improves connection to alluvial fan. Still affected by road.	3	Restoration actions address high priority ecological concerns associated with Peripheral and Transitional Habitat and Channel Structure and Form.	2	Wood treatment will help to aggrade the channel and treat incision to improve floodplain connectivity.	12	2	Typical log jam structures and moderate to low level of excavation.	6	Med	In-channel work with remote access- some distance from road to channel; little infrastructure; USFS coordination.
B1	Project Area 12	0-0.7	0.7	4	5	1	PA 12 provides local opportunity for increasing wood levels and aggradation to reduce incision.	2	Lower level of use for Chinook spawning in tributaries	2	Addresses lack of wood loading and supports increased side channel hydrology.	3	Restoration actions address high priority ecological concerns associated with Peripheral and Transitional Habitat and Channel Structure and Form.	2	Wood treatment will help to aggrade the channel and treat incision to improve floodplain connectivity.	10	2	Typical log jam structures and moderate to low level of excavation.	5	High	In-channel work with remote access; little infrastructure; USFS coordination.

Appendix D

Historic Aerial Photographs

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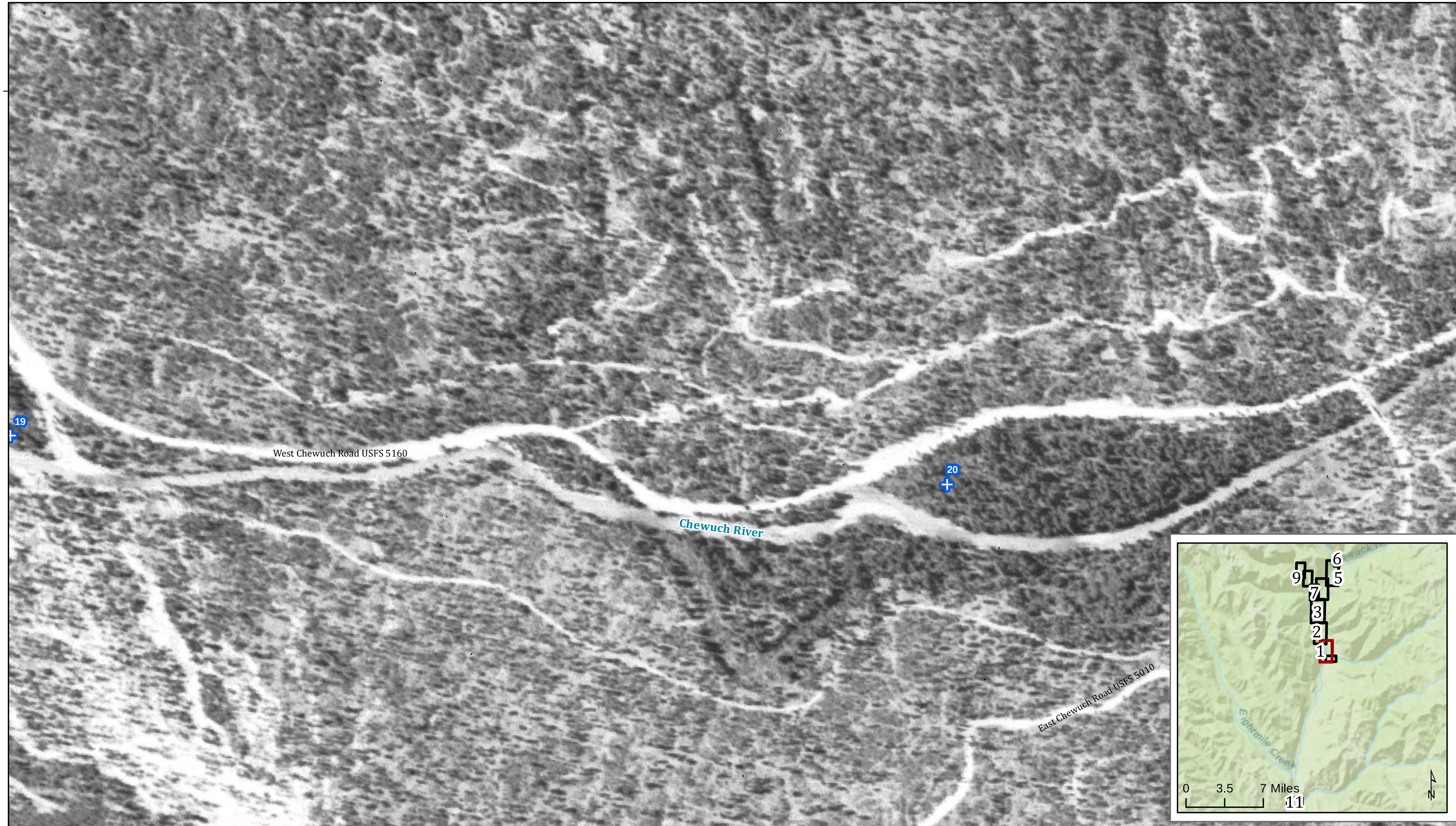


Robert Dohrn, NSD Date: 2/14/2019 Path: P:\Projects\Yakama Nation\Upper Chewuch Habitat Assessment\GIS\maps\mxd\Historic_ReachMap.mxd

Upper Chewuch Habitat Assessment

1953 Air Photo Reach Map - Chewuch Reach 10a, Map 1

Topographic data source: 2015 Okanogan lidar data - collected by Quantum Spatial between 6/19/15 and 7/10/15.
Other data: USGS NHD (1:24,000), US Census Bureau Roads (2010), Google Earth Air Photos (2017), USGS Earth Explorer Historic Air Photos.

0 500 1,000 Feet

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)

15 USGS River Mile
Streams
Roads

Yakama Nation Fisheries

Natural Systems Design

Robert Dohrn, NSD Date: 2/14/2019 Path: P:\Projects\Yakama Nation\Upper Chewuch Habitat Assessment\GIS\maps\mxd\Historic_ReachMap.mxd

Upper Chewuch Habitat Assessment

1953 Air Photo Reach Map - Chewuch Reach 10b, Map 2

Topographic data source: 2015 Okanogan lidar data - collected by Quantum Spatial between 6/19/15 and 7/10/15.
Other data: USGS NHD (1:24,000), US Census Bureau Roads (2010), Google Earth Air Photos (2017), USGS Earth Explorer Historic Air Photos.

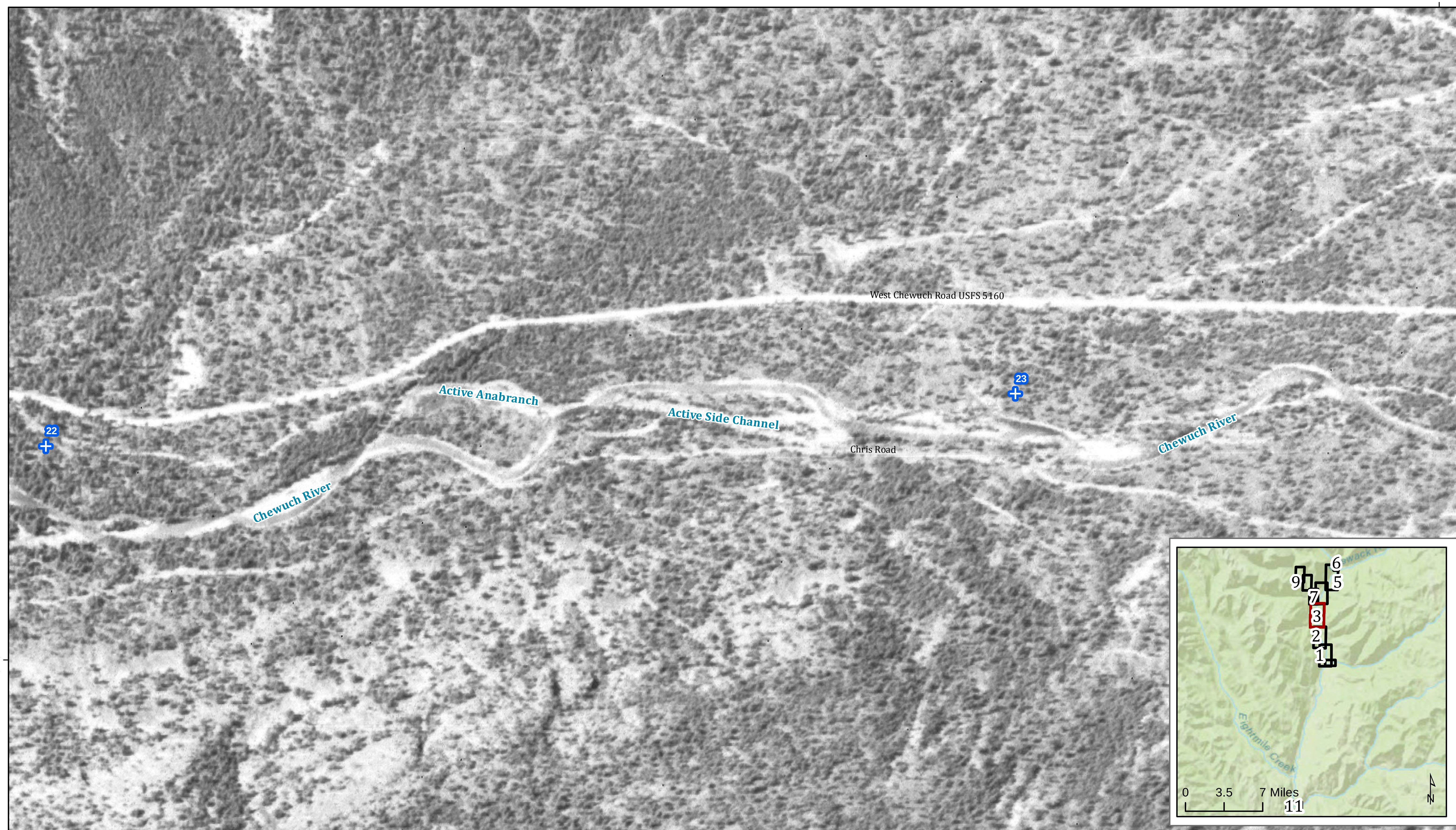
0 500 1,000 Feet

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)

15 USGS River Mile
Streams
Roads

Yakama Nation Fisheries

Natural Systems Design



Robert Dohrn, NSD Date: 2/14/2019 Path: P:\Projects\Yakama Nation\Upper Chewuch Habitat Assessment\GIS\maps\mxd\Historic_ReachMap.mxd

Upper Chewuch Habitat Assessment

1953 Air Photo Reach Map - Chewuch Reach 11, Map 3

Topographic data source: 2015 Okanogan lidar data - collected by Quantum Spatial between 6/19/15 and 7/10/15.
Other data: USGS NHD (1:24,000), US Census Bureau Roads (2010), Google Earth Air Photos (2017), USGS Earth Explorer Historic Air Photos.

N

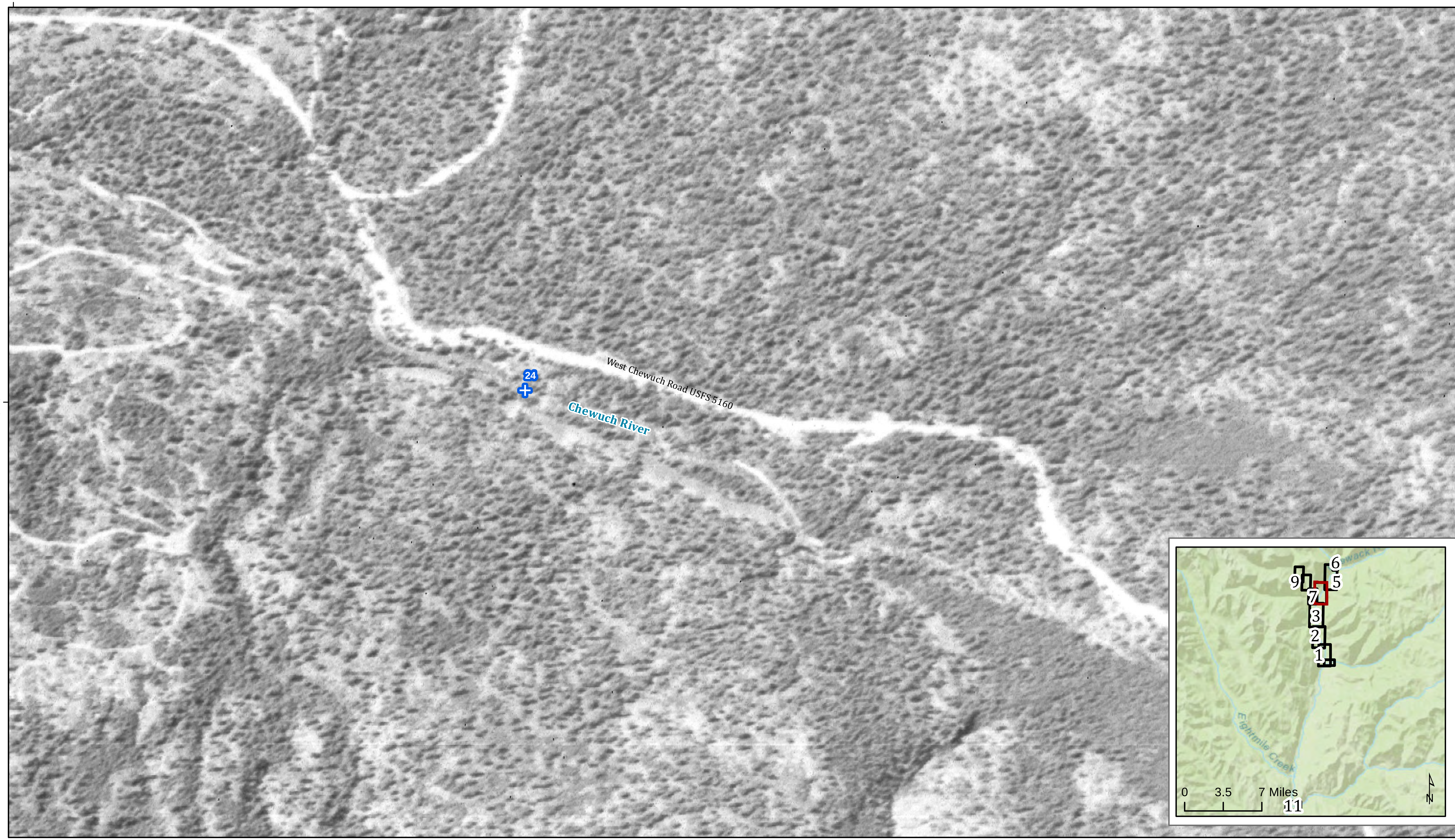
0 500 1,000 Feet

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)

15 USGS River Mile
Streams
Roads

Yakama Nation Fisheries

Natural Systems Design



Robert Dohrn, NSD Date: 2/14/2019 Path: P:\Projects\Yakama Nation\Upper Chewuch Habitat Assessment\GIS\maps\mxd\Historic_ReachMap.mxd

Upper Chewuch Habitat Assessment

1953 Air Photo Reach Map - Chewuch Reach 12, Map 4

Topographic data source: 2015 Okanogan lidar data - collected by Quantum Spatial between 6/19/15 and 7/10/15.
Other data: USGS NHD (1:24,000), US Census Bureau Roads (2010), Google Earth Air Photos (2017), USGS Earth Explorer Historic Air Photos.

0 500 1,000 Feet

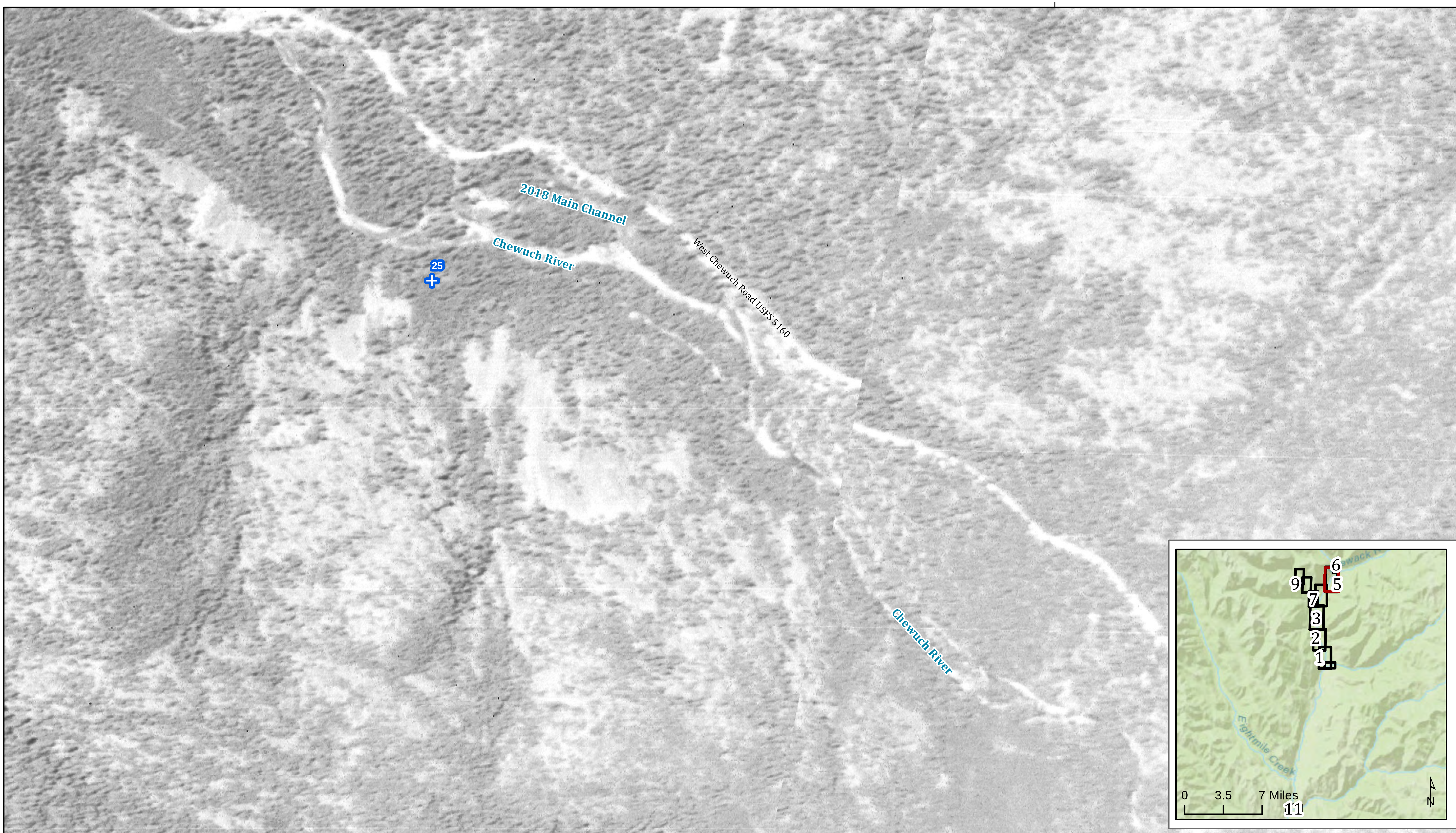
Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)

15 USGS River Mile
Streams
Roads

Yakama Nation Fisheries

Natural Systems Design

650,000



Robert Dohrn, NSD Date: 2/14/2019 Path: P:\Projects\Yakama Nation\Upper Chewuch Habitat Assessment\GIS\maps\mxd\Historic_ReachMaps.mxd

Upper Chewuch Habitat Assessment

1953 Air Photo Reach Map - Chewuch Reach 13, Map 5

Topographic data source: 2015 Okanogan lidar data - collected by Quantum Spatial between 6/19/15 and 7/10/15.
Other data: USGS NHD (1:24,000), US Census Bureau Roads (2010), Google Earth Air Photos (2017), USGS Earth Explorer Historic Air Photos.

0 500 1,000 Feet

N

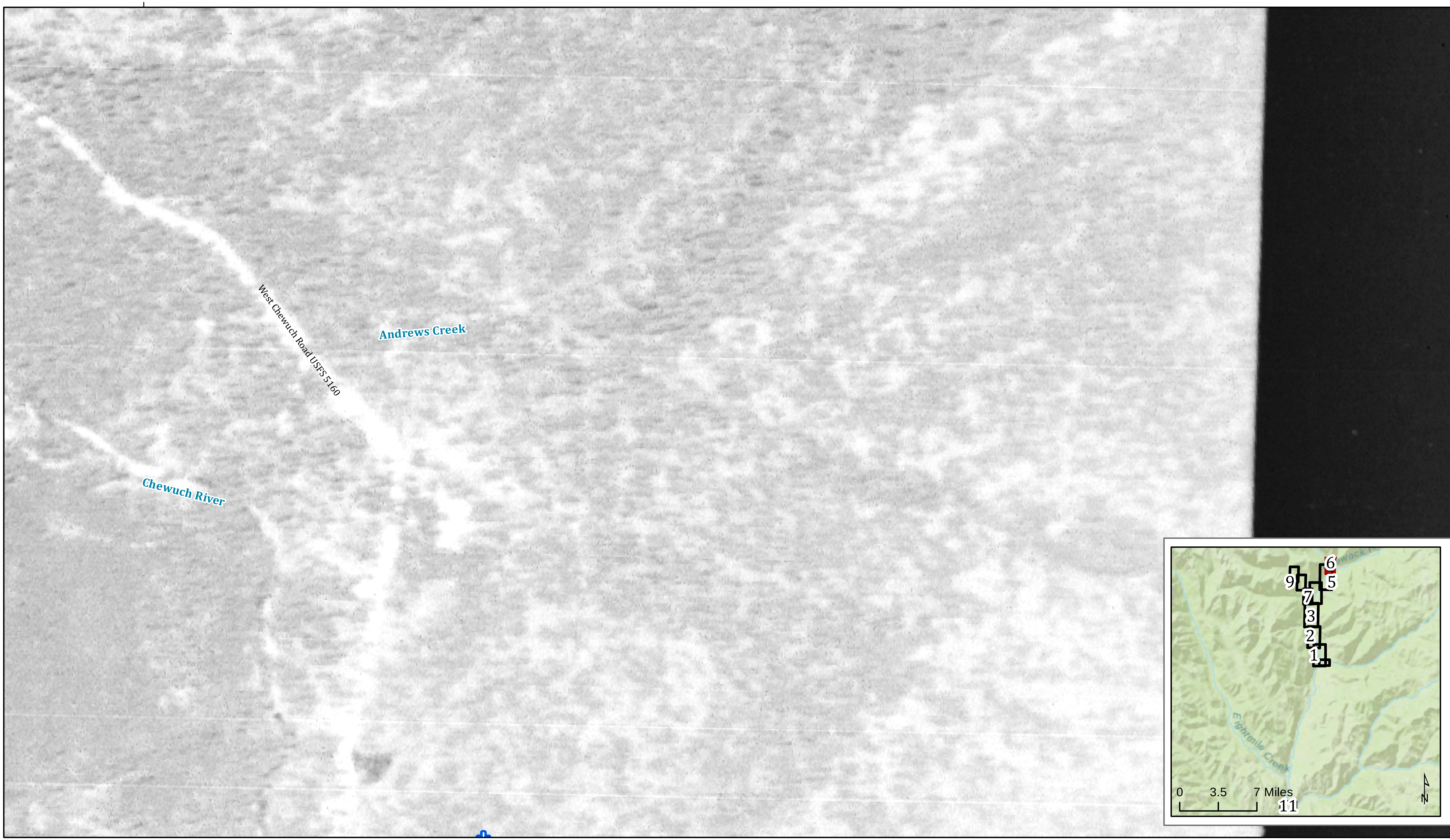
Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)

15 USGS River Mile
Streams
Roads

Yakama Nation Fisheries

Natural Systems Design

650,000



Robert Dohrn, NSD Date: 2/14/2019 Path: P:\Projects\Yakama Nation\Upper Chewuch Habitat Assessment\GIS\maps\mxd\Historic_ReachMap.mxd

Upper Chewuch Habitat Assessment

1953 Air Photo Reach Map - Andrews Creek, Map 6

Topographic data source: 2015 Okanogan lidar data - collected by Quantum Spatial between 6/19/15 and 7/10/15.
Other data: USGS NHD (1:24,000), US Census Bureau Roads (2010), Google Earth Air Photos (2017), USGS Earth Explorer Historic Air Photos.

N

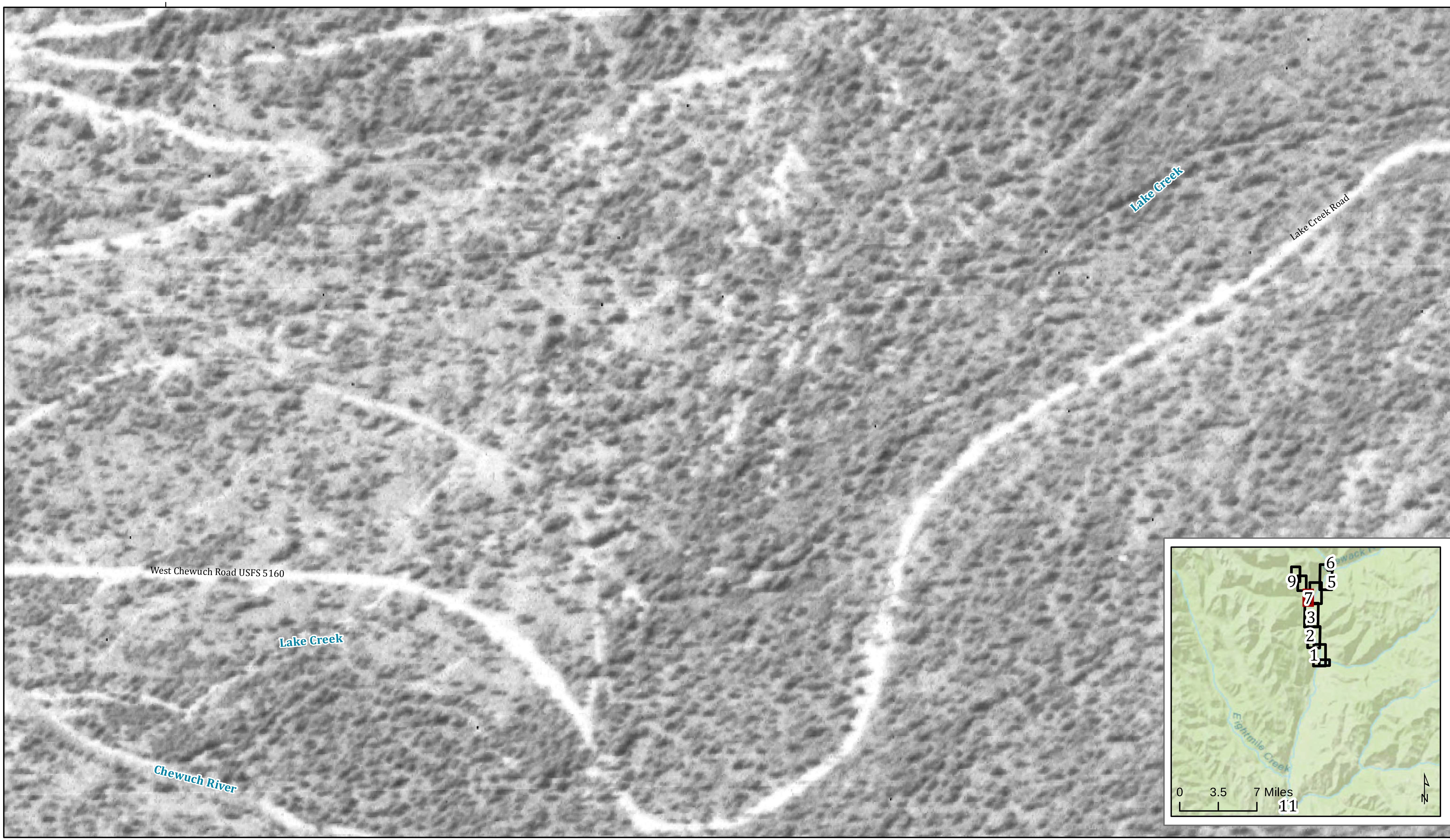
0 500 1,000 Feet

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)

15 USGS River Mile
Streams
Roads

Yakama Nation Fisheries

Natural Systems Design



Upper Chewuch Habitat Assessment

1953 Air Photo Reach Map - Lake Creek Reach 1 & 2a, Map 7

Topographic data source: 2015 Okanogan lidar data - collected by Quantum Spatial between 6/19/15 and 7/10/15.
Other data: USGS NHD (1:24,000), US Census Bureau Roads (2010), Google Earth Air Photos (2017), USGS Earth Explorer Historic Air Photos.

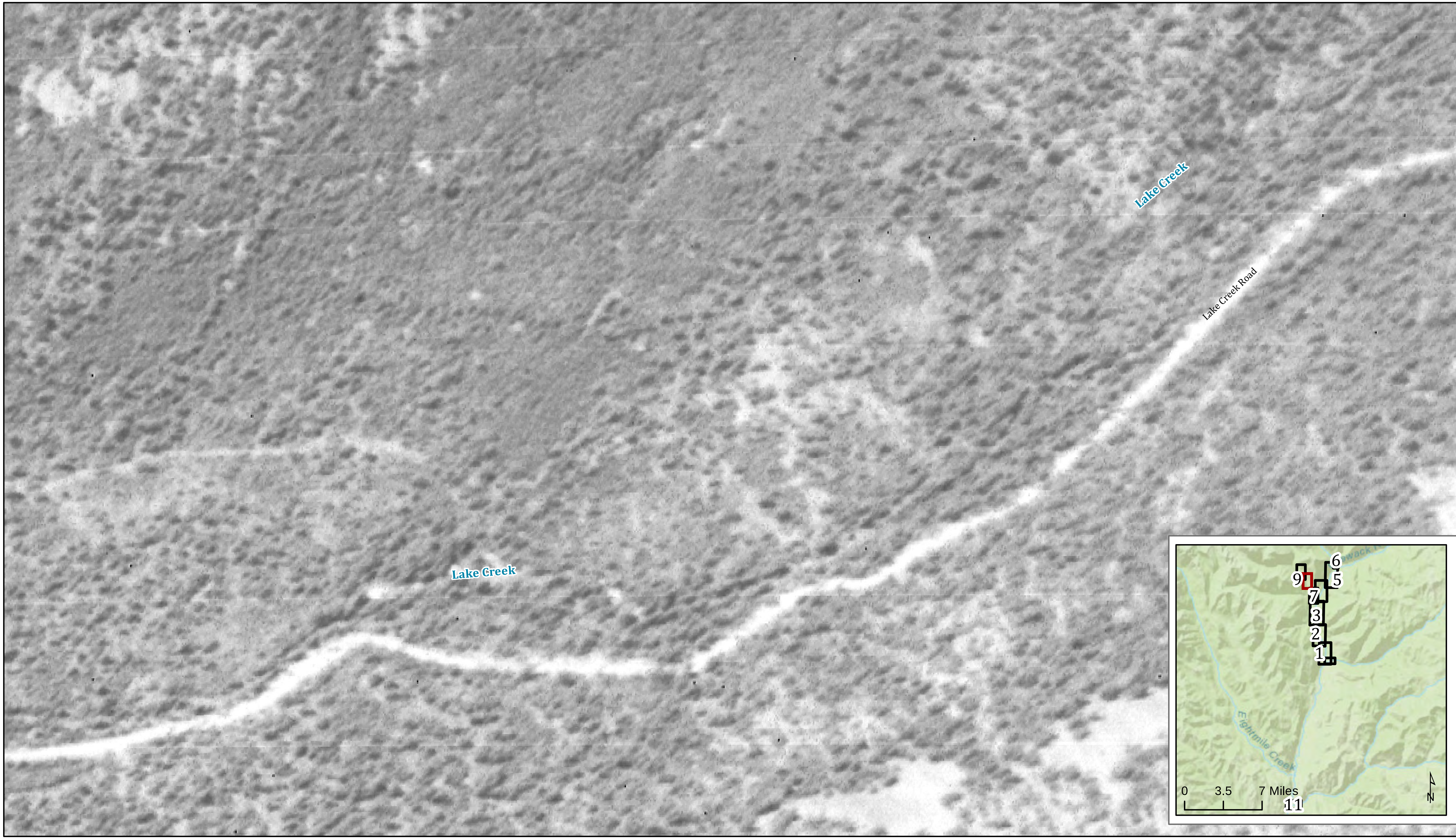
0 500 1,000 Feet

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)

15 USGS River Mile
Streams
Roads

Yakama Nation Fisheries

Natural Systems Design



Robert Dohrn, NSD Date: 2/14/2019 Path: P:\Projects\Yakama Nation\Upper Chewuch Habitat Assessment\GIS\maps\mxd\Historic_ReachMap.mxd

Upper Chewuch Habitat Assessment

1953 Air Photo Reach Map - Lake Creek Reach 2b, Map 8

Topographic data source: 2015 Okanogan lidar data - collected by Quantum Spatial between 6/19/15 and 7/10/15.
Other data: USGS NHD (1:24,000), US Census Bureau Roads (2010), Google Earth Air Photos (2017), USGS Earth Explorer Historic Air Photos.

N

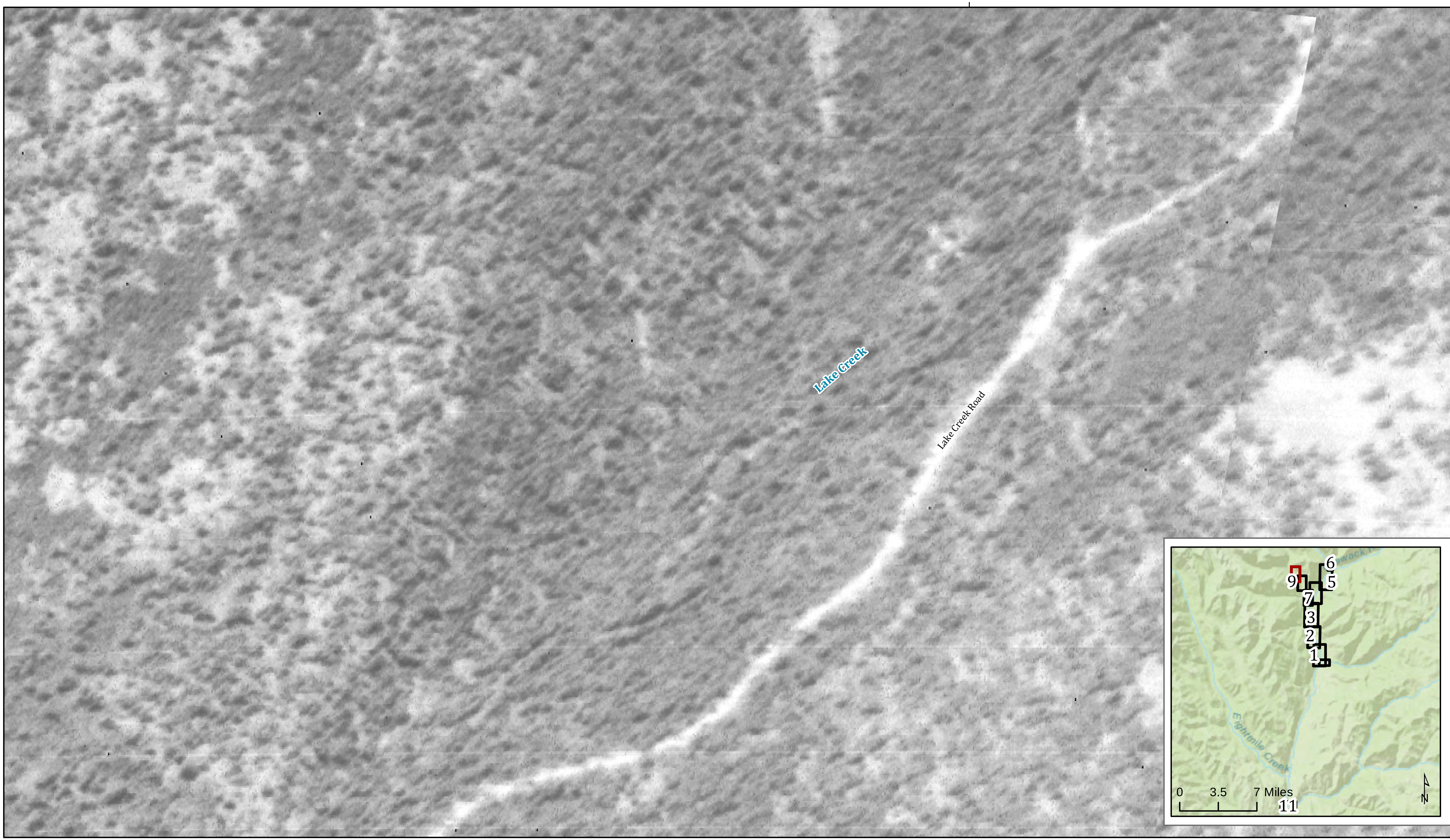
0 500 1,000 Feet

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)

15 USGS River Mile
Streams
Roads

Yakama Nation Fisheries

Natural Systems Design



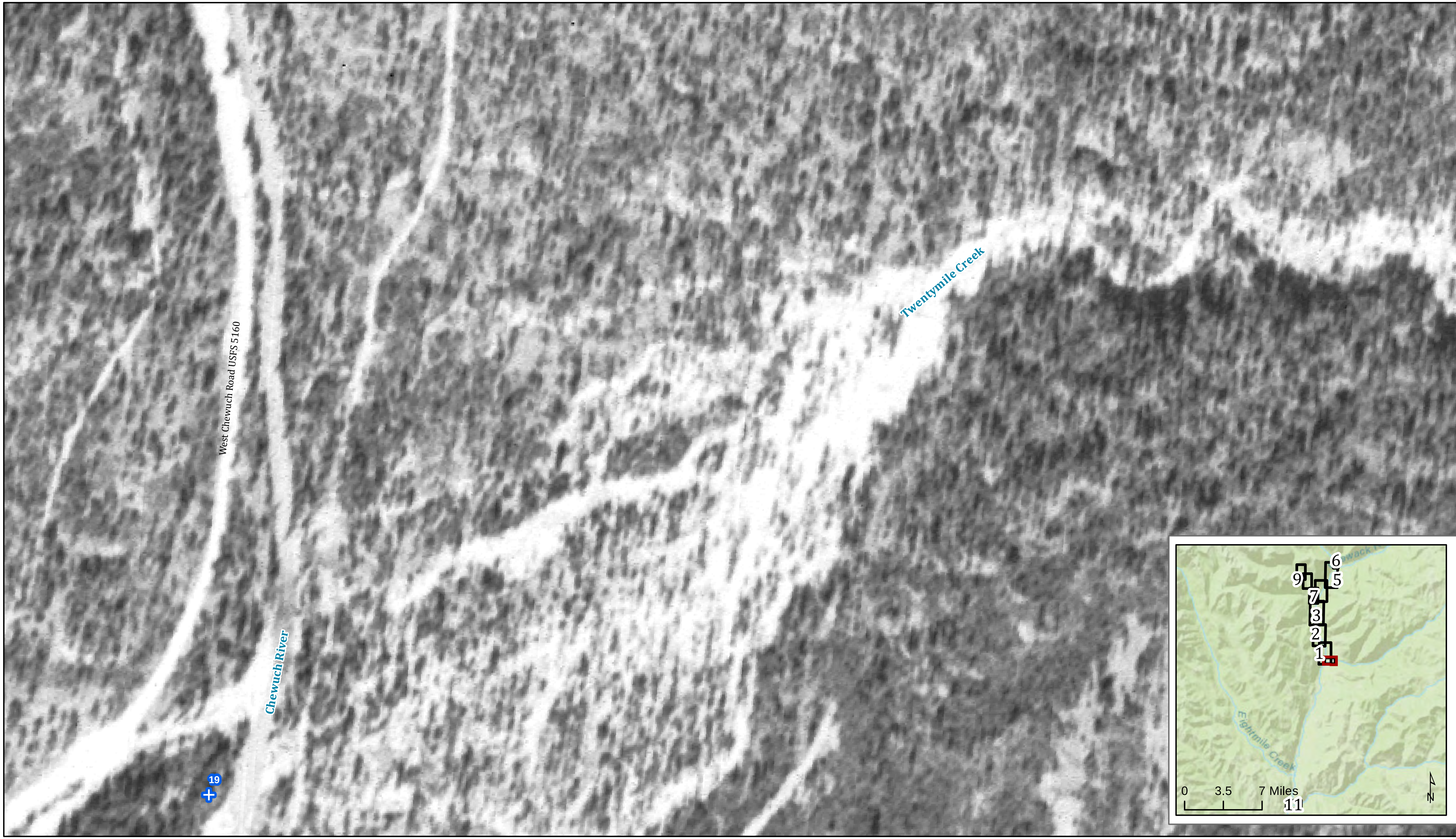
Robert Dohrn, NSD Date: 2/14/2019 Path: P:\Projects\Yakama Nation\Upper Chewuch Habitat Assessment\GIS\maps\mxd\Historic_ReachMap.mxd

Upper Chewuch Habitat Assessment

1953 Air Photo Reach Map - Lake Creek Reach 2c, Map 9

Topographic data source: 2015 Okanogan lidar data - collected by Quantum Spatial between 6/19/15 and 7/10/15.
Other data: USGS NHD (1:24,000), US Census Bureau Roads (2010), Google Earth Air Photos (2017), USGS Earth Explorer Historic Air Photos.

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)



Robert Dohrn, NSD Date: 2/14/2019 Path: P:\Projects\Yakama Nation\Upper Chewuch Habitat Assessment\GIS\maps\mxd\Historic_ReachMap.mxd

Upper Chewuch Habitat Assessment

1953 Air Photo Reach Map - Twentymile Creek, Map 10

Topographic data source: 2015 Okanogan lidar data - collected by Quantum Spatial between 6/19/15 and 7/10/15.
Other data: USGS NHD (1:24,000), US Census Bureau Roads (2010), Google Earth Air Photos (2017), USGS Earth Explorer Historic Air Photos.

N

0 500 1,000 Feet

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)

15 USGS River Mile
Streams
Roads

Yakama Nation Fisheries

Natural Systems Design

Robert Dohrn, NSD Date: 2/14/2019 Path: P:\Projects\Yakama Nation\Upper Chewuch Habitat Assessment\GIS\maps\mxd\Historic_ReachMap.mxd

Upper Chewuch Habitat Assessment

1953 Air Photo Reach Map - Boulder Creek, Map 11

Topographic data source: 2015 Okanogan lidar data - collected by Quantum Spatial between 6/19/15 and 7/10/15.
Other data: USGS NHD (1:24,000), US Census Bureau Roads (2010), Google Earth Air Photos (2017), USGS Earth Explorer Historic Air Photos.

N

0 500 1,000 Feet

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)

15 USGS River Mile
Streams
Roads

Yakama Nation Fisheries

Natural Systems Design

Appendix E

Hydraulic Model Output

Natural Systems Design

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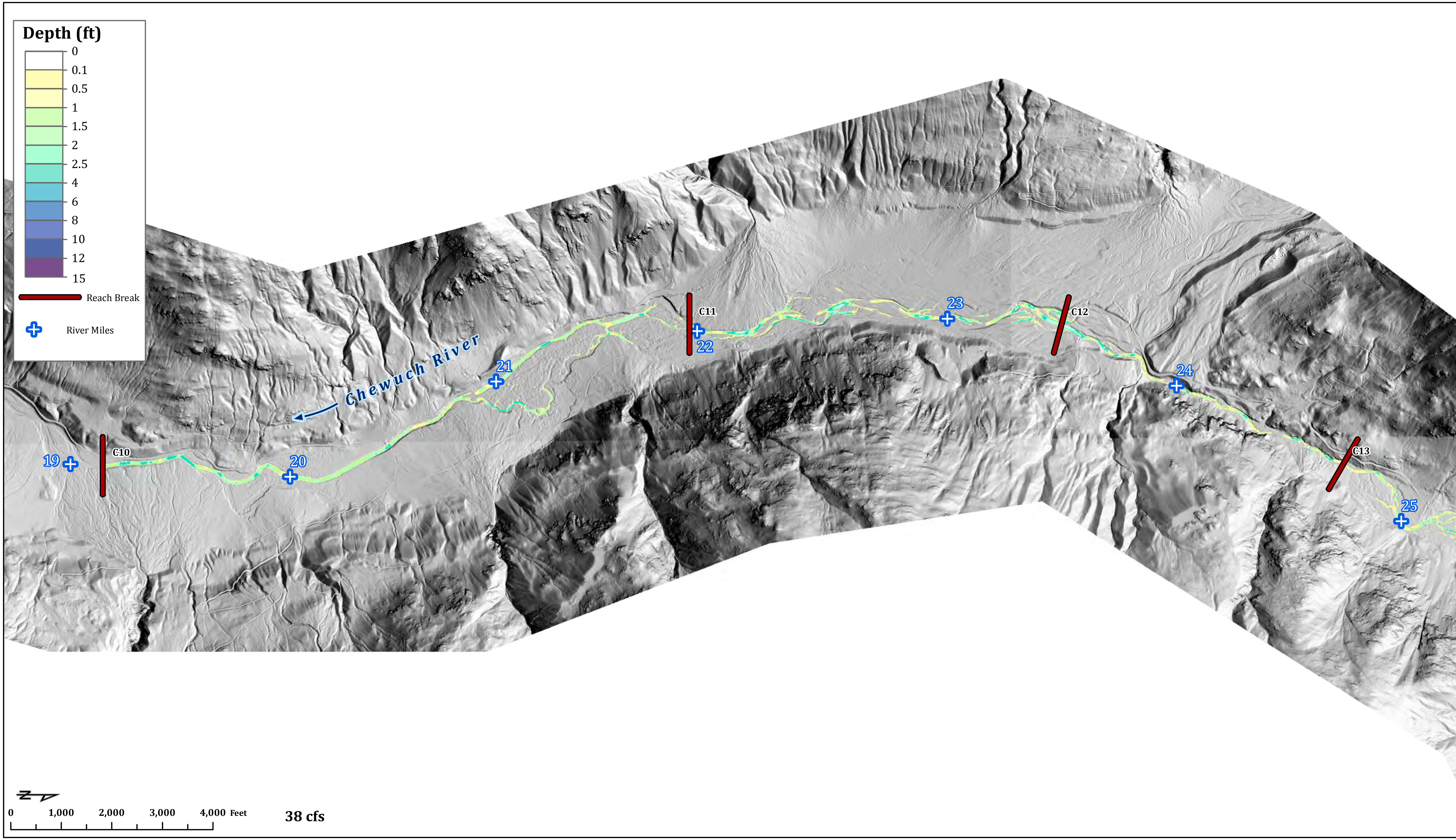
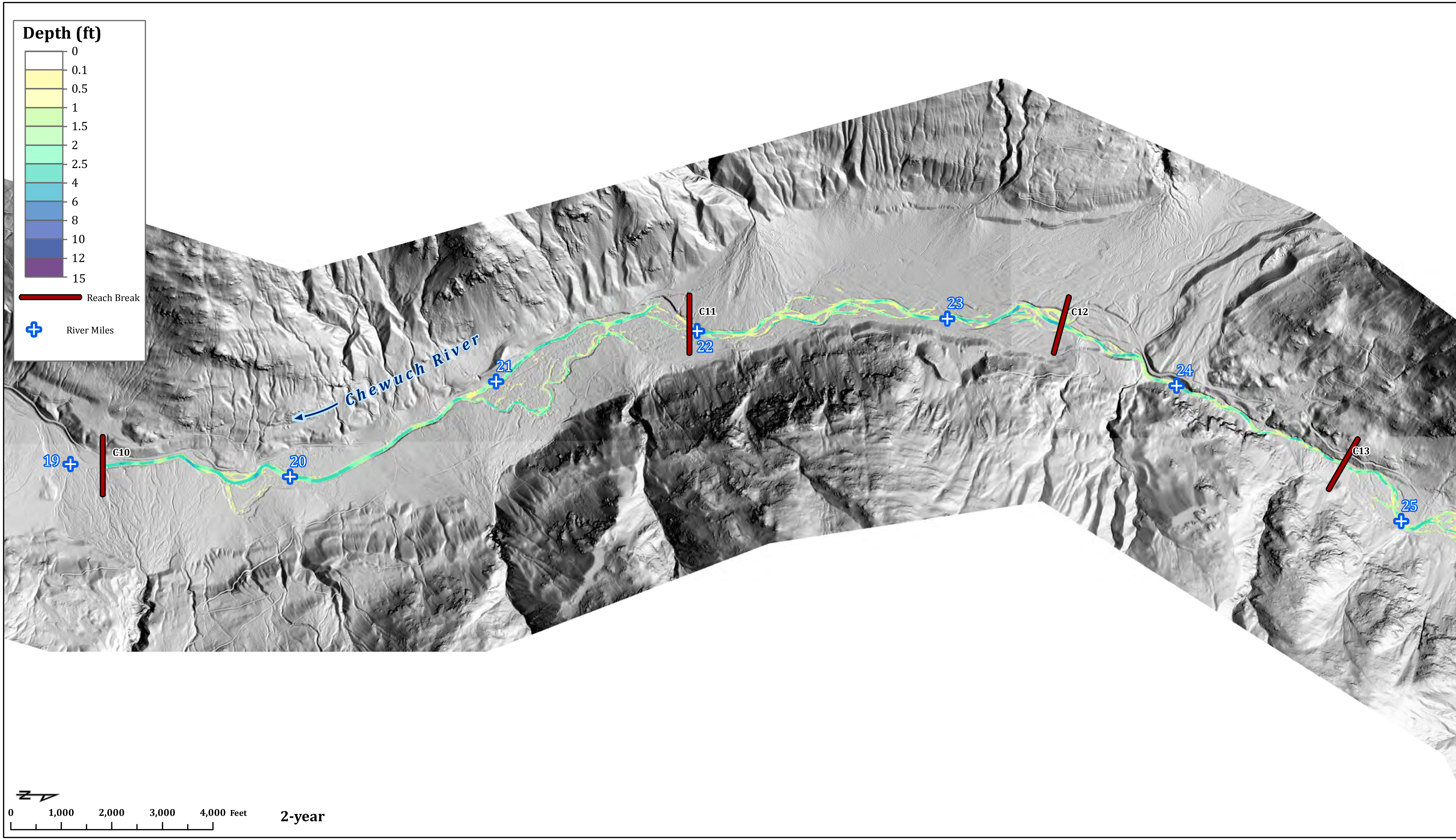
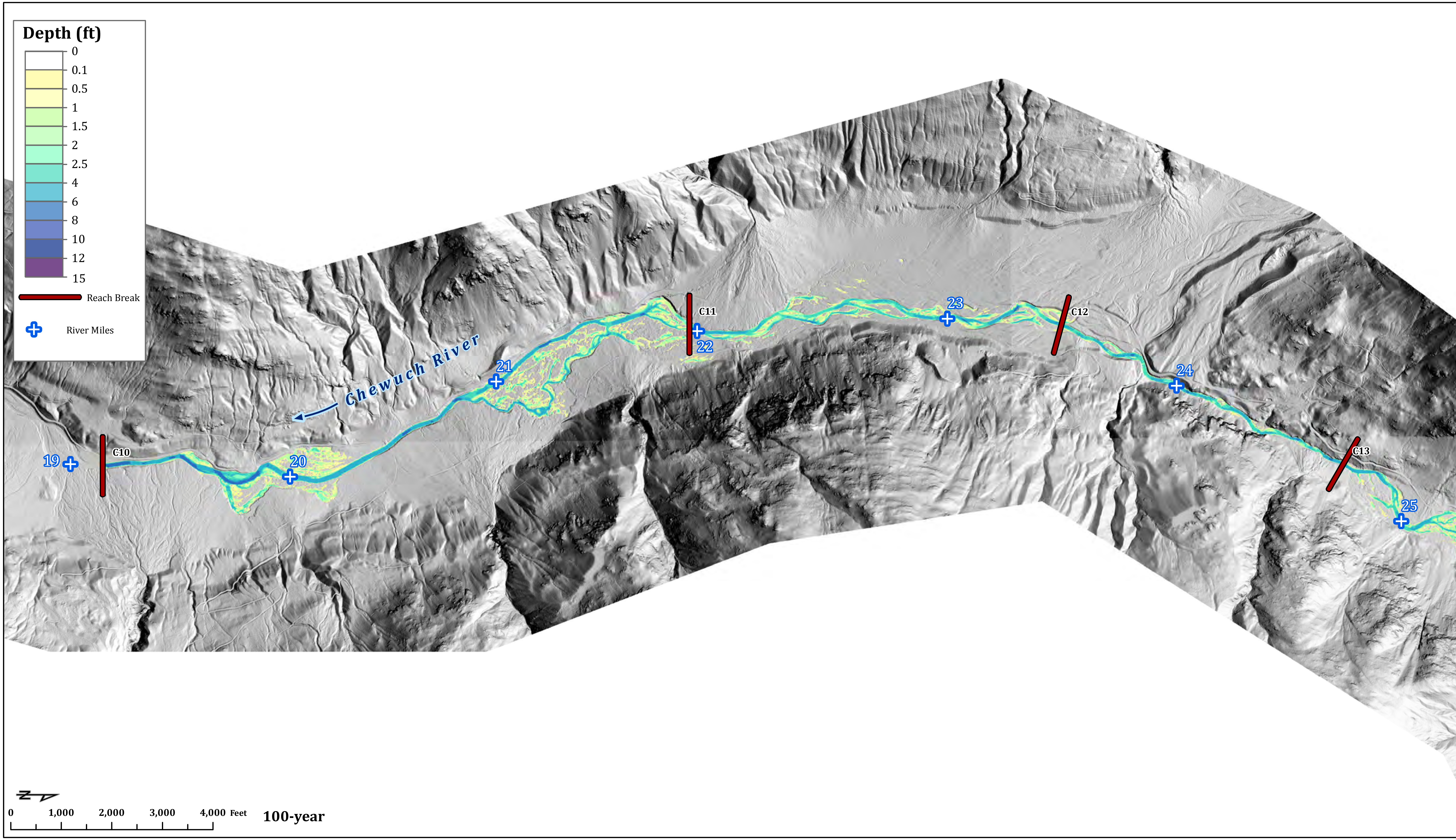


Depth (ft)
0
0.1
0.5
1
1.5
2
2.5
4
6
8
10
12
15
Reach Break
River Miles
Chewuch River
C10
C11
C12
C13
19
20
21
22
23
24
25
0
1,000
2,000
3,000
4,000
Feet
38 cfs



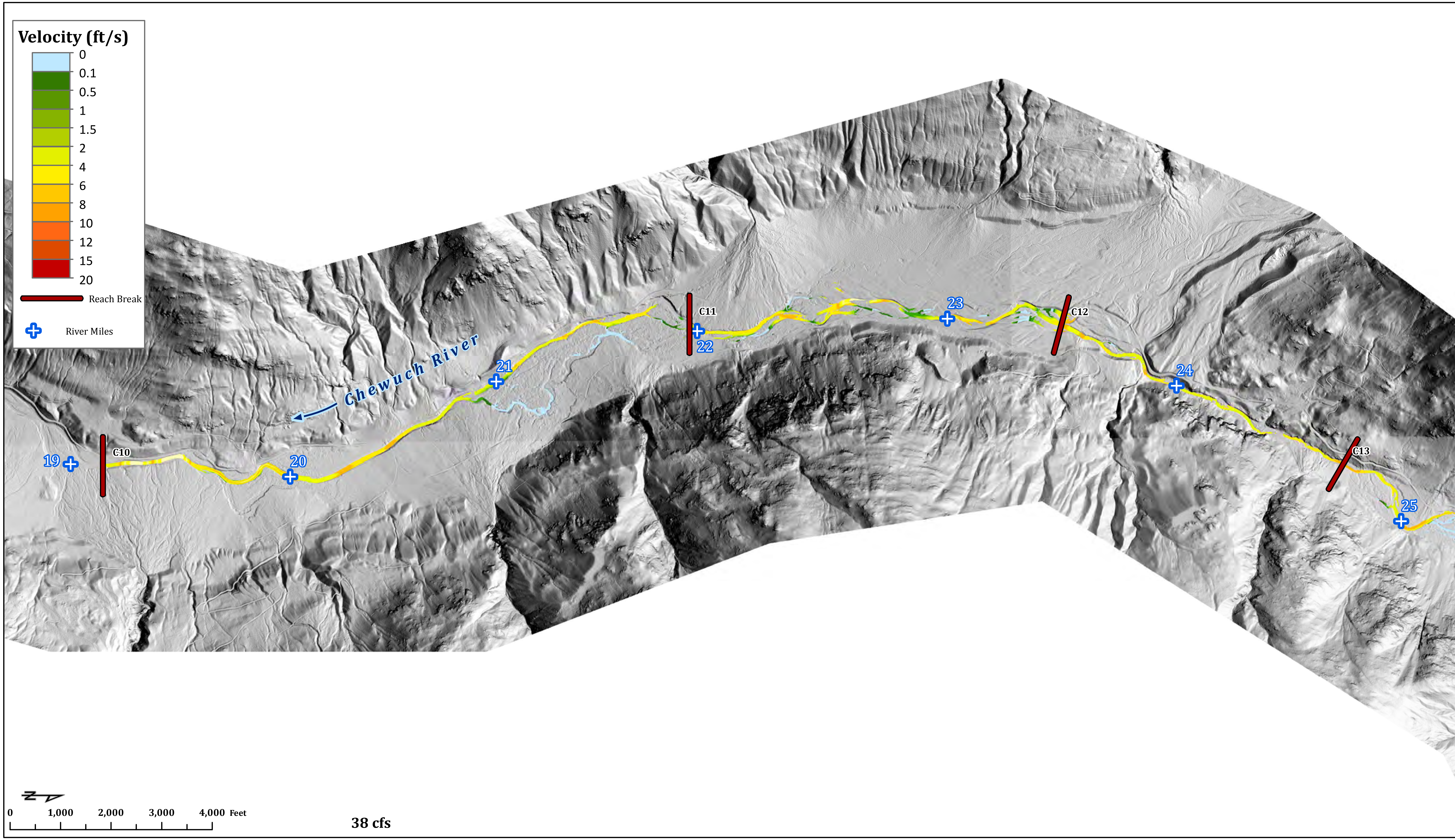
Yakama Nation Fisheries

Natural Systems Design



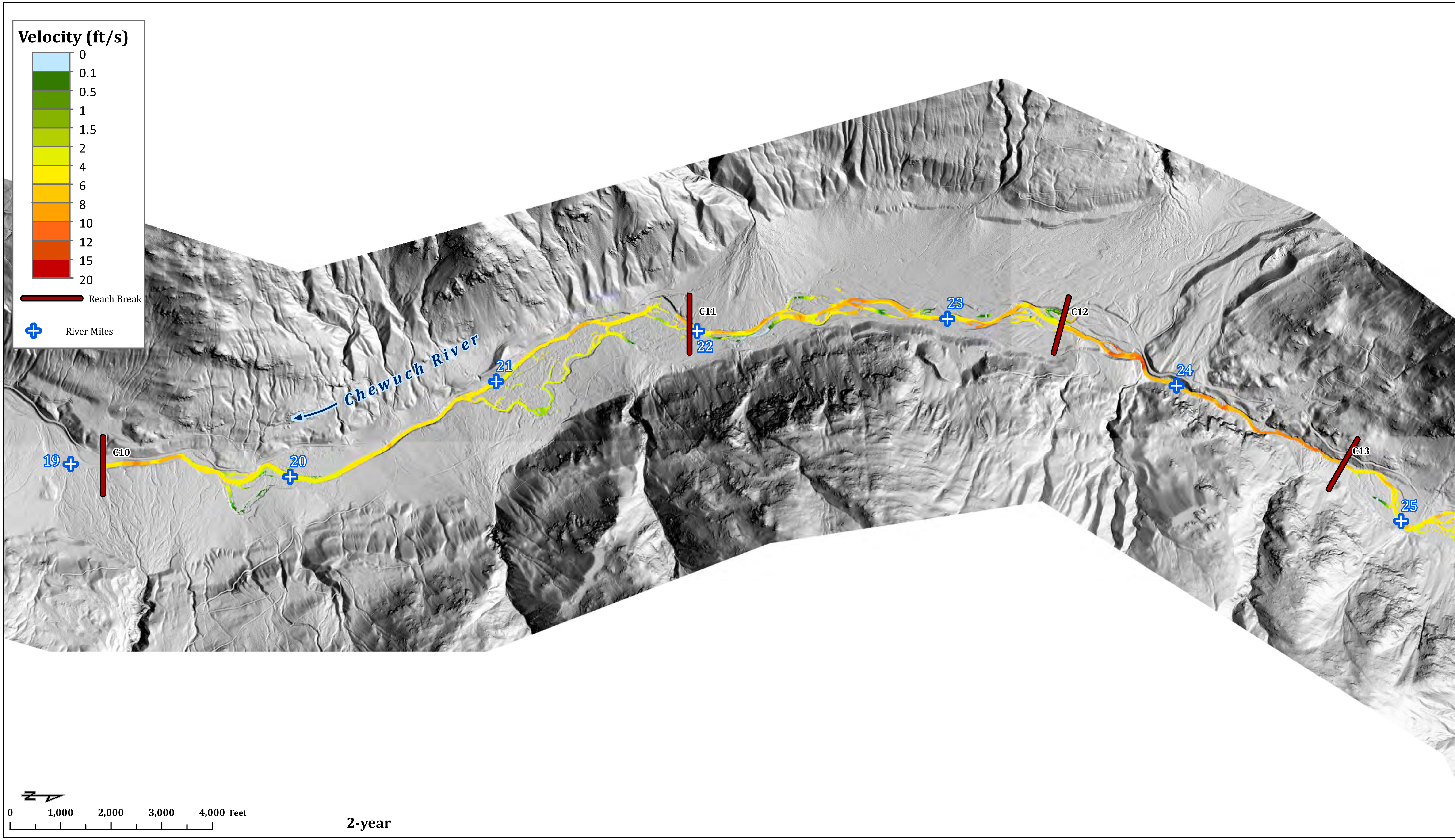
Yakama Nation Fisheries

Natural Systems Design



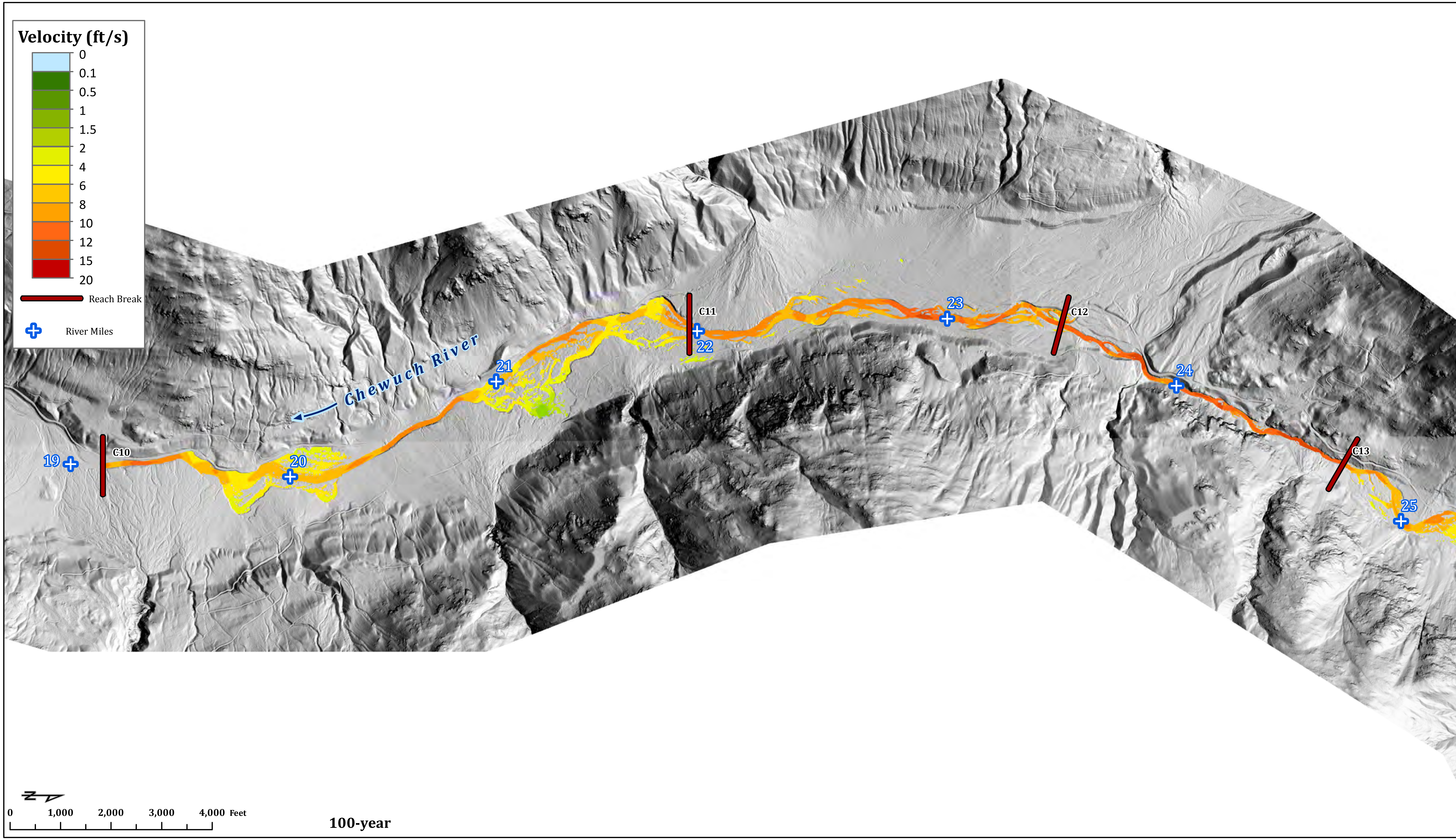
Yakama Nation Fisheries

Natural Systems Design



Yakama Nation Fisheries

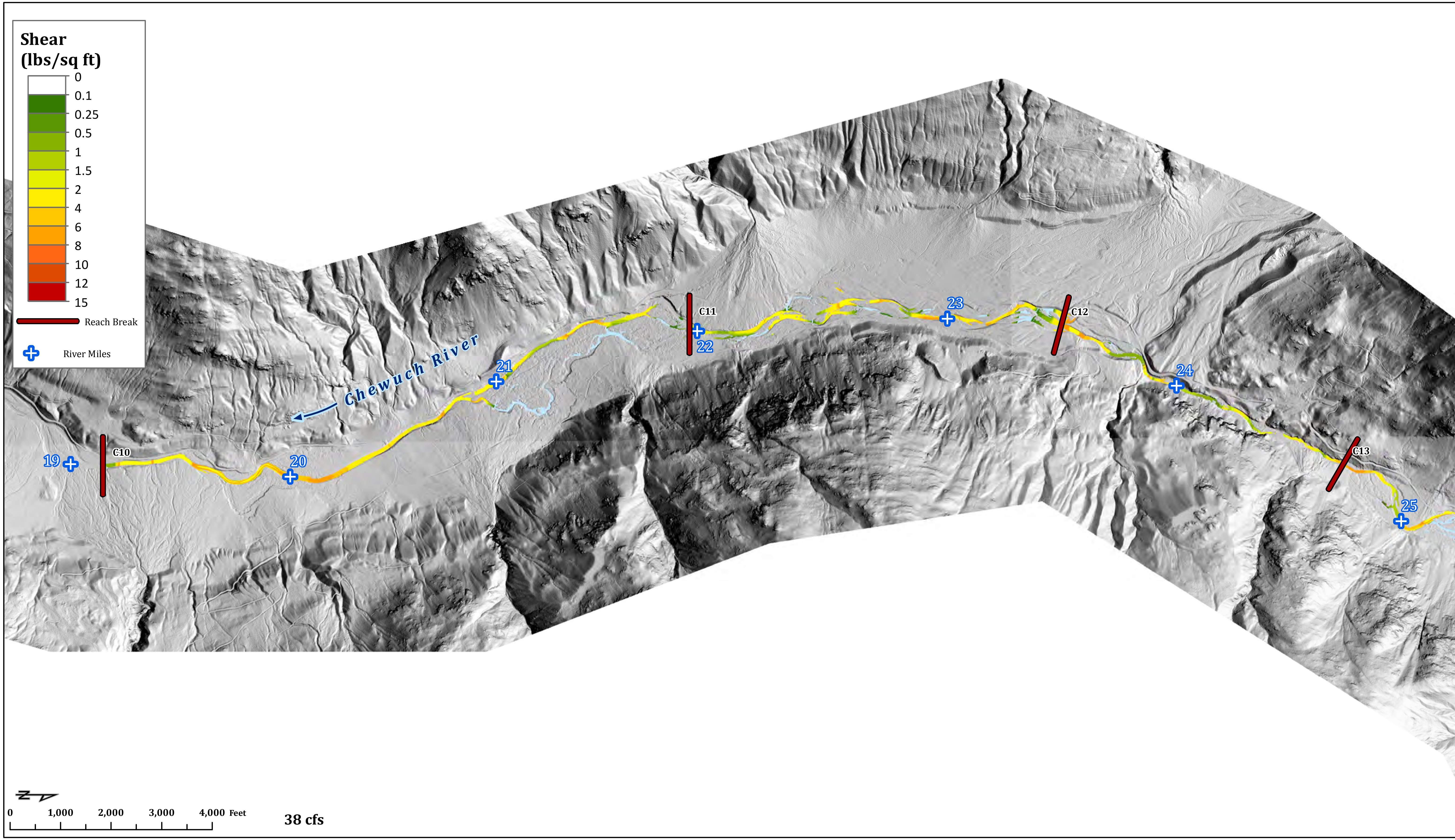
Natural Systems Design



100-year

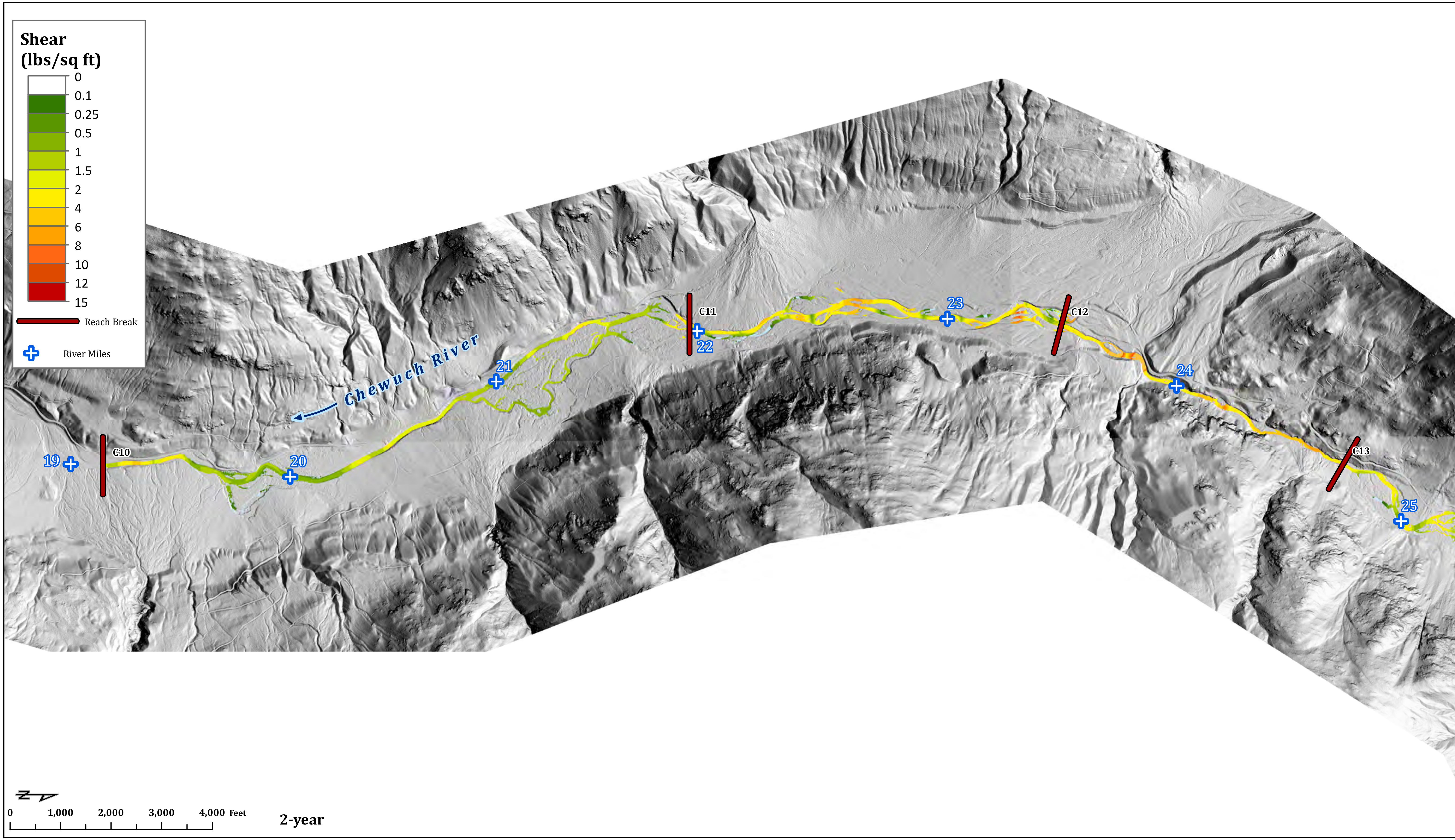
Yakama Nation Fisheries

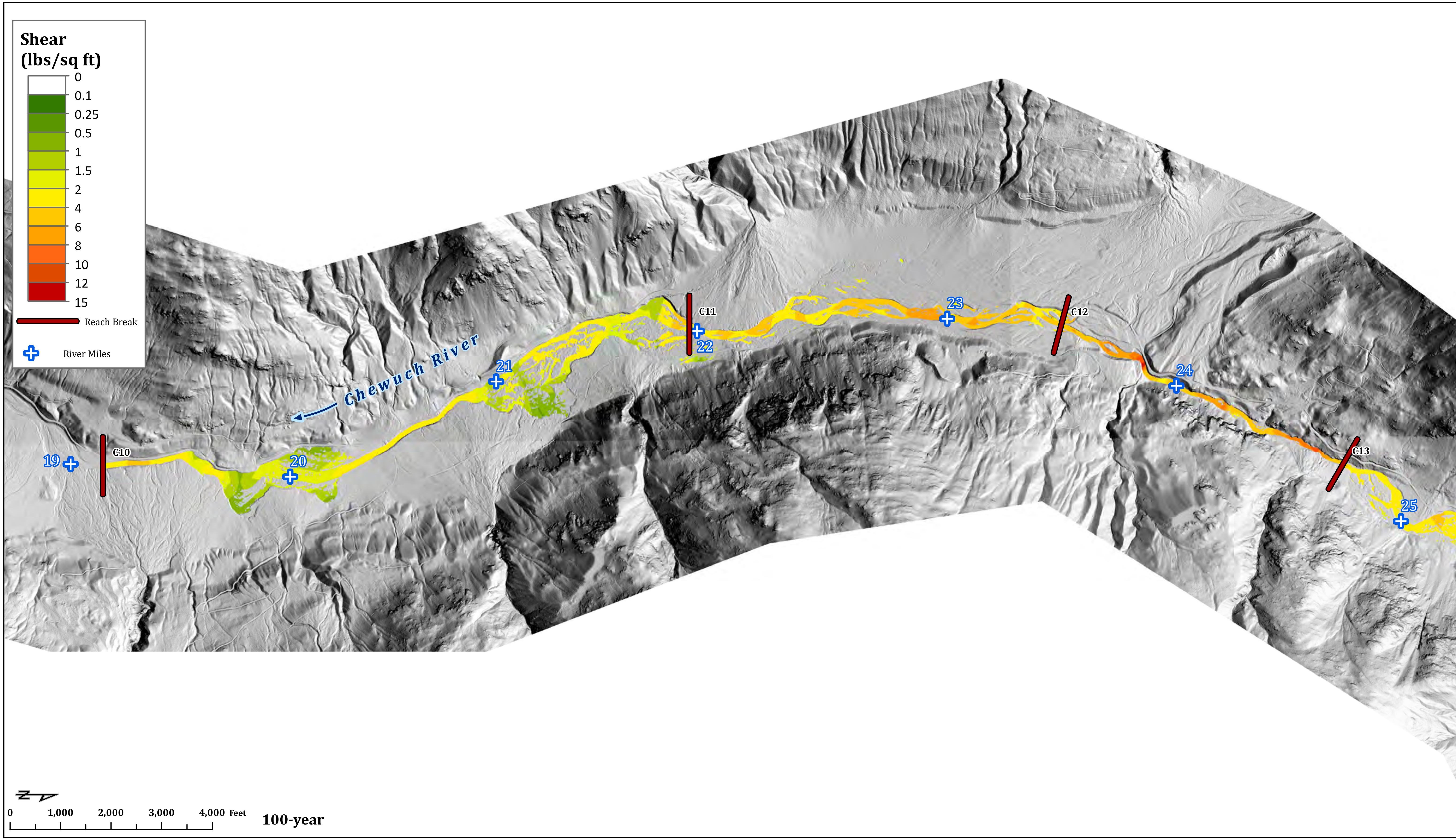
Natural Systems Design



Yakama Nation Fisheries

Natural Systems Design


Shear
(lbs/sq ft)
0
0.1
0.25
0.5
1
1.5
2
4
6
8
10
12
15
Reach Break
River Miles
Chewuch River
19
20
21
22
23
24
25
C10
C11
C12
C13
0
1,000
2,000
3,000
4,000
Feet
2-year



Yakama Nation Fisheries

Natural Systems Design