

Appendix A

REI Analysis Details

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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/mi², 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/mi², which is still within adequate condition.

Boulder Creek Watershed Condition: At risk

Road density for the Boulder Creek Watershed is 1.8 mi/mi² 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 Winthrop, 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 shift 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).

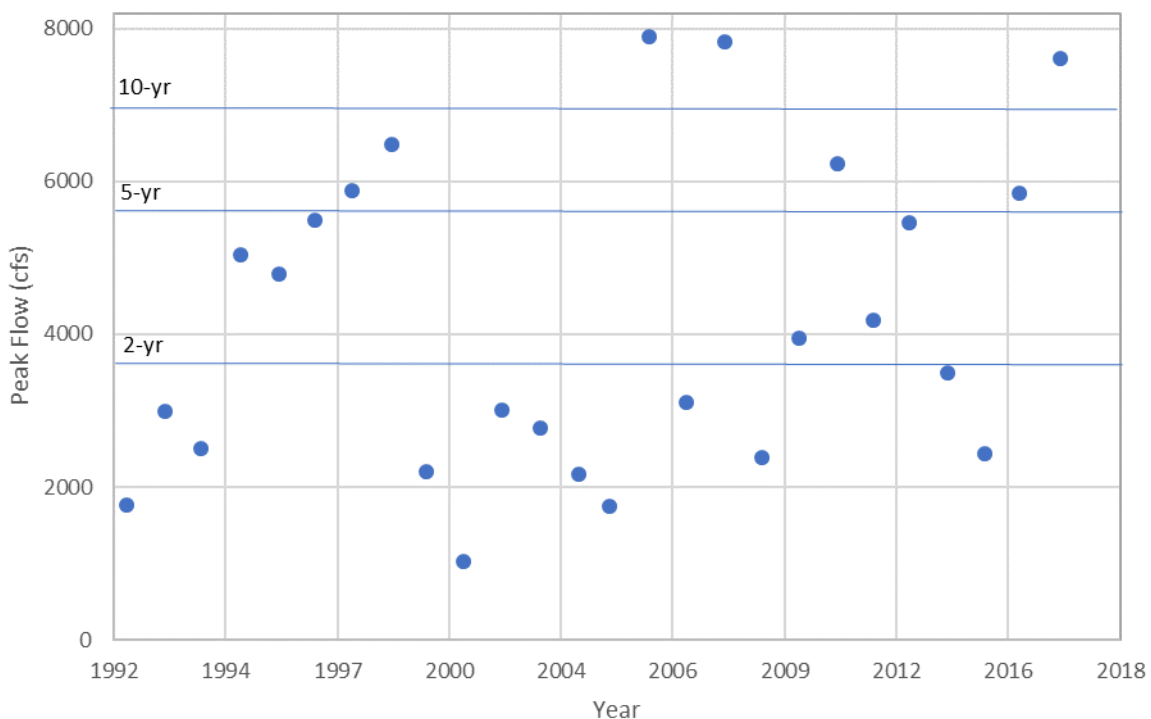


Figure 1. Peak flows for the Chewuch River from USGS gage 12448000 with 2, 5, and 10 year flows indicated in solid blue lines.

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

SUBSTRATE 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
Unacceptable	Unacceptable	Adequate	Adequate	At Risk	Unacceptable	Unacceptable	At Risk	Unacceptable

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	CHEWUC H C10	CHEWUC H C11	CHEWUC H C12	CHEWUC H 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	CHEWUC H C10	CHEWUC H C11	CHEWUC H C12	CHEWUC H 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	Unacceptable	Unacceptable	Adequate	Unacceptable	Unacceptable	Unacceptable	At Risk	Unacceptable

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 Channel in C10 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	Unacceptable

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
Unacceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable

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	Unacceptable	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/mi ² 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/mi ² 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/mi ² 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	Unacceptable	At Risk	Unacceptable	Unacceptable

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 \geq 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.

6. REFERENCES

- Beechie, T., H. Imaki, J. Greene, A. Wade, H. Wu, G. Pess, P. Roni, J. Kimball, J. Stanford, P. Kiffney, and N. Mantua. 2013. Restoring salmon habitat for a changing climate. River Research and Applications 29:939-960.
- Bureau of Reclamation and U.S. Army Corps of Engineers (USBOR and USACE). 2015. National Large Wood Manual: Assessment, Planning, Design, and Maintenance of Large Wood in Fluvial Ecosystems: Restoring Process, Function, and Structure. 628 pages + Appendix. Available: www.usbr.gov/pn/
- R. Crawford. 2003. Riparian Vegetation Classification of the Columbia Basin, Washington. Washington Department of Natural Resources Natural Heritage Report 2003-03. Olympia, WA. 124 p.
- Fox, M. and S. Bolton. 2007. A Regional and Geomorphic Reference for Quantities and Volumes of Instream Wood in Unmanaged Forested Basins of Washington State. North American Journal of Fisheries Management 27: 342-359.
- Gaines, W. L., D. W. Peterson, C. A. Thomas, and R. J. Harrod. 2012. Adaptations to Climate Change: Colville and Okanogan-Wenatchee National Forests. United States Forest Service, Pacific Northwest Research Station. General Technical Report PNW-GTR-862.
- Hillman, T.W. and A. E. Giorgi. 2002. Monitoring Protocols: Effectiveness Monitoring of Physical/Environmental Indicators in Tributary Habitats. BioAnalysts, Inc. Prepared for Bonneville Power Administration.

- Inter-Fluve. 2010. Chewuch River Reach Assessment. Prepared for the Yakama Nation Fisheries Program, Toppenish, WA. 172 p.
- Kondolf, G. M., M. G. Wolman. 1993. The sizes of salmonid spawning gravels. *Water Resources Research*. 29:7, pp. 2275-2285.
- Mantua, N., I. Tohver, and A. Hamlet. 2010. Climate change impacts on streamflow extremes and summertime stream temperature and their possible consequences for freshwater salmon habitat in Washington State. *Climatic Change* vol 102: 187-223.
- Montgomery, D. R., J. M Buffington, R. D. Smith, K. M. Schmidt, and G. Pess. 1995. Pool spacing in forest channels. *Water Resources Research*. Vol 31 No 4. Pp 1097-1105.
- Moore, R. D., D. L. Spittlehouse, and A. Story. 2005. Riparian microclimate and stream temperature response to forest harvesting: a review. *Journal of American Water Resources Association*. 41(4): 813-834.
- NMFS (National Marine Fisheries Service). 1996. Making Endangered Species Act determinations of effect for individual or grouped actions at the watershed scale. Lacey, Washington. National Marine Fisheries Service, Environmental and Technical Services Division, Habitat Conservation Branch.
- Northwest Power and Conservation Council (NPCC). 2004. Methow Subbasin Plan. Portland, OR. 814 p.
- Quinn, T. 2005. *The behavior and ecology of Pacific Salmon and Trout*. 1st edition. American Fisheries Society and University of Washington Press.
- Reid, L. M., T. Dunne, and C. J. Cederholm. 1981. Application of sediment budget studies to the evaluation of logging road impact. University of Washington, Seattle, WA
- Roni, P., T. J. Beechie, R. E. Bilby, F. E. Leonetti, M. M. Pollock, G. R. Pess. 2002. A Review of Stream Restoration Techniques and a Hierarchical Strategy for Prioritizing Restoration in Pacific Northwest Watersheds. *North American Journal of Fisheries Management* 22 pp 1-20
- Shakesby, R. A. and S. H. Doerr. 2006. Wildfire as a hydrological and geomorphological agent. *Earth-Science Reviews* 74: 269-307.
- Sommer, T. R., M. L. Nobriga, W. C. Harrell, W. Batham, and W. J. Kimmerer. 2001. Floodplain rearing and juvenile chinook salmon: evidence of enhanced growth and survival. *Canadian Journal of Fisheries and Aquatic Resources* 58(2): 325-333.
- Upper Columbia Regional Technical Team (UCRTT). 2017. A biological strategy to protect and restore salmonid habitat in the Upper Columbia Region. A draft report to the Upper Columbia Salmon Recovery Board.
- USDA Forest Service (USFS). 2007. Biological Assessment for Steelhead, Spring Chinook, and Bull Trout in the Chewuch Watershed Okanogan County, Washington. Baseline Conditions and Effects of Tripod Suppression, Suppression restoration, and BAER. Revision #4. Methow Valley and Tonasket Ranger Districts. Okanogan and Wenatchee National Forests.
- USFWS (U.S. Fish and Wildlife Service). 1998. A framework to assist in making Endangered Species Act determinations of effect for individual or grouped actions at the bull trout subpopulation scale. USFWS. Department of the Interior.
- Washington Department of Ecology (WA DOE). 2016. Water Quality Standards for Surface Waters of the State of Washington, Chapter 173-201A WAC. Updated August 1, 2016.

Washington Department of Ecology (WA DOE). 2014. Water Quality Listing ID: 77664.

Washington Department of Ecology (WA DOE). 2011. Waters Requiring Supplemental Spawning and Incubation Protection for Salmonid Species. Publication 06-10-038. Revised January 2011.

Appendix B

Project Concepts Map – LiDAR

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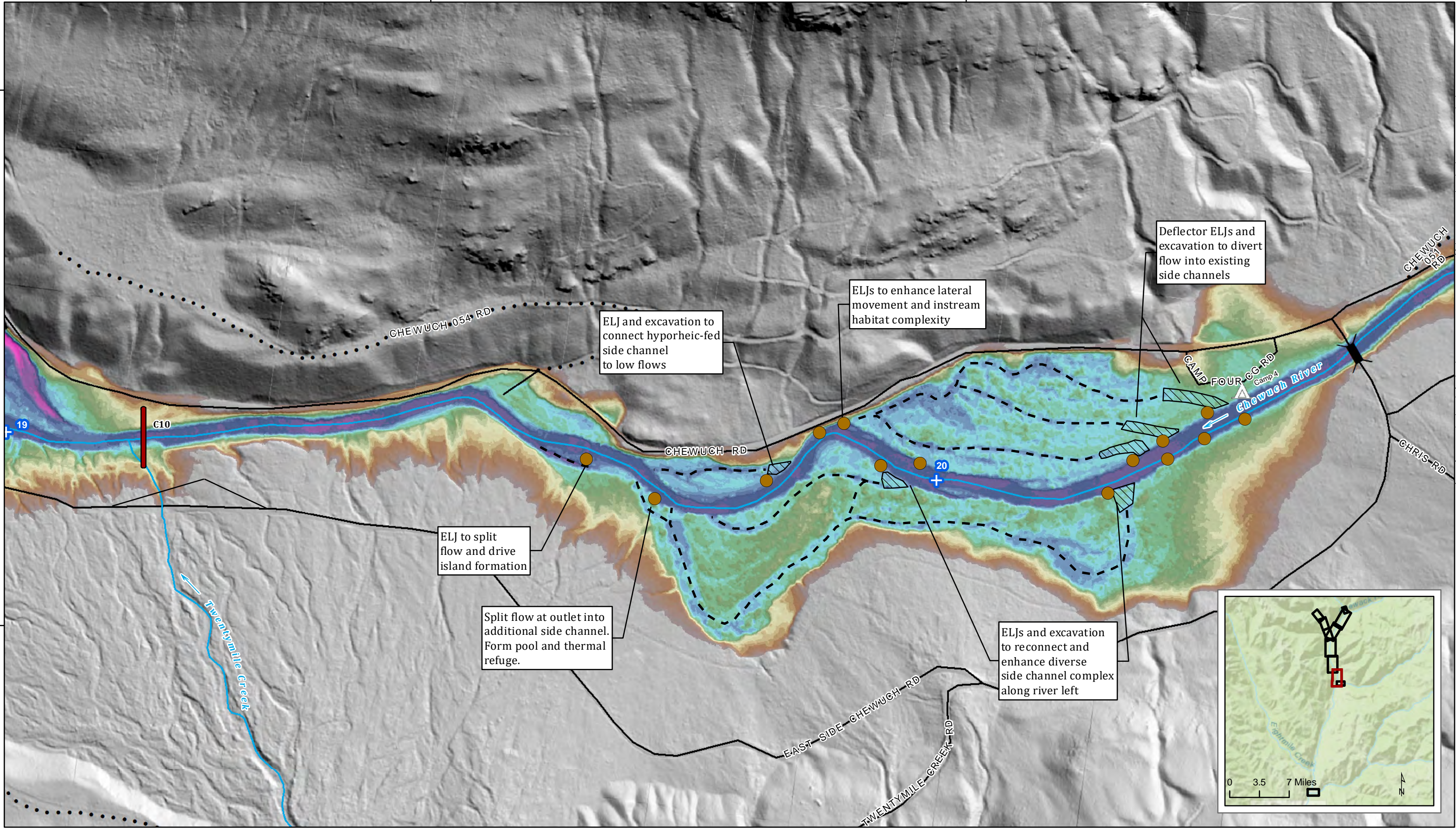
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ELJ to split flow and drive island formation

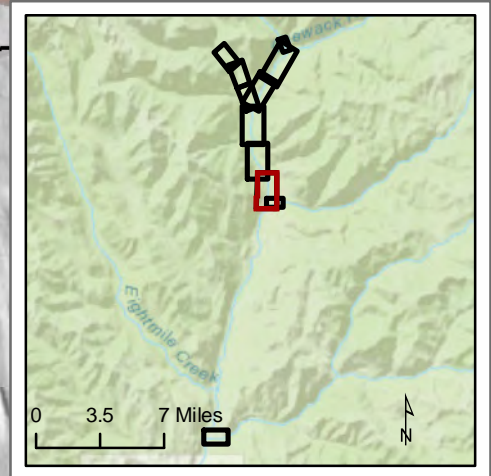
Split flow at outlet into additional side channel. Form pool and thermal refuge.

ELJ and excavation to connect hyporheic-fed side channel to low flows

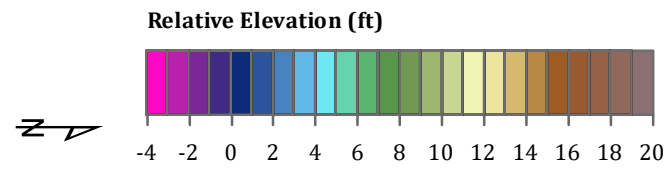
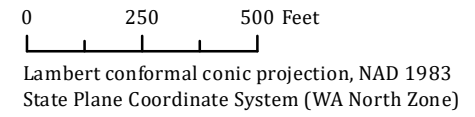
ELJs to enhance lateral movement and instream habitat complexity

Deflector ELJs and excavation to divert flow into existing side channels

ELJs and excavation to reconnect and enhance diverse side channel complex along river left

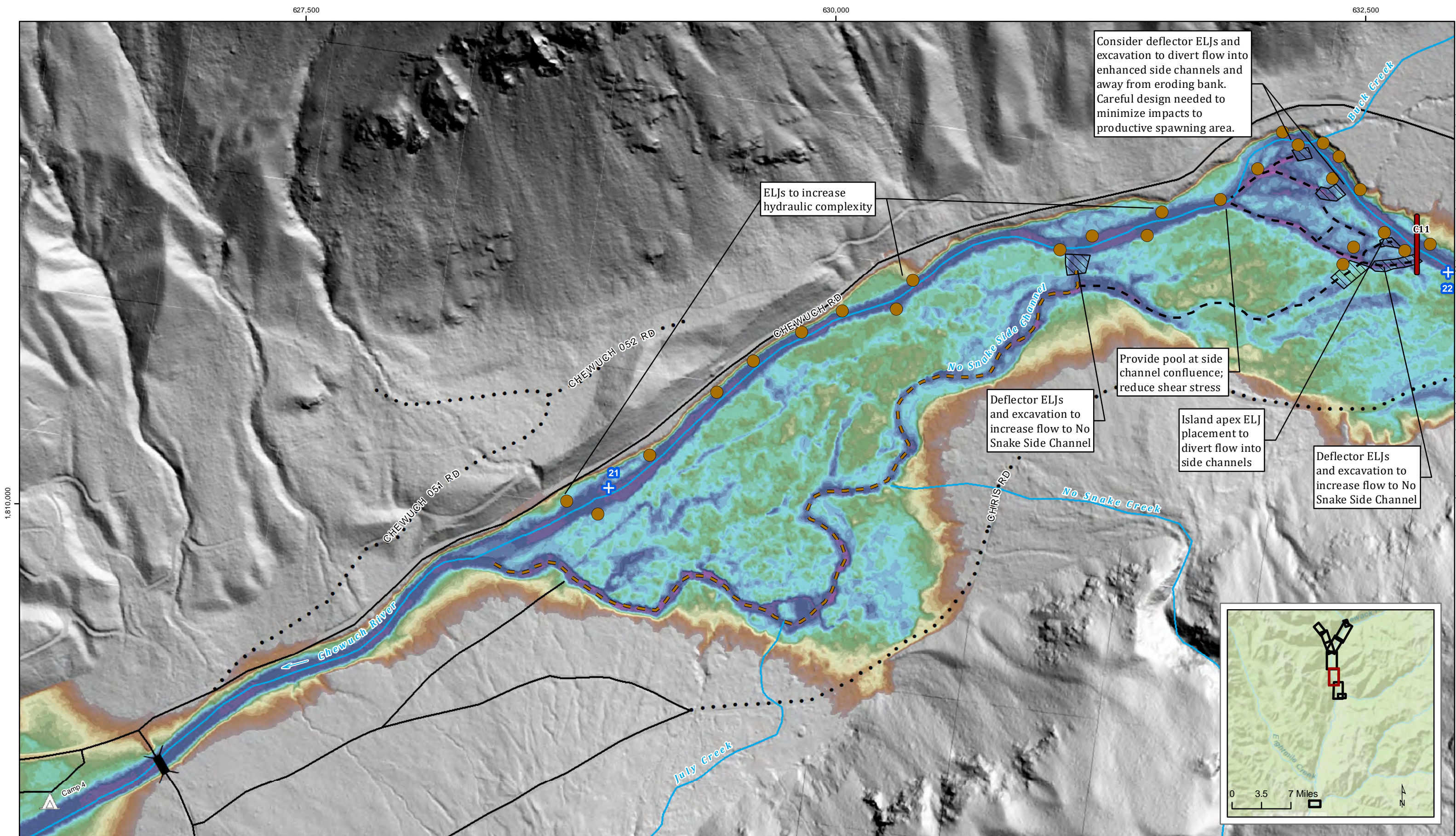


Upper Chewuch Habitat Assessment
Restoration Concepts - Map 1, Chewuch Reach 10a
 Relative elevation is derived as the difference between bare earth elevations and a reference plane representing the low flow water surface. Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).

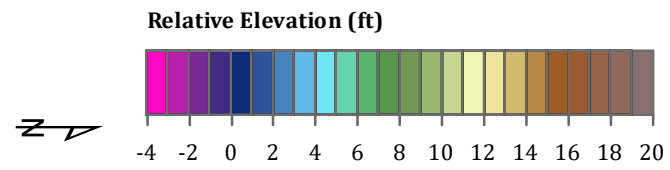
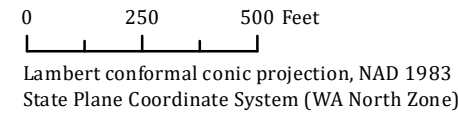


- Machine Placed ELJ
- Channel Excavation
- Road
- Pile Array
- Levee Removal
- Closed Road
- Enhanced Side Channel
- Reach Break
- Unimproved Road
- Loosely Anchored Wood Loading
- River Miles
- Bridge
- Stream

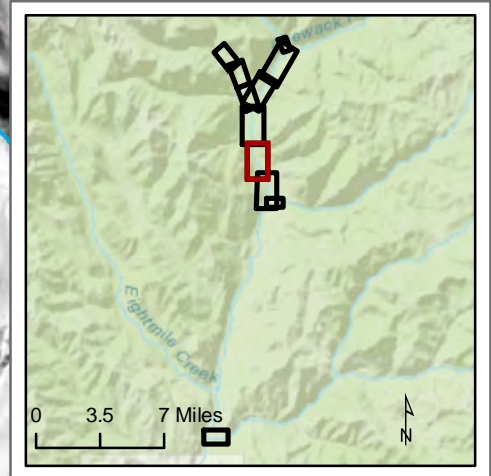




Upper Chewuch Habitat Assessment
Restoration Concepts - Map 2, Chewuch Reach 10b
 Relative elevation is derived as the difference between bare earth elevations and a reference plane representing the low flow water surface. Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).

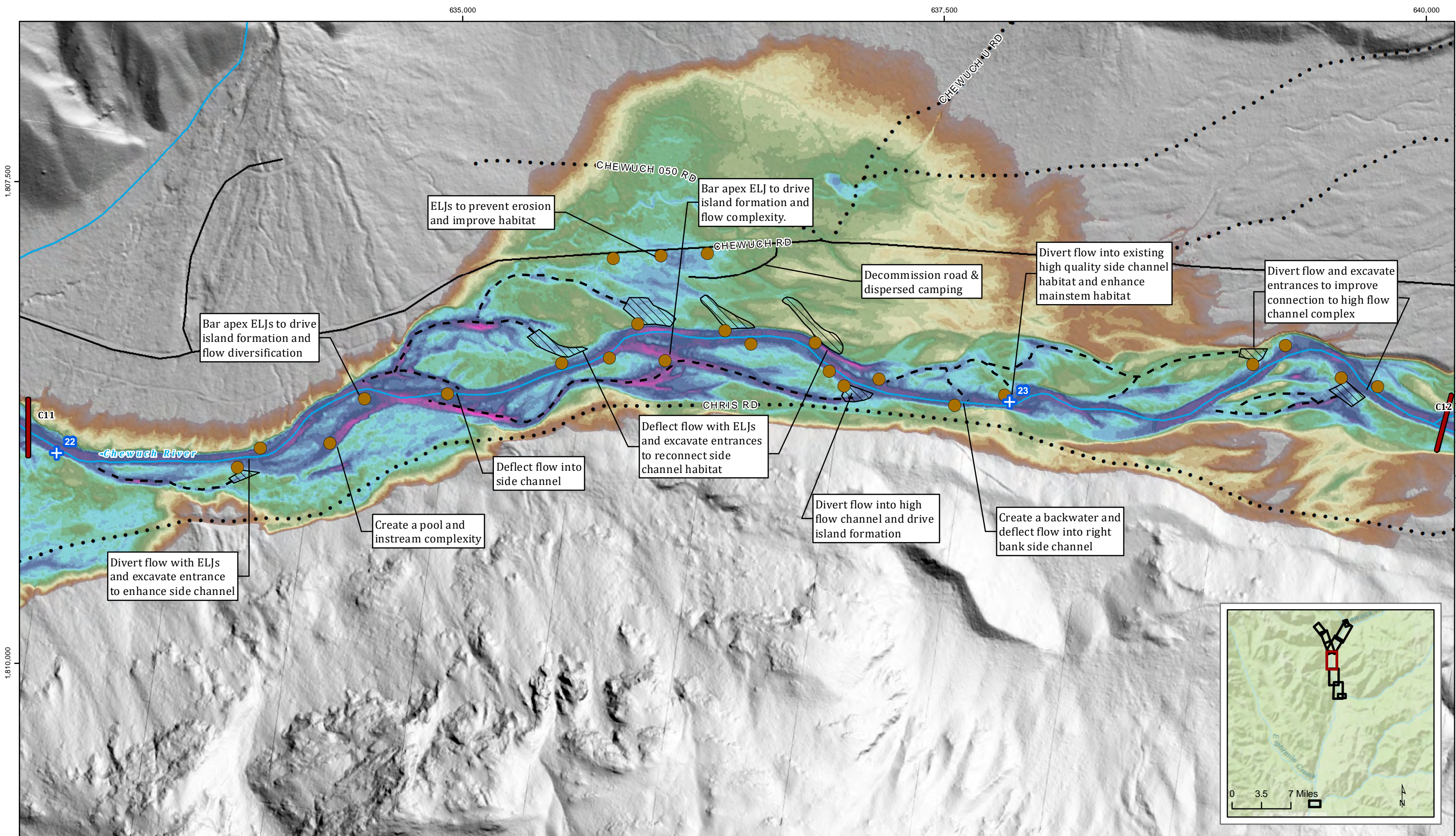


- Machine Placed ELJ
- Pile Array
- Enhanced Side Channel
- Loosely Annotated Wood Loading
- Channel Excavation
- Levee Removal
- Reach Break
- River Miles
- Stream
- Road
- Closed Road
- Unimproved Road
- Bridge

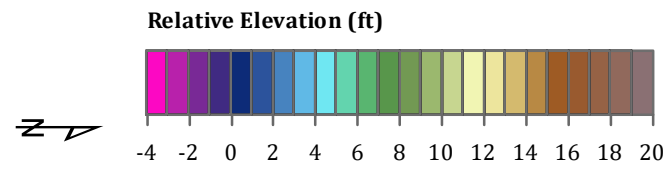
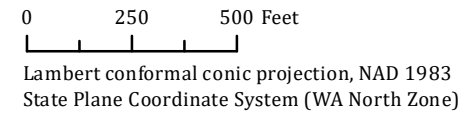


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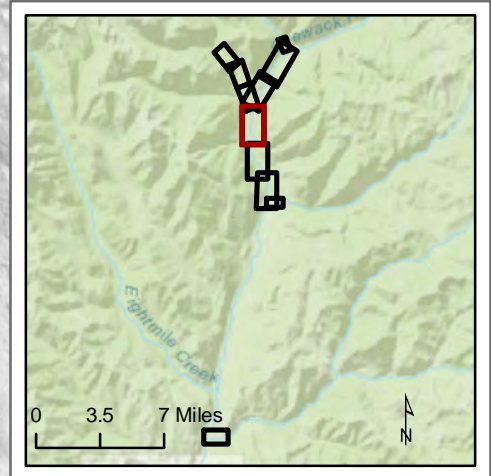




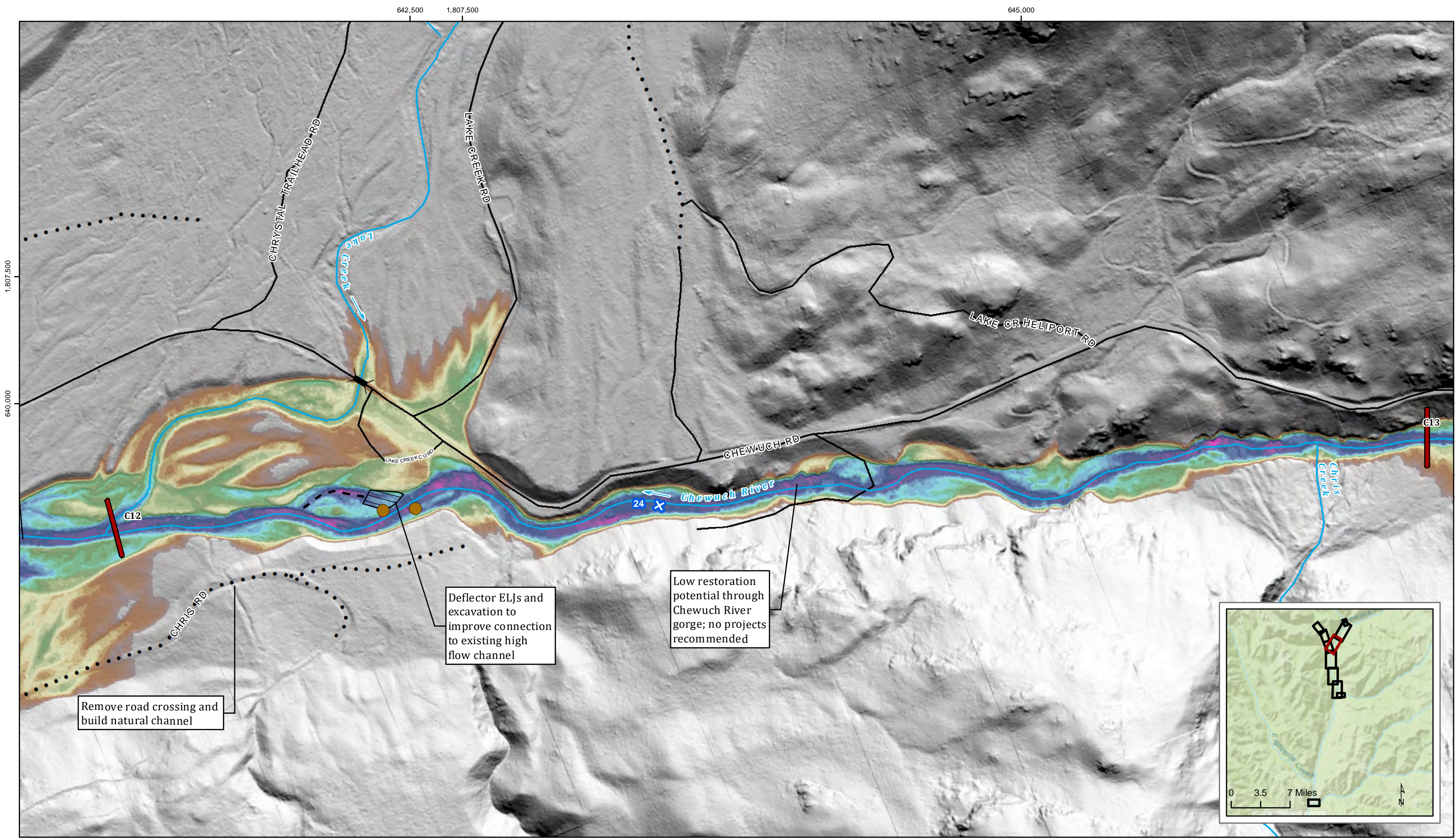
Upper Chewuch Habitat Assessment
Restoration Concepts - Map 3, Chewuch Reach 11
 Relative elevation is derived as the difference between bare earth elevations and a reference plane representing the low flow water surface. Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).



- 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

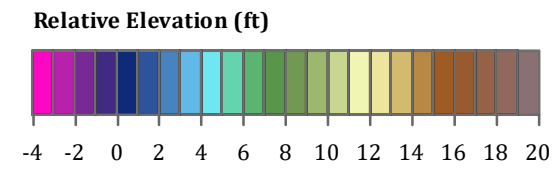
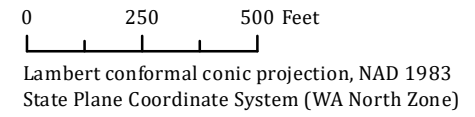


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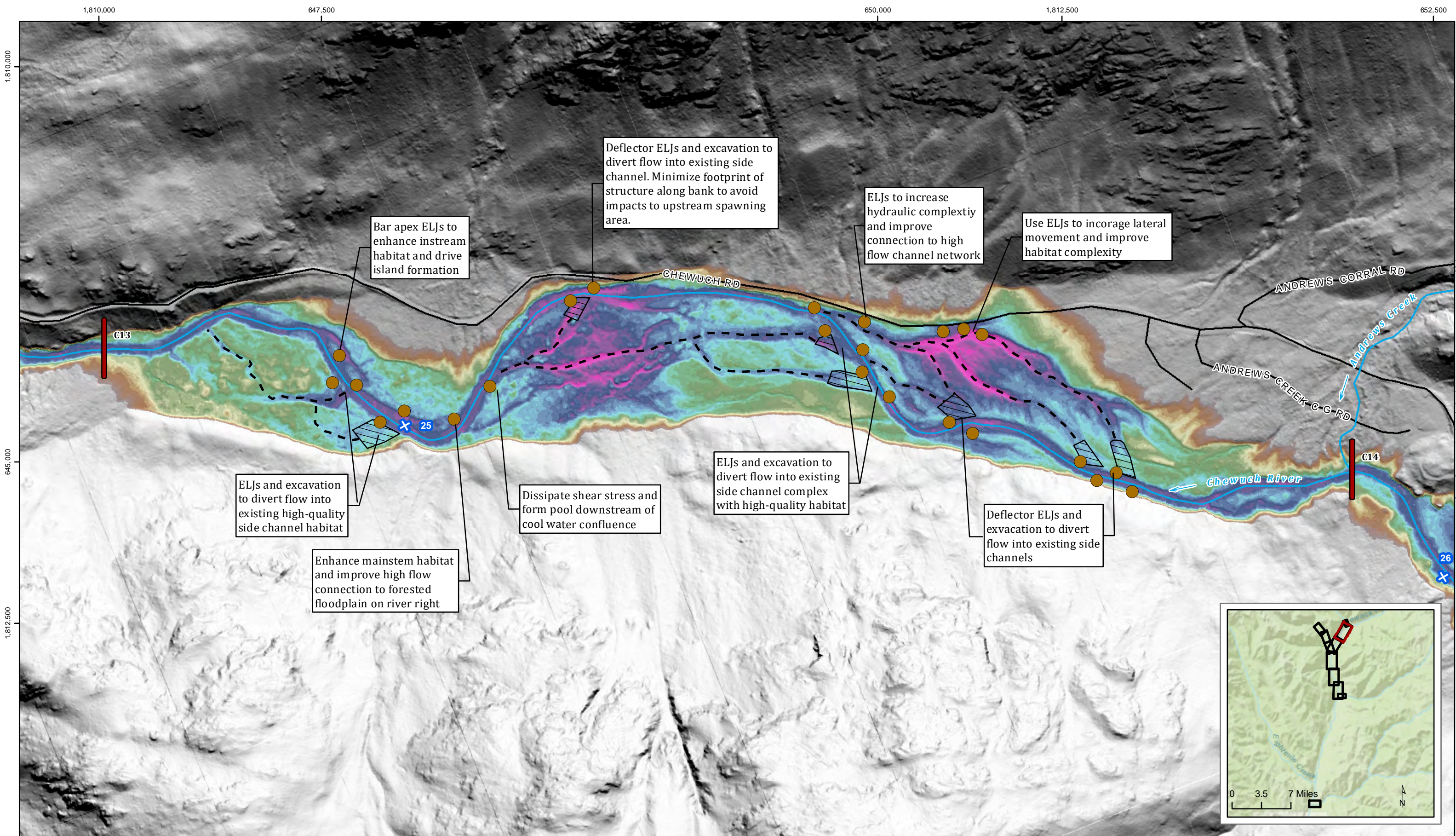
Upper Chewuch Habitat Assessment
Restoration Concepts - Map 4, Chewuch Reach 12

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).



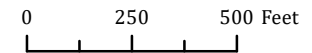
- Machine Placed ELJ
- Pile Array
- Enhanced Side Channel
- Loosely Anchored Wood Loading
- Channel Excavation
- Levee Removal
- Reach Break
- River Miles
- Stream
- Road
- ⋯ Closed Road
- Unimproved Road
- Bridge



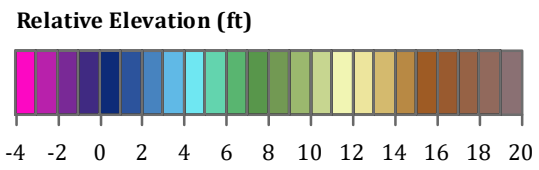


Upper Chewuch Habitat Assessment
Restoration Concepts - Map 5, Chewuch Reach 13

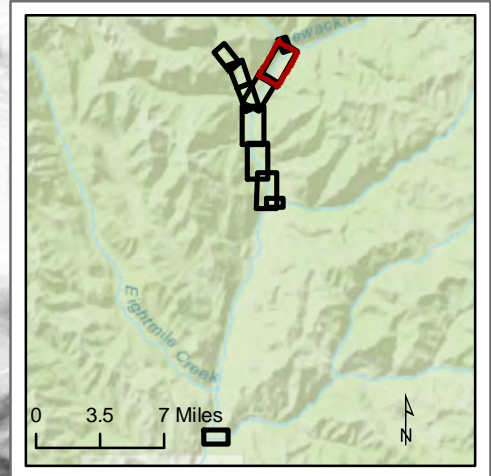
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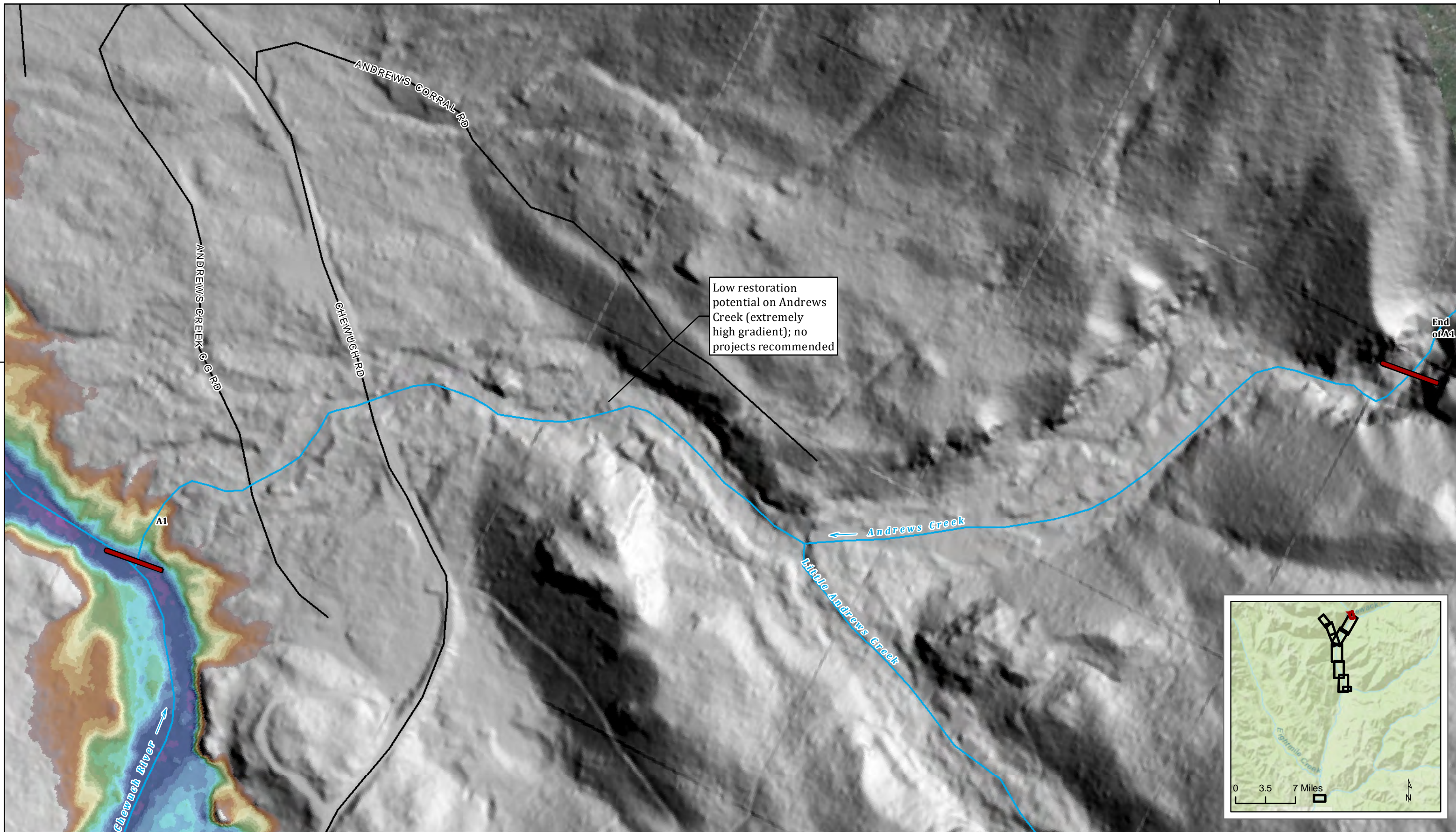


Lambert conformal conic projection, NAD 1983
 State Plane Coordinate System (WA North Zone)



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

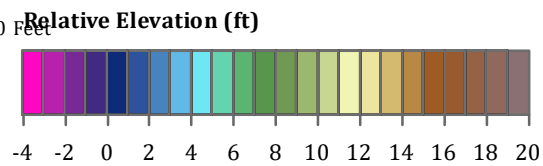
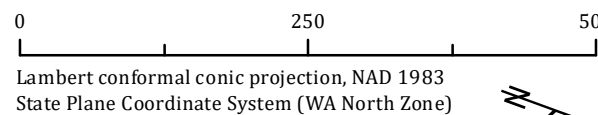




Upper Chewuch Habitat Assessment

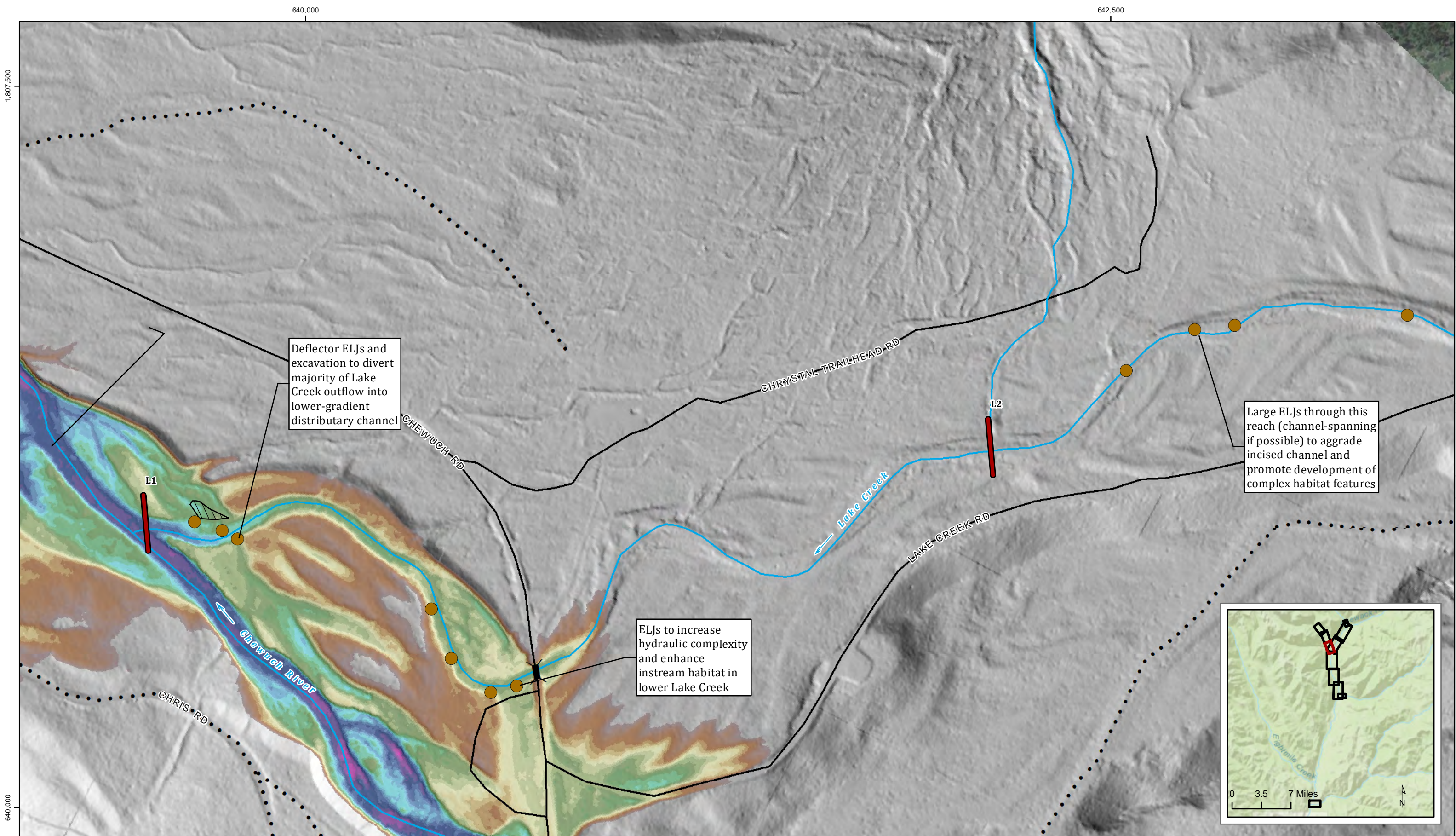
Restoration Concepts - Map 6, Andrews Creek

Relative elevation is derived from 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).



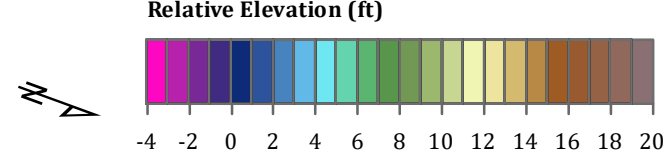
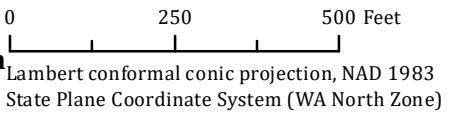
- Machine Placed ELJ
- Pile Array
- Enhanced Side Channel
- Loosely Anchored Wood Loading
- Channel Excavation
- Levee Removal
- Reach Break
- River Miles
- Stream
- Road
- Closed Road
- Unimproved Road
- Bridge





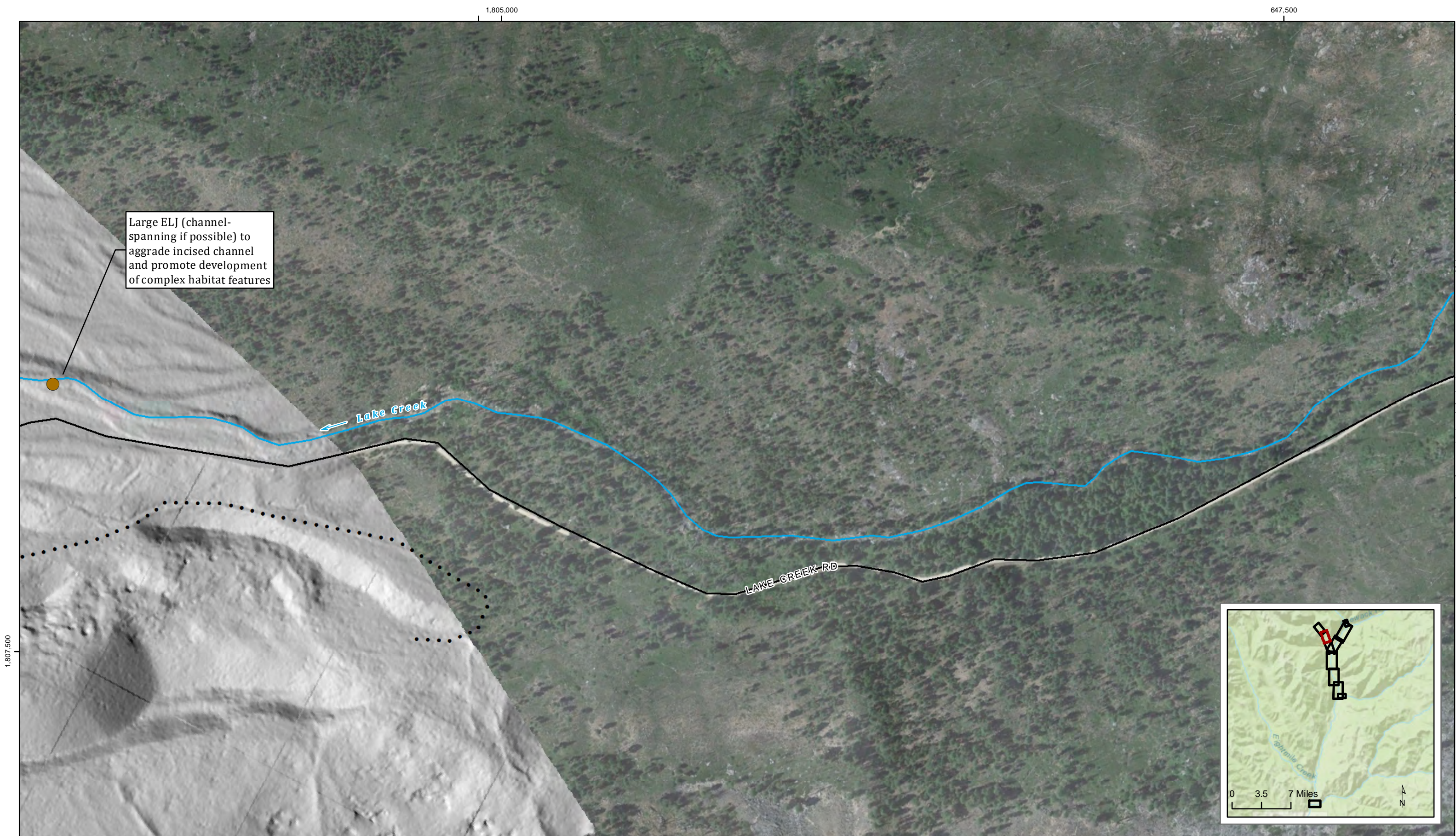
Upper Chewuch Habitat Assessment
Restoration Concepts - Map 7, Lake Creek Reach 1 & 2a

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).



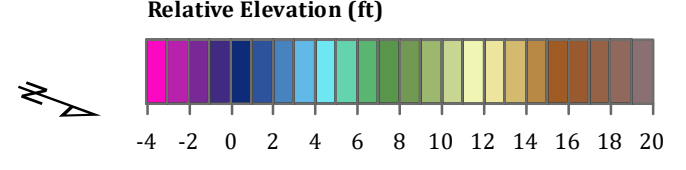
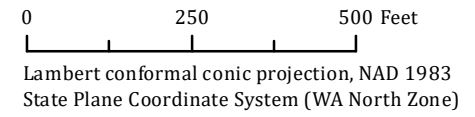
- Machine Placed ELJ
- Channel Excavation
- Road
- Pile Array
- Levee Removal
- Closed Road
- Enhanced Side Channel
- Reach Break
- Unimproved Road
- Loosely Anchored Wood Loading
- River Miles
- Bridge
- Stream



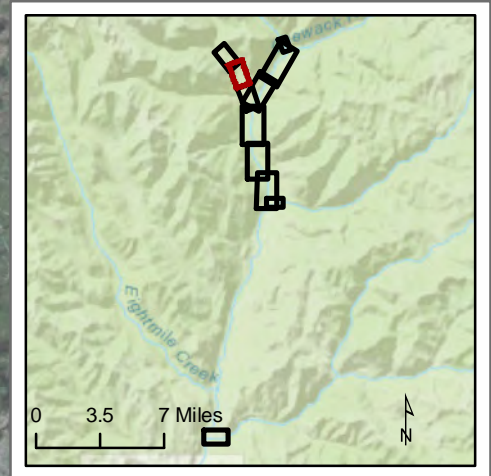


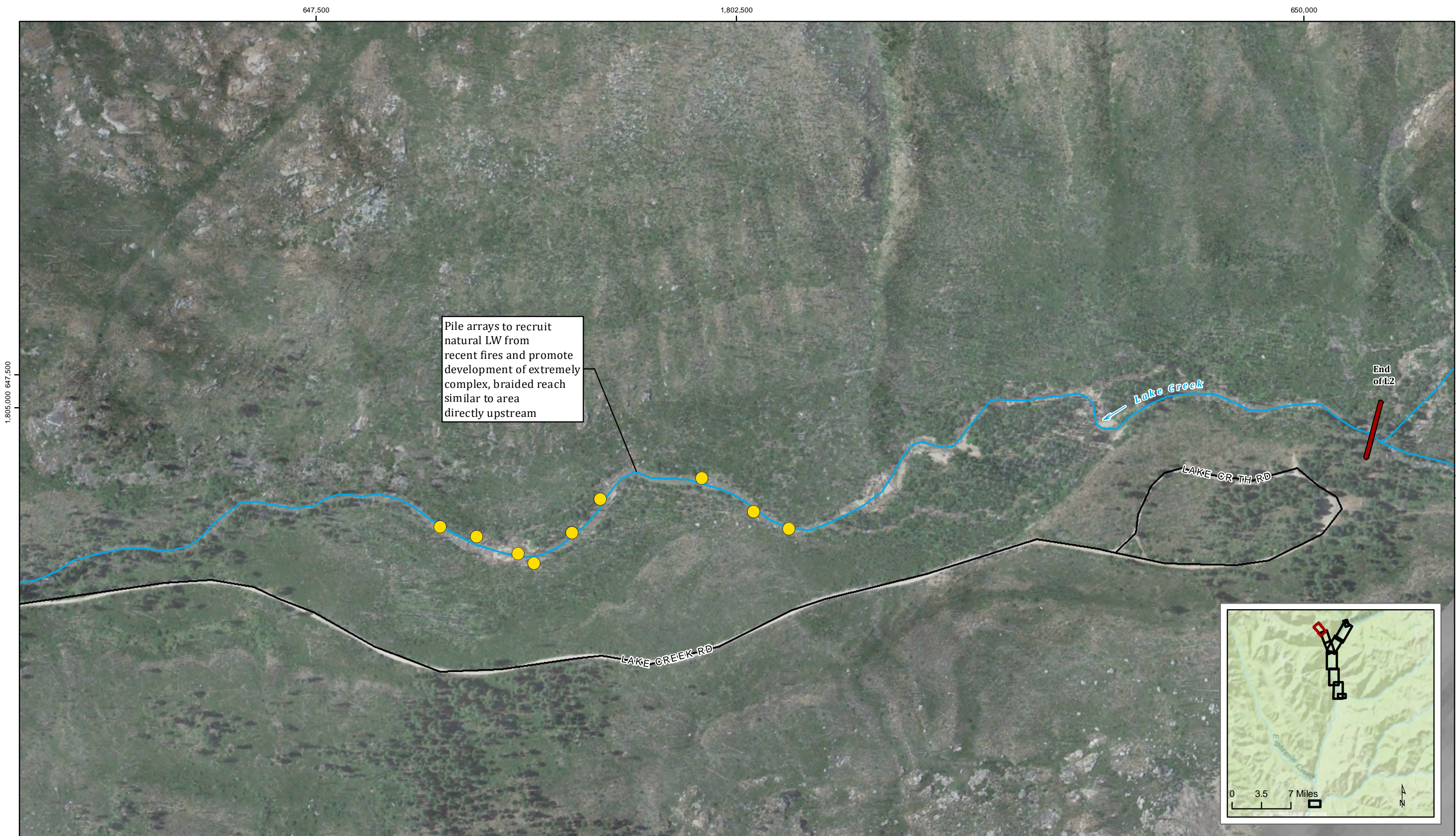
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Upper Chewuch Habitat Assessment
Restoration Concepts - Map 8, Lake Creek Reach 2b
 Relative elevation is derived as the difference between bare earth elevations and a reference plane representing the low flow water surface. Topographic data source: 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).



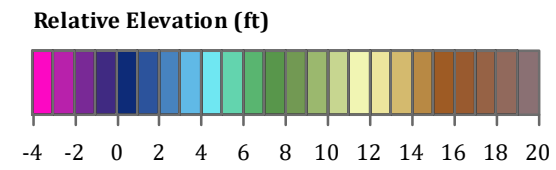
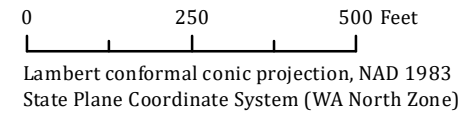
- Machine Placed ELJ
- Pile Array
- Enhanced Side Channel
- Loosely Anchored Wood Loading
- Channel Excavation
- Levee Removal
- Reach Break
- River Miles
- Stream
- Road
- Closed Road
- Unimproved Road
- Bridge



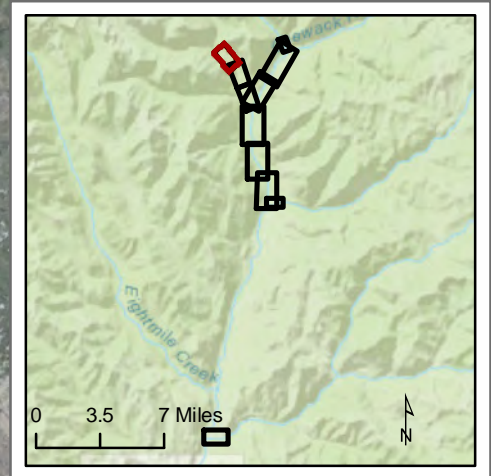


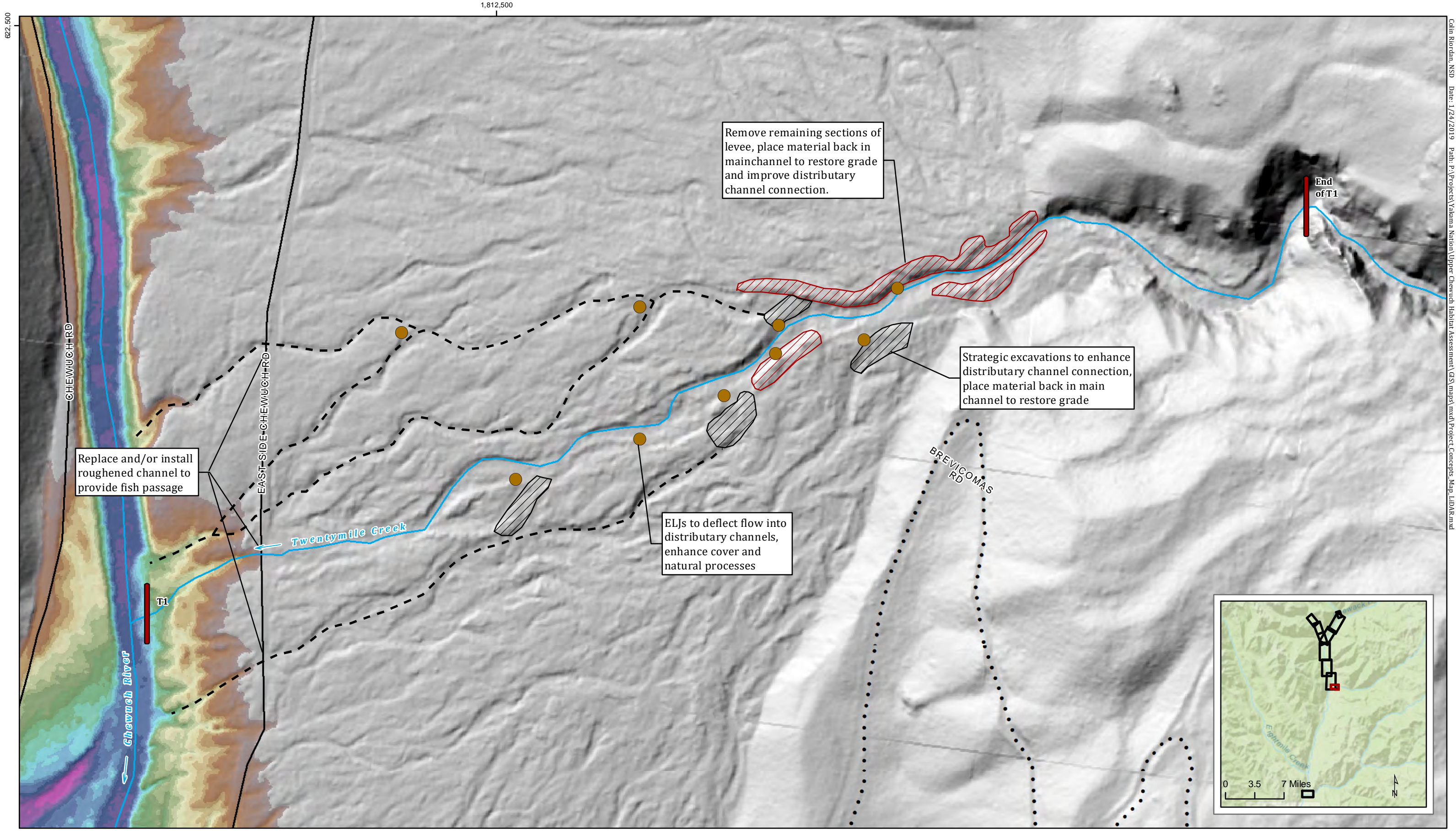
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Upper Chewuch Habitat Assessment
Restoration Concepts - Map 9, Lake Creek Reach 2c
 Relative elevation is derived as the difference between bare earth elevations and a reference plane representing the low flow water surface. Topographic data source: 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).

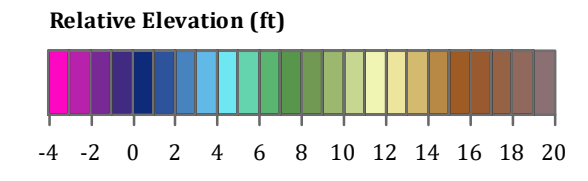
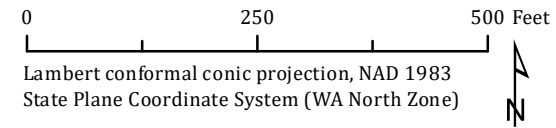


- Machine Placed ELJ
- Pile Array
- Enhanced Side Channel
- Loosely Anchored Wood Loading
- Channel Excavation
- Levee Removal
- Reach Break
- River Miles
- Stream
- Road
- Closed Road
- Unimproved Road
- Bridge



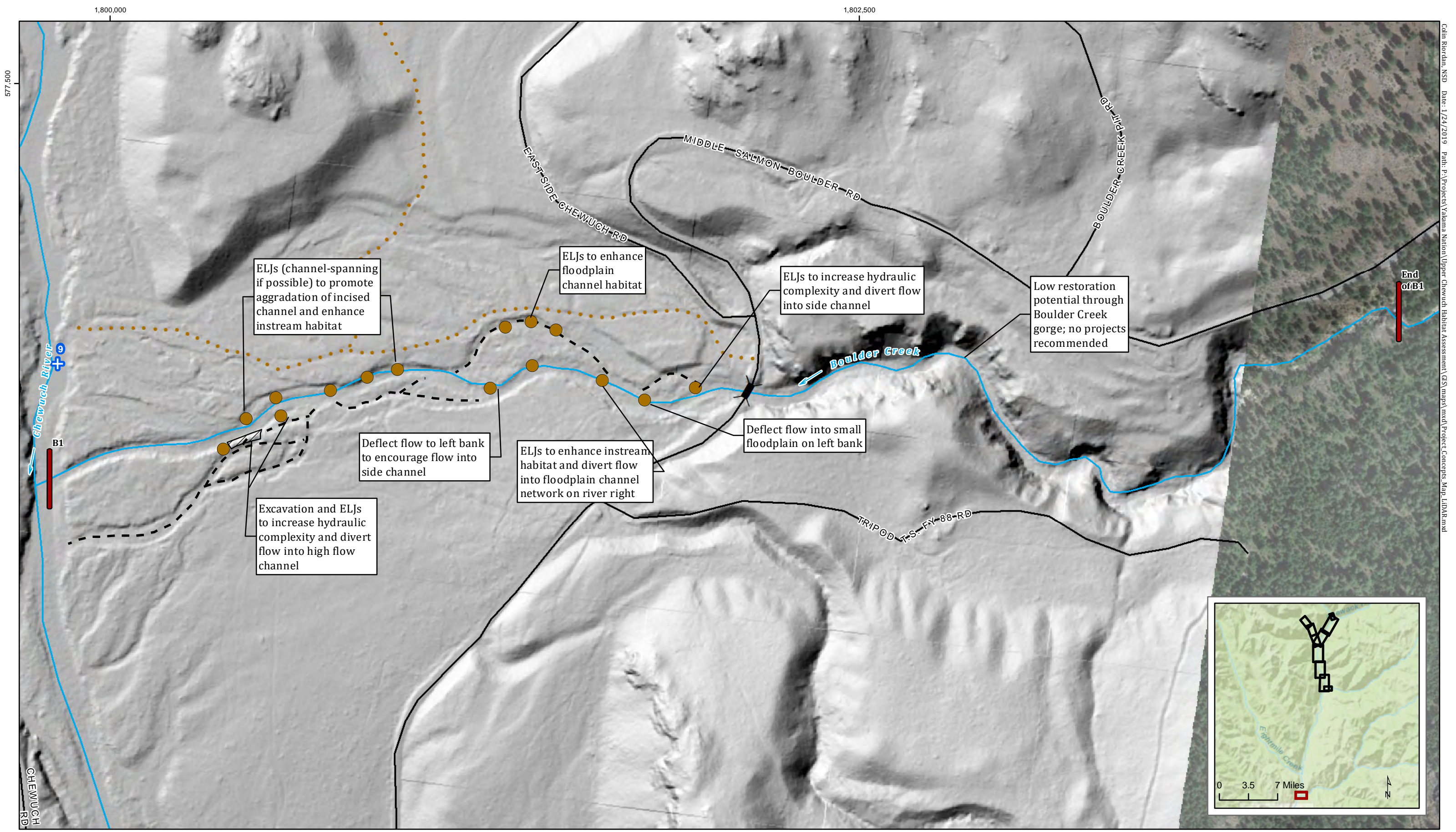


Upper Chewuch Habitat Assessment
Restoration Concepts - Map 10, Twentymile Creek
 Relative elevation is derived as the difference between bare earth elevations and a reference plane representing the low flow water surface. Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).



- 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

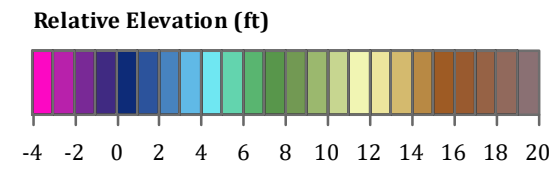
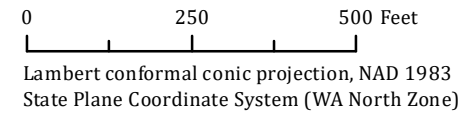




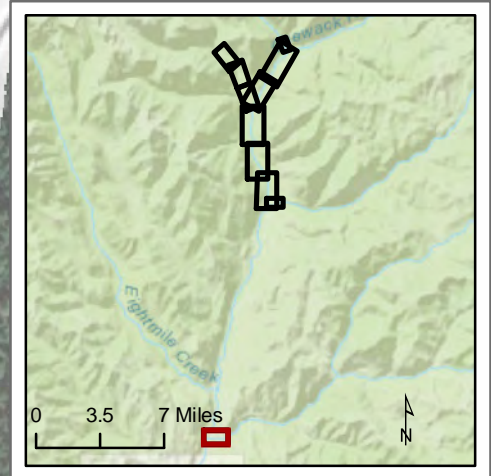
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Upper Chewuch Habitat Assessment
Restoration Concepts - Map 11, Boulder Creek

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).



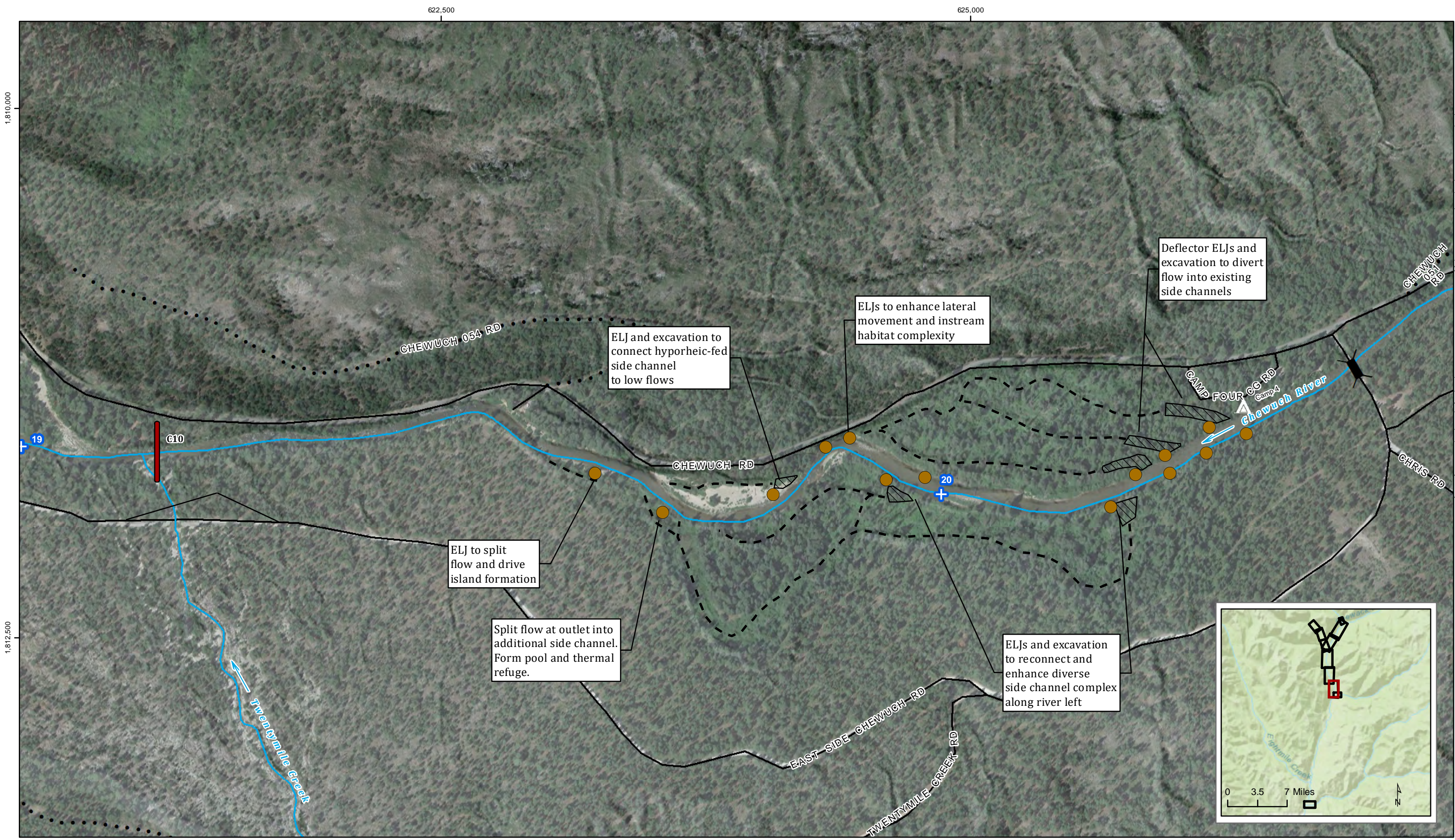
- Machine Placed ELJ
- Pile Array
- Enhanced Side Channel
- Loosely Anchored Wood Loading
- Channel Excavation
- Levee Removal
- Reach Break
- River Miles
- Stream
- Road
- Closed Road
- Unimproved Road
- Bridge



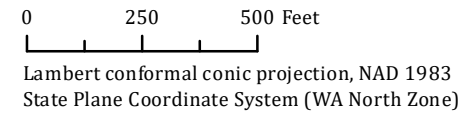
Appendix B

Project Concepts Map – Aerial

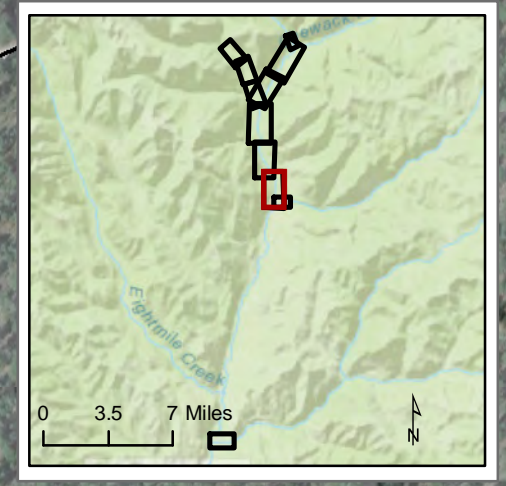
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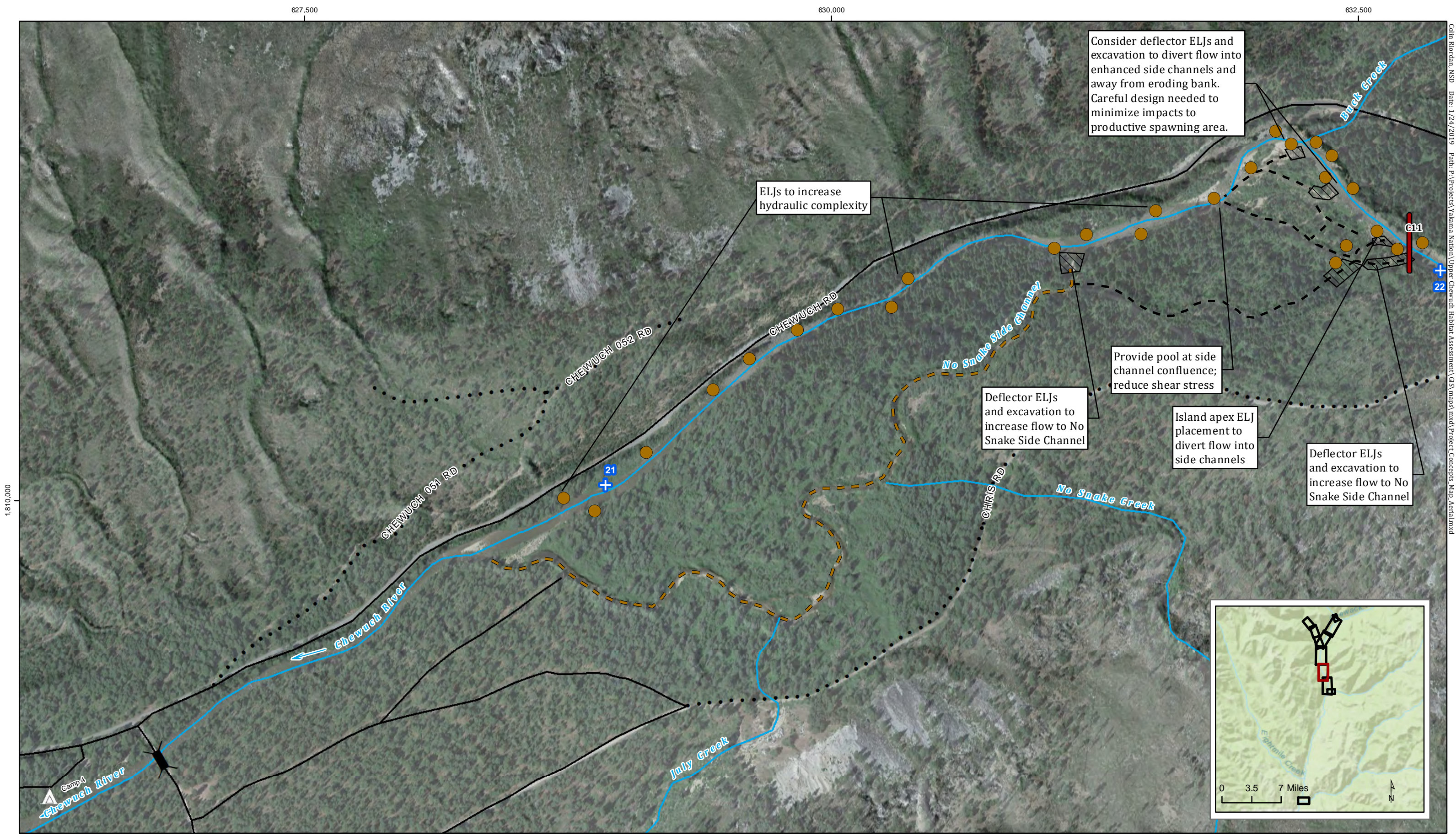


Upper Chewuch Habitat Assessment
Restoration Concepts - Map 1, Chewuch Reach 10a
 Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).



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

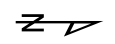




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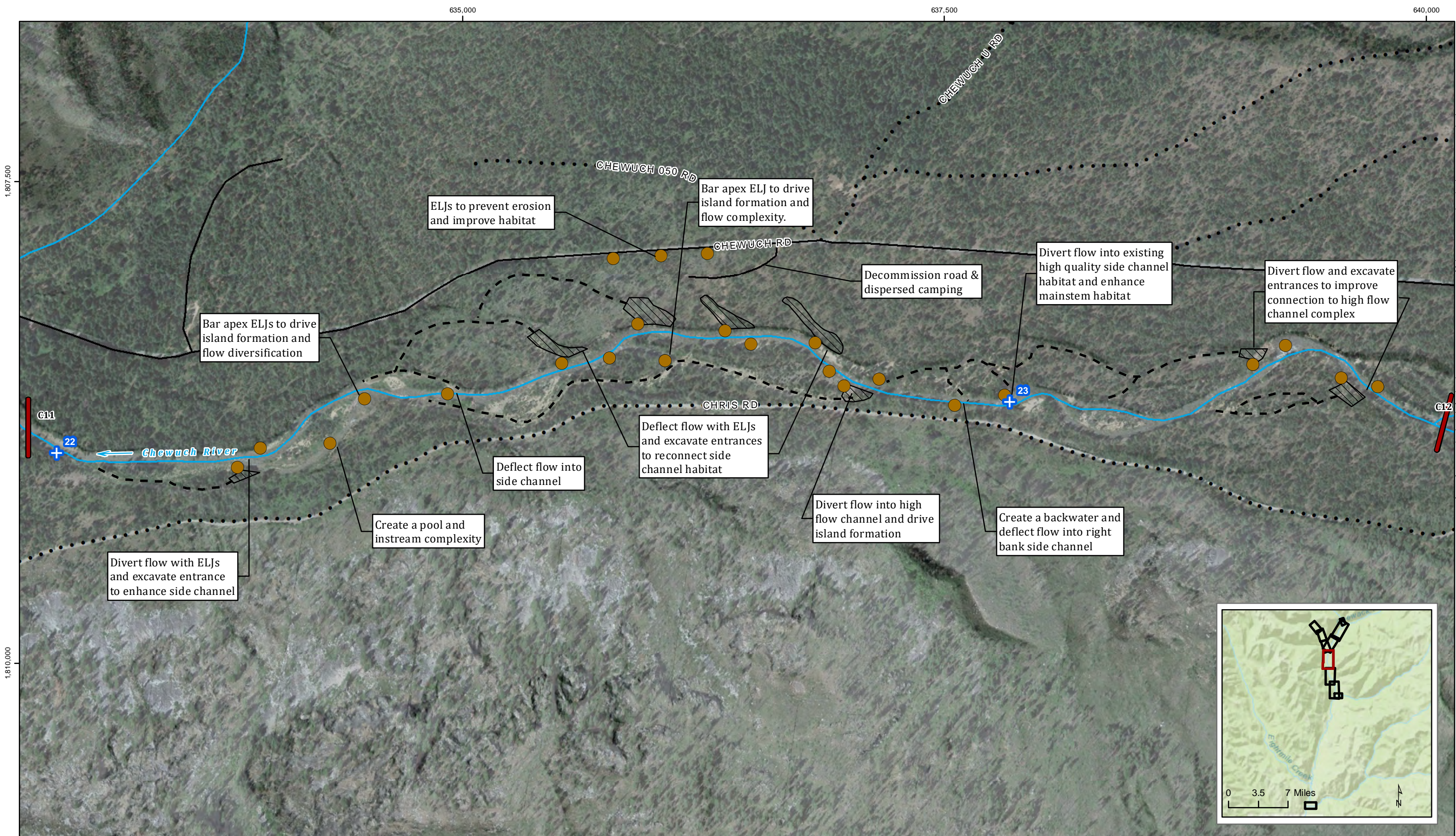
Upper Chewuch Habitat Assessment
Restoration Concepts - Map 2, Chewuch Reach 10b
 Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).

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

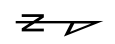




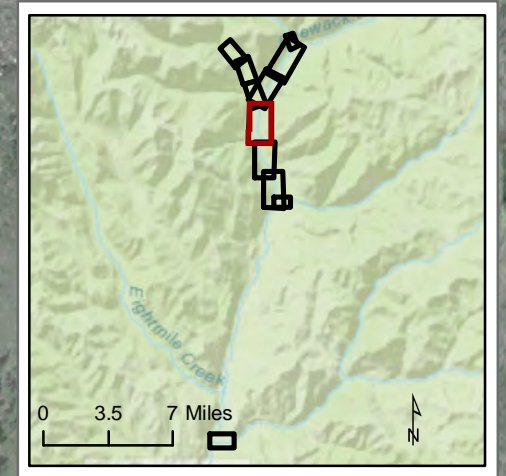
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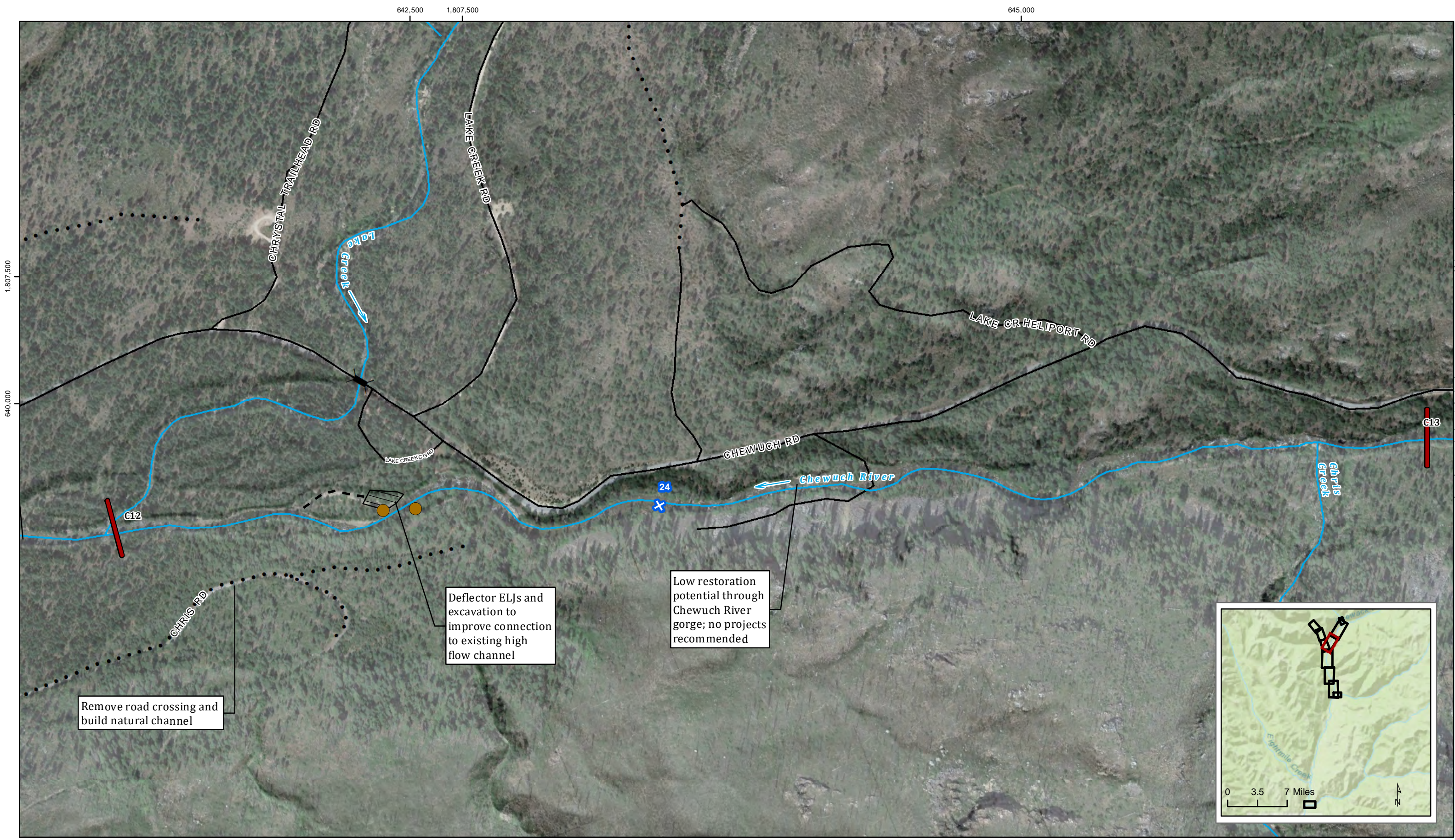
Upper Chewuch Habitat Assessment
Restoration Concepts - Map 3, Chewuch Reach 11
 Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).

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





Remove road crossing and build natural channel

Deflector ELJs and excavation to improve connection to existing high flow channel

Low restoration potential through Chewuch River gorge; no projects recommended

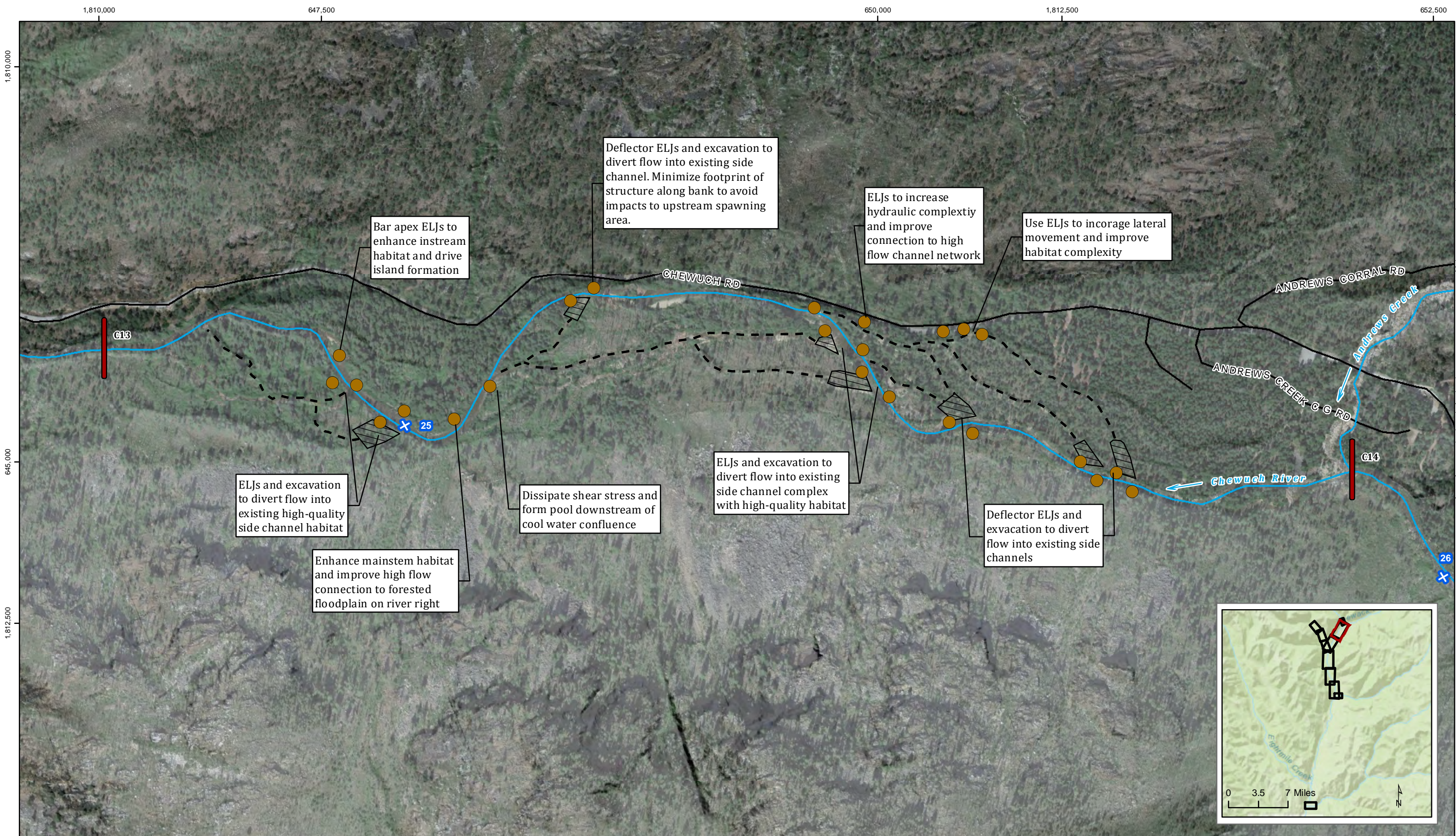
Upper Chewuch Habitat Assessment
Restoration Concepts - Map 4, Chewuch Reach 12
 Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).

0 250 500 Feet
 Lambert conformal conic projection, NAD 1983
 State Plane Coordinate System (WA North Zone)



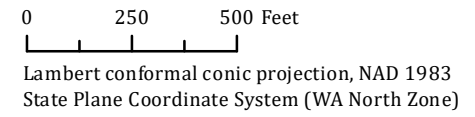
- Machine Placed ELJ
- Channel Excavation
- Road
- Pile Array
- Levee Removal
- Closed Road
- Enhanced Side Channel
- Reach Break
- Unimproved Road
- Loosely Anchored Wood Loading
- River Miles
- Bridge
- Stream





Cabin Riordan, NSD Date: 1/24/2019 Path: P:\Projects\Yakama Nation\Upper Chewuch Habitat Assessment\GIS\maps\mxd\Project_Concepts_Map_Aerial.mxd

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).



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

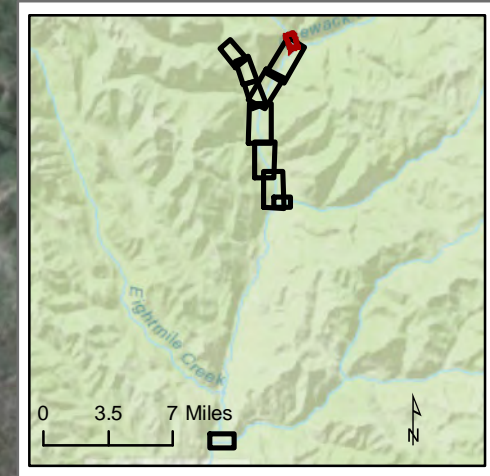


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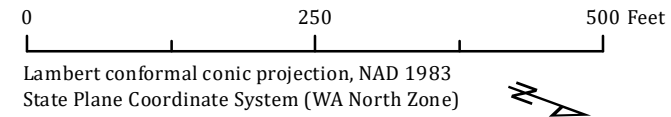


Low restoration potential on Andrews Creek (extremely high gradient); no projects recommended

End of A1

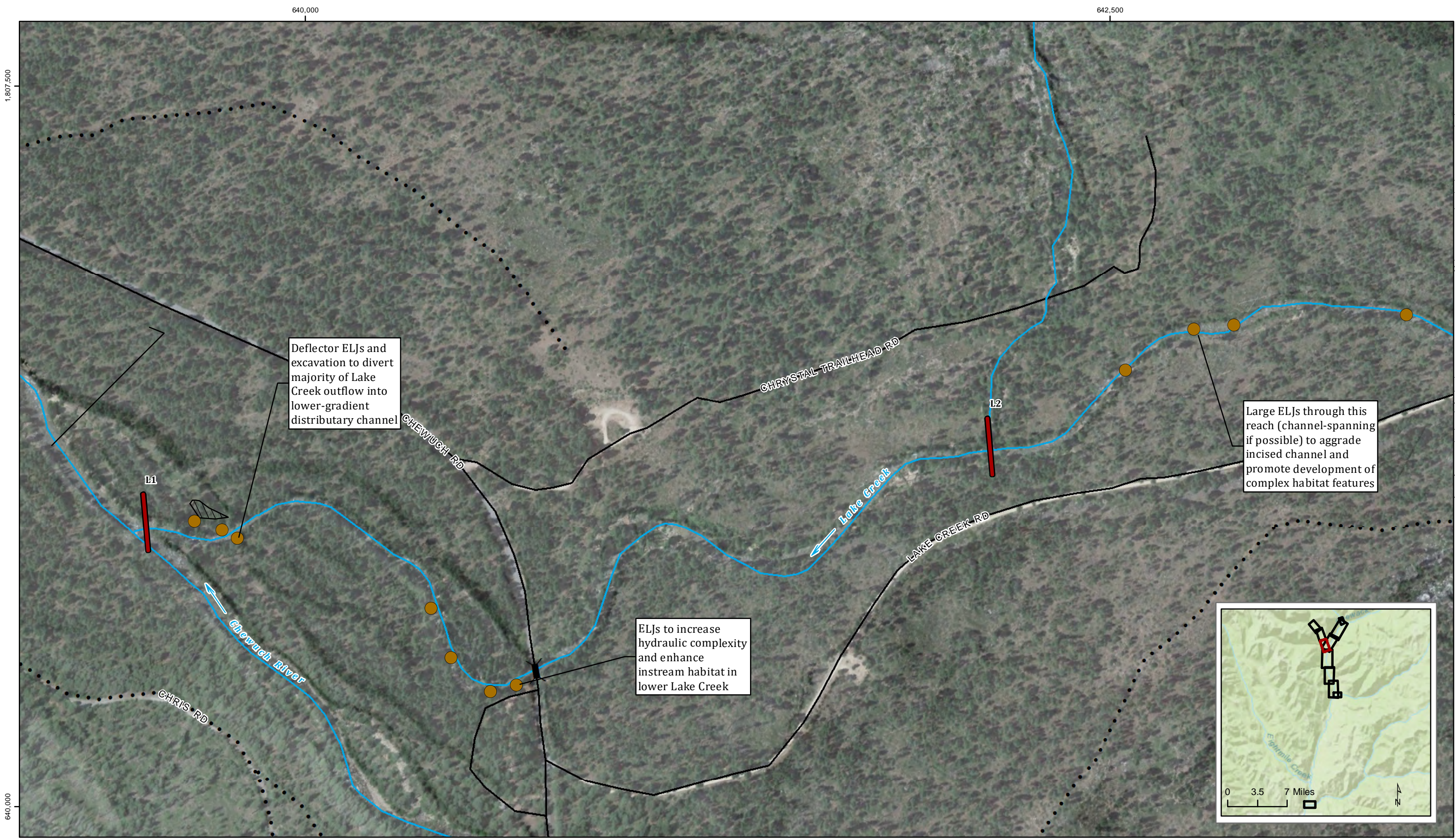


Upper Chewuch Habitat Assessment
Restoration Concepts - Map 6, Andrews Creek
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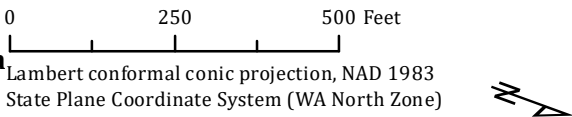


- Machine Placed ELJ
- Channel Excavation
- Road
- Pile Array
- Levee Removal
- Closed Road
- Enhanced Side Channel
- Reach Break
- Unimproved Road
- Loosely Anchored Wood Loading
- River Miles
- Bridge
- Stream



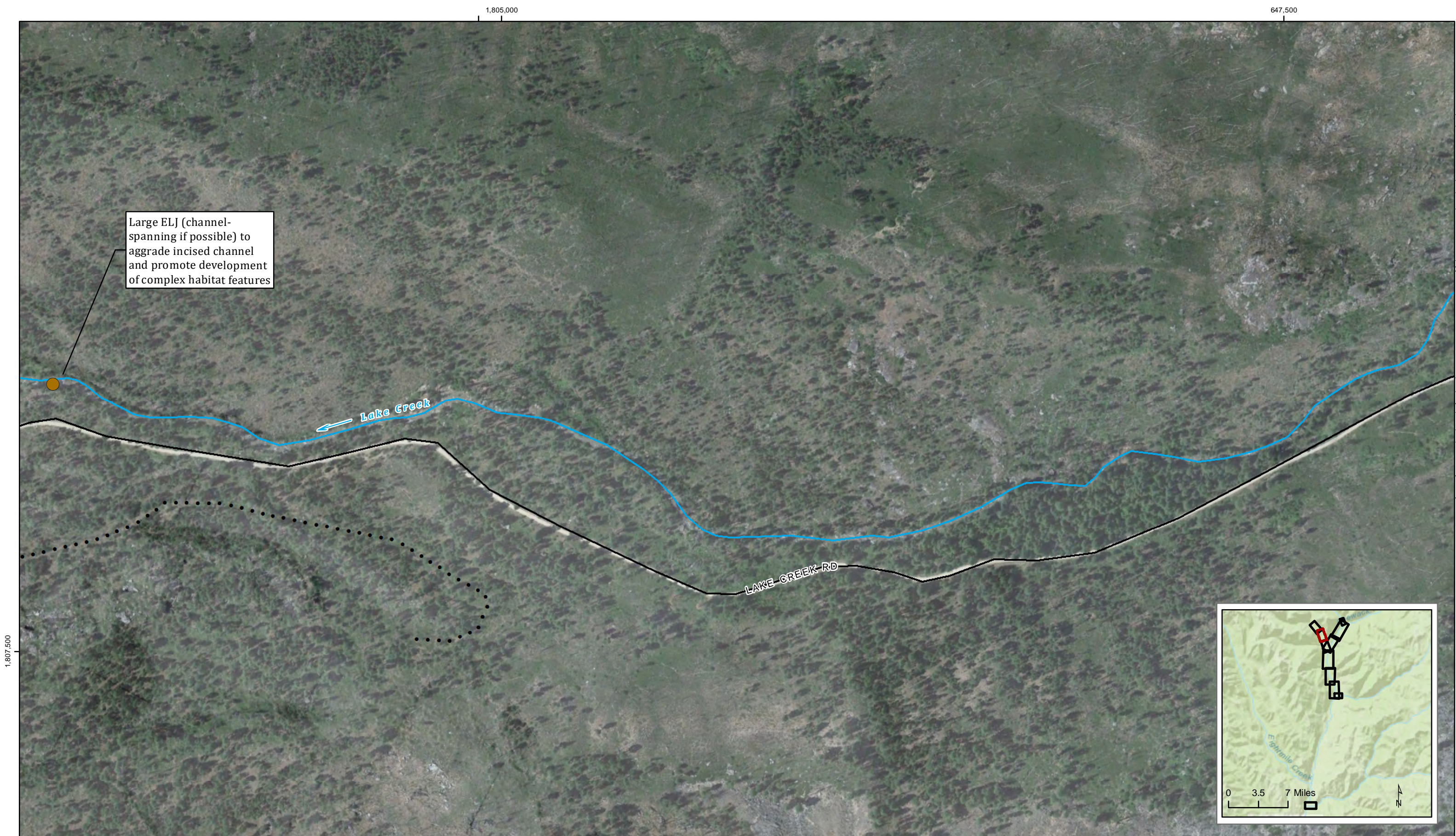


Upper Chewuch Habitat Assessment
Restoration Concepts - Map 7, Lake Creek Reach 1 & 2a
 Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).

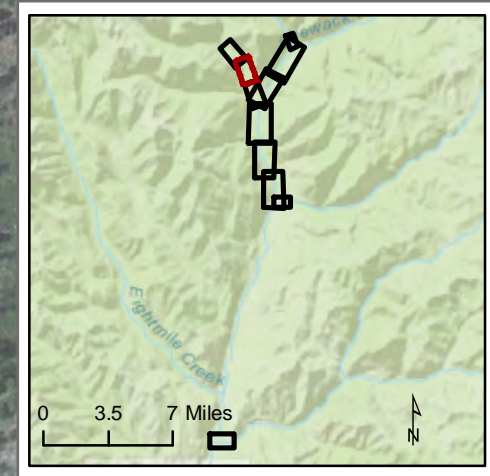


- Machine Placed ELJ
- Pile Array
- Enhanced Side Channel
- Loosely Anchored Wood Loading
- Channel Excavation
- Levee Removal
- Reach Break
- + River Miles
- ~ Stream
- Road
- Closed Road
- Unimproved Road
- Bridge

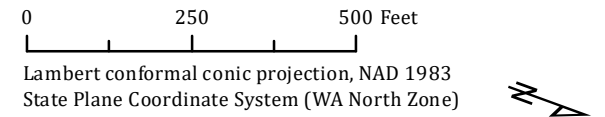




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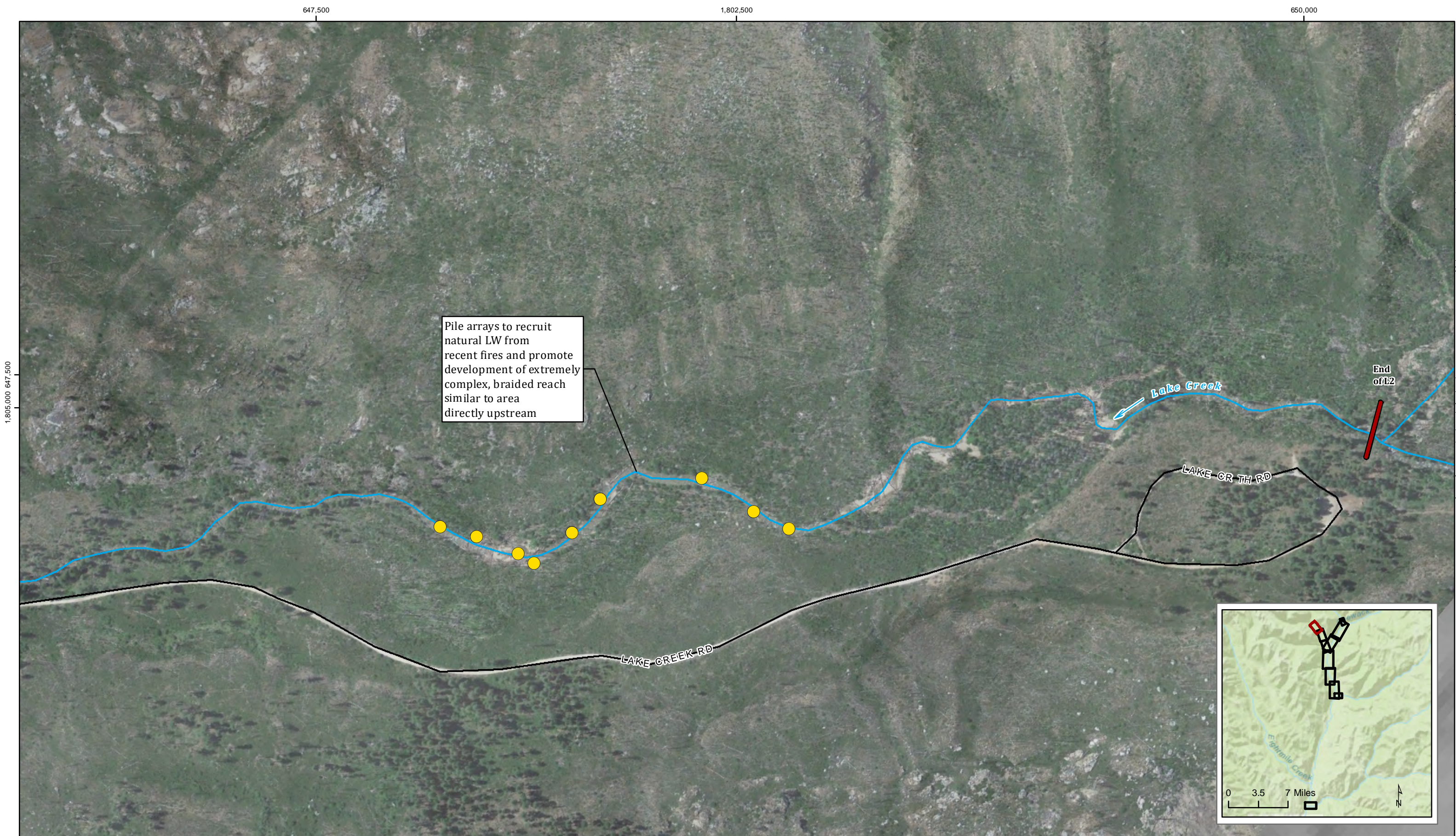


Upper Chewuch Habitat Assessment
Restoration Concepts - Map 8, Lake Creek Reach 2b
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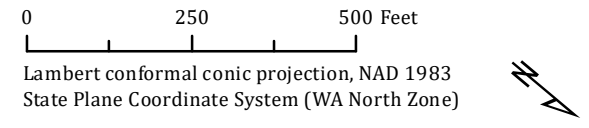
- | | | |
|-------------------------------|--------------------|-----------------|
| Machine Placed ELJ | Channel Excavation | Road |
| Pile Array | Levee Removal | Closed Road |
| Enhanced Side Channel | Reach Break | Unimproved Road |
| Loosely Anchored Wood Loading | River Miles | Bridge |
| | Stream | |





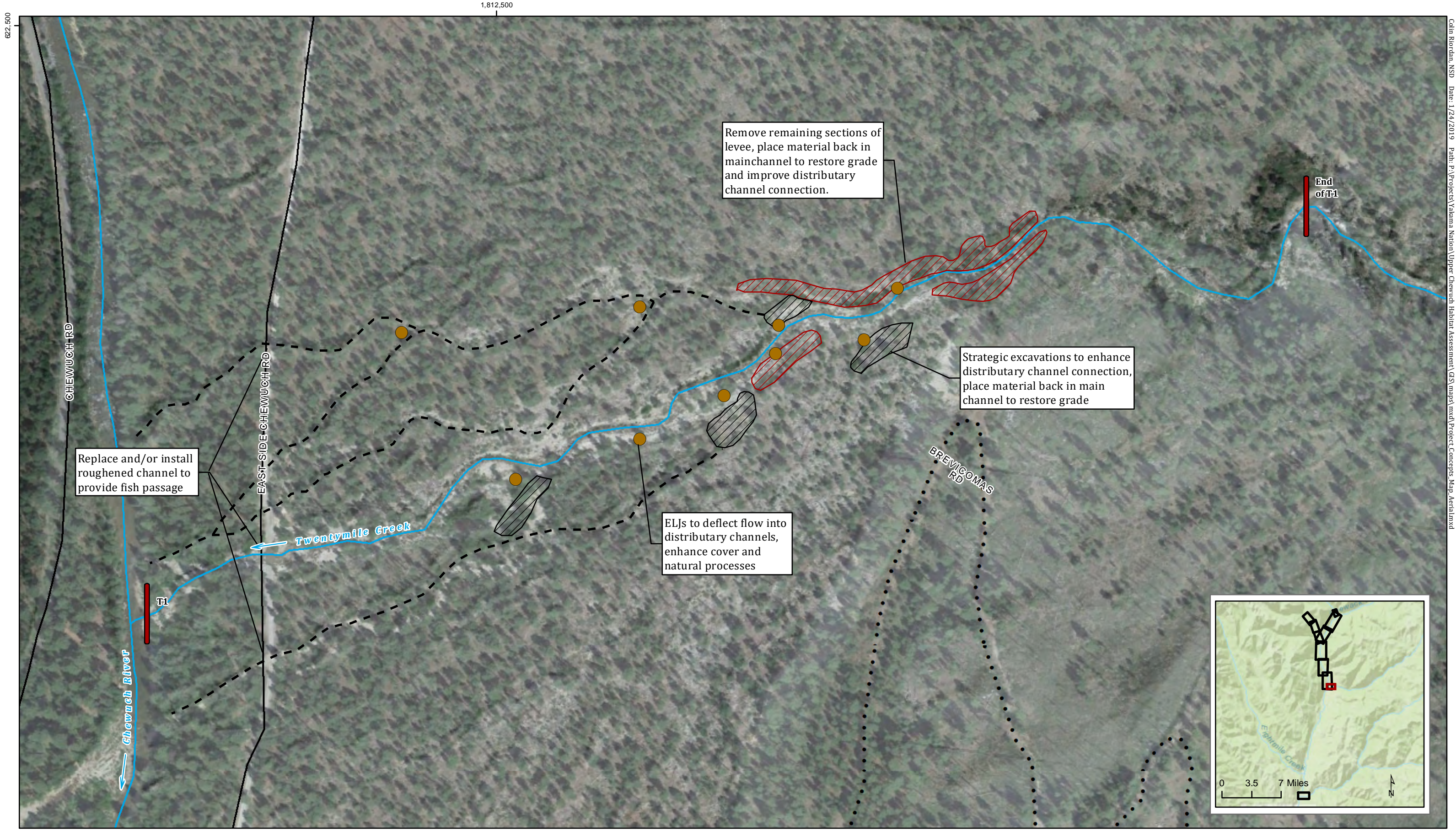
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Upper Chewuch Habitat Assessment
Restoration Concepts - Map 9, Lake Creek Reach 2c
 Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).



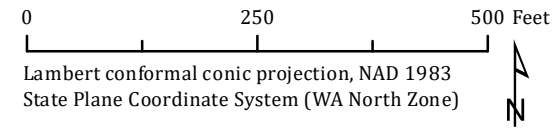
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|---------------------------------|----------------------|---------------------|
| ● Machine Placed ELJ | ⊕ Channel Excavation | — Road |
| ● Pile Array | ⊖ Levee Removal | ••• Closed Road |
| — Enhanced Side Channel | — Reach Break | ●●● Unimproved Road |
| — Loosely Anchored Wood Loading | ⊕ River Miles | ⊖ Bridge |
| | ~ Stream | |



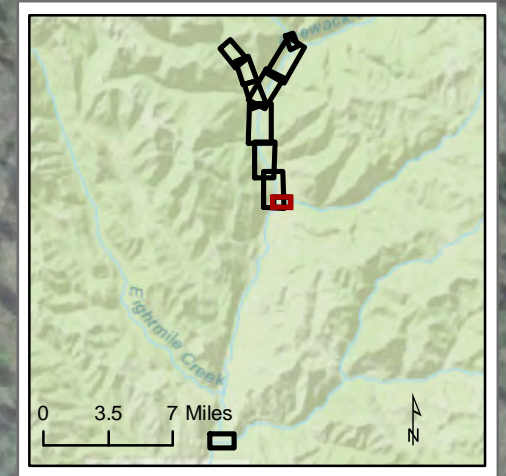


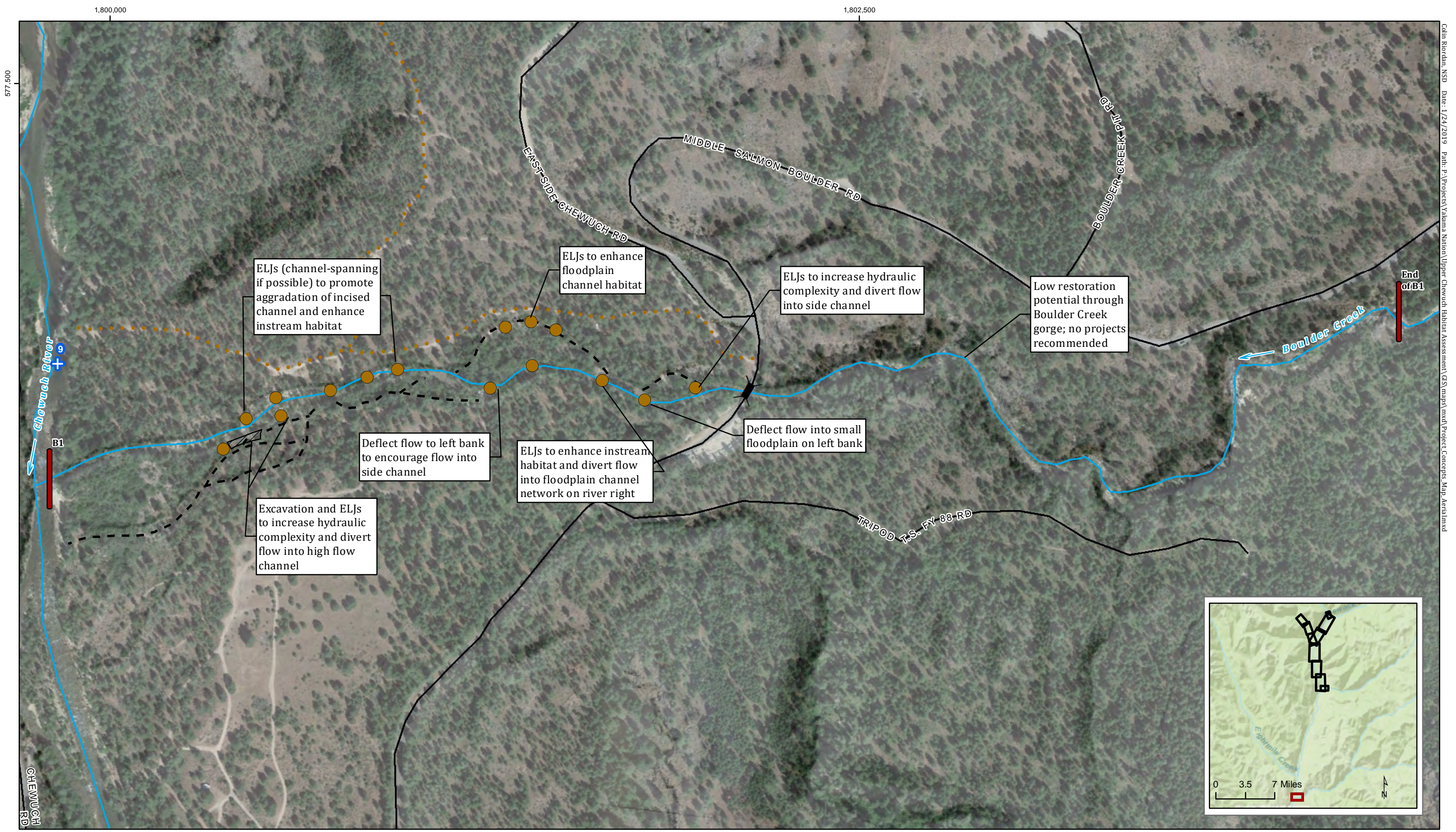
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Upper Chewuch Habitat Assessment
Restoration Concepts - Map 10, Twentymile Creek
 Topographic data source: 2015 Okanogan lidar data. Other data: USGS NHD (1:24,000) edited so flowline represents main channel of each stream, US Forest Service Roads, Google Earth Air Photos (2017).



- 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

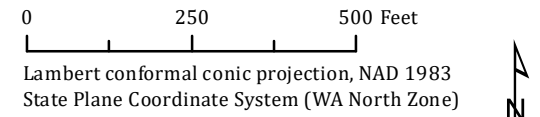




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Upper Chewuch Habitat Assessment
Restoration Concepts - Map 11, Boulder Creek

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).



- 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



Appendix C

Project Prioritization Matrix

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Appendix D. Project Prioritization Matrix

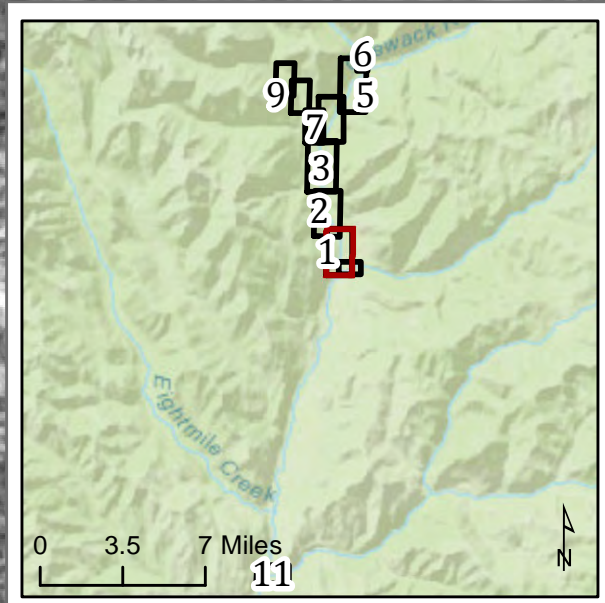
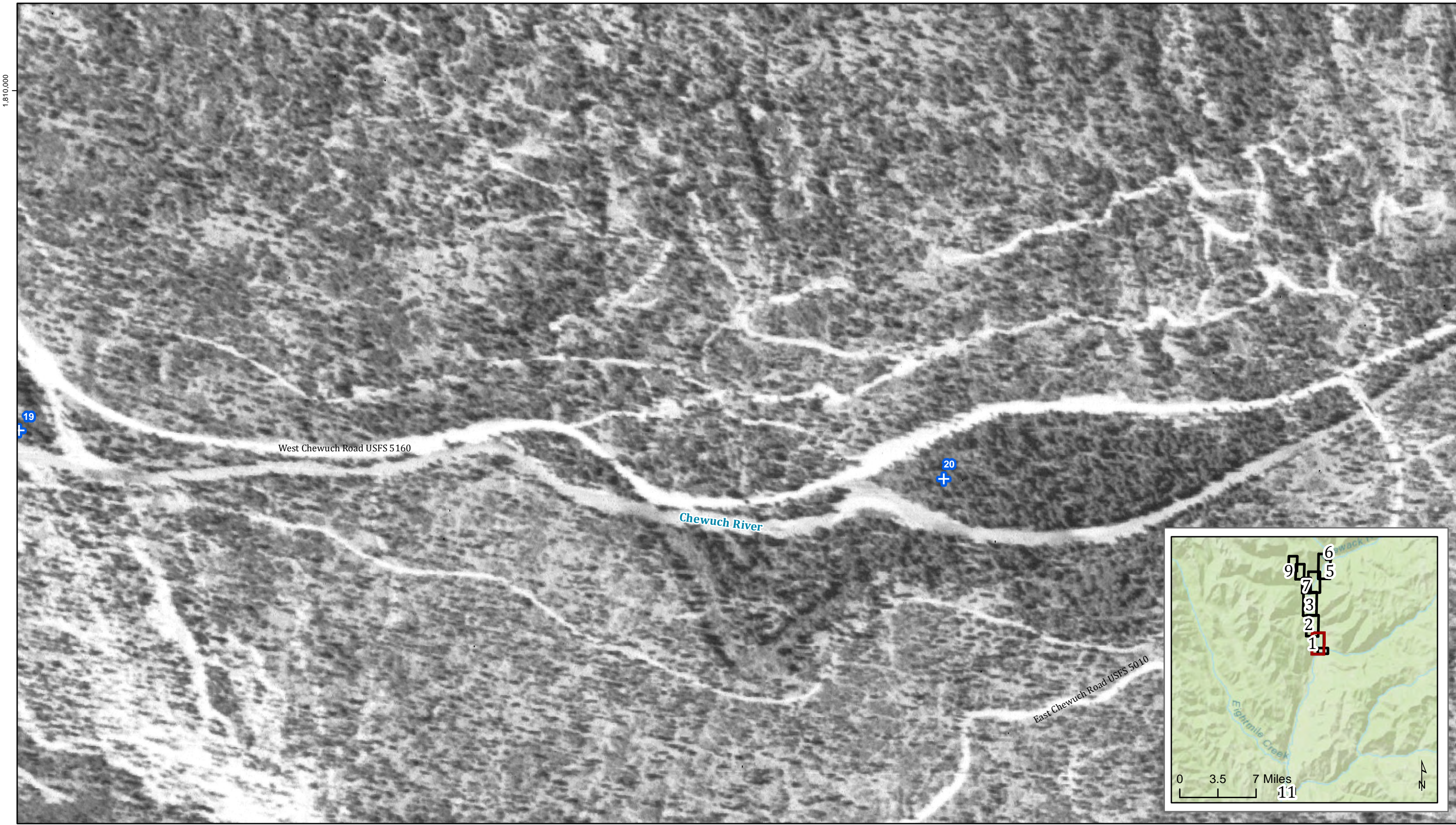
Project Information			Benefit Score													Cost Score		Cost Benefit	Feasibility Designation		
Project Name	Project Location (RM - RM)	Total Length (mi)	Restoration Gap Analysis				Existing and Potential Fish Use		Root Causes		Ecological Concerns		Climate Change		Total Benefits Score	Score (1-3)	Rationale/Assumptions	Benefit to Cost Score	Feasibility Designation	Rationale/Assumptions	
			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							
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 quality 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 extensive 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 quality 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 increase 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

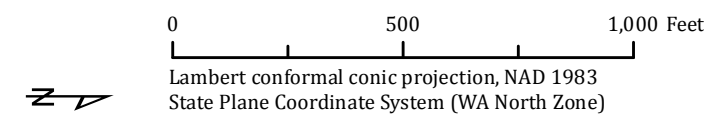
Historic Aerial Photographs

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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.

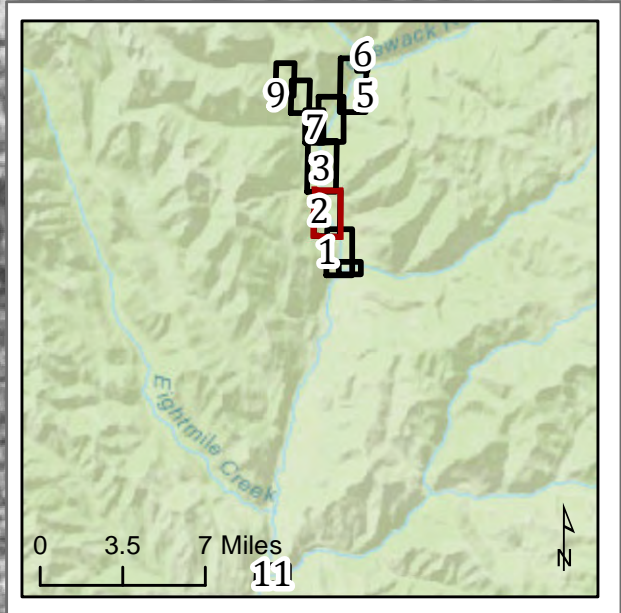


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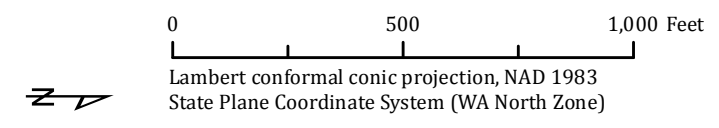


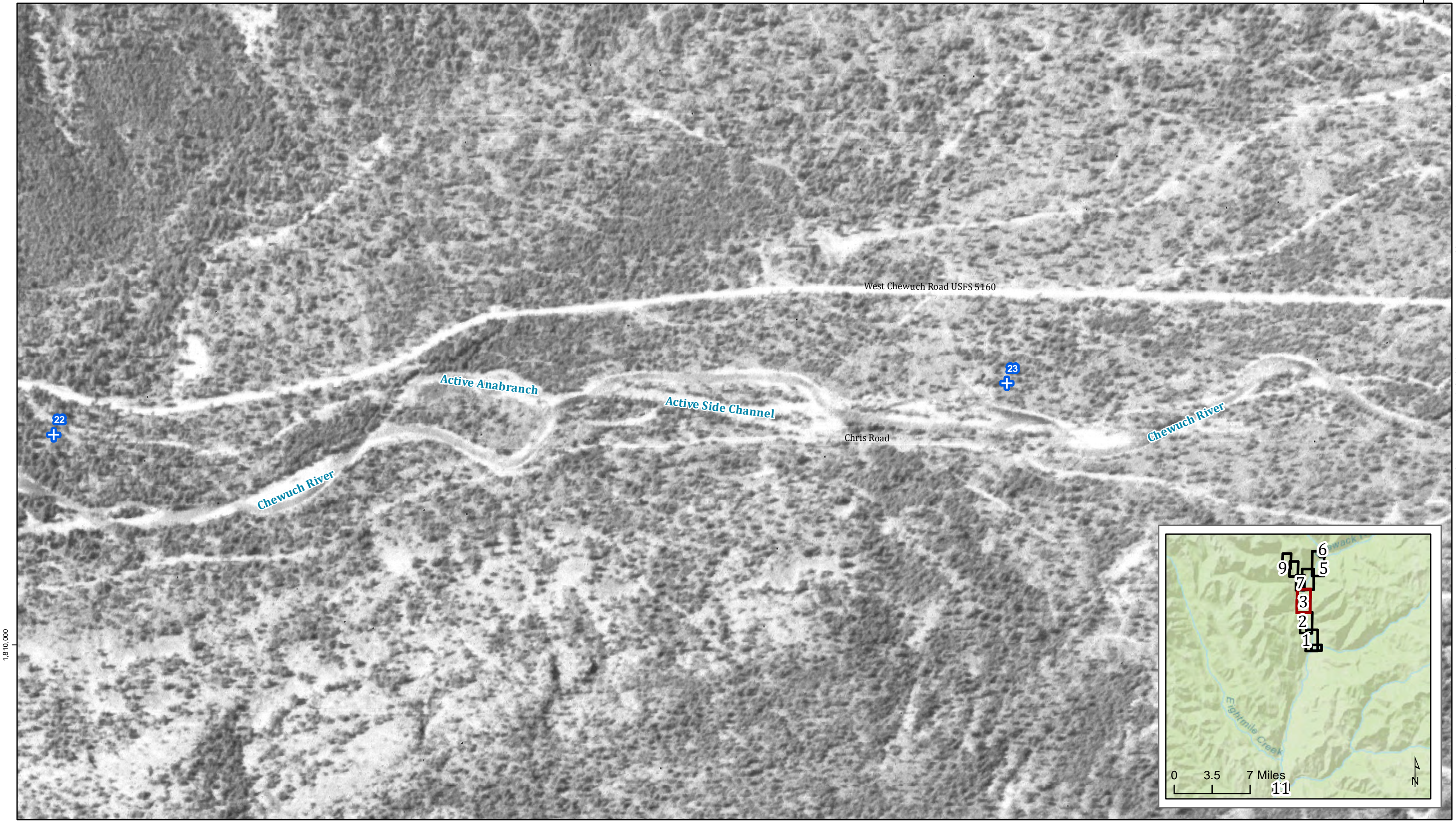
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Upper Chewuch Habitat Assessment
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Topographic data source: 2015 Okanogan lidar data - collected by Quantum Spatial between 6/19/15 and 7/10/15.
 Other data: USGS NHD (1:24,000), US Census Bureau Roads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

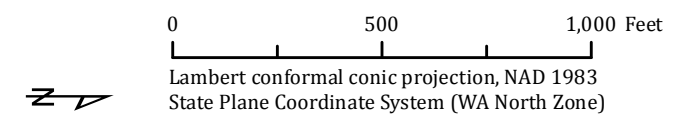




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Upper Chewuch Habitat Assessment
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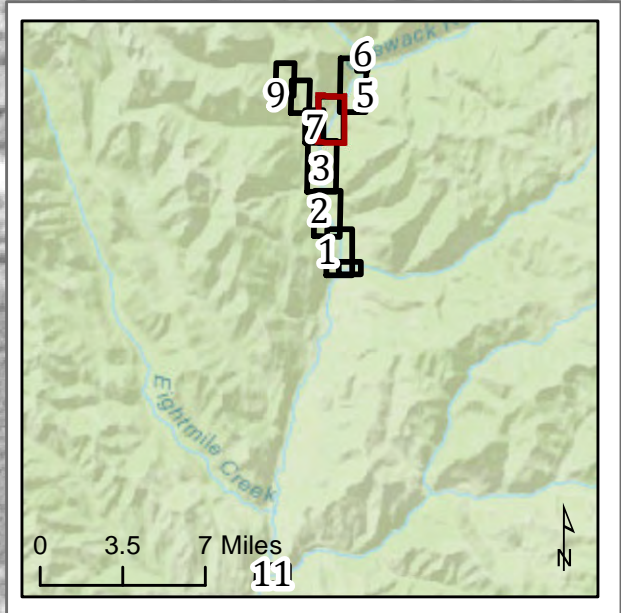
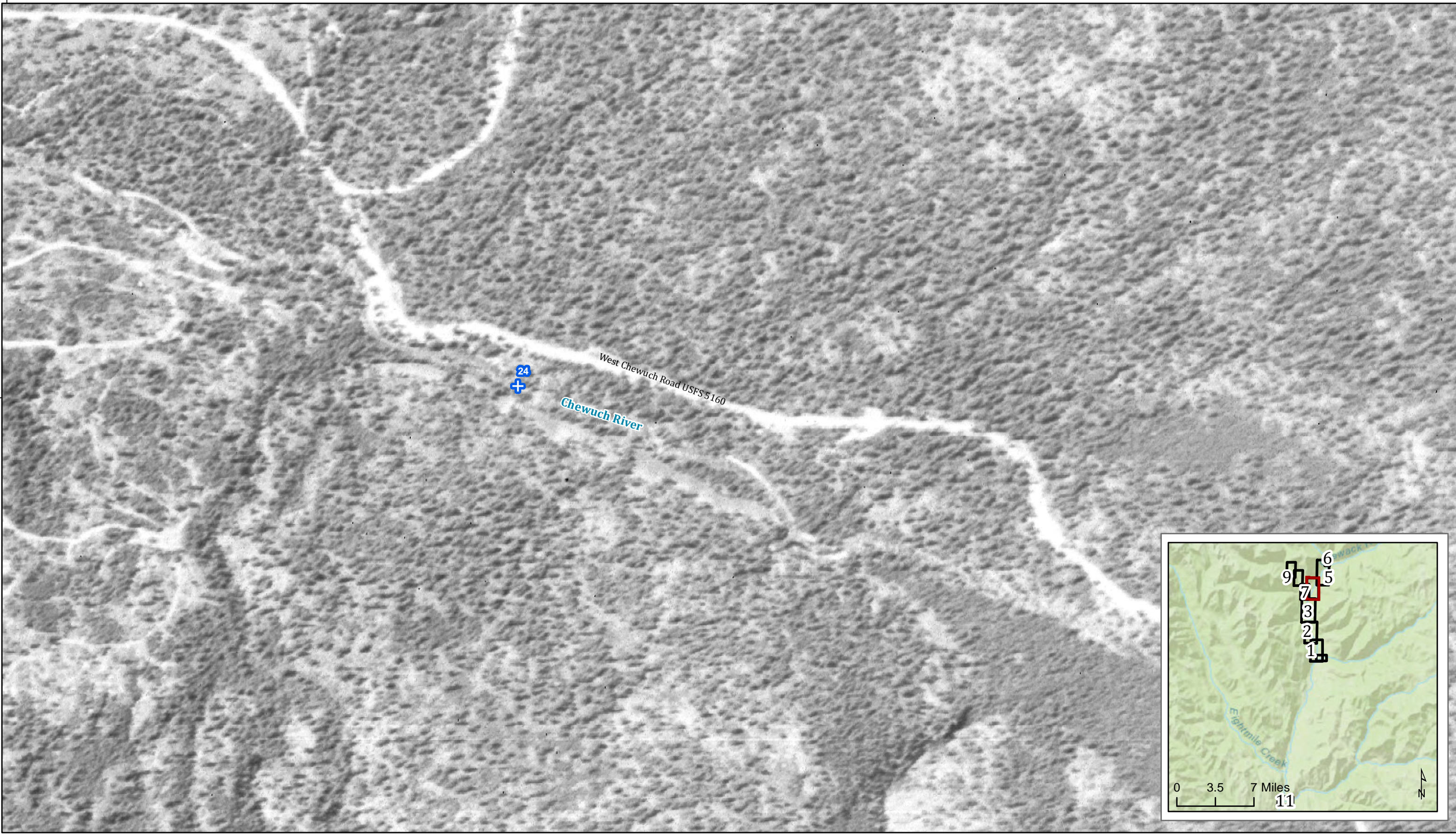
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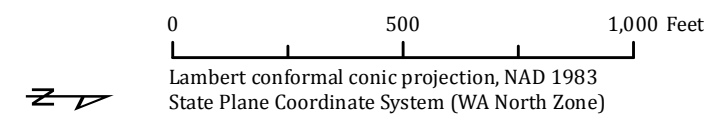
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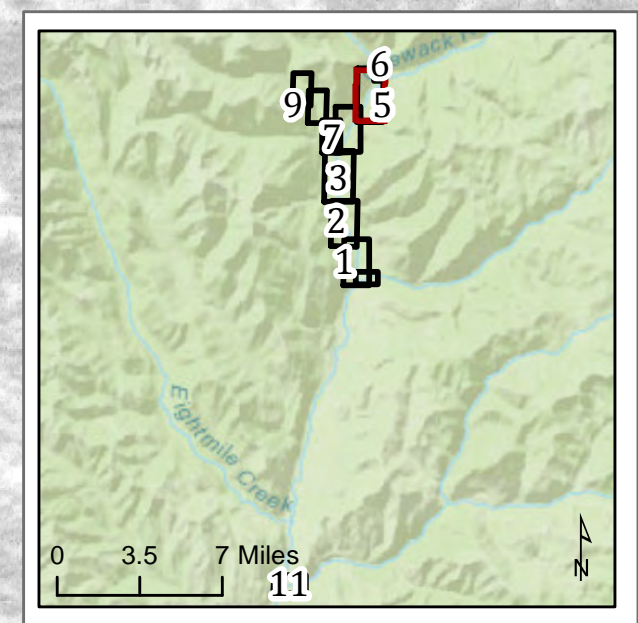
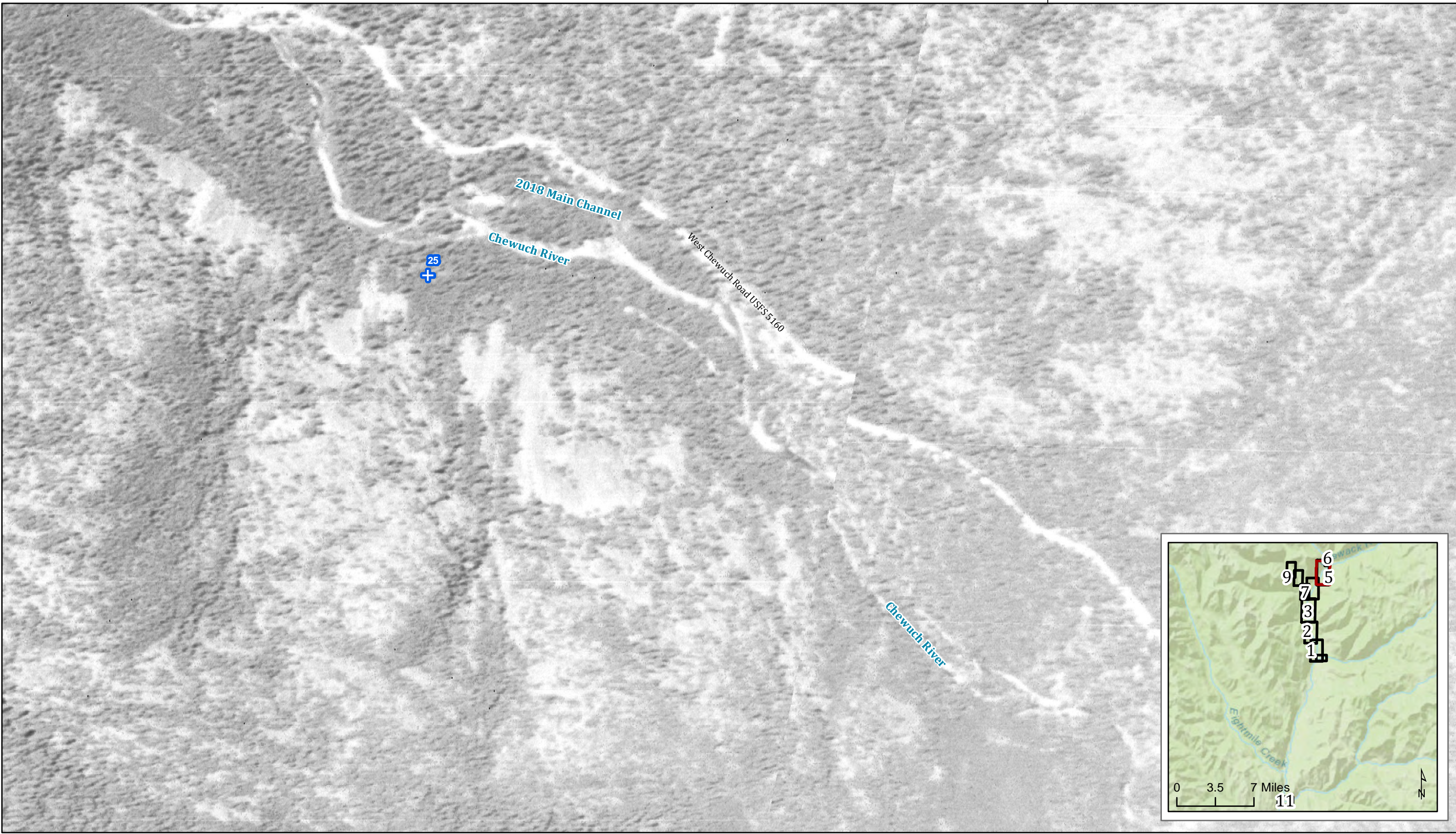
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Upper Chewuch Habitat Assessment
1953 Air Photo Reach Map - Chewuch Reach 12, Map 4

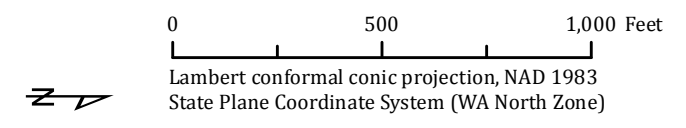
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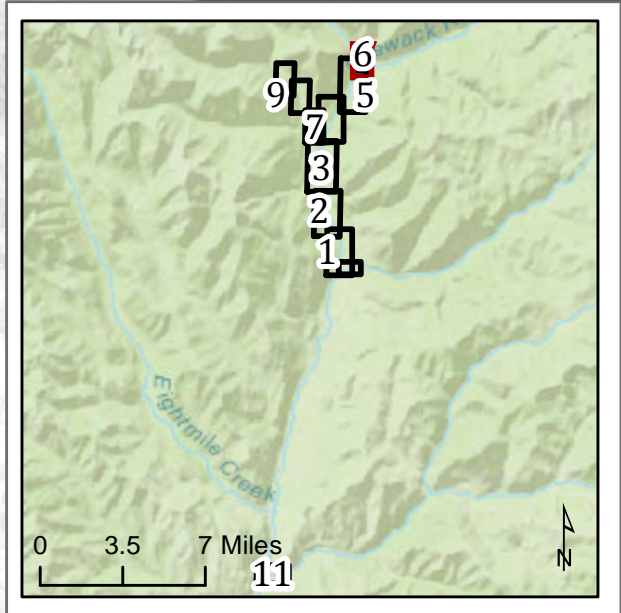
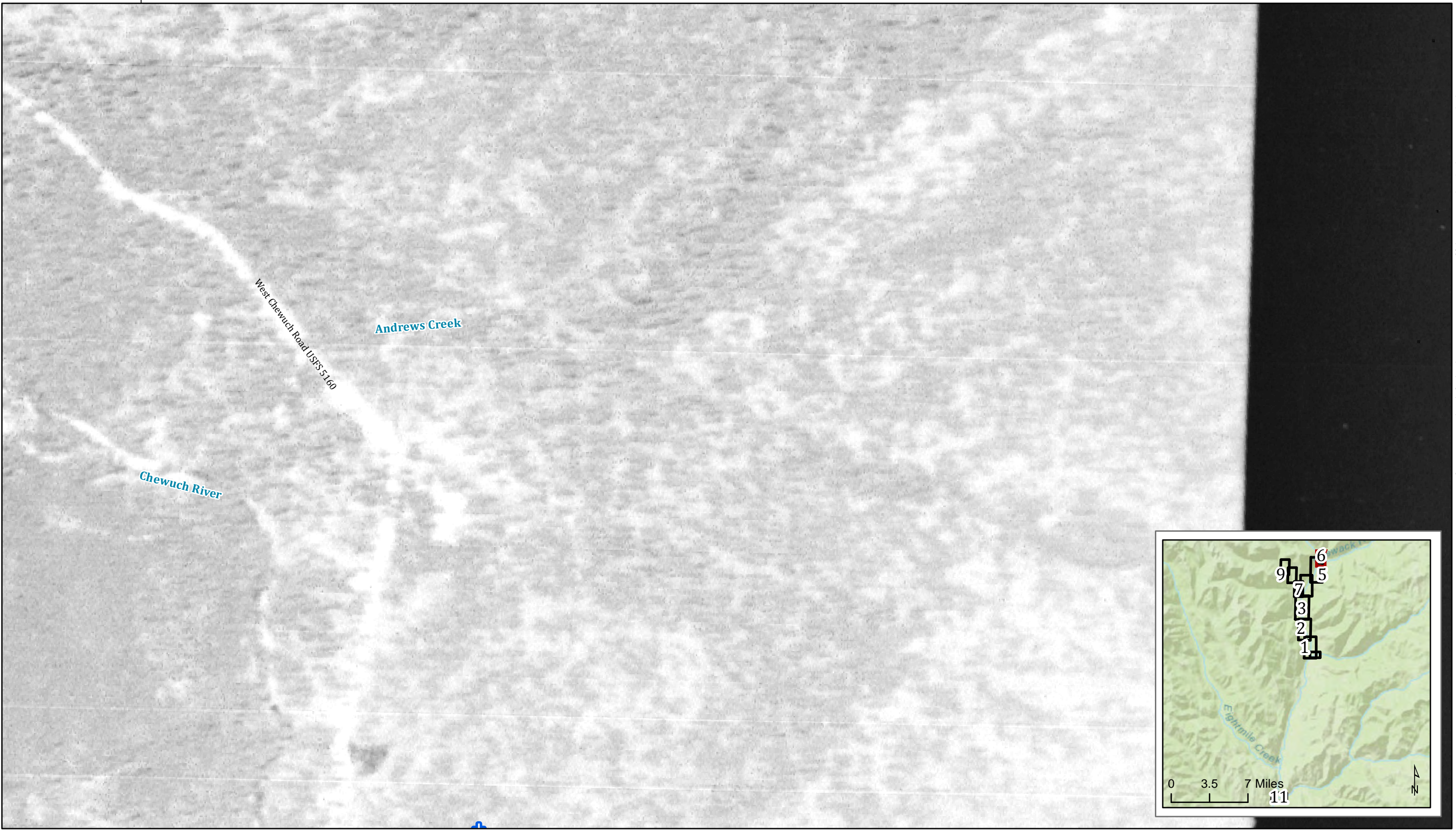


Upper Chewuch Habitat Assessment
1953 Air Photo Reach Map - Chewuch Reach 13, Map 5

Topographic data source: 2015 Okanogan lidar data - collected by Quantum Spatial between 6/19/15 and 7/10/15.
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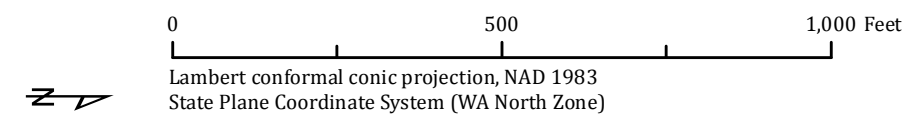


650,000



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.
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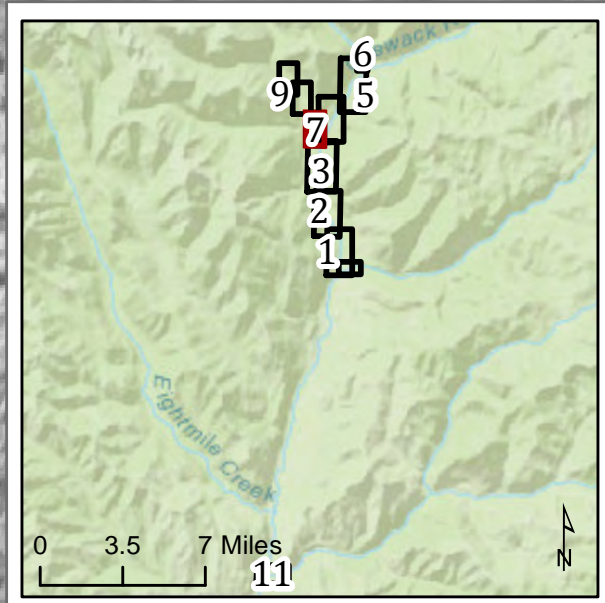
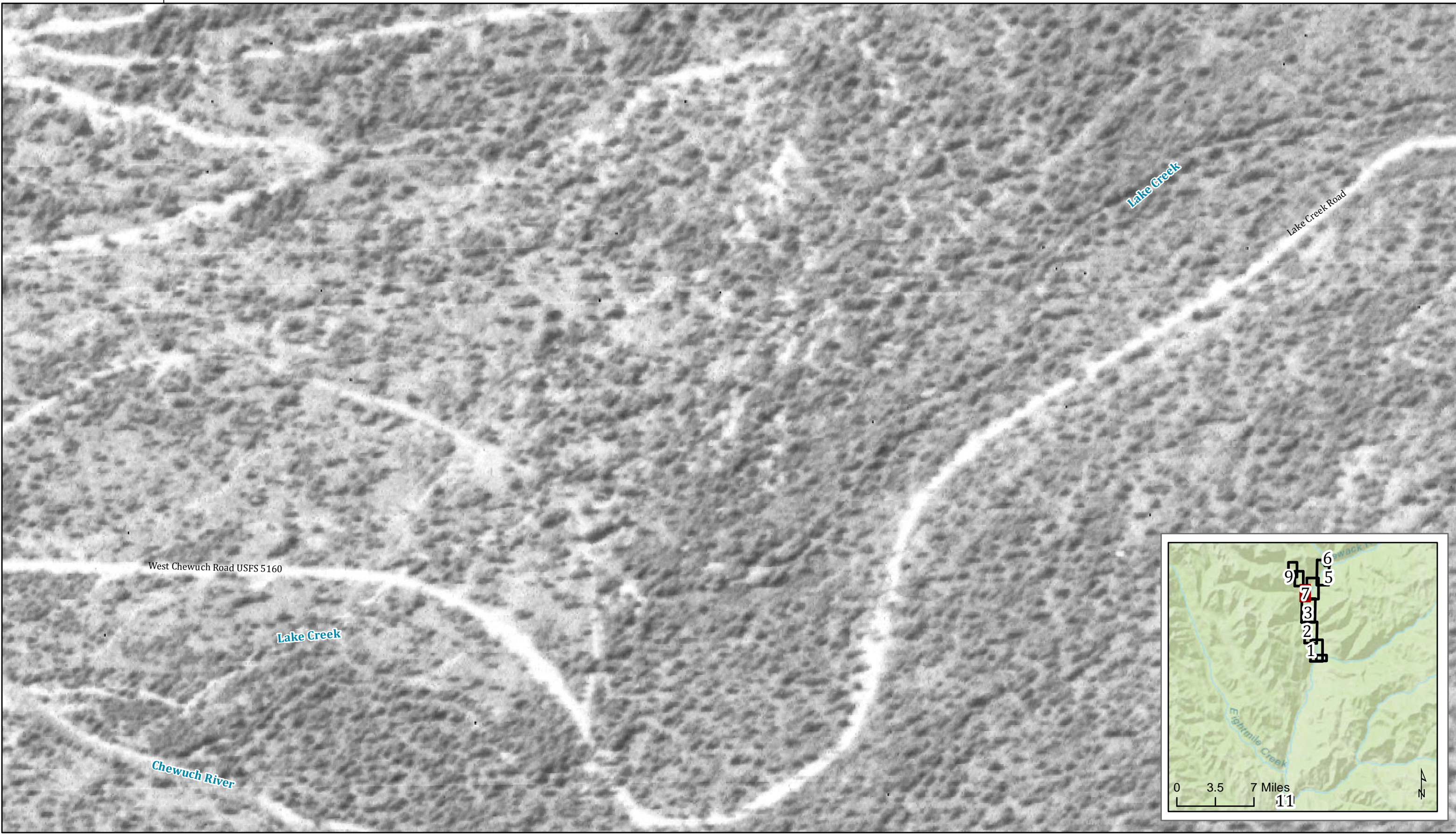


-  15 USGS River Mile
-  Streams
-  Roads



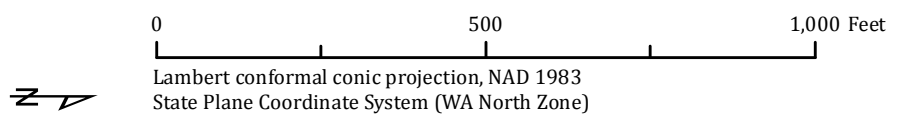
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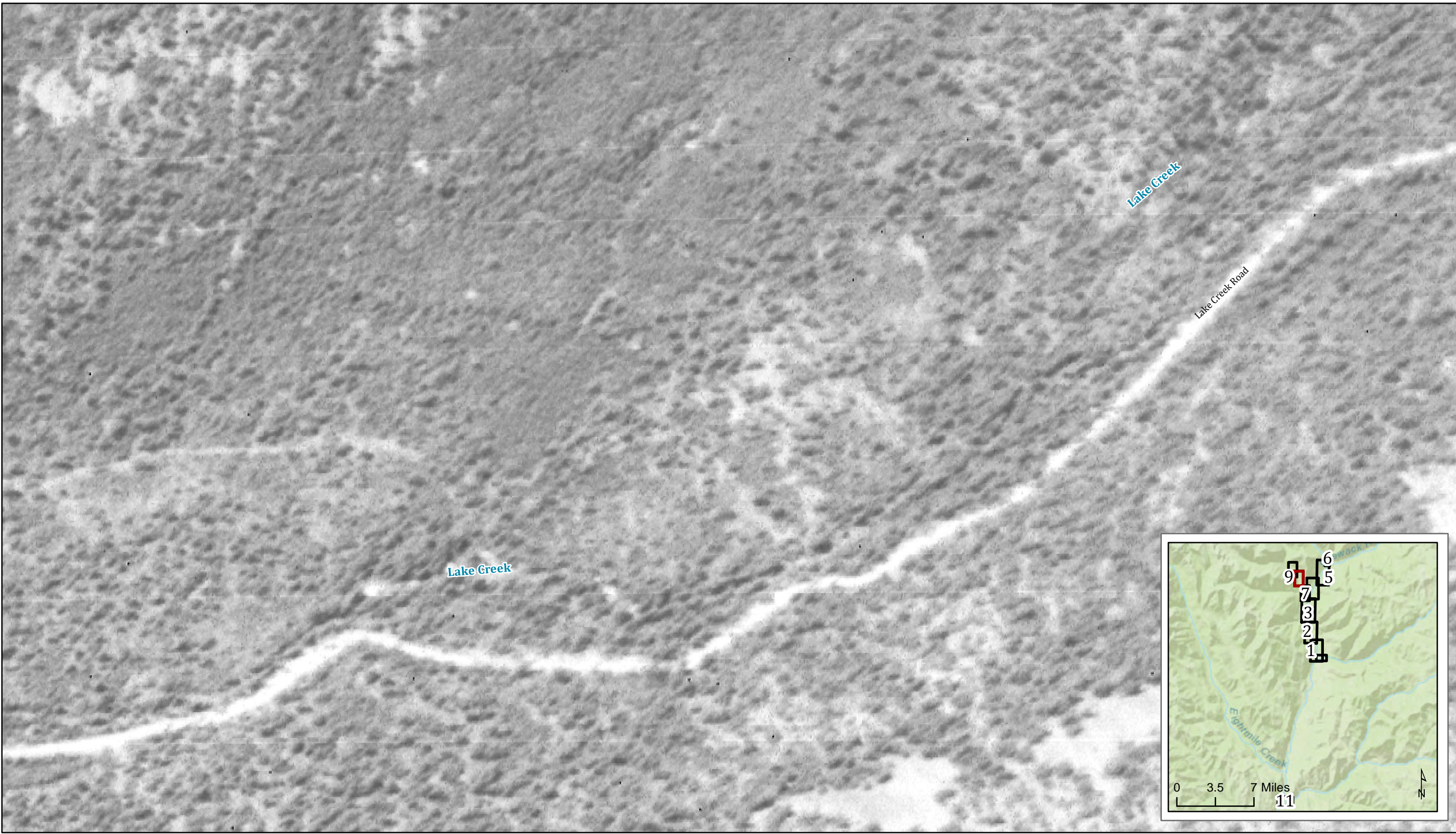
Upper Chewuch Habitat Assessment
1953 Air Photo Reach Map - Lake Creek Reach 1 & 2a, Map 7

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.



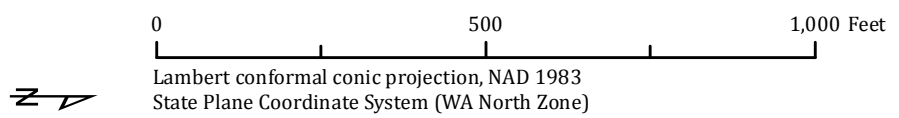
-  15 USGS River Mile
-  Streams
-  Roads

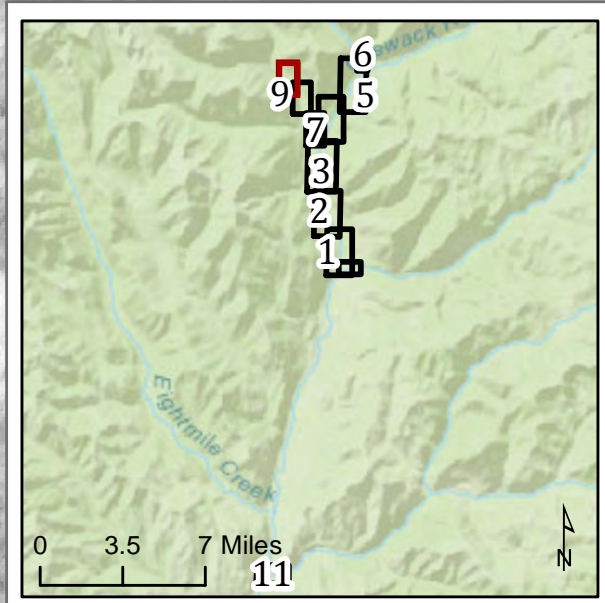
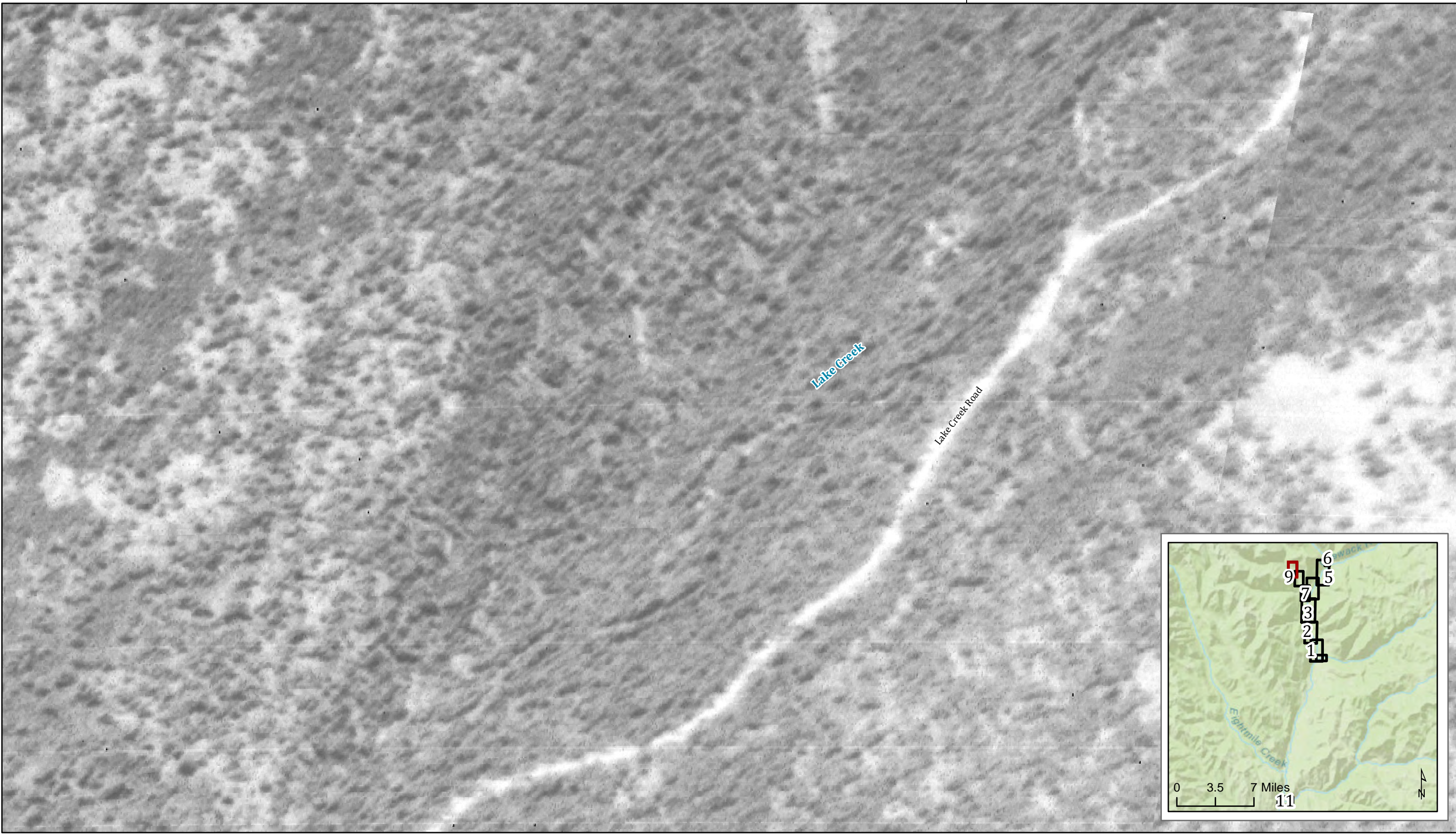




Upper Chewuch Habitat Assessment
1953 Air Photo Reach Map - Lake Creek Reach 2b, Map 8

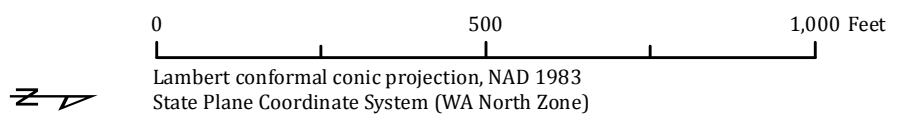
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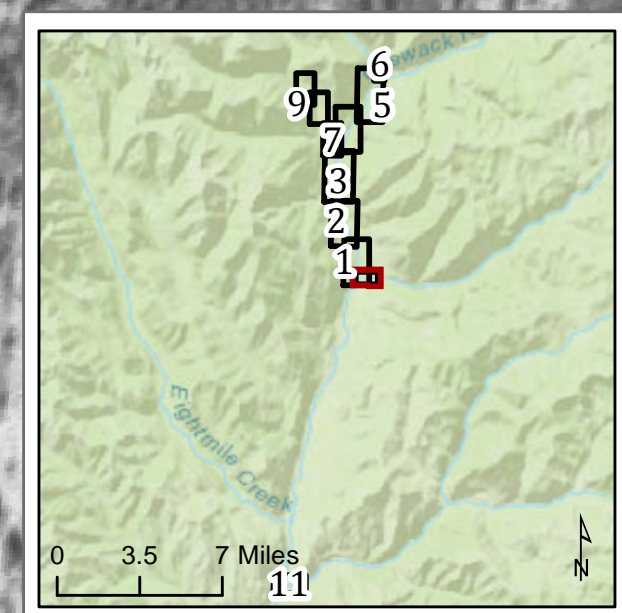
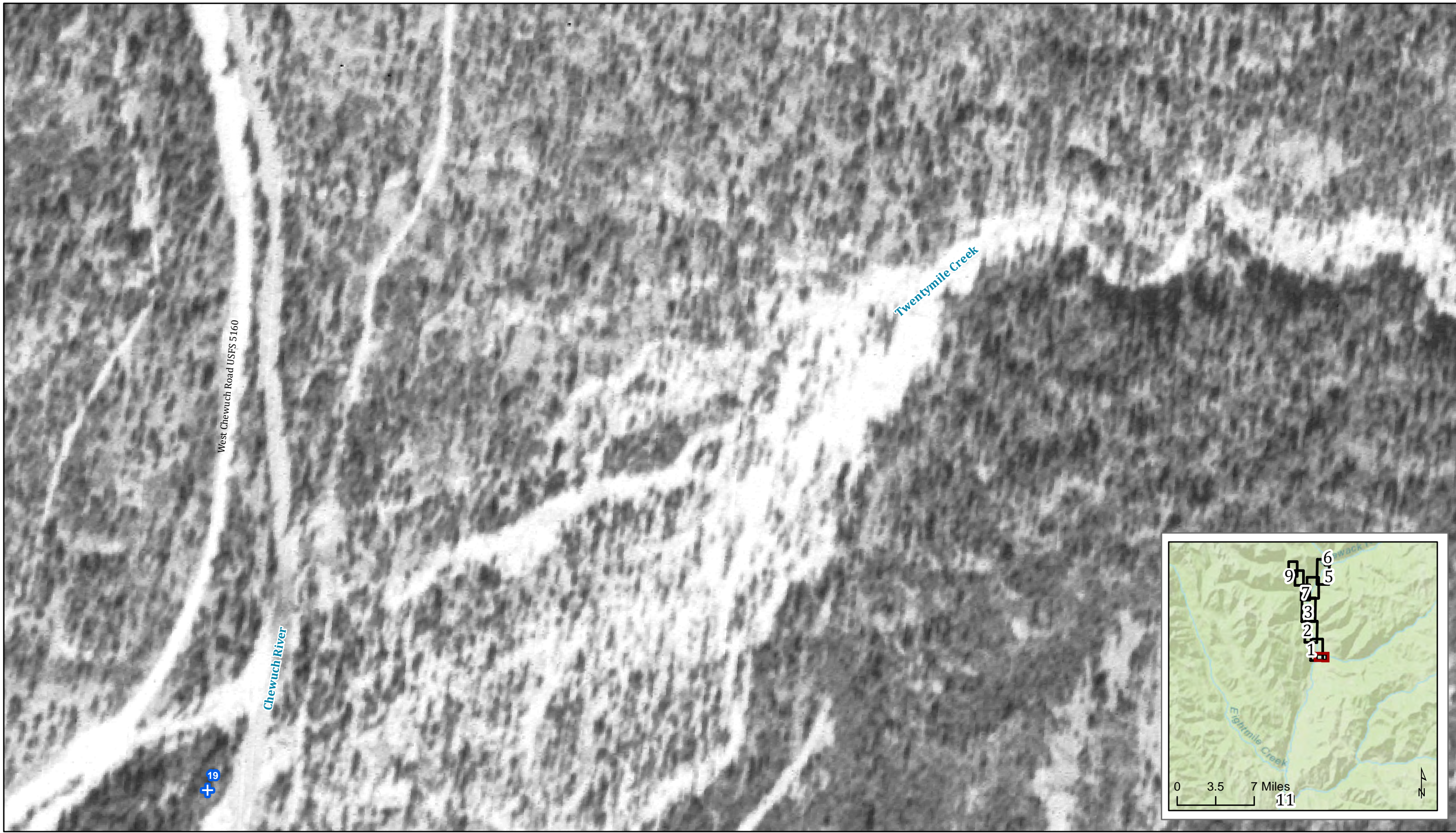




Upper Chewuch Habitat Assessment
1953 Air Photo Reach Map - Lake Creek Reach 2c, Map 9

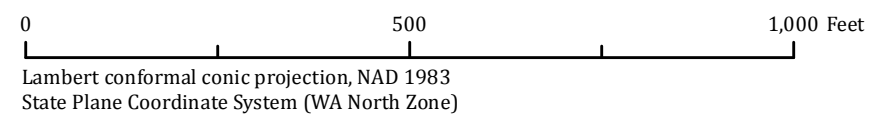
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 Other data: USGS NHD (1:24,000), US Census Bureau Roads (2010), Google Earth Air Photos (2017), USGS Earth Explorer Historic Air Photos.





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.



- 15 USGS River Mile
- Streams
- Roads



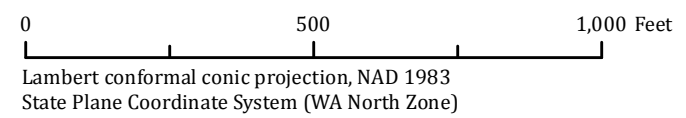
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Upper Chewuch Habitat Assessment
1953 Air Photo Reach Map - Boulder Creek, Map 11

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.



-  USGS River Mile
-  Streams
-  Roads

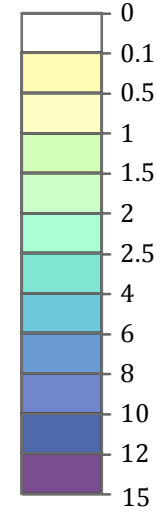


Appendix E

Hydraulic Model Output

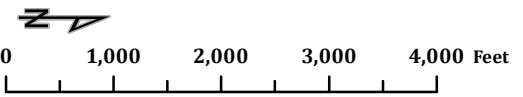
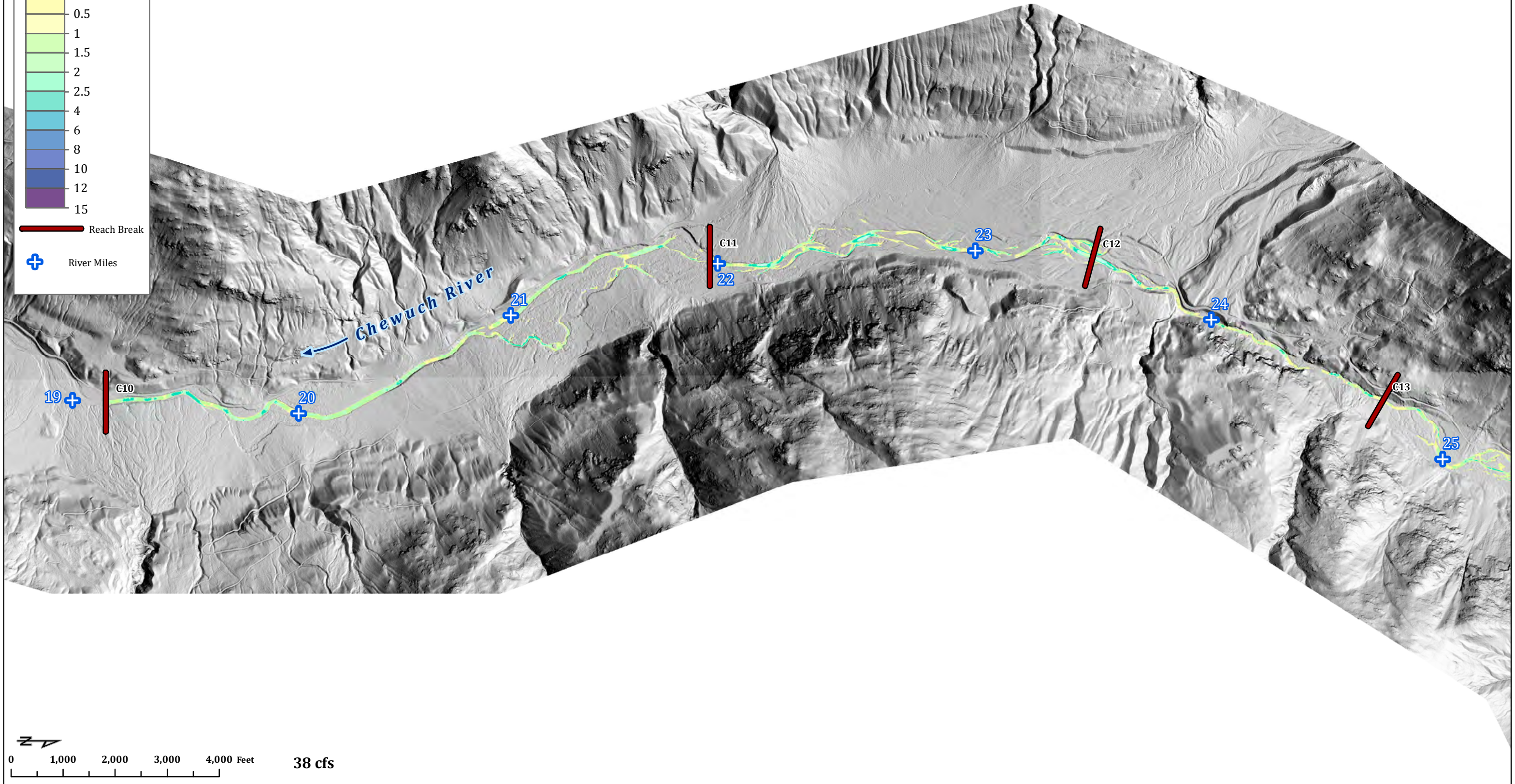
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Depth (ft)



— Reach Break

+ River Miles



38 cfs



