Middle Twisp River
Reach Assessment & Restoration Strategy

SUBMITTED TO
Yakama Nation Fisheries Program

FEBRUARY 2015

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1 Introduction and Background

1.1 OVERVIEW

This assessment evaluates aquatic habitat and watershed process conditions in the Middle Twisp Reach of the Twisp River and identifies habitat restoration strategies. The Twisp River Basin is located on the eastern slope of the Cascade Mountains in Northern Washington (Figure 1). The Twisp River is a tributary to the Methow River, entering the Methow at RM 40.2. The Methow continues down the Methow valley until it joins the Columbia River at the town of Pateros, Washington. The assessment area is the mainstem Twisp River from river mile (RM) 7.8 to RM 18.1.

This reach assessment provides the technical foundation for understanding existing conditions and for identifying restoration strategies and specific restoration opportunities within the Middle Twisp Reach. Conditions are assessed from both the valley- and reach-scales. The aim is to identify restoration actions that address significant factors limiting the productivity of native salmonids, and to ensure that these actions fit within the appropriate geomorphic context of the system. While the proposed restoration measures are expected to benefit a large suite of native aquatic and terrestrial species, there is a particular emphasis on recovery of Endangered Species Act (ESA) listed salmonids, including spring Chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*Oncorhynchus mykiss*), and bull trout (*Salvelinus confluentus*).

This study builds on considerable data collection and assessment work performed by others as part of past studies, including the Methow Subbasin Geomorphic Assessment (USBR 2008) and the Twisp Watershed Assessment (PWI 2003). This Reach Assessment updates and further refines previous data collection and assessment efforts and provides a new comprehensive habitat restoration strategy that identifies restoration targets and recommends specific actions to address habitat and stream process impairments. Restoration strategies were developed by comparing existing aquatic habitat conditions to target conditions obtained from reference areas and regional habitat thresholds.

This report includes the following components:

- Study area characterization – Evaluation of valley- and basin-scale factors influencing aquatic habitat and stream geomorphic processes
- Reach-scale characterization – Inventory and analysis of habitat and geomorphic conditions at the reach and sub-reach scales
- Stream habitat assessment – Aquatic habitat inventory at the reach-scale
- Reach-Based Ecosystem Indicators (REI) analysis – Comparison of habitat conditions to established functional thresholds

- Restoration strategy – A comparison of existing conditions to target conditions and identification of recommended reach-scale restoration measures
- Specific project opportunities – A list of specific potential project opportunities and areas that would help to achieve the reach-scale restoration strategies.

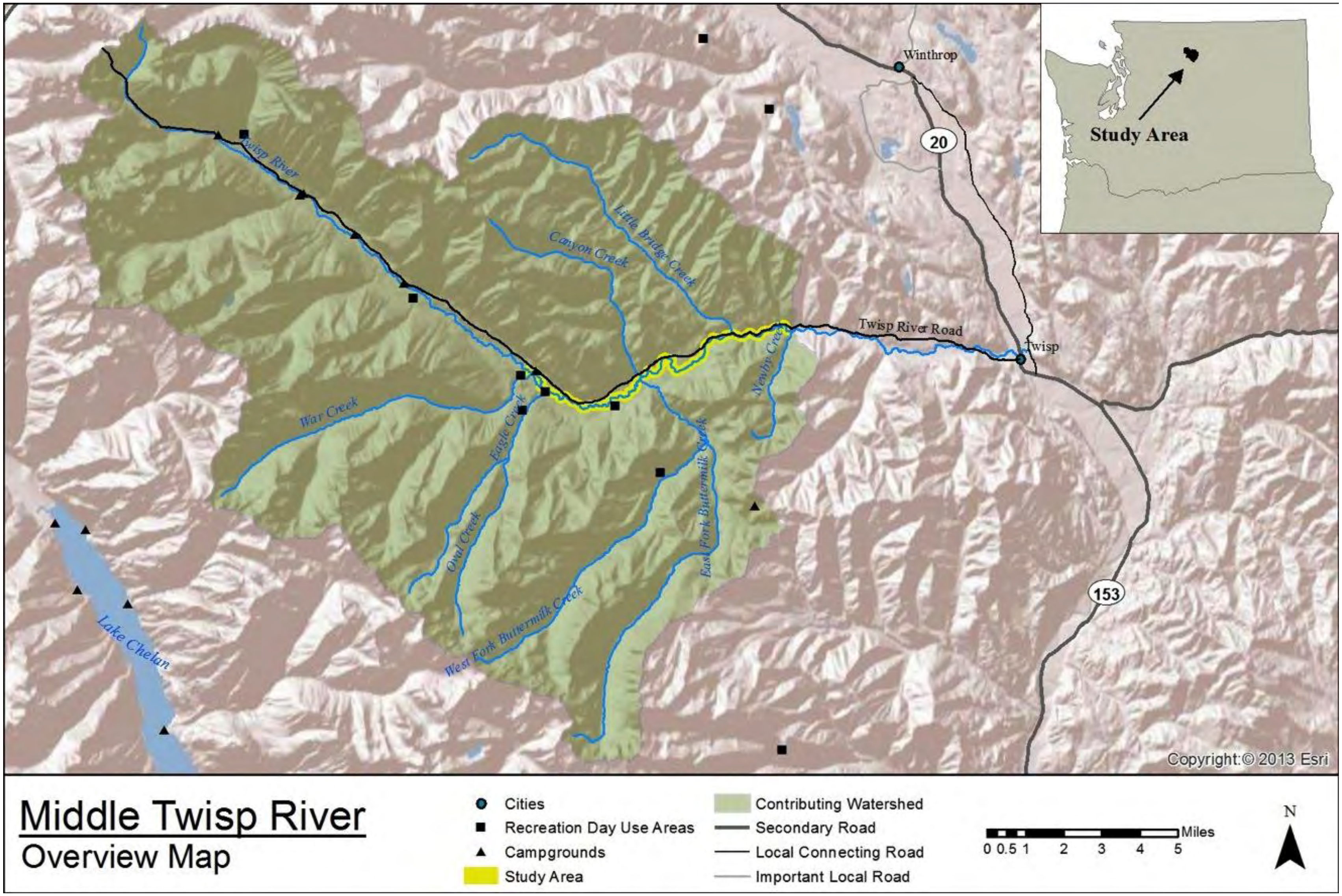

Figure 1. Middle Twisp River study area. The study area extends from RM 7.8 to RM 18.1.

1.2 BACKGROUND

This effort is being conducted as part of the Yakama Nation's Upper Columbia Habitat Restoration Project (UCHRP), which implements projects to recover habitat for ESA-listed salmon and steelhead in the Upper Columbia region. Restoration efforts by the UCHRP work to achieve the objectives of the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (Recovery Plan, UCSRB 2007) and the associated Biological Strategy (UCRRT 2013).

This assessment builds off of a large body of work produced in the basin beginning in the early 1990s and proceeding throughout the 2000s. Assessment and analysis work to date has included physical assessments, biological assessments, and restoration recommendations for portions of the Twisp River. One such previous assessment includes the U.S. Bureau of Reclamation's 2008 Methow Subbasin Geomorphic Assessment, the Methow Watershed Plan (MBPU 2005), the Methow Subbasin Plan (KWA et al. 3004), PWI's Twisp Watershed Assessment, and the USFS's Twisp Watershed Assessment (1995). This assessment included the Twisp River, and overlaps with the USBR's reaches T4 (RM 7.8 to RM 9.8), T5 (RM 9.8 to RM 13.5), and T6 (RM 13.5 to RM 18.1). The Yakama Nation also completed a reach assessment on the Lower Twisp River in 2010 (Inter-Fluve 2010). This Middle Twisp Reach Assessment is the next segment upstream from the lower Twisp study area.

1.3 PURPOSE

The purpose of this assessment is to document and evaluate hydrologic processes, geomorphic processes, and aquatic habitat conditions in the Middle Twisp Reach (RM 7.8 to RM 18.1) of the Twisp River and to present a comprehensive reach-based restoration strategy to address limiting factors to aquatic habitat. Evaluations used in this assessment include historical characterization, geomorphic assessment, hydraulic assessment, and an aquatic habitat inventory.

Specific goals and outcomes of this assessment include:

- Provide a comprehensive inventory and assessment of geomorphic and physical habitat conditions and trends
- Identify strategies and actions that address critical aquatic habitat impairments limiting the productivity of local salmonid populations
- Identify strategies and actions that protect and restore the dynamic landscape processes that support sustainable riparian and salmonid habitat
- Coordinate efforts with local landowners, resource managers, and other stakeholders in order to establish collaborative efforts that contribute to the success of restoration strategies

1.4 SALMONID USE AND POPULATION STATUS

Salmonid use of the middle Twisp includes spring Chinook salmon, steelhead, bull trout, westslope cutthroat trout, rainbow trout, and brook trout. Spring Chinook salmon are listed as Endangered under the ESA, and steelhead and bull trout are listed as Threatened. Life-stage usage and ESA status for each species are summarized in Table 1.

Table 1. Species usage in the Middle Twisp. Adapted from NMFS 1998 and Mullen 1992.

Population	ESA Status	General Use	Timeframe	Distribution	Abundance	Productivity
Spring Chinook	Endangered	Spawning & Rearing	Historical	High	Moderate	Moderate
		Spawning & Rearing	Current	Moderate-High	Low-Moderate	Low-Moderate
Steelhead	Threatened	Spawning & Rearing	Historical	High	Low-Moderate	Moderate
		Spawning & Rearing	Current	Moderate-High	Low	Low
Bull trout	Threatened	Foraging, Migration, Over-wintering	Historical	High	Moderate	Moderate
		Foraging, Migration, Over-wintering	Current	Moderate	Low-Moderate	Low-Moderate

Spring Chinook salmon, steelhead, and bull trout are the most abundant species documented in the Twisp River and tributaries. A distribution map for steelhead and Chinook is presented in Figure 2. Spring Chinook spawning primarily occurs from RM 10 to RM 27. Spawning occurs in August and September. Juvenile rearing occurs year-round throughout the lower river downstream of RM 27. Steelhead trout use the entire Twisp River for spawning, in- and out-migration, and rearing. Spawning occurs March through May and juvenile rearing occurs year-round. Bull trout use the upper Twisp River from near RM 15 to RM 29 for year-round rearing, foraging, and over-wintering. Most bull trout spawning occurs between RM 22 and RM 29 in September and October (USBR 2008, App F).

The Twisp River has suitable spawning gravel throughout the mainstem and many of its tributaries, but the upper portion of the river provides higher quality spawning habitat due to less channelization, confinement, and bank hardening. Large wood in the upper Twisp River also contributes to higher quality rearing and spawning habitat, with more cool-water refugia and cover for adults and juveniles.

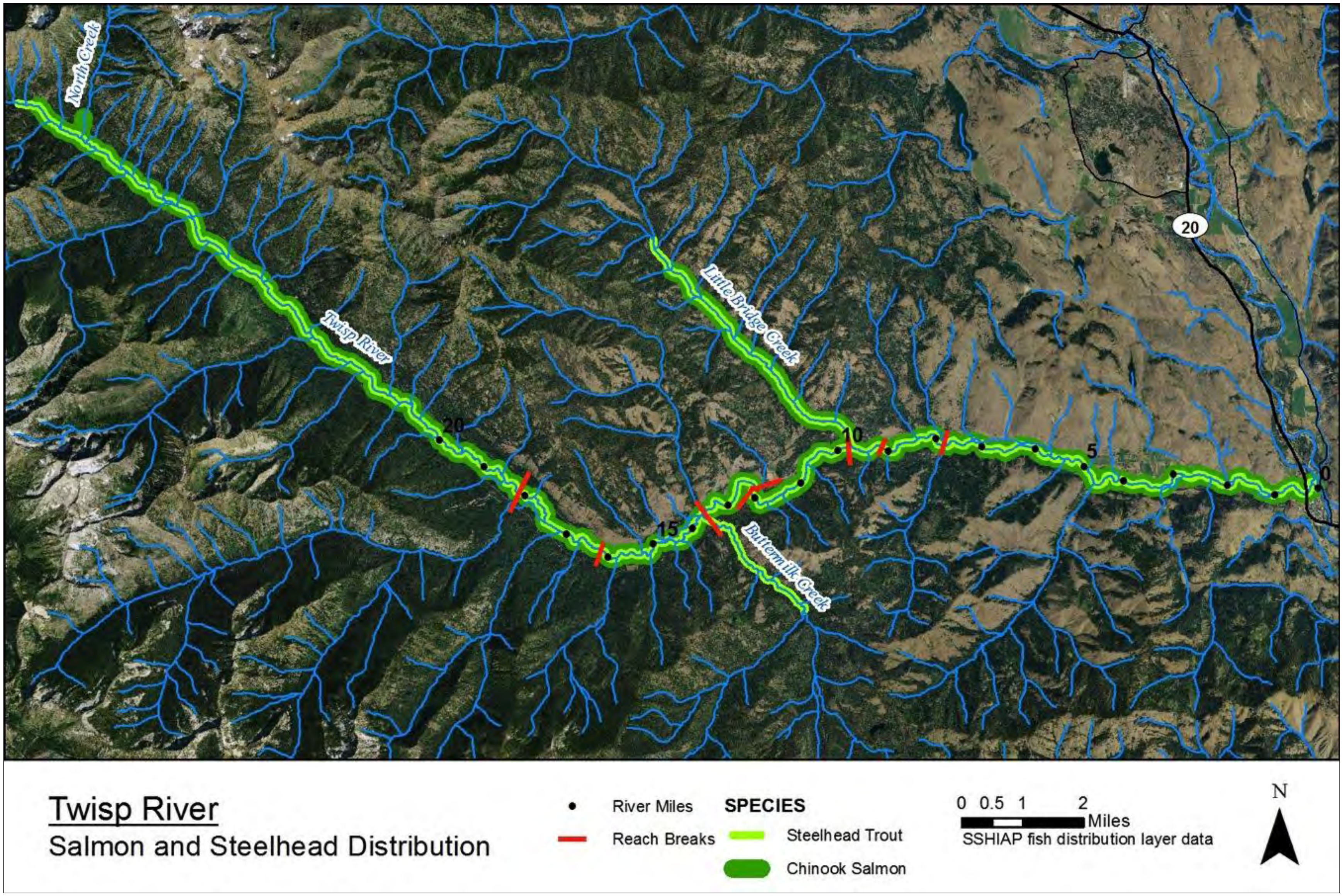

Figure 2. Chinook salmon and steelhead trout distribution throughout in the Twisp River and major tributaries.

1.5 RECOVERY PLANNING CONTEXT

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

The following habitat restoration and preservation objectives were set forth in the Recovery Plan (UCSRB 2007). These objectives apply to spring Chinook, steelhead, and bull trout and are consistent with the Methow Subbasin Plan (KWA et al. 2004) and the Methow Watershed Plan (MBPU 2005). The objectives are intended to reduce threats to the habitat needs of the listed species. Objectives that apply to areas outside the study area or that are outside the scope of this plan are not included. A list of regional objectives (applicable to all streams in the Recovery Planning area) is provided. These objectives provided a framework and guidance for the Reach Assessment and ultimate selection of specific restoration and preservation activities conducted as part of this assessment and included in this report.

1.5.1 Short-Term Objectives

- Protect existing areas where high ecological integrity and natural ecosystem processes persist
- Restore connectivity (access) throughout the historical range where feasible and practical for each listed species
- Protect and restore water quality where feasible and practical within natural constraints
- Increase habitat diversity in the short term by adding instream structures (e.g. large wood, boulders) where appropriate
- Protect and restore riparian habitat along spawning and rearing streams and identify long-term opportunities for riparian habitat enhancement
- Protect and restore floodplain function and reconnection, off-channel habitat, and channel migration processes where appropriate and identify long-term opportunities for enhancing these conditions
- Restore natural sediment delivery processes by improving road network, restoring natural floodplain connectivity, riparian health, natural bank erosion, and wood recruitment

1.5.2 Long-Term Objectives

- Protect areas with high ecological integrity and natural ecosystem processes
- Maintain connectivity through the range of the listed species where feasible and practical

1.5.3 Restoration Objectives Specific to the Methow Basin

- Preserve, protect, and manage instream water uses to balance flows for local uses (e.g. agriculture) and instream habitat where appropriate
- Protect and restore riparian corridors where feasible
- Remove or recondition human infrastructure that currently limits habitat connectivity and complexity (e.g. culverts, riprap) where feasible
- Increase diversity and complexity of habitat types by adding instream structures (e.g. large wood, boulders) where appropriate

2 Assessment Area Conditions

2.1 SETTING

The Twisp River Basin is located in Okanagan County in North Central Washington State on the east side of the Cascade Mountains within the Columbia Cascade Ecological Province. Headwater drainages originate in the far western portion of the divide in North Cascades National park. The total catchment area is 246 square miles. The study area includes RM 7.8 to RM 18.1. The catchment area contributing to the downstream extent of the study area (7.8) includes several small drainages such as War Creek, Eagle Creek, Oval Creek, Canyon Creek, Buttermilk Creek, Little Bridge Creek, and Newby Creek.

Six distinct geomorphic reaches were delineated within the study area (Figure 3). Reach delineation was based on basin size (i.e. major tributary confluences), valley confinement, underlying geology, channel gradient, and channel type (e.g. dominant bed morphology). Reach delineation was initially conducted using remotely available data (e.g. aerial photos, LiDAR, and geology maps) and was field-verified during surveys.

2.2 GEOLOGY

This section provides a brief overview of geology; more information on the geologic setting and history of the study area is provided in Appendix D.

The Twisp River Basin is located within the eastern portion of the Northern Cascades geologic province. Within this province, the Twisp River lies within the Methow Terrane. This terrane is a combination of sandstone and shale sediments left behind by the Methow Ocean, which covered today's Methow valley region 200 to 100 million years ago. The terrane also contains traces of riverine deposited sedimentary rocks (tributaries of the Methow Ocean) as well as volcanic rocks deposited during the Cretaceous period (100 million years ago) (USGS 2004).

Fault systems in this region create topographical and hydrographic divides in the Middle Twisp River study area, and affect the position of the major structural blocks and bedrock elements in the channel. A graben-bounding fault crosses the channel at RM 9, which creates an erosion-resistant "step", or noticeable increase in grade, between RM 9 and RM 10. This location coincides with a major slope break in the long profile of the Twisp with slope being flatter upstream and steeper downstream. This is also the approximate location where glaciation extended down to during the period of last glaciation.

Current channel and valley form, including the Twisp River's U-shaped valley in the upstream portion of the study area, is most directly influenced by consecutive glaciation cycles, the last of which occurred as recently as 9,500 years ago (USBR 2008). During periods of alpine glaciation, ice streams moved from higher elevations in the basin downslope, carving out rock masses and leaving behind glacial features including U-shaped valleys, till deposits (moraines), outwash deposits (terraces), and glacial erratics.

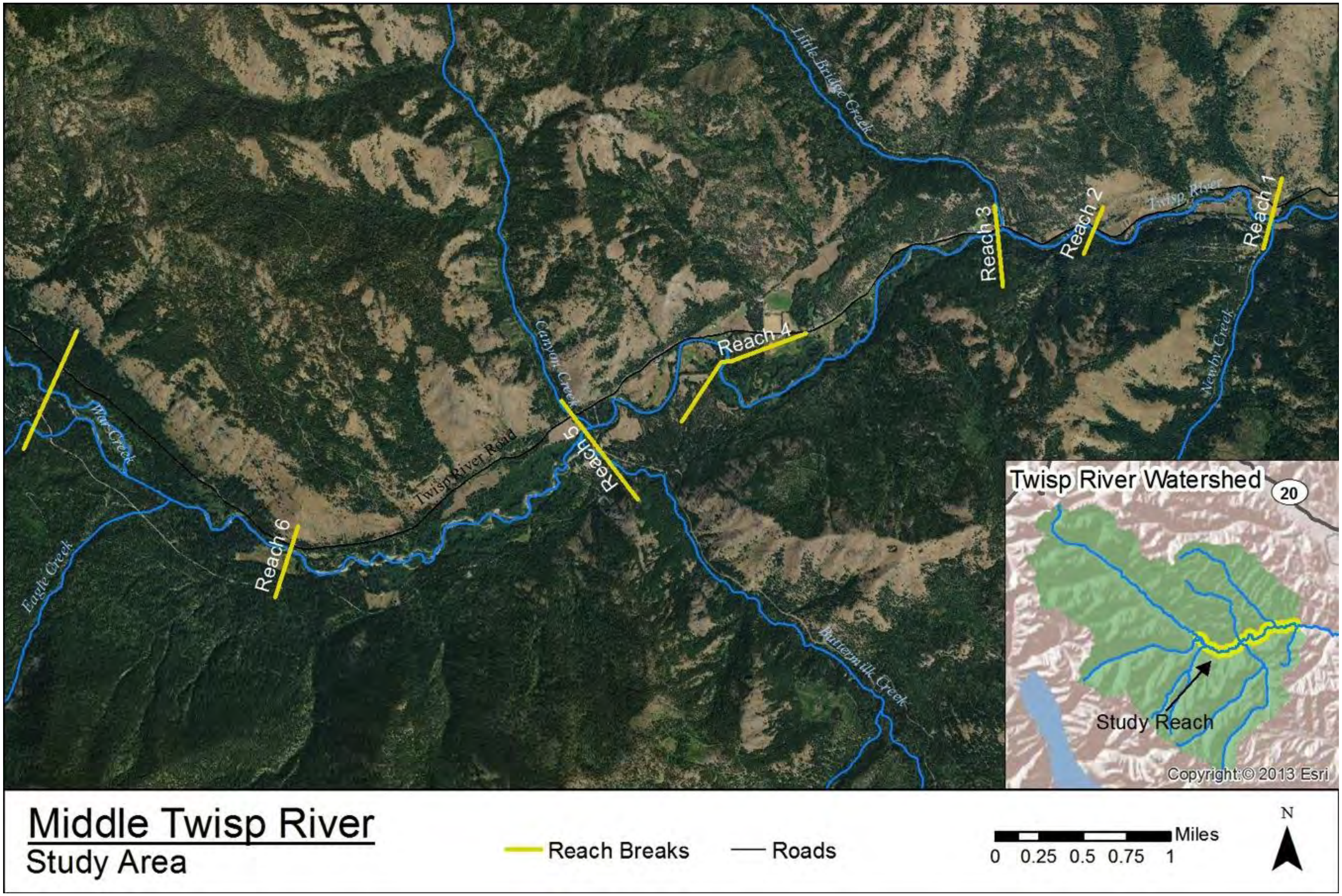

Figure 3. Geomorphic reach breaks in the Middle Twisp Study Area.

2.3 HISTORICAL FORMS AND PROCESSES

Within this Reach Assessment, historical conditions are considered as those that would have existed just previous to Euro-American settlement (i.e. prior to large-scale human alteration). Historical conditions represent the conditions to which native species such as salmonids were presumably best adapted, prior to the population crashes that ensued as human interventions increased on the landscape. In many cases, restoration to historical conditions will be impossible or inappropriate; however, historical conditions nevertheless provide a reference point for helping to determine how habitats and processes have changed and can help inform the identification of restoration objectives. This section provides a brief summary of historical conditions; more information is provided in Appendix E.

Historical habitat conditions in the study area would have been influenced by the underlying geology (described previously) and the geomorphic setting. The relatively wide floodplain of the Twisp River Basin can be traced to the Pleistocene era (approximately 2.5 million –11,700 years ago), when the climate in the area was cooler, there were higher annual precipitation volumes, and glaciers dominated the landscape. High volume flooding resulted in mass-wasting deposits and alluvial fan inputs that deposited large amounts of material into the system. Following the Pleistocene was a warmer, drier climate cycle during which glaciers retreated, and the channel was no longer filled with high volumes of water to span the valley floor. Thick glacial deposits (glacial terraces) from the upstream extent of the study area to RM 10 were left behind. As the now 'underfit' Twisp River attempted to cut through its wide channel bed, lateral channel migration was limited by bedrock outcrops, mass-wasting deposits, and alluvial fan inputs from contributing drainages throughout the study reach.

Historical habitat conditions within the study area would have varied depending on the specific geomorphic conditions within each reach. In general, the confined reaches (Reaches 1 and 2) would have had high lateral and vertical stability. Due to their natural confinement, these reaches have likely changed the least compared to historical conditions, since modern human alterations such as bank armoring only have limited impacts on channel processes such as flooding and channel migration. The moderately confined reaches (Reaches 3, 4, and 6) would have had greater complexity, with more off-channel habitat, pools, log jams, and gravel deposits for spawning. Much of Reach 3, which is now considered moderately confined, would have been unconfined historically due to the absence of human confinement. The unconfined reaches (Reach 5 and historically Reach 3) would have had the most complex habitat, with extensive split flow conditions, connected off-channel wetlands, many large log jams, variable-aged riparian communities, abundant pools, and abundant spawning gravels.

As with many other Pacific Northwest river systems, large wood would have been one of the primary drivers of geomorphic form and process, and would have provided instream habitat availability and complexity. The sizes and species would have been variable, depending on the disturbance history, but likely ranged from 500-year-old trees to smaller hardwoods (USBR 2008).

Recruitment would have occurred via chronic (i.e. single tree) mortality as well as large-scale disturbances. The unconfined reaches would have recruited wood via lateral and transverse scrolling of the channel, whereas recruitment in the more confined reaches would have occurred primarily through single-tree mortality. Retention of large wood in rivers is correlated with characteristics of the wood itself and the stream size and complexity. The larger wood of the era likely would have been retained, forming large jams. In addition, the greater channel complexity would have helped in not only retaining wood, but would have promoted both geomorphic and habitat functions including creation of pools, sediment retention and sorting, creation of mid-channel vegetated islands, and providing cover and complexity for fish.

2.4 HUMAN DISTURBANCE HISTORY

This section provides an overview of human disturbance history; more information is provided in Appendix F.

Euro-American settlement began in the 1880s, sprouting three major industries that became the backbone of the economy and heavily impacted the land and water of the region: mining, agriculture and grazing, and timber harvest. Fire suppression and direct habitat alterations related to settlement have also heavily impacted the area.

The Methow Valley mining rush began in 1886 (Smith 2013). Mining likely impacted the Twisp River by altering the hydrologic and sediment regime via the removal of instream gravels, diversion of water, and deposition of mining waste in the channel and floodplain.

Agriculture and grazing were first documented in the region in 1889. By World War 1, it's estimated that over 75,000 sheep were grazing the headwaters of the Twisp River (McLean 2011). Cattle and sheep grazing resulted in localized soil compaction, bank erosion, and loss of riparian understory seedlings and shrubs. One of the most significant of the agricultural impacts, however, was water diversions, which began in the early 1900s and resulted in significant fish mortalities until the 1930s when screens were required at diversion points.

Timber harvest began in the region in the 1880s to clear land for farming and grazing (USBR 2008). It continued until the 1970s when the US Forest Service shifted logging policy to focus on salvage operations following wildfires (MVCC 2000). Overall, logging in the upland and valley floor impacted the hydrologic and sediment regime by increasing the number and scale of landslides and debris flows. In the lowlands, removal of riparian vegetation led to a loss in channel functions including streambank stability, floodplain hydraulic roughness, nutrient dynamics, moderation of stream temperature (i.e. via stream shade), and large wood recruitment.

Fire suppression, which began in 1911, has altered the fire regime and has increased the risk of moderate to high intensity burns. It has also shifted the vegetative composition from more open stands of fire-tolerant species (primarily ponderosa pine) to higher density stands of less fire-tolerant species (primarily Douglas fir). The result is fewer large trees in the riparian zone that can provide important geomorphic and habitat functions.

Human disturbances since the 1950s have resulted in significant impacts to sediment, wood, and hydrologic processes. Much of the private property has undergone vegetation clearing, floodplain grading, and residential development (Table 2). Flood mitigation practices of the mid- to late-1970s led to removal of native substrate and habitat elements such as log jams. Those practices also included the construction of levees to prevent flooding on private property, which reduces floodplain connectivity and lateral channel migration. Riprap was also used intermittently throughout the study area as a method of bank stabilization for residential properties as well as roadway embankments and bridge abutments. This armoring limits natural lateral channel migration and sediment sourcing from streambanks.

Table 2. Human alterations and development in the study area. The low geomorphic surface includes the contemporary floodplain and alluvial terraces.

Metric	Value in the Low Geomorphic Surface
Road Density	3.4 mi/mi^2
Public Land	31.3%
Private Land	68.7%
Portion of Channel with Levees and Bank Armoring	27.5%
Developed and Cleared Land	18.8%

2.5 HYDROLOGY

The Twisp River drains 245 square miles of the eastern Cascades. All of the runoff generated from the Twisp River drainage basin empties into the Methow River near Twisp, Washington. Dominant hydrologic patterns are driven by precipitation in the form of snow and subsequent spring snowmelt. Peak runoff usually occurs from April to August, with the highest rates typically in June (Figure 4). Stream discharge typically returns to baseflow by September. Mean daily flow is 268 cubic feet per second and the mean annual precipitation is 43.1 inches (USGS 2013).

Precipitation amounts vary with elevation and distance from source areas. In the higher elevation areas of the basin, which top out at 8,780 feet, average annual precipitation is 65-70 inches falling mainly as snow. The downstream end of the study area is at an elevation of 1,600 ft. Tributaries in the study area include Myer Creek (RM 7.82), Coal Creek (RM 8.5), Little Bridge Creek (RM 9.78), Canyon Creek (RM 13.86), Lime Creek (RM 15.45), Scaffold Camp Creek (RM 15.86), Eagle Creek (RM 17.14), War Creek (RM 17.42), and a number of unnamed tributaries and ephemeral drainages.

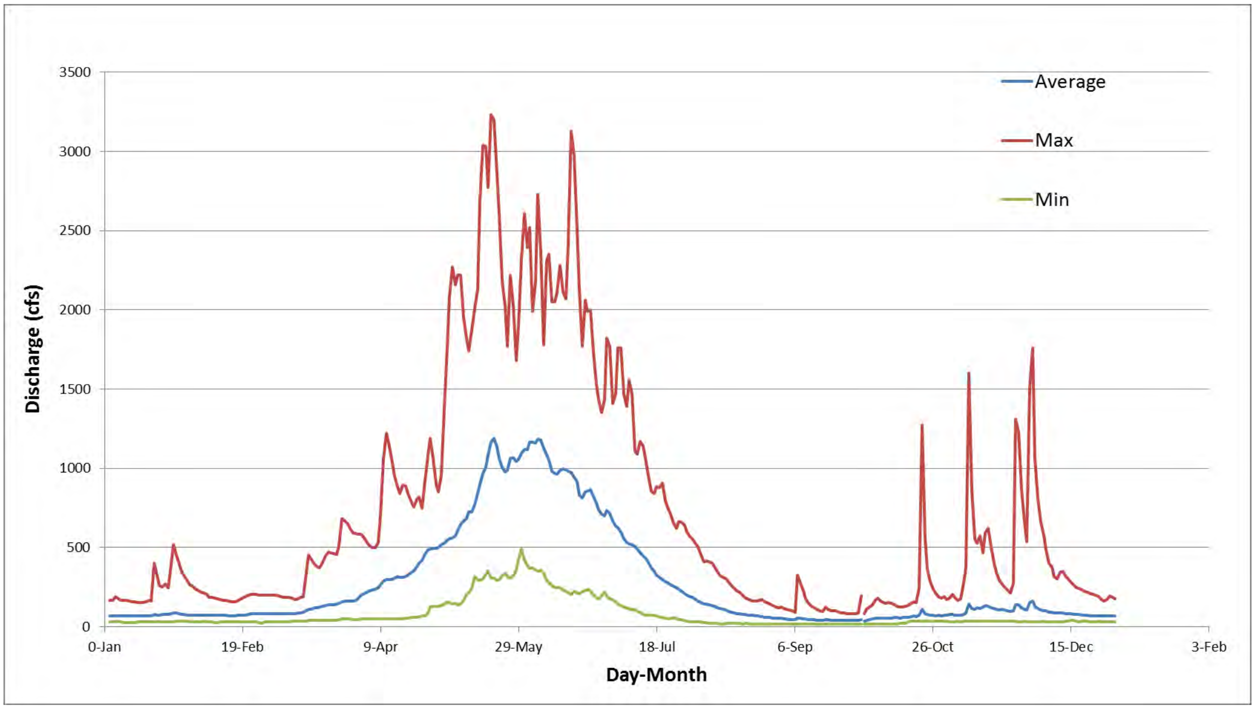

Figure 4. Average, maximum, and minimum values of average daily flows for the period between 10/1/1989 to 9/30/2013 (as measured at USGS gage number 12448998).

The timing (month) of annual peak flows from this gage is plotted in Figure 5. These data show that the flood regime is strongly influenced by spring snowmelt; out of 23 total peaks in the record, 22 of them have occurred in May and June, which is typical of rivers in the region.

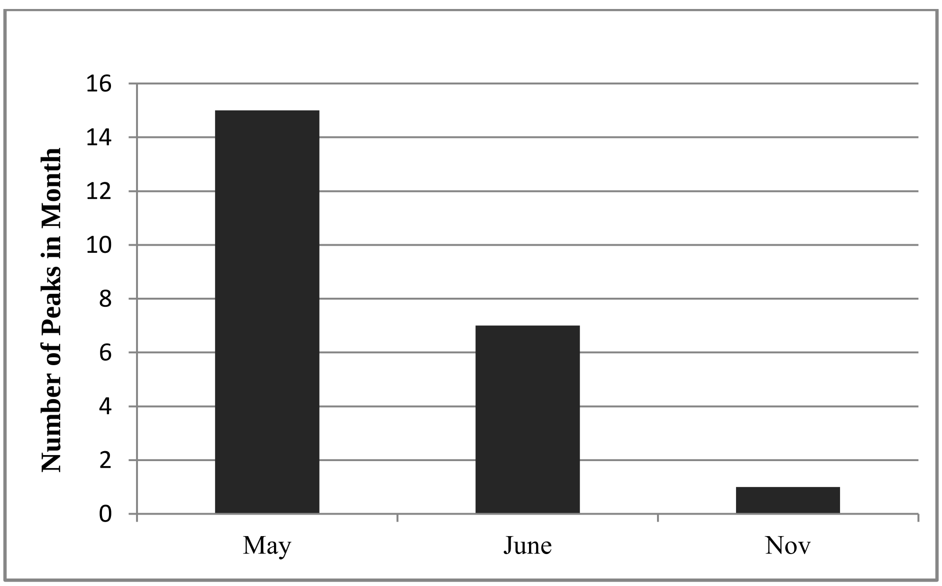

Figure 5. Month of occurrence for annual peak flow events recorded at the USGS gage on the Twisp River (as measured at USGS gage number 12448998).

There is one USGS real-time stream gage on the Twisp (USGS gage number 12448998) located at RM 1.6, with a period of record from 1989 to 2013. A list of the ten largest flood events on record is presented in Table 3. The Twisp River gage was also used to perform a flood recurrence analysis (Table 4).

Table 3. List of 10 largest measured flood peaks since 1989 (USGS gage number 12448998).

Year	Day	Discharge (ft^3/s)
2006	May 19	3230
1991	May 20	3200
1999	June 17	3130
1997	May 16	3040
2008	May 19	2930
2007	June 5	2730
1995	May 31	2610
2011	May 16	2440
1998	May 5	2270
1996	June 5	2170

Table 4. Flood Recurrence Analysis for USGS Twisp River gage (USGS gage number 12448998). Period of record from 1989 to 2013. Data retrieved on 14 November 2013.

Exceedance Probability (% Chance)	1	2	5	10	20	50
Recurrence Interval (years)	100	50	25	10	5	2
Discharge (cfs)	6,390	5,610	4,860	3,890	3,160	2,120

2.6 HYDRAULICS

2.6.1 Background

A hydraulics analysis was used to support this geomorphic assessment and subsequent restoration planning efforts. This analysis utilized available LiDAR data to run a one-dimensional hydraulic model (HEC-RAS version 4.0) for the entire study area (Reaches 1-6). The model is used as one of several tools for analyzing flood inundation levels and for comparing stream energy patterns among reaches within the study area.

2.6.2 Methods

Hydraulic Model

The hydraulic model was built using AutoCAD and 2013 aerial photographs to define the stream centerline, bank stations, overbank flowpaths and cross sections. These features were overlaid on a digital elevation model (in this case, LiDAR (Watershed Sciences 2007) from which elevations were extracted for all components of the geometric data set. Cross sections were spaced at a minimum of every 100 feet, with additional cross sections added through areas around meander bends, upstream and downstream of bridges, or where additional resolution was warranted. Once the geometric data was developed, the model was exported from AutoCAD and brought into HEC-RAS 4.0, a one-dimensional water surface profiling program. Steady-flow data was input based on flood frequency data presented in Table 5. Flows ranging from the Q2 (2-year) to the Q100 (100-year) floods were modeled (USBR 2009). Modeled flows are presented in Table 5. For the purposes of this effort, we used Manning's roughness coefficient (n) values ranging from 0.038 to 0.045 for the channel. Manning's values represent resistance to flow, and are applied both to in-channel and overbank (floodplain) areas. Values were based on field observation of median size of channel substrate and calibrated according to photographic comparisons in Barnes 1967, with reference to values provided in Acrement and Schneider (1989). Floodplain roughness varied from 0.05 to 0.08 based on overbank area conditions observed during the field survey.

Table 5. Flood frequency data used in the hydraulic model developed for the inundation analyses based on hydrologic analyses by USBR (2008). Flow change locations are listed by River Mile (RM) and closest hydraulic cross-section HEC-RAS. Discharge units at each reach are cubic feet per second.

Flood Recurrence Interval (Station)	RM 18.12 (62905.56)	RM 17.2 (57498.07)	RM 15.9 (39345.93)	RM 13.7 (39141)	RM 13.6 (38654.12)	RM 9.7 (18608.64)	RM8.4 (11566.3)	RM7.8 (8106.47)
Q2	814	936	1152	1468	1587	1803	1838	1888
Q5	1222	1404	1714	2185	2362	2683	2735	2810
Q10	1512	1737	2111	2691	2910	3306	3370	3461
Q25	1898	2181	2639	3364	3637	4132	4212	4327
Q50	2199	2527	3050	3887	4202	4774	4867	4999
Q100	2511	2886	3473	4427	4786	5438	5543	5694

There are limitations for utilizing LiDAR to model floodplain inundations. The LiDAR data available for the Twisp River is capable of producing elevation data in terrestrial environments, but cannot produce ground elevations below water (i.e. bathymetry) and the data includes errors of at least up to 0.5 feet. Consequently, results of these analyses should not be used for detailed modeling, restoration, or infrastructure planning purposes. Despite this limitation, the inundation analysis is assumed to be relatively accurate for larger flood flows (i.e. 2-year return interval and above), where the topography errors would have less effect (proportionally) on the results.

Flood Inundation Analysis

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

Stream Power Analysis

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

$$\Omega = \gamma Qs$$

Where:

γ	=	the specific weight of water
Q	=	discharge
S	=	Energy Gradient Slope

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

Sediment Competence Analysis

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

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

The shear stress applied to the bed is:

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

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

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

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

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

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

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

Where:

τ	=	bed shear stress	τ_c	=	critical shear stress (lb. /ft^2)
ρ	=	density of water (lb. /ft^3)	D_{84}	=	84th percentile of grain size (ft.)
g	=	gravity (ft/s)	D_{50}	=	median grain size (ft.)
R	=	hydraulic radius	s	=	slope
ρ_s	=	density of sediment (lb. /ft^3)	τ^*_{c50}	=	critical dimensionless shear stress (Shields Parameter)

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

A total of 12 pebble counts were conducted at riffle crests to evaluate the stream substrate that is providing grade control. Pebble count data were used to evaluate sediment mobility conditions. Pebble counts were compared to hydraulic conditions of the closest hydraulic cross-section in the model, so data is only a snapshot of sediment mobility conditions, and should not be generalized to the whole reach. Due to the limited quantity of pebble counts and the fact that hydraulic parameters are based on LiDAR, data should only be utilized to understand sediment transport patterns at a conceptual level, and should not be utilized for design purposes.

2.6.3 Results

Floodplain Inundation

Inundation analysis results for the entire study area are presented below in Figure 8 and Figure 9. These maps provide a broad overview of inundation patterns at the study area scale. Higher resolution, reach-scale flood inundation maps are included in the reach-specific sections later in this document. Throughout the confined reaches (Reaches 1 and 2), flows for both the 2-year and 100-year flood events remain largely in-channel. Throughout the moderately confined and unconfined reaches (Reaches 3 – 6), water surface elevations extend beyond the main channel boundaries. In many places these flows activate side channels and inundate floodplain surfaces.

Hydraulics

Results of the 2-year and 100-year flood event hydraulic analyses are presented in Table 6 and Table 7. For both the 2-year and 100-year events, Reaches 1 and 2 had the highest stream power, average shear stress, and velocities, with Reach 2 having the maximum values for all of these parameters. These results are consistent with the higher gradient and confinement of these reaches. Stream power, shear stress, and velocity were low in Reaches 5 and 6, likely due to braided conditions and lower gradient.

Table 6. Hydraulic analysis results for the 2-year flood event.

	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Avg Velocity (ft /sec)	7.56	7.56	5.61	5.82	4.54	5.26
Shear stress (avg)	1.73	1.72	1.00	1.06	0.76	1.01
Stream Power (lb/ft/s)	12.86	13.71	6.04	6.92	3.96	5.91
Incipient Particle Size (in)	8.13	8.32	4.45	5.18	2.32	4.35

Table 7. Hydraulic analysis results for the 100-year flood event.

	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Avg Velocity (ft /sec)	10.58	10.52	8.08	8.11	6.54	7.4
Shear stress (avg)	2.78	2.74	1.68	1.72	1.33	1.65
Stream Power (lb/ft/s)	30.41	30.9	14.59	15.97	10.35	13.4
Incipient Particle Size (in)	13.01	13.26	6.87	7.31	3.68	5.95

Sediment Competence

Although these results cannot be generalized throughout the entire study area, sediment competence analyses suggests that at all but three of the analyzed flows (Reach 2 and 4 using Q100 Komar and Reach 4 using Q2 Komar), the D50 and D84 size sediment is not mobile (Figure 7).

2.6.4 Discussion

The results of the hydraulic modeling indicate that Reaches 1 and 2 have the largest shear stresses and average velocities observed within the study area. These reaches also had the largest estimated stream power during flood events and low rates of floodplain inundation. The confined nature of the channel in this area, combined with the high stream energy and large shear stresses are associated with increased sediment transport capacity, which coincides with the transport nature of Reaches 1 and 2 noted in the geomorphic assessment. Conversely, greater floodplain inundation and lower stream energy was observed in the less confined reaches (Reaches 3 – 6), which is consistent with a more depositional system. Analyzing the hydraulic analysis in combination with the geomorphic and habitat assessments shows that current channel and floodplain complexity increases in reaches with greater floodplain inundation.

Floodplain inundation modeling provided insight into the geologic processes of incision. As this section of the Twisp River has adjusted to the drier contemporary hydrologic regime, it has naturally incised, leaving behind abandoned floodplain terraces, likely formed during and following the period of last glaciation. The hydraulic inundation models of the 100-year flood helped to verify the boundaries between abandoned terraces and modern floodplain surfaces.

The modeling results also provide quantifiable evidence of the impact that human alterations have had on floodplain inundation patterns, stream energy, and incision processes. One area of significant impact is in the river-left floodplain at the upstream end of Reach 5, where there is bank armoring, multiple push-up levees, floodplain grading, and excavated borrow pits. These features have reduced floodplain inundation rates and floodplain flow patterns. They also have impacts on lateral channel dynamics. In the absence of these human impacts, the river-left floodplain in this area would be expected to be well-connected to the river during floods. Instead, the river now has limited access to this surface, which primarily occurs through backwatering from downstream gaps in the levee system or through groundwater connections.

Floodplain inundation modeling also shows the impacts that bridge constrictions have on floodplain processes and channel migration. The bridge crossings at the upstream end of Reach 6 (RM 18.1) and the upstream end of Reach 4 (RM 13.5) are the primary examples of this. These bridges, and their associated approach fills, interrupt floodplain flow by routing flow back into the channel at the crossing. They also limit any potential channel migration due to the bridge abutments and associated riprap. These impacts not only disrupt floodplain connectivity but they also contribute to stream channel incision and habitat simplification in the areas around the crossings. The effect of the Reach 6 bridge (RM 18.1) on floodplain inundation patterns is shown in Figure 6.

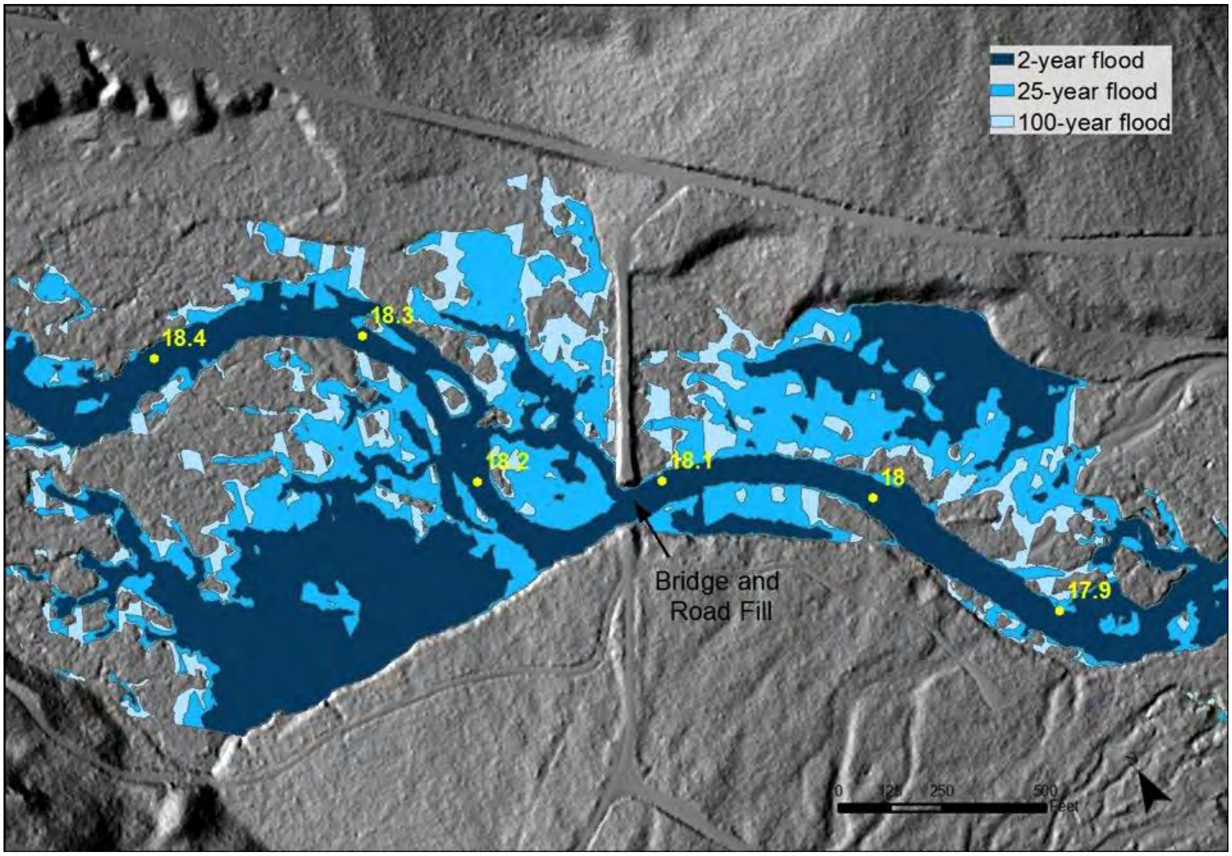

Figure 6. LiDAR hillshade map showing the effect of the Reach 6 bridge (RM 18.1) on floodplain inundation pattern.

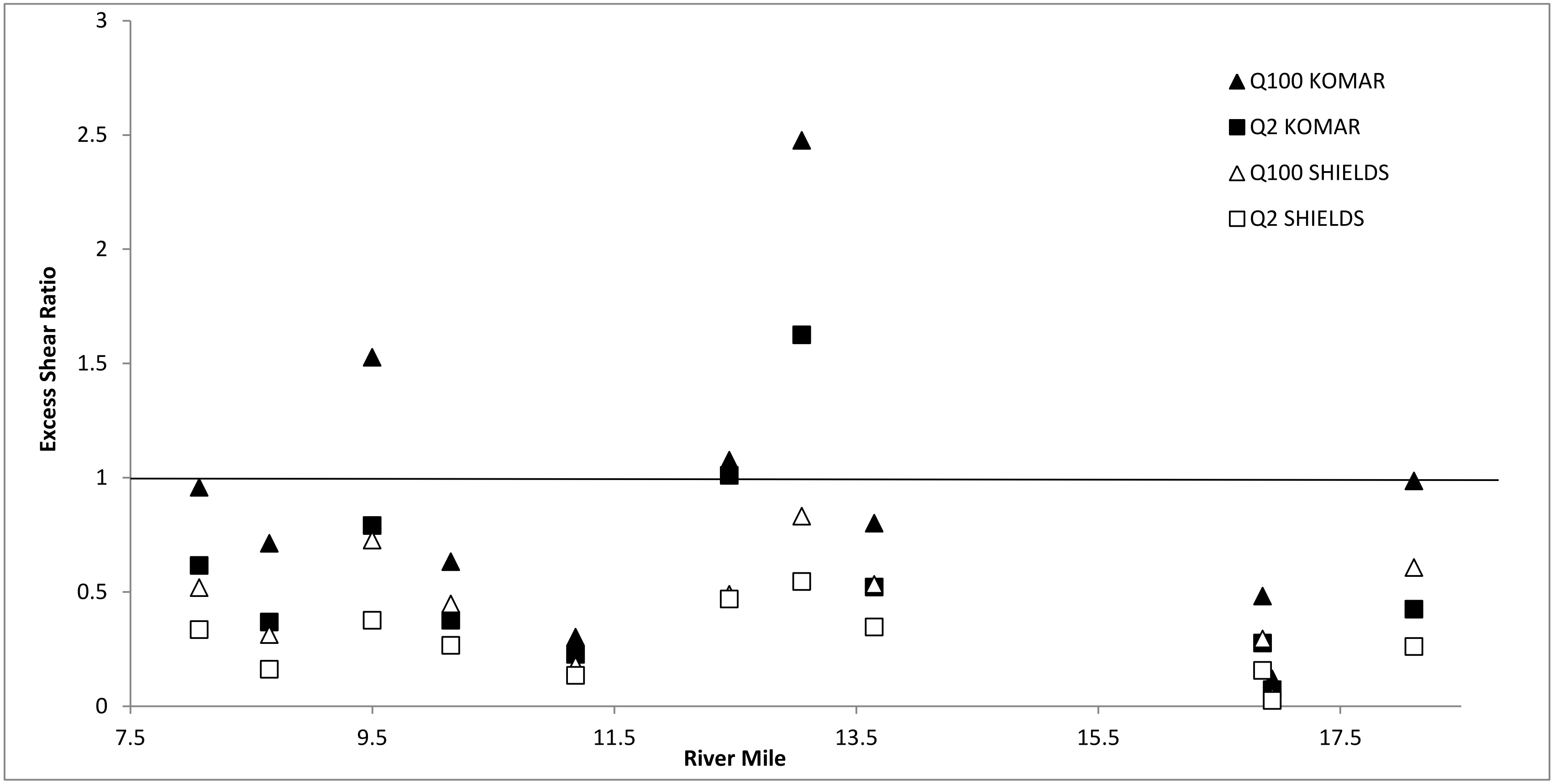

Figure 7. Excess shear ratio based on modeling and pebble count data for select locations in the study area.

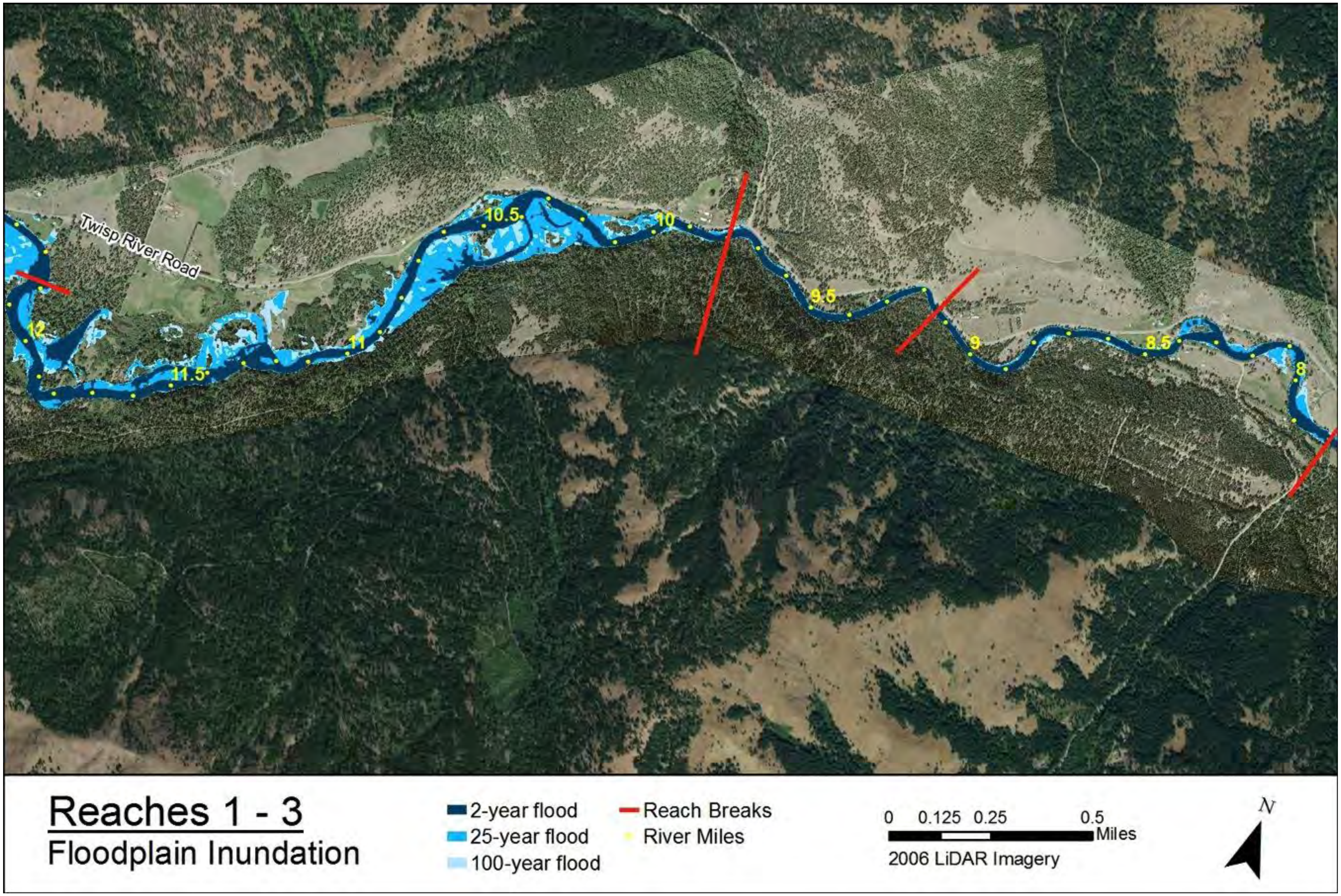

Figure 8. Reaches 1 -3 modeled floodplain inundation for the 2-, 25- and 100-year flood events.

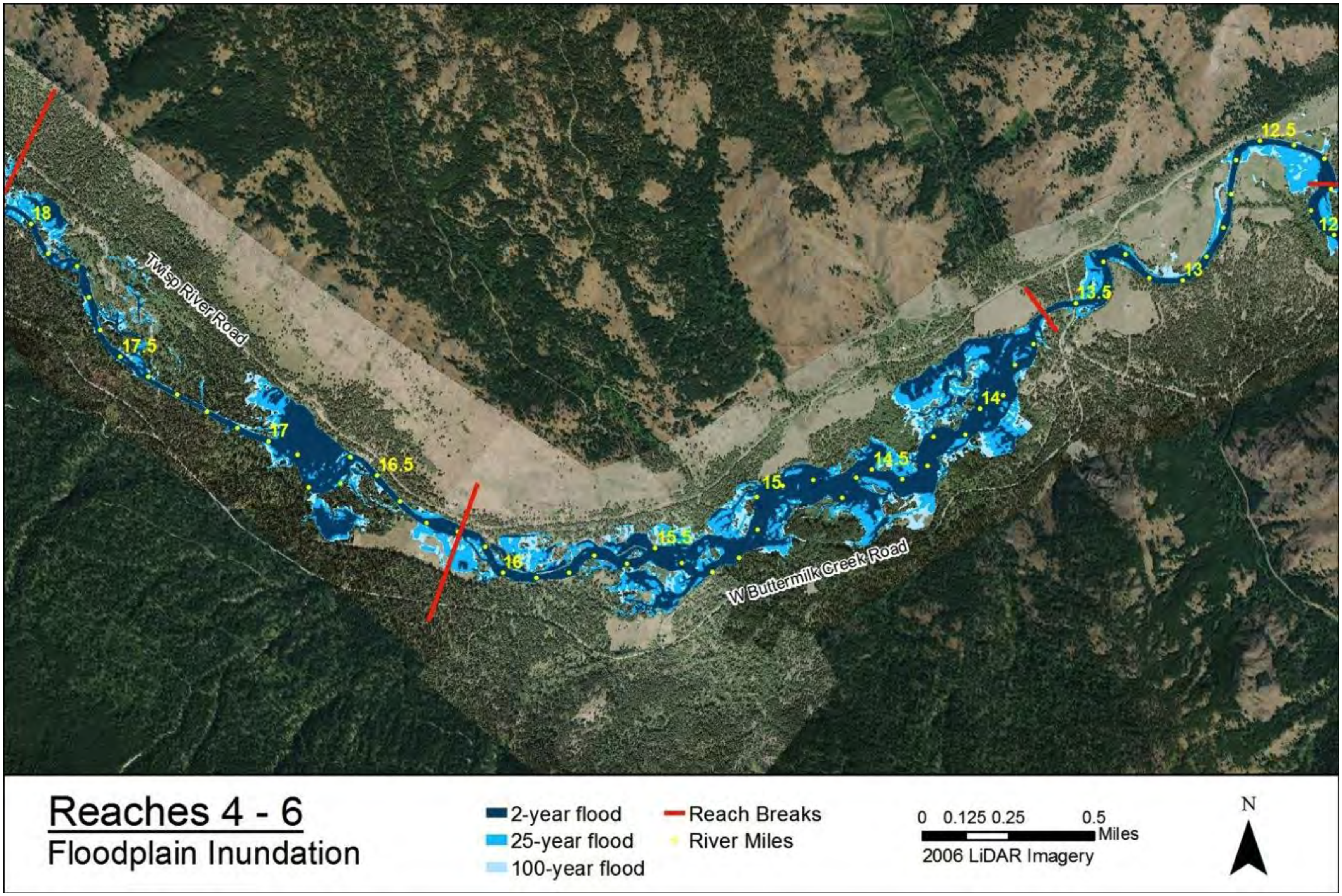

Figure 9. Reaches 4-6 modeled floodplain inundation for the 2-, 25- and 100-year flood events.

2.7 GEOMORPHOLOGY

2.7.1 Valley Morphology

The Middle Twisp River study reach meanders southeasterly with channel sinuosity ranging from 1.11 to 1.49. Valley form is principally governed by historical glaciation cycles and by a number of fault systems in the area. Glacial action within the study area left behind a classic U-shaped valley cross-section at many locations. At the widest areas, maximum valley width exceeds 4,000 feet.

As part of the Methow Subbasin Geomorphic Assessment, the USBR (2008) mapped geomorphic surfaces in the Twisp River valley. This dataset was refined for the study area based on field surveys and hydraulics analysis, which helped to identify active floodplain surfaces. The revised geomorphic surface data is provided in Figure 10, with more detail at the reach-scale provided in Section 3.

Valley morphology within the study area is dictated by bedrock type, remnants of glaciation, and hillslope processes. Upstream of RM 10, the crystalline bedrock lithology is highly erosion resistant, while downstream of RM 10 the underlying lithology is more easily erodible. Adjacent hillslopes and occasional bedrock outcrops provide lateral barriers to channel migration and vertical barriers to incision throughout the study reach. Glacial till and outwash deposits create much of the valley fill within the study area. The Twisp River has naturally incised into these deposits during the late Pleistocene and Holocene. Many terraces are believed to have been created more by decay of remnant ice blocks, rather than retreat of glacial ice sheets (i.e. these are not true moraines) (Waitt 1972). As the river has incised into these behind abandoned terraces, they serve as controls on lateral migration and provide localized sources of sediment.

Alluvial fans continue to play a significant role in determining valley- and reach- scale floodplain and river corridor morphology. Fans of various sizes and configurations have accumulated at the mouths of many of the tributaries on both sides of the valley. In some cases, such as with the large Buttermilk Creek fan, these fans have a large influence on channel position and lateral confinement. Mapping of geomorphic surfaces including alluvial fans, terrace deposits, and the modern floodplain is presented in the reach-specific sections later in this report.

2.7.2 Channel Morphology

The contemporary channel form of the Twisp River is largely influenced by underlying geology and glaciation, with some influence created by anthropogenic hydromodifications. Glaciers extended down into the study reach to RM 10, leaving behind glacial outwash, till, and in-situ terraces. As glaciers retreated and the climate began to become warmer and drier through the early Holocene, water and sediment flux was reduced and the channel incised into valley fill. This has left behind abandoned alluvial terraces, which historically were active floodplain surfaces. This process is similar to the classic channel evolution model described by Schumm et al. 1984, detailing how a channel incises due to changes in flow or sediment regime, then readjusts to a new equilibrium base elevation, and then develops new floodplains inset within the now abandoned terraces.

Today, much of the channel is predominantly confined by these alluvial terraces, glacial features (i.e. till), bedrock, and active and inactive alluvial fans. Mapping of these surfaces is included in the reach-specific sections later in this document. Confinement ranges within the study area between confined (Reaches 1 and 2), moderately confined (Reaches 3 and 4), and unconfined (Reaches 5 and 6). In the moderately confined and unconfined reaches, the channel has migrated laterally to form contemporary active floodplain surfaces.

Bed morphology was characterized as part of the Habitat Assessment (Appendix A). Bed morphology for the study area is predominantly pool-riffle in the less confined sections and plane-bed in the more confined sections. Reach slopes range from 0.57% to 1.16%. Floodprone widths are largest in the unconfined reaches, where gradient is low and the channel is more depositional, as evidenced by increased meanders, side-channels, and abundant gravel bars. Confined reaches flow through areas with narrower active floodplains where channel migration processes are naturally limited by abandoned alluvial terraces, tributary alluvial fans, and occasional bedrock outcrops. In some confined reaches, a small narrow inset floodplain is developing within the channel banks as the channel adjusts to its current equilibrium base level.

Sediment is contributed to the Middle Twisp from alluvial fan contributions, tributaries, occasional mass-wasting processes, near-channel banks, and hillslopes. These banks and hillslopes provide localized sediment from the easily erodible unconsolidated glacial till and alluvial terraces. Sediment contributions from lateral migration and vertical incision are primarily limited to the moderately confined and unconfined reaches. Channel morphologic characteristics are summarized in Figure 11 and Table 8. More detailed geomorphic descriptions for each reach can be found in the reach-specific sections later in this document.

Table 8. Summary of geomorphic and habitat conditions at the valley and channel scale among geomorphic reaches in the Middle Twisp Reach. See the Stream Habitat Assessment (Appendix A) for additional information on how these values were obtained and the methods for the habitat surveys.

	Metric	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Channel	River Miles	7.80 – 9.14	9.14 – 9.79	9.79 – 12.22	12.22 – 13.6	13.6 – 16.19	16.19 – 18.12
	Gradient (%)	1.14	1.16	0.57	0.69	0.59	0.95
	Sinuosity	1.29	1.22	1.43	1.49	1.34	1.11
	Dominant Channel Morphology	Riffle	Riffle	Riffle	Riffle	Glide	Riffle
	Average Bankfull Width (ft)	82	91	102	80	93	72
	Confinement	Confined	Confined	Moderately Confined	Moderately Confined	Un-confined	Moderately Confined
Floodplain	Average Floodprone Width (ft)	170	117.5	320	120.8	393.1	374
% Habitat Area	Pool	12	1	14	14	23	15
	Glide	11	18	15	15	29	15
	Riffle	74	81	69	69	21	69
	Rapid	0	0	0	0	0	0
	Cascade	0	0	0	0	0	0
	Side Channel	3	0	2	2	18	1
	Braided	0	0	0	0	0	0

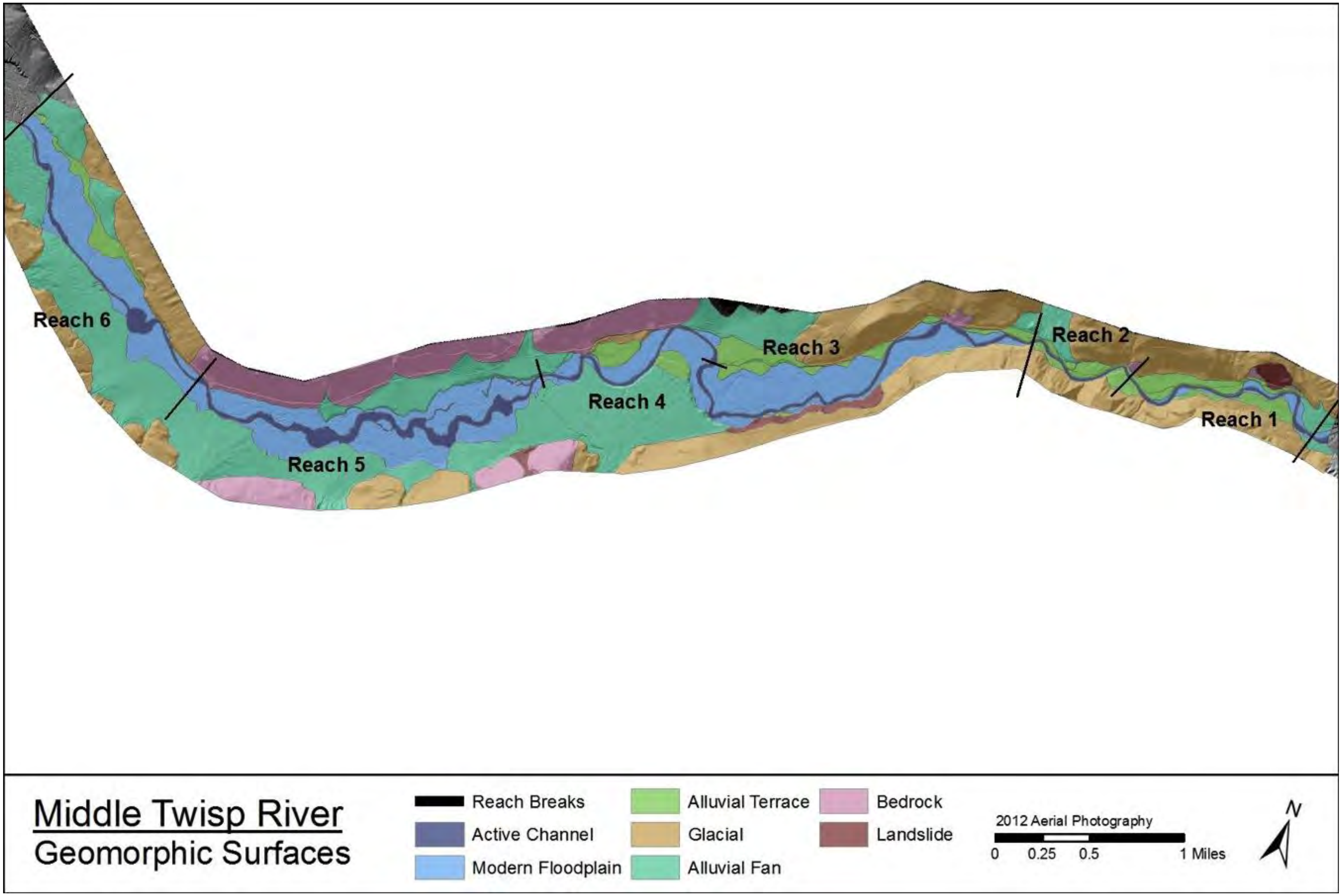

Figure 10. Geomorphic surfaces of the study area. These data are a refined version of the geomorphic surfaces data from USBR (2008), refined for the study area based on field surveys and hydraulics analysis to delineate the modern floodplain surface.

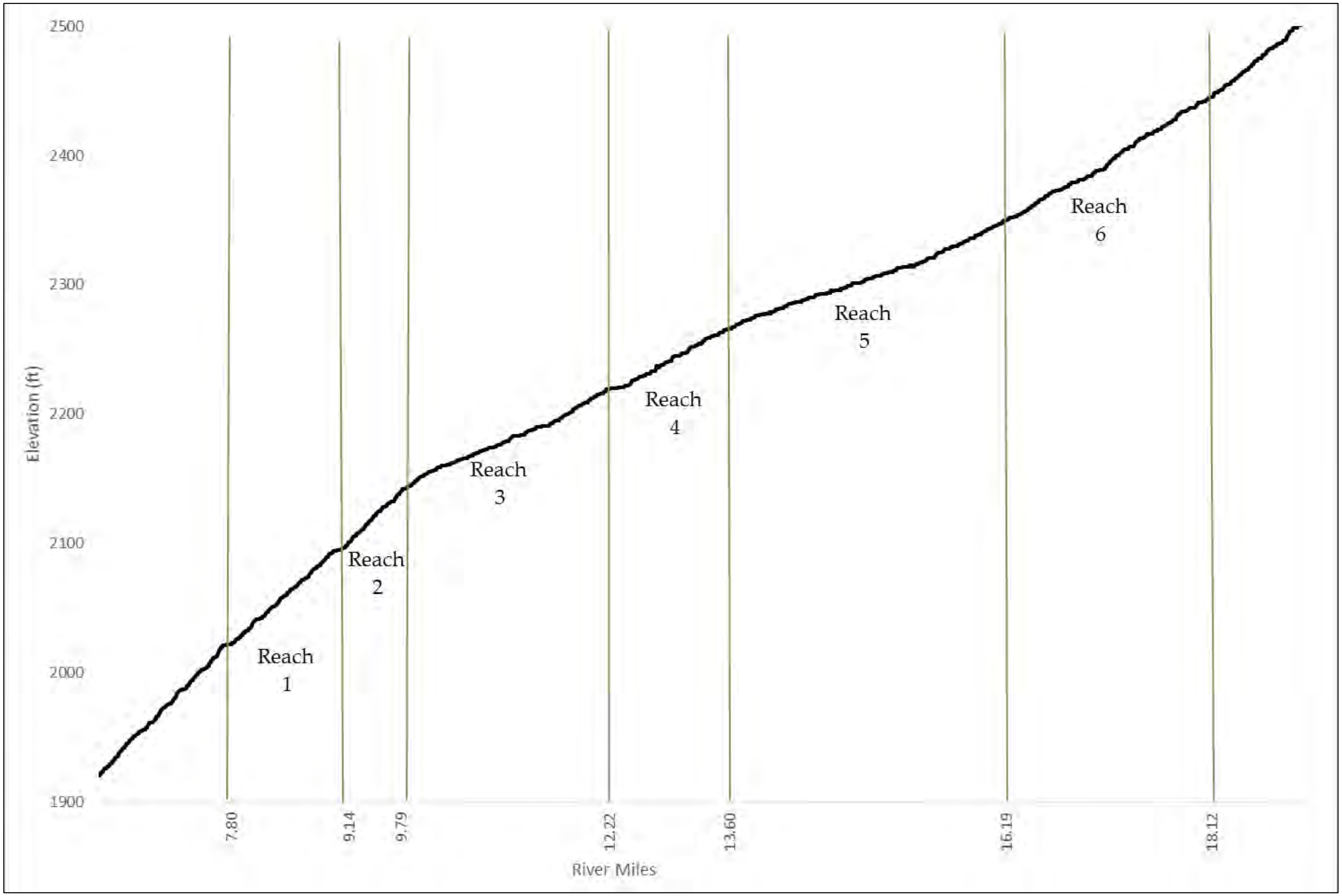

Figure 11. Longitudinal profile of the Middle Twisp Study Area. Elevation data derived from the 2006 LiDAR data.

2.7.3 Large Wood Dynamics

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

Sources

Large wood is still sourced from riparian areas. However, the quantity and quality of contemporary large wood sources have been altered by timber harvest and fire suppression within the study area and within upstream contributing areas. Upland and riparian clearing dating to the late-1800s has and will continue to impact large wood loading for the foreseeable future. Reforested timberlands now dominate the riparian buffers and the trees are considerably smaller than what would be expected under non-harvested conditions. The 2013 habitat survey (Appendix A) classified 97% of the riparian canopy as being dominated by trees less than 21 inches diameter (diameter at breast height). It will be decades or centuries before riparian areas mature to the degree that they are able to provide a large wood recruitment source that resembles historical conditions.

Recruitment

In unconfined reaches, channel scrolling and floodplain avulsions lead to riparian and floodplain tree recruitment. This is particularly evident in the highly sinuous downstream portion of Reach 5 as well as other unconfined portions of the study area (primarily in Reaches 3, 5, and 6). This recruitment is principally driven by scour at the toe of channel banks that leads to bank failure and tree recruitment, but it also happens in avulsions (i.e. meander cutoffs). Confined areas with non-erodible banks (e.g. bedrock) only experience riparian tree recruitment through tree-fall, or from fluvial transport from upstream. Large wood is also recruited to the channel through episodic mass wasting events, particularly from debris flows and landslides during large flood events. Recruitment processes are mostly intact throughout the study area except for areas where lateral channel dynamics or bank stability have been modified through human alterations. The most common human alteration to LW recruitment in the study area is the presence of the Twisp River Road, which lies adjacent to the channel through much of Reaches 1 and 2 and within portions of the other reaches. Bank armoring associated with the road limits not only the available riparian sources for large wood, but also the potential for wood to be recruited through natural bank erosion processes. Bridge constrictions also limit channel migration processes that reduce the potential for LW recruitment. Other relatively minor areas of bank armoring associated with streamside residences also limit local recruitment.

Retention

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

The legacy of in-channel wood clearing may have some effect on contemporary retention processes, especially in the lower portion of the study area (downstream of Little Bridge Creek) where clearing was known to occur. This clearing may have also led to the removal of large boulders, channel straightening, and simplification of channel margins, which would have reduced the potential for the channel to retain wood.

The currently available wood size also affects the ability of the channel to retain wood. The wood that is now contributed to the channel mostly represents second or third growth timber that is smaller than historical wood sizes and does not have the same ability to self-stabilize within the channel. Even though the habitat assessment (Appendix A) found an average of 96 pieces of wood per mile (>6 inches diam; >20 ft long), on average, only 10 of these pieces were 20 inches in diameter, which means the number of key pieces necessary to initiate jam formation are lacking. The shift in riparian seral stage, and the corresponding reduction in available key pieces, has reduced the ability of wood to accumulate and stay in place throughout the river. Shifts in species compositions from fire-tolerant to fire-intolerant species may have also impacted tree size, retention, and the potential for jam formation.

2.7.4 River Ice

River ice on the Twisp is a driver of geomorphic form and process. The Twisp River often forms a frozen layer on the water’s surface (surface ice), and occasionally freezes from the bottom up, which is known as anchor ice. Icing events create both localized channel impacts and larger-scale channel impacts. Localized impacts occur to the channel during a freeze event where ice attaches to and then breaks off of stream banks and contributes to bed and bank scour. Larger scale impacts occur when river ice begins to break-up during warming or thawing events. During these events blocks of ice move downstream and build up behind other blocks of river ice or other obstructions (e.g. islands). Areas prone to ice-damming include transitions from riffles to pools, meander bends, and mid-channel bars. Water then builds up behind these “dams” until enough pressure is formed to burst the dam. This has been linked to multiple flooding events, especially when winter freshets and rapid thawing events occur (e.g. Wenatchee World 2005). There is at least one recorded instance of using dynamite to remove ice jams from the Twisp River (Wenatchee World 2009). The frequency of occurrence of ice-related flooding events in the Twisp is fairly well documented, but the frequency of freezing events in the Middle Twisp is less well known. Similarly, the specific extent and geomorphic impact of ice jams, anchor ice, and frazil ice on the Middle Twisp is uncertain.

Anchor and frazil ice has been linked to adverse impacts to habitat in rivers similar to the Twisp, including fish mortalities (e.g. Brown et al. 1994, Simpkins et al. 2000). Anchor ice has been demonstrated to force juvenile and adult salmonids to abandon overwintering habitats, including pools (Brown and Mackay 1995, Jakober et al. 1998, Brown 1999). Anchor ice is more common in areas with limited riparian vegetation, as the moderating impacts of canopy cover limit the likelihood of anchor ice. Complex habitat, specifically the amount of large wood material, has been linked to increased survival of coastal populations of overwintering salmonid juveniles (Quinn and Peterson 1996). Despite these findings, the extent and types of impacts of ice to salmonid populations on the Middle Twisp is uncertain.

Figure 12. Photo of surface ice on lower Twisp River (Stamper 2013).

2.8 HABITAT CONDITIONS

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

Pool frequency ranged from 1.5 to 13.1 pools/mile at the reach-scale and totaled approximately 15% of the total habitat in the study area. Glides were the predominant habitat type at 59% of the total study area, with riffles at 20% and side channels at 6% of total habitat area, respectively. Reach 5 had the greatest area of side-channel habitat with 15% of total habitat area in the reach.

An average of 165 pieces of wood per mile was counted in the study area (>6 inches diameter; > 20 feet long); 70% of these were “small” pieces with diameters between 6 and 12 inches. Wood frequency at the reach-scale ranged from 28 (Reach 2) to 537 (Reach 5) pieces/mile. As discussed previously, the size, availability, and quantity of wood is lower than what would have been expected historically, which has affected instream channel dynamics and habitat suitability for salmonids.

Bed substrate was predominantly cobble (55%) and gravel (34%). Suitable spawning areas were observed throughout the study area, primarily in the unconfined reaches.

Riparian areas were dominated by native riparian forest vegetation, although natural forest fire cycles and past timber harvest have reduced overall stand ages. Residential development and agricultural uses have impacted riparian conditions in many locations, particularly in Reaches 1 – 4. Results for riparian forest stand ages at the study area scale were 13% small tree (9 – 21” diameter at breast height (DBH), 13% each for sapling/pole (5 – 9” DBH), 23% for shrub seedling (1-5” DBH), and 3 % large tree (≥ 21” DBH).

2.9 WATER QUALITY

As of 2012, the Twisp River is listed as a "waters of concern" by the Department of Ecology for temperature. This determination was made based on measurements collected in 1999 at station ‘Twisp River at War Creek CG’ which exceeded the established criterion. Near the mouth of the Twisp the highest 7-day average daily maximum temperature recorded during the summer exceeded 16°C by about 26% in 2001 and 30% in 2005, with the threshold criterion also exceeded by over 15% at two other locations in those years. More recent measurements show that the Lower Twisp River continues to have high temperatures throughout the summer months; data from 2008 and 2009 continue to show 7-day average daily maximum temperatures with over 15% exceedance of 16°C consistently from mid-July through mid-September at the mouth of the Twisp River (USBR 2008, App I).

In 2001 and 2009, airborne thermal infrared remote sensing surveys were performed for the Twisp River. Comparisons between the longitudinal temperature profiles from the 2001 and 2009 surveys indicate that many of the same cool-water input mechanisms are still in place and act to lessen the downstream warming effect (Figure 13). There is a general warming trend over the 33 miles of the Twisp River as the water moves downstream, as can be seen in the temperature profiles. There are three notable locations of departure from this trend, two of which are located within the Middle Twisp study area (RM 10.08 and 14.48; Figure 13). Cooler water temperatures noted at RM 14.48 (Reach 5) were likely a result of hyporheic flow in the form of several small seeps and a side channel contributing cool water at this location. A second cooling trend was noted between RMs 5.51 and 10.08 during the TIR survey. The decreasing temperature in that section was likely a result of the river channel narrowing into a canyon, increasing subsurface exchange. Both locations also have tributaries entering the Twisp River, which may contribute cooler water and provide for groundwater upwelling and additional subsurface exchange.

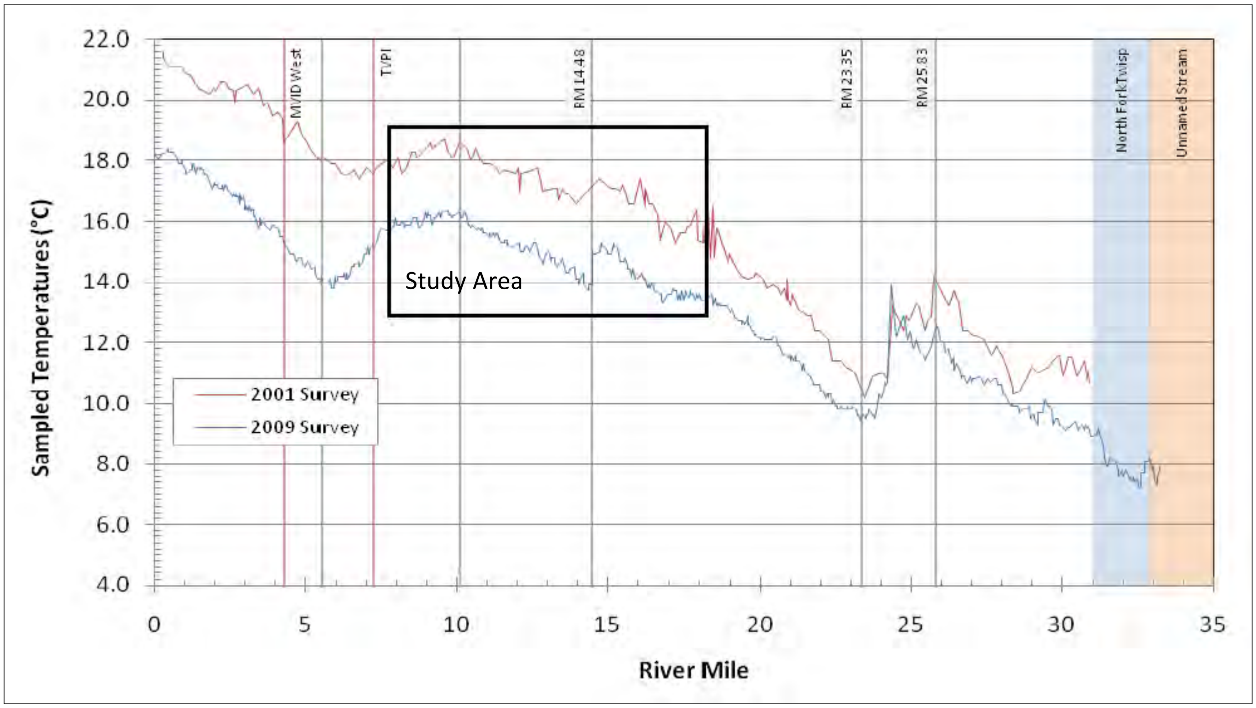

Figure 13. Longitudinal TIR temperature profiles for 2001 and 2009 for the Twisp River from Watershed Sciences, Inc.'s 2009 TIR Report. The temperature discrepancy between the two years was attributed to slightly lower water levels and higher ambient temperature during the 2001 survey compared to 2009.

Water temperature ratings for the Twisp River were developed by the USBR based on NMFS and USFWS salmonid habitat guidelines. Within the Middle Twisp River study area (from approximately RM 7.8 – 18.2), water temperature was given an "At Risk" rating for steelhead rearing and Chinook salmon migration, rearing, and spawning. The lower portion of the Twisp River had a "Not Properly Functioning" rating for steelhead, Chinook salmon, and bull trout rearing, as well as Chinook salmon spawning and migration (USBR 2008, App I). The timing of the temperature increases is also important. High water temperatures throughout the summer months, and particularly in August and September during spring Chinook spawning, may be even more detrimental to the long-term use of the Twisp River as salmon habitat (See Section 1.4 for additional fish use information). Cool water refugia during these warmer months of the year throughout the Twisp River is important for the continuance of spawning and survival of juveniles to their next life stage, as only temporary excursions through water with high temperatures can be tolerated by many salmonids.

Outside of temperature data, there is very little water quality data for the Twisp River; although it is worth noting that there is livestock grazing occurring within the watershed which may impact water quality through nutrient and sediment loading.

2.10 REACH-BASED ECOSYSTEM INDICATORS

This section presents an overview and summary of the REI results (Table 13), which are presented in more detail in the REI Report (Appendix B). The REI applies habitat survey data and other analysis results to a suite of REI indicators in order to develop reach-scale ratings of functionality with respect to each indicator. Functional ratings include adequate, at risk, or unacceptable. The REI analysis helps to summarize habitat impairments and to distill the impairments down to a consistent value that can be compared among reaches. This analysis is also used to help derive restoration targets as part of the restoration strategy presented later in this document. The rating definitions, and explanations of how the ratings were made, can be found in Appendix B.

There were no fish passage barriers within the study area so each reach was therefore given a rating of adequate for this indicator. For the remainder of the indicators, some general patterns are observed. Reaches in the downstream portion of the study area (Reaches 1-2) were the most impacted reaches in the study area having the highest number of at risk and unacceptable ratings. The upstream reaches (5 and 6) were generally more functional overall with fewer at risk and only one unacceptable rating. Reaches 3 and 4 were intermediate between the upper and lower reaches. Habitat quality and riparian vegetation metrics were the most impaired. For the study area as a whole, at risk was the most common rating (33), followed by unacceptable (17), then adequate (16). Additional detail is provided in Appendix B.

Table 9. Reach-Based Ecosystem Indicator (REI) results. See Appendix B for the REI report.

General Characteristics	General Indicators	Specific Indicators	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Habitat Assess-ment	Physical Barriers	Main Channel Barriers	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate
Habitat Quality	Substrate	Dominant Substrate/Fine Sediment	Adequate	At Risk	Adequate	At Risk	Adequate	At Risk
	LWM	Pieces per mile at bankfull	Unacceptable	Unacceptable	Unacceptable	Unacceptable	Adequate	Unacceptable
	Pools	Pool frequency and quality	At Risk	Unacceptable	At Risk	At Risk	Adequate	At Risk
	Off-Channel Habitat	Connect-ivity with main channel	At Risk	Unacceptable	At Risk	At Risk	Adequate	At Risk
Channel	Dynamics	Floodplain connect-ivity	At Risk	Adequate	At Risk	At Risk	At Risk	Adequate
		Bank stability/ Channel migration	At Risk	At Risk	At Risk	At Risk	At Risk	Adequate
		Vertical channel stability	At Risk	Adequate	At Risk	At Risk	At Risk	At Risk
Riparian Vegetation	Condition	Structure	Unacceptable	Unacceptable	At Risk	Unacceptable	At Risk	At Risk
		Disturb-ance (human)	Unacceptable	Unacceptable	At Risk	Unacceptable	At Risk	At Risk
		Canopy Cover	Unacceptable	Unacceptable	Unacceptable	Unacceptable	At Risk	At Risk

3 Reach-Scale Conditions

3.1 REACH 1

3.1.1 Reach Overview

Reach 1 extends from RM 7.8 (Newby Creek) to RM 9.14 for a total distance of 1.34 miles (Figure 2). The reach is a naturally confined, single thread channel with a steep gradient (Figure 14). Overall, human alterations have less of an impact on channel dynamics in this reach due to natural confinement. However, some of the most extensive riprap and levees observed in the study area occur in this reach, resulting in disconnection of the already limited floodplain. Much of the floodplain habitat that does exist has been cleared, filled, and graded. Road construction along river-left and clearing for residential and agricultural purposes has resulted in minimal wood available for future recruitment and has a significant impact on riparian vegetation. The road embankment and associated riprap have severely impacted stream bank complexity. The landownership throughout this reach is primarily private with the exception of river-right from approximately RM 8.85 to 9.05, which is Okanogan National Forest (Figure 15).

Figure 14. A representative section of Reach 1 at RM 8.

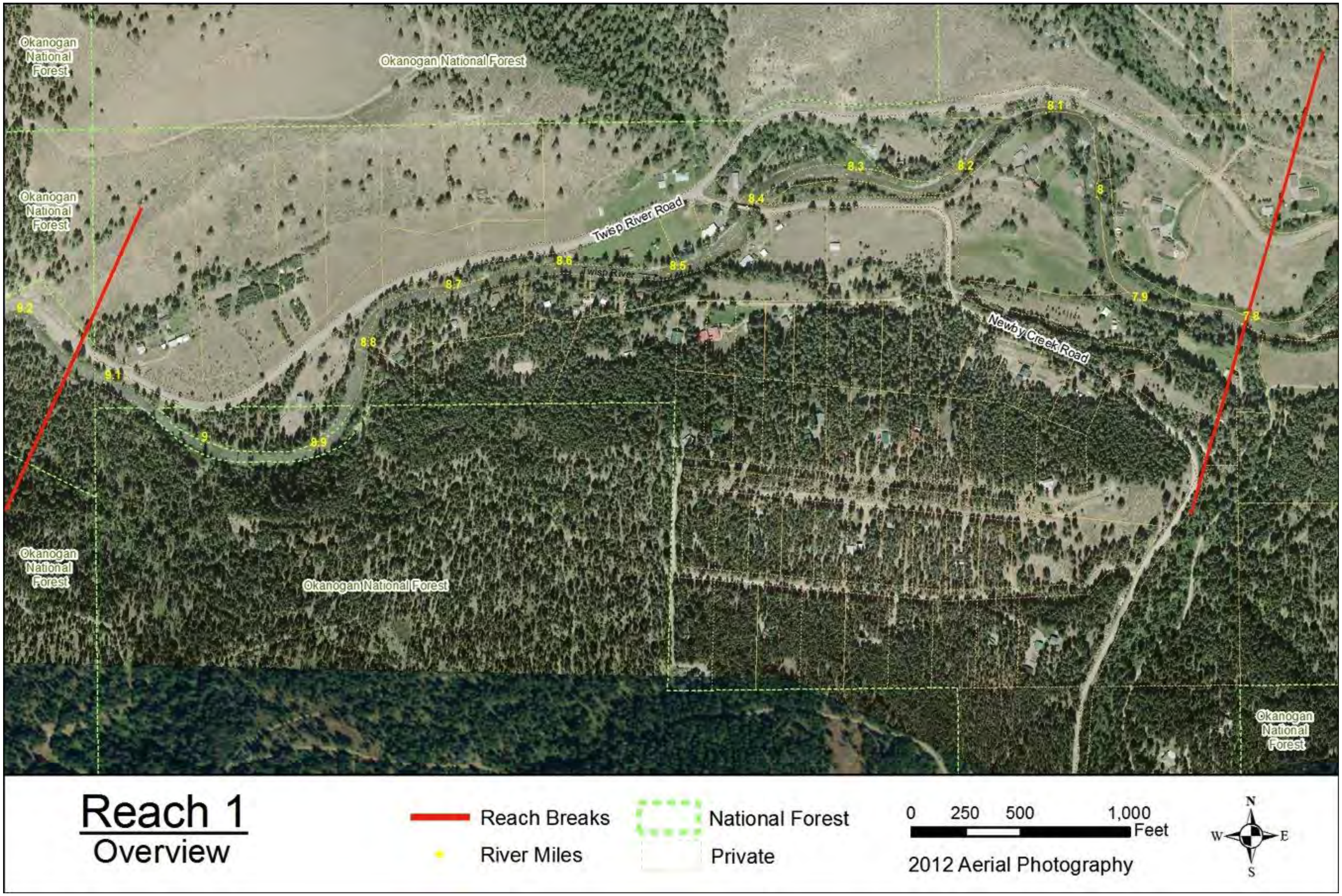

Figure 15. Overview map of Reach 1 showing land ownership.

Table 10: Summary of Reach 1 characteristics.

Metric	Value
Reach Length	1.34 miles
River miles	7.8 to 9.14
Valley gradient	1.38%
Stream gradient	1.14%
Sinuosity	1.29
Dominant Channel Type	Plane-bed
Avg bankfull width	81.7 ft
Avg floodplain width	170 ft
Dominant substrate	Cobble

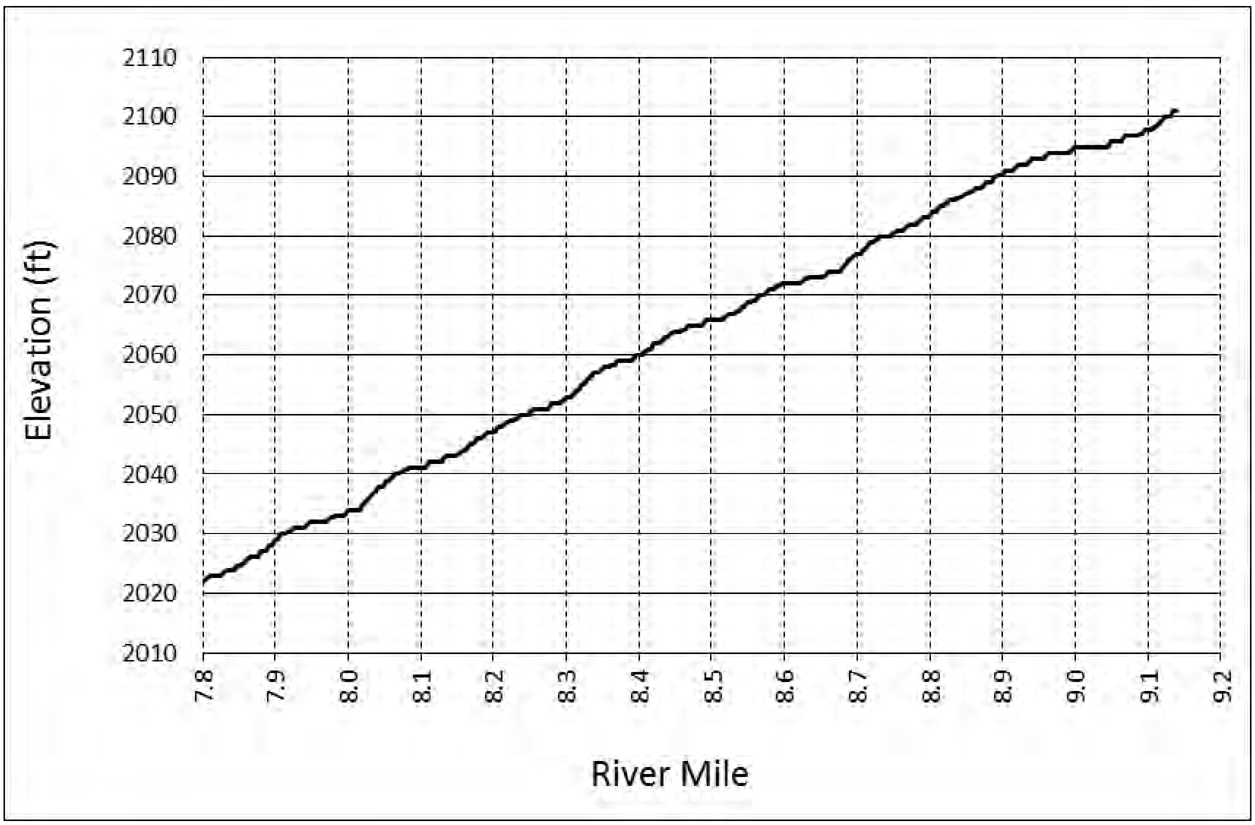

Figure 16. Longitudinal profile of Reach 1. Elevation data is derived from the 2006 LiDAR data and so represents water surface at the time of the LiDAR flight.

3.1.2 River Morphology and Geomorphic Processes

Geology and Landforms

Abandoned glacial and alluvial terraces provide lateral constraints to the river throughout Reach 1, accounting for the reduced floodplain width and single thread nature of the channel. These lateral constraints on the channel, in combination with the steep gradient and low channel sinuosity, result in a boulder-step riffle planform interspersed with long glides. Comparison to a previous habitat survey in 2001 (PWI report, Appendix A) shows that the quantity of pools meeting depth criteria has decreased from 5.2/mile to 2.5/mile, indicating an increase in fast water units within this reach over the past 12 years.

Hydrology

A small tributary enters the channel along river-left at RM 8.4 and provides less than 2% of the total channel flow to the river at this location. The tributary is not a large sediment source to the river. There are few hyporheic flow inputs due to the confinement. There may be hillslope groundwater sources in some areas but the extent of them is unknown.

Floodplain and Channel Migration Zone

The reach has high vertical stability and is naturally laterally constricted by glacial terraces on both sides of the channel with a modern alluvial terrace on the intermediate surface on the river-left. The confinement limits lateral migration and sinuosity and the large substrate observed on the streambed (see Sediment section below) provides vertical stability for the channel. The single thread nature of the channel and lack of lateral migration is apparent when comparing the channel boundaries observed over the historical record (Figure 19).

With the exception of a couple of discrete locations, a majority of the flood events are contained within the channel, including the 100-year event (Figure 18). The lack of floodplain inundation and single thread nature of the channel results in minimal habitat availability, especially in comparison with the braided channels downstream of this reach. Extensive amounts of riprap and numerous levees were constructed within this reach and much of the limited floodplain habitat that does exist has been cleared, filled and graded. The highest amount of human alterations in the study area occurred within this reach, but due to the natural channel confinement, these alterations have less of an impact on channel dynamics and habitat.

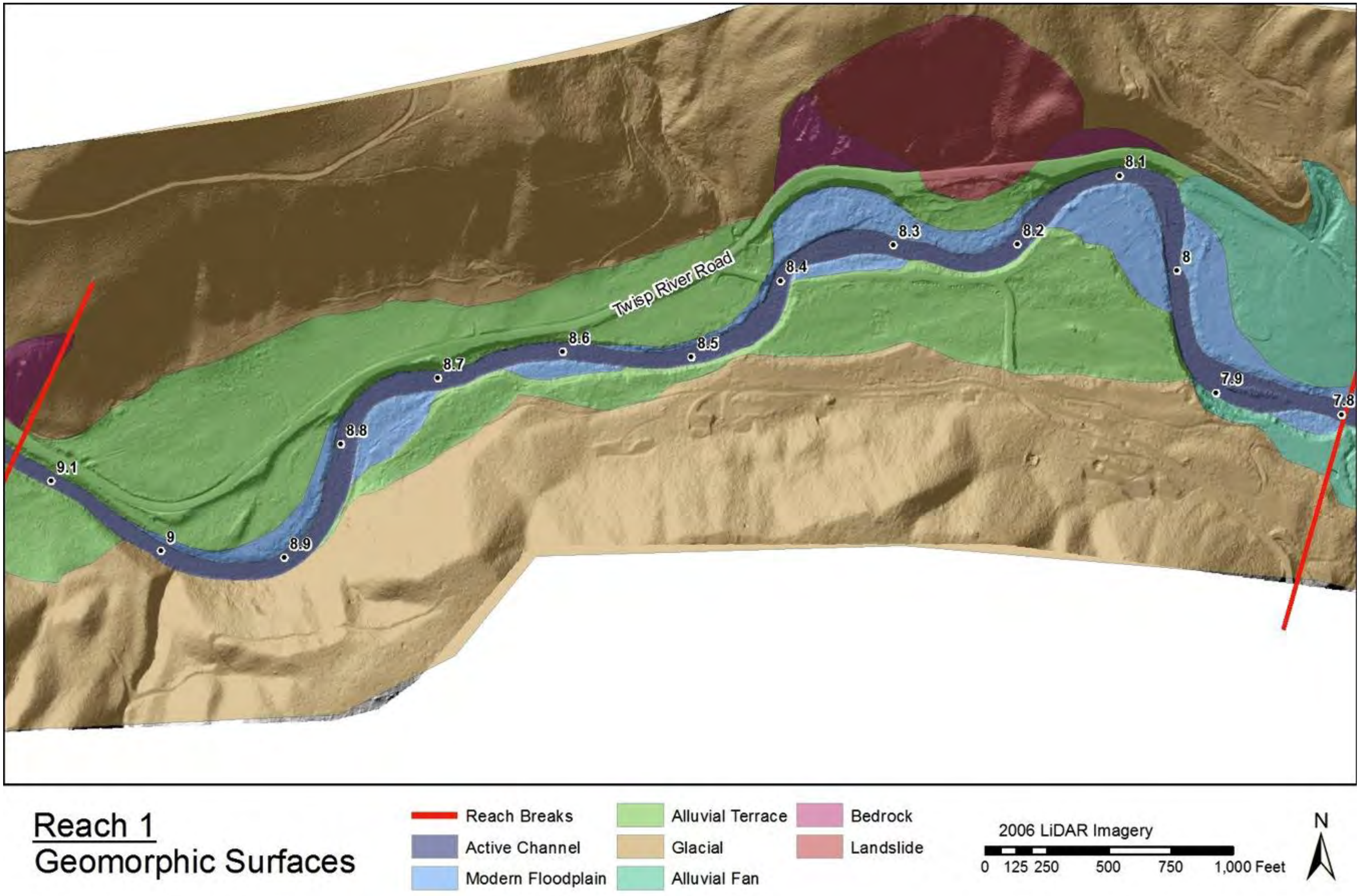

Figure 17. Geomorphic surfaces for Reach 1.

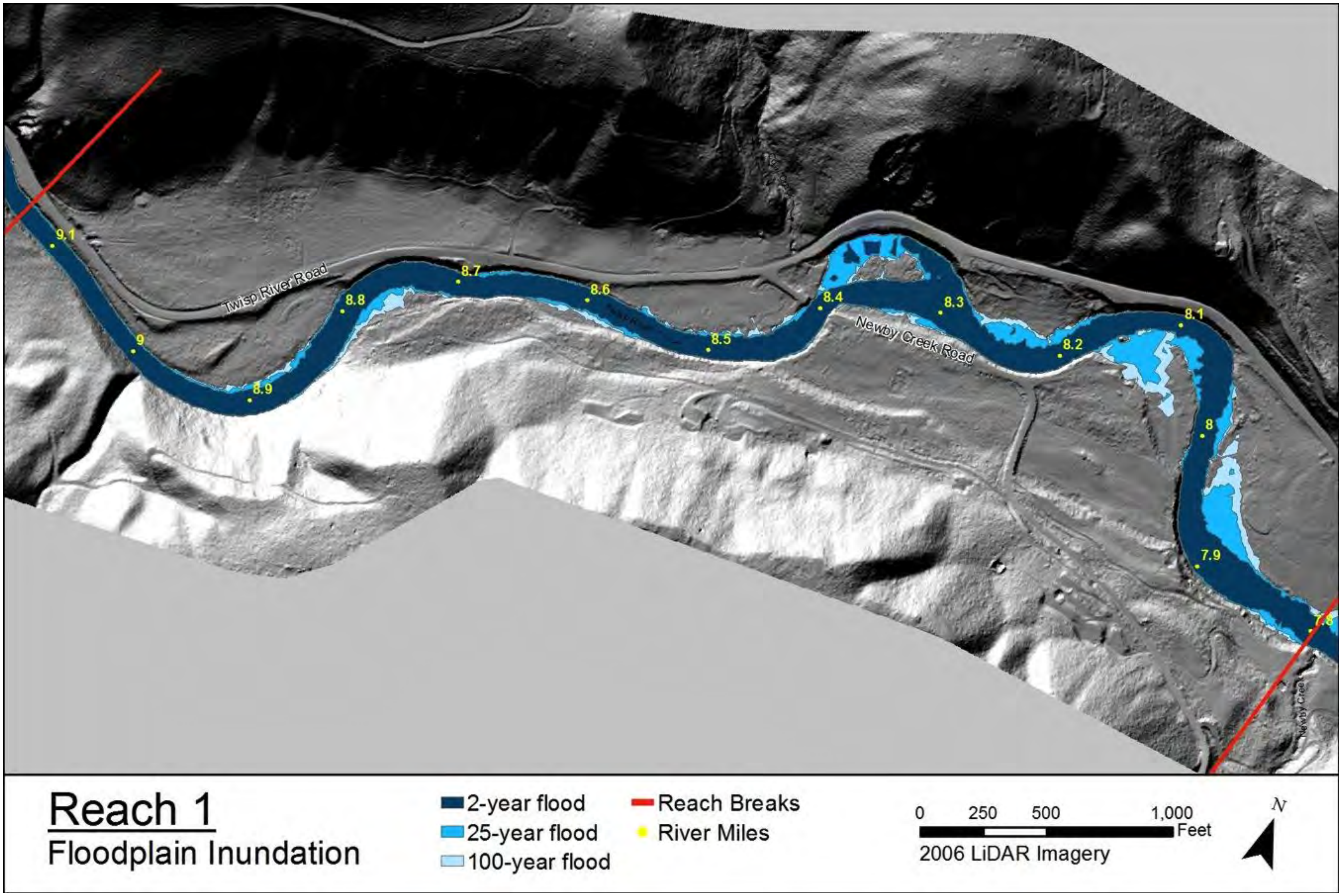

Figure 18: Floodplain inundation mapping for Reach 1

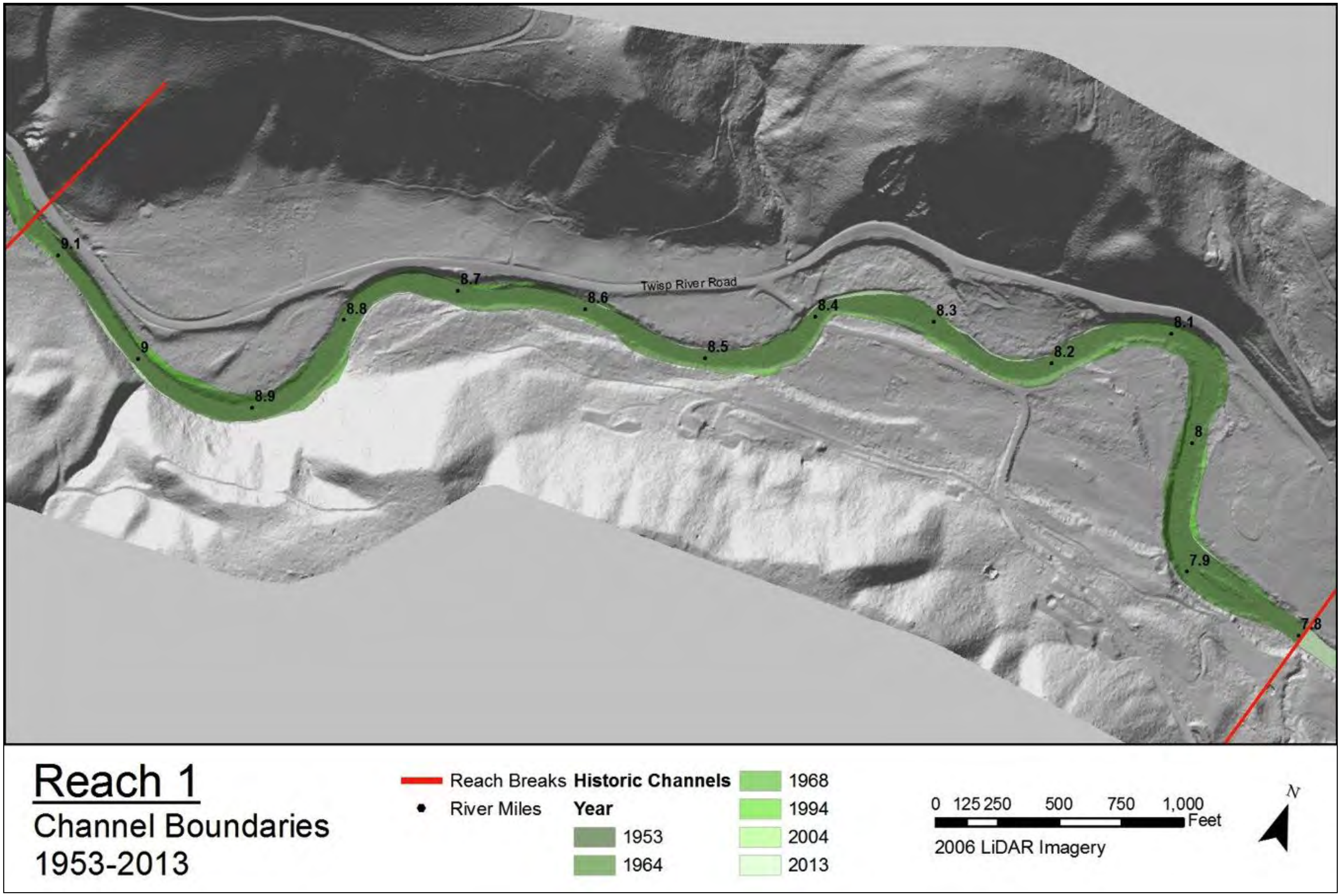

Figure 19. Historical Channel Boundaries for Reach 1.

Sediment

This reach has abundant boulders and large cobble (61% cobble), the majority of which have likely been sourced from hillslopes and glacial lag. The gradient of the reach and lack of accumulation of fine sediment on the majority of the channel bed suggest that most fine sediment is transported through this reach, with the exception of in-channel gravel deposition in some of the glides. Sediment sourcing from the terraces has taken place, resulting in the presence of large boulders within the channel. The colluvial boulders act as large hydraulic roughness and provide the extent of geomorphic and habitat complexity in Reach 1. The boulders create localized scour pools throughout the reach, which in turn provides holding habitat for fish.

Vegetation

The upstream portion of Reach 1 has a high density of riparian vegetation along the south side of the channel with significant reduction of vegetation along the north side of the channel and the downstream portion of the south side of the channel. The majority of the riparian clearing was prevalent on the south side of the river for the first half of the reach, and on the north side of the river for the second half of the reach. Based on the habitat survey, Reach 1 had a variable riparian corridor with a majority of the reach composed of grassland/ forbes (75%) and small trees (25%). Species composition was variable with most of the understory identified as hawthorne, dogwood, and willow; the overstory was largely composed of cottonwood, Douglas fir, and ponderosa pine. The first return LiDAR image indicates that in areas where clearing did not take place, a majority of the overstory was between 25 and 100 feet tall. The channel banks were primarily composed of old growth conifers on the terraces that provide shade to the channel as well as act as a potential source for large wood recruitment to the channel (Figure 20).

Figure 20 Potential for large wood recruitment along river-right terrace at RM 8.5. There are several mature conifers with exposed root masses on the edge of the terrace.

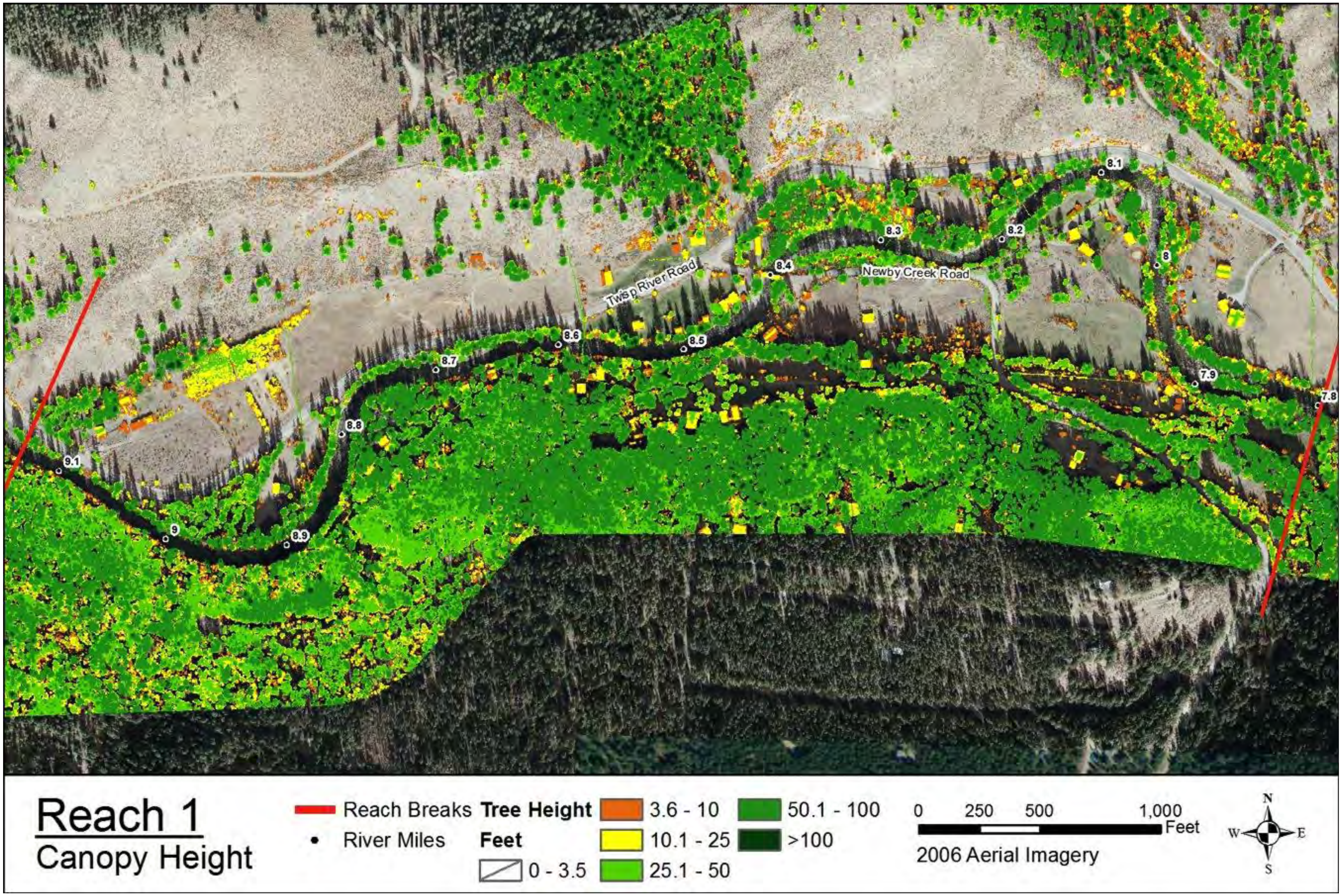

Figure 21. LiDAR first return (highest hit) data for Reach 1. These data show vegetation canopy heights. Buildings and other human infrastructure are also included in this data.

3.1.3 Human Alterations

Significant amounts of human alterations have occurred within Reach 1, with some of the most extensive riprap and levees of the study area (Figure 22). Much of the limited floodplain habitat that exists has been cleared, filled, and graded for residential and agricultural purposes. The construction of Twisp River Road and the associated road embankments and riprap have severely limited stream bank complexity. The riparian impacts are significant and result in minimal wood available for recruitment in the future.

Loss of Already-Limited Floodplain Function

Human alterations to the floodplain have impacted geomorphic processes throughout Reach 1. The majority of channel and floodplain alterations are associated with residential clearing and development (Figure 22). Along the right bank, the riparian corridor has been cleared, the floodplain has been graded and a pushup levee was constructed. These alterations have removed hydraulic roughness, with the potential for accelerated bank erosion as well as disconnecting the active floodplain from the channel.

The roadway construction, embankment creation, and riprap installation that has occurred in Reach 1 impedes stream bank complexity but does not seem to greatly impact natural channel migration, as the channel is naturally confined. Lateral channel dynamics have been impacted by the bridge and its associated abutments at RM 8.4 (Figure 23). The bridge does not have piers in the channel and appears to be appropriately sized, but the riprap along both sides of the channel, up and downstream of the structure, is acting as a lateral constriction to the channel upstream of the bridge. Riprap was also installed to protect the property banks in locations where residential clearing and grading occurred (Figure 22). The use of riprap along those banks, as well as the pushup levee along river-right (RM 8.8), disconnects the river from the floodplain by reducing the frequency and extent of floodplain inundation.

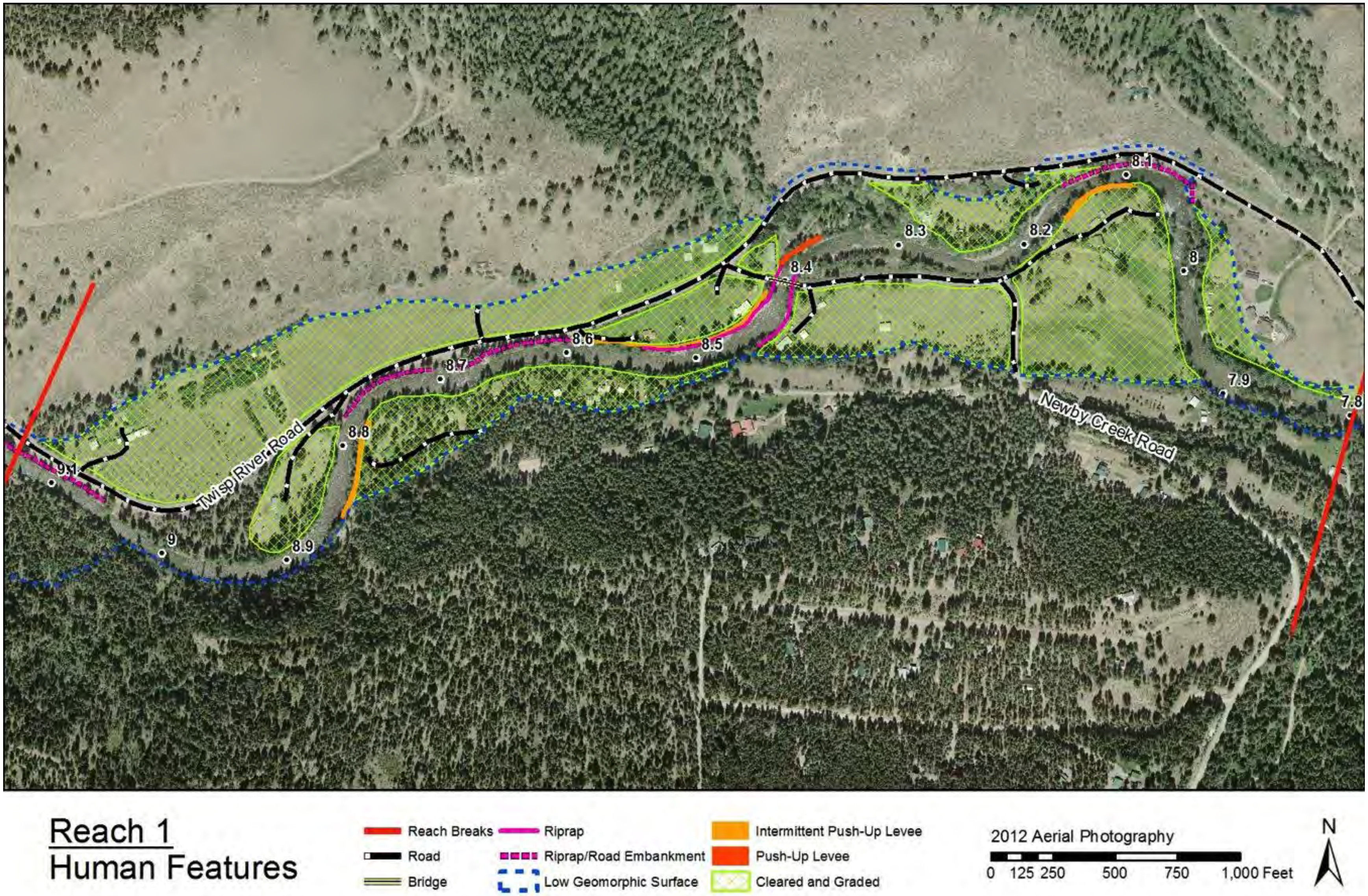

Figure 22. Human features in Reach 1 that are within the low surface.

Figure 23 Looking upstream at the bridge at RM 8.4.

Significant Riparian Impacts

Riparian vegetation has been greatly impaired due to human alterations throughout this portion of the study area, with almost the entire north side of the channel exhibiting loss of vegetation due to clearing and grading for residential and agricultural purposes, as well as the construction of the roadway and its associated embankments (Figure 22). The loss of large wood that has occurred reduces the amount of shade provided to the channel, as well as limits the potential for large wood recruitment in the future. The amount of clearing that has occurred is significant and has a large impact on the presence of large wood counted within the channel throughout this reach.

Loss of Streambank Complexity

While the construction of Twisp River Road did not impact lateral channel migration due to natural confinement, it did severely limit streambank complexity. The roadway forms the channel margins throughout the reach along the north side of the channel. The installation of riprap inhibits toe erosion and the potential for localized scour that can act as a source of sediment to the system and aid in the recruitment of large wood to the channel. Currently, there is very little bank complexity in the form of undercut banks, overhanging vegetation, alcoves, and wood cover.

3.2 REACH 2

3.2.1 Reach Overview

Reach 2 corresponds to the upstream portion of Reach T4 from the Methow Subbasin Geomorphic Assessment (USBR 2008). This reach extends from RM 9.14 to RM 9.79 (the confluence of Little Bridge Creek) for a total distance of 0.65 miles. A representative photo is shown in Figure 24 and an overview map is included as Figure 25. This steep-gradient, riffle-dominated, single thread channel is naturally confined by glacial terraces and alluvial fan deposits. The natural confinement of this reach has resulted in minimal changes to the location of the channel over the historical photo record (dating back to 1953). It also lessens the amount of off-channel and side habitat available as well as the impact that human alterations have on channel dynamics in this location. There are significant impacts to the riparian zone as a result of the road on river-left and clearing for residential and agricultural uses. The human alterations to the riparian zone on river-left reduce hydraulic roughness across that surface as well as large wood available for recruitment into the river in the future. The construction of the road embankments and installation of riprap along the toe has also impacted the complexity of the stream bank. The landownership directly abutting the channel is primarily private, with the exception of river-right from approximately RM 9.43 to 9.6 which is the Okanogan National Forest (Figure 25).

Figure 24. A representative photo of Reach 2 taken at RM 9.4.

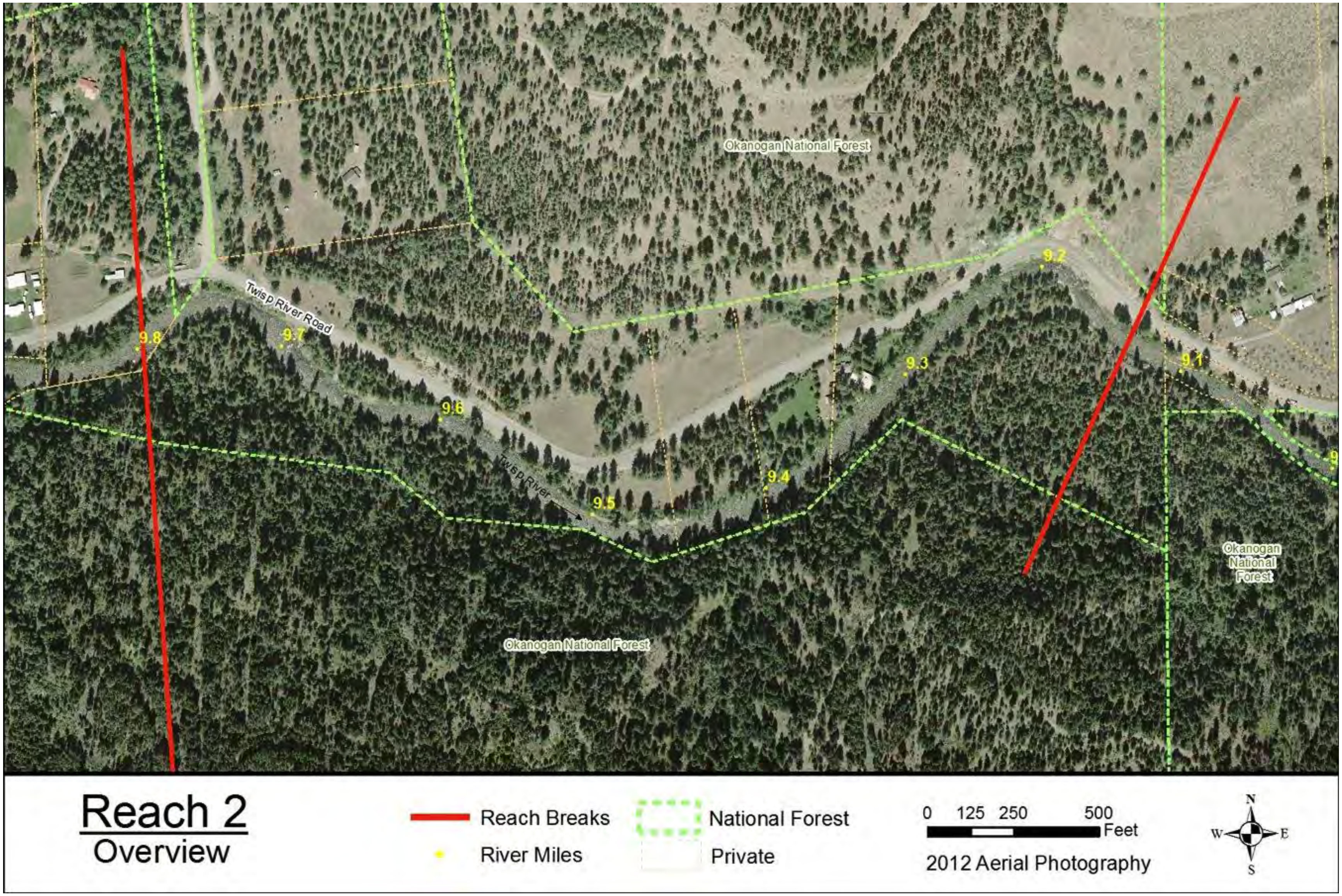

Figure 25. Overview map of Reach 2 showing land ownership.

Table 11. Table 1: Key descriptive and geomorphic metrics for Reach 2.

Metric	Value
Reach Length	0.65 miles
River miles	9.14 to 9.79
Valley gradient	1.26%
Stream gradient	1.16%
Sinuosity	1.22
Dominant Channel Type	Plane-bed
Avg bankfull width	91 ft
Avg floodplain width	118 ft
Dominant substrate	cobble

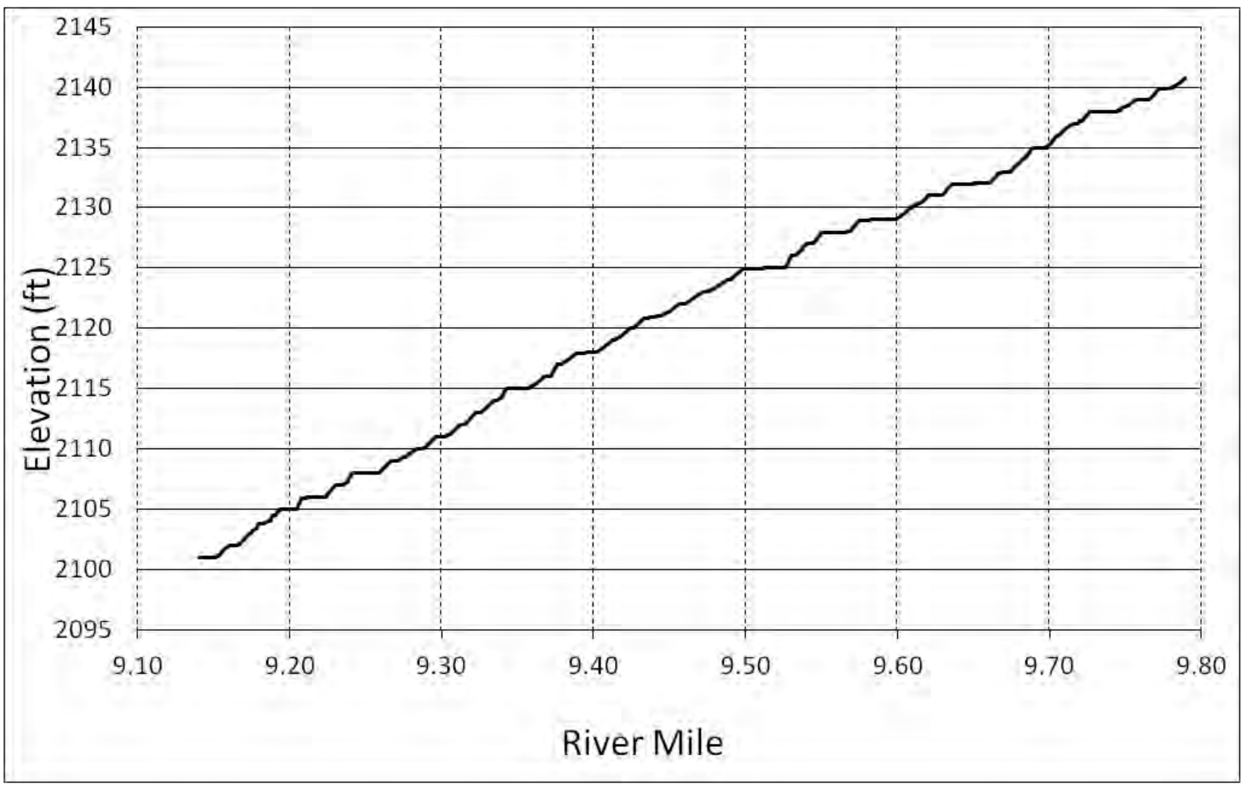

Figure 26. Longitudinal profile of Reach 2. Elevation data is derived from the 2006 LiDAR data and so represents water surface at the time of the LiDAR flight.

3.2.2 River Morphology and Geomorphic Processes

Geology and Landforms

Reach 2 is laterally constrained primarily by alluvial fan deposits generated from Little Bridge Creek along the north side of the valley and also by glacial terraces that form a steep bank along the south side (Figure 27). There is evidence of erosion along the toe of the alluvial fan in the downstream portion of the reach, but the intermediate surface has since been abandoned due to channel incision. The channel has generally maintained its current location throughout the period of record (through 1953). These geomorphic units lining the channel provide great lateral control through the reach, resulting in a single-thread morphology through this steep (1.16% gradient; Figure 26), riffle dominated (81%) reach. The lack of lateral migration is also evidenced in the low calculated sinuosity and low channel complexity in comparison with surrounding reaches.

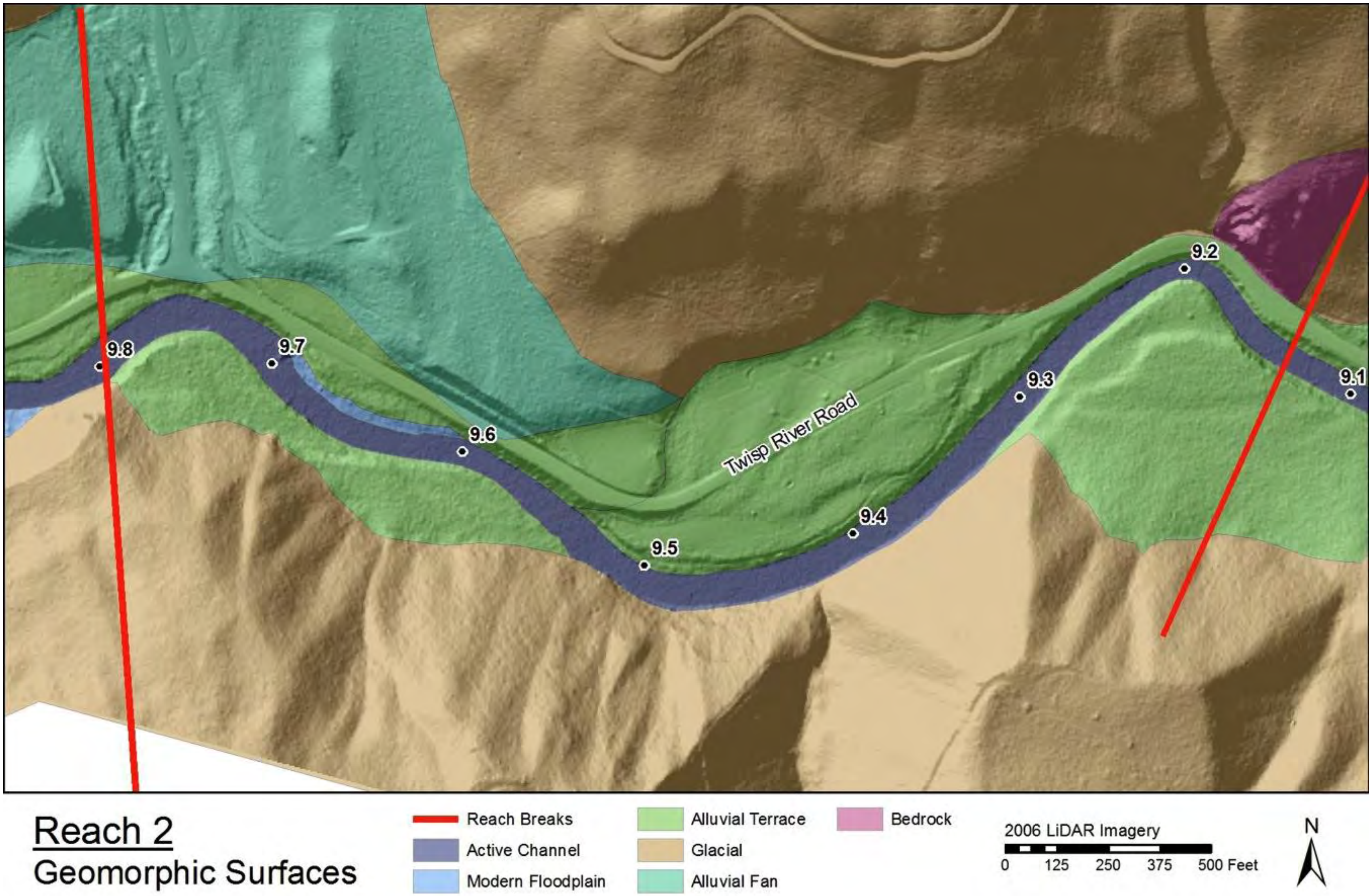

Figure 27. Geomorphic surfaces map showing the natural confinement found on both sides of Reach 2.

Hydrology

Little Bridge Creek enters the main channel along the north side of the channel, in the upstream portion of this reach. It is connected to the mainstem of the Twisp River through a large bottomless arch culvert that runs under Twisp River Road. This tributary contributes about 10% of the flow to the Twisp River at this location. Little Bridge Creek is a naturally laterally and vertically confined boulder-step-pool system with a boulder-cobble bed. The aggradation observed within the culvert at the mouth of the tributary provides evidence that Little Bridge Creek is contributing sediment to the main channel (Figure 28).

Figure 28 Looking upstream at Little Bridge Creek

Floodplain and Channel Migration Zone

There is minimal floodplain availability due to the naturally confined valley morphology of this reach. Lateral stability has limited the formation of side channels and lateral scour pools throughout this reach. Channel changes were mapped from aerial photos dating back to 1953 (Figure 30) and show the stability of this reach. All of the flood events that were modeled as part of the hydraulics analysis (up to the 100-year event) were confined within the extents of the main channel (Figure 29).

The LiDAR provides evidence that channel incision has previously taken place resulting in the abandoning of intermediate surfaces in the downstream portion of the reach. The road embankment and associated riprap provide some floodplain and channel migration zone impacts and are discussed further in the Human Alterations section.

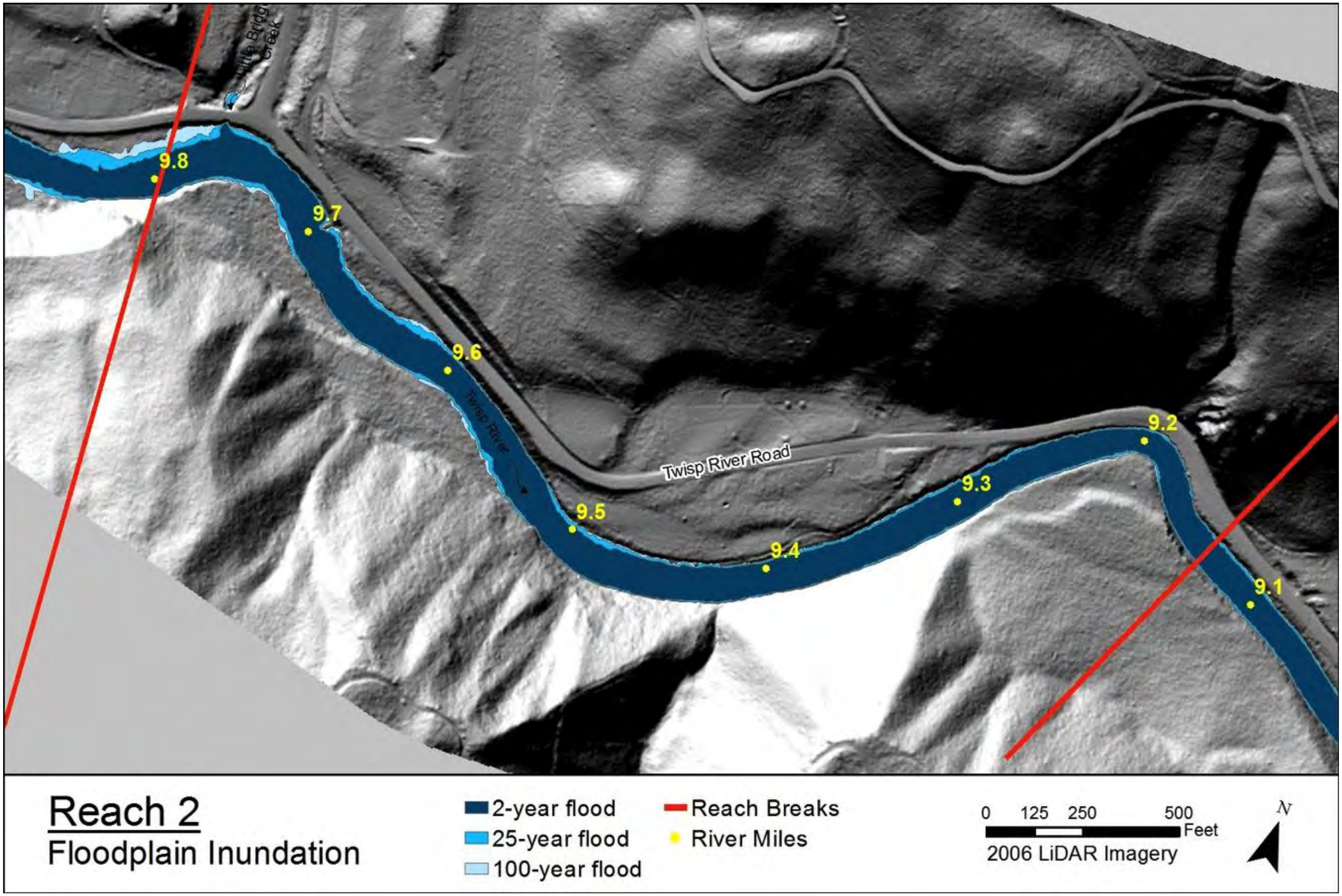

Figure 29. Floodplain inundation for selected years.

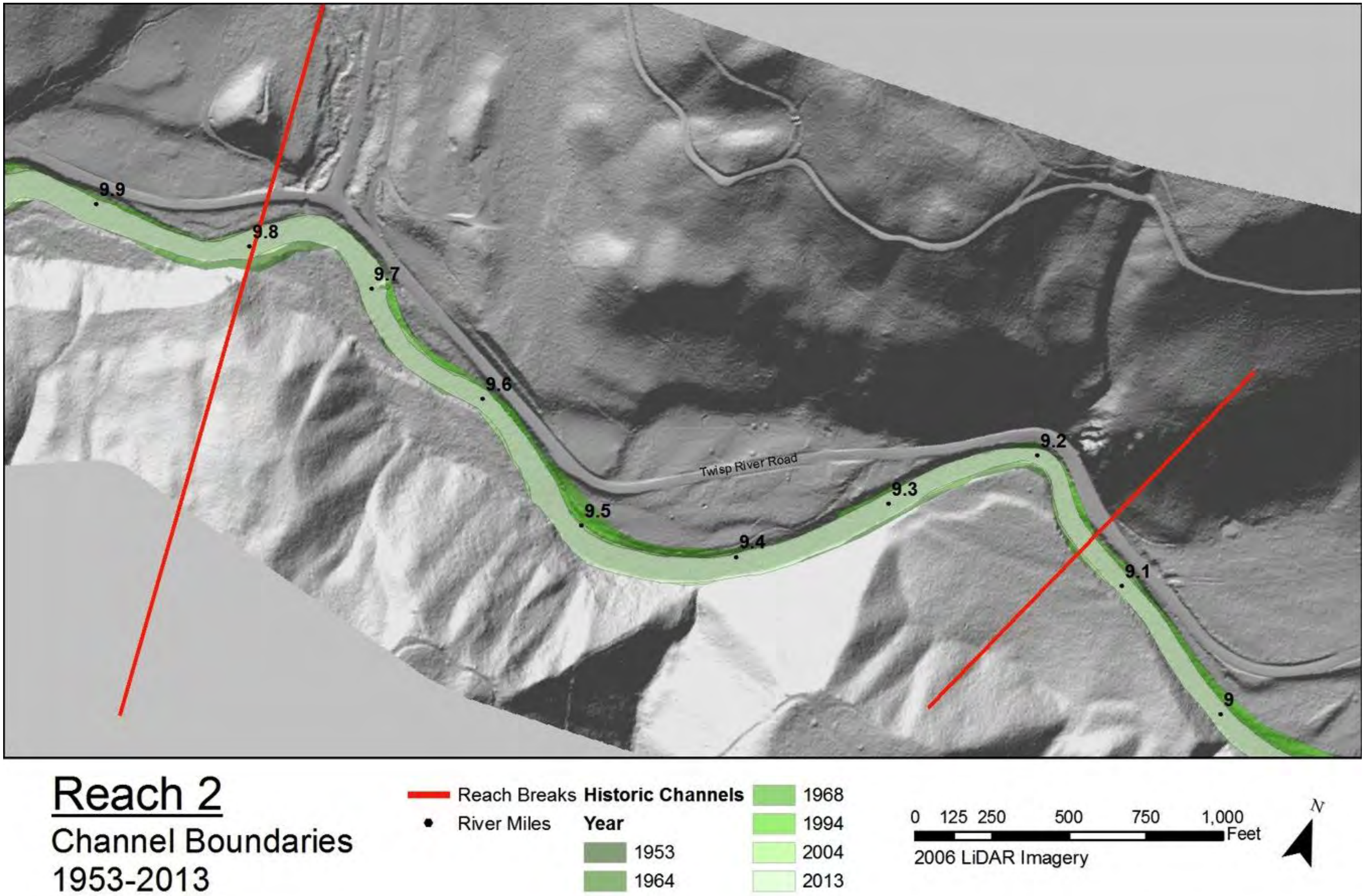

Figure 30. Historical channel boundaries for Reach 2.

Sediment

Due to the steep, single thread nature of this channel, it is predominately a transport reach for sediment that enters the system. The channel substrate is primarily cobble (45%) with the presence of gravels and boulders that have likely been sourced from local alluvial fan deposits. The large bed material limits vertical incision as well as provides a limited amount of instream habitat complexity. Boulders provide hydraulic complexity that create localized pocket water throughout the channel for salmonid resting and holding.

There are several sediment sources to this reach including contributions from Little Bridge Creek, bank erosion from the road embankment, and older alluvial fan deposits that the river has eroded into. At the upstream end of the reach, Little Bridge Creek contributes sediment during floods as evidenced by the sediment accumulation at the mouth of the tributary (Figure 31). The Twisp River Road embankment along the north side of the channel is unvegetated and provides fine sediment and limited amounts of gravel to the channel throughout this reach (Figure 32).

Figure 31 Sediment accumulation in the bottomless culvert at the confluence of the Little Bridge Creek tributary and the Twisp River.

Figure 32 The roadway on river-left acts as a source for fine sediment, sand, and gravel entering the channel.

Large Wood

Reach 2 had the lowest wood counts of the entire study area (18 total pieces total) and did not have any log jams. A fallen conifer was noted in this reach at RM 9.7 (Figure 33) and resulted in an area of localized cobble accumulation, but the overall lack of wood in the reach, swift current, and large substrate are indicative of a transport reach that lacks instream habitat. The steep, heavily vegetated banks, primarily along the south side of the river, are potential sources of additional large wood recruitment to the system.

Figure 33 large wood recruitment at RM 9.7.

Vegetation

The riparian vegetation in Reach 2 is severely impacted by human alterations on the north side of the channel, whereas the south side is relatively untouched. There were large areas of clearing, primarily along the north side of the channel, as well as about 75 feet of unstable banks at RM 9.65. In portions of the reach where the riparian corridor is undisturbed, the overstory species was exclusively Douglas fir (100%) and the understory was 50% unknown softwoods and 50% alder. The riparian vegetation within Reach 2 was dominated by small trees as shown in the first return LiDAR data (less than 50 feet; Figure 34), which do not provide much potential for large wood recruitment or shade to the channel along the north side of the channel due to the nearby roadway. Riparian vegetation on the south side of the channel provided good shade throughout the reach.

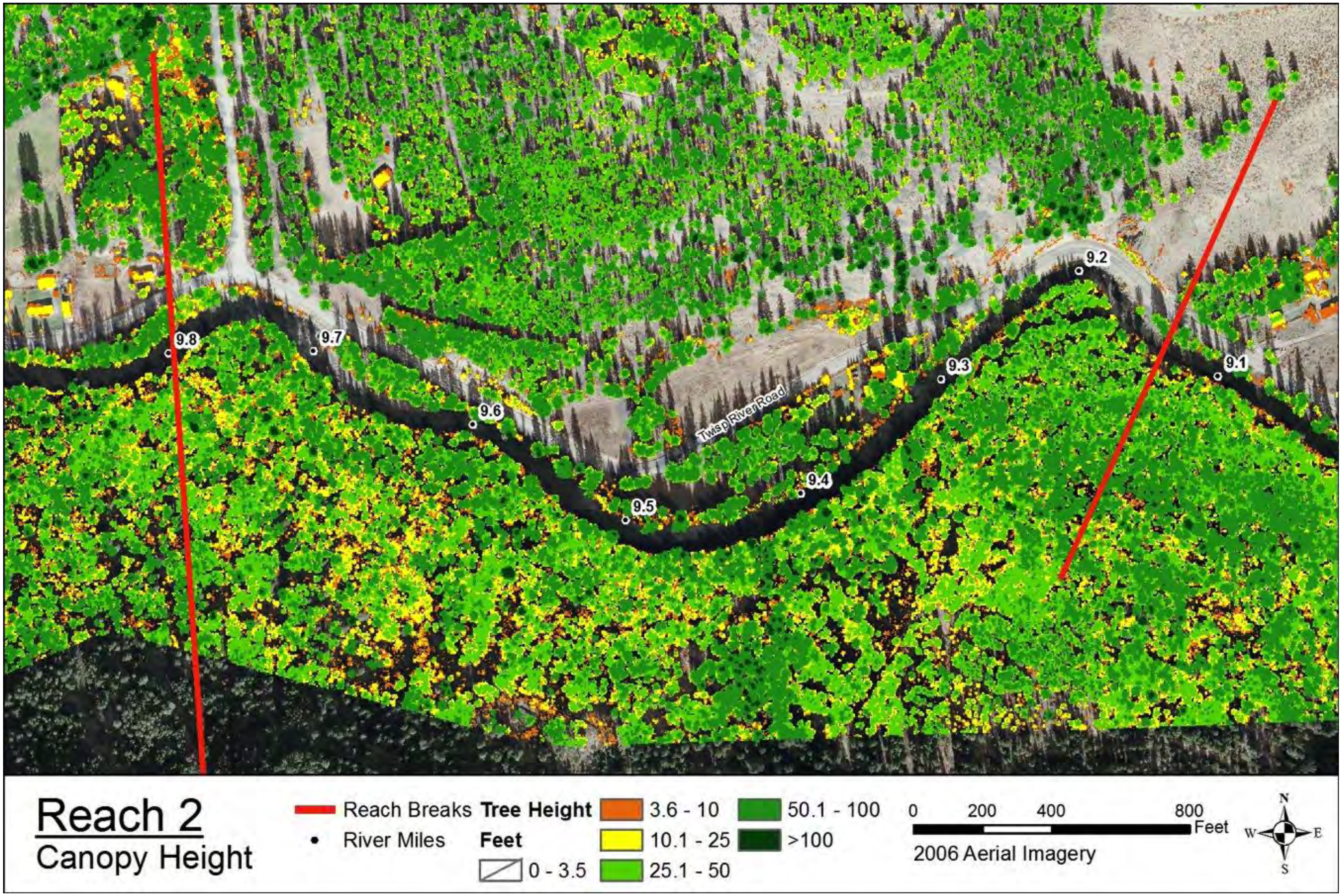

Figure 34. LiDAR first return (highest hit) data for Reach 2. These data show vegetation canopy heights. Buildings and other human infrastructure are also included in this data.

3.2.3 Human Alterations

Overall, human impacts have less impact on channel dynamics in this reach since the channel is naturally confined. However, there are significant human alterations that limit the amount of large wood and reduce streambank complexity (Figure 35).

Loss of Streambank Complexity

Twisp River Road forms the channel margin along river-left for a majority of this reach. The associated road embankments and riprap have severely impacted streambank complexity. The roadway was constructed in the modern alluvial terrace and the alluvial fan and does not appear to be limiting lateral channel migration; however, it is acting as a source of fine sediment, sand, and gravel to the channel. The fine sediment entering the system as a result of the embankment can accumulate in-between flood flows and have the potential to reduce spawning habitat availability.

Large angular riprap has been installed along the base of the road embankment along river-left (Figure 36). The riprap likely does not have a significant impact on channel migration due to the confined nature of the reach, but it does have some effect on gravel and large wood recruitment processes along the channel margins. There is a large bottomless culvert at the confluence of Little Bridge Creek and the Twisp River (approximately RM 9.75) along river-left (Figure 31). Sediment deposition within the culvert has occurred, which is a result of the change in profile of Little Bridge Creek as it meets the Twisp.

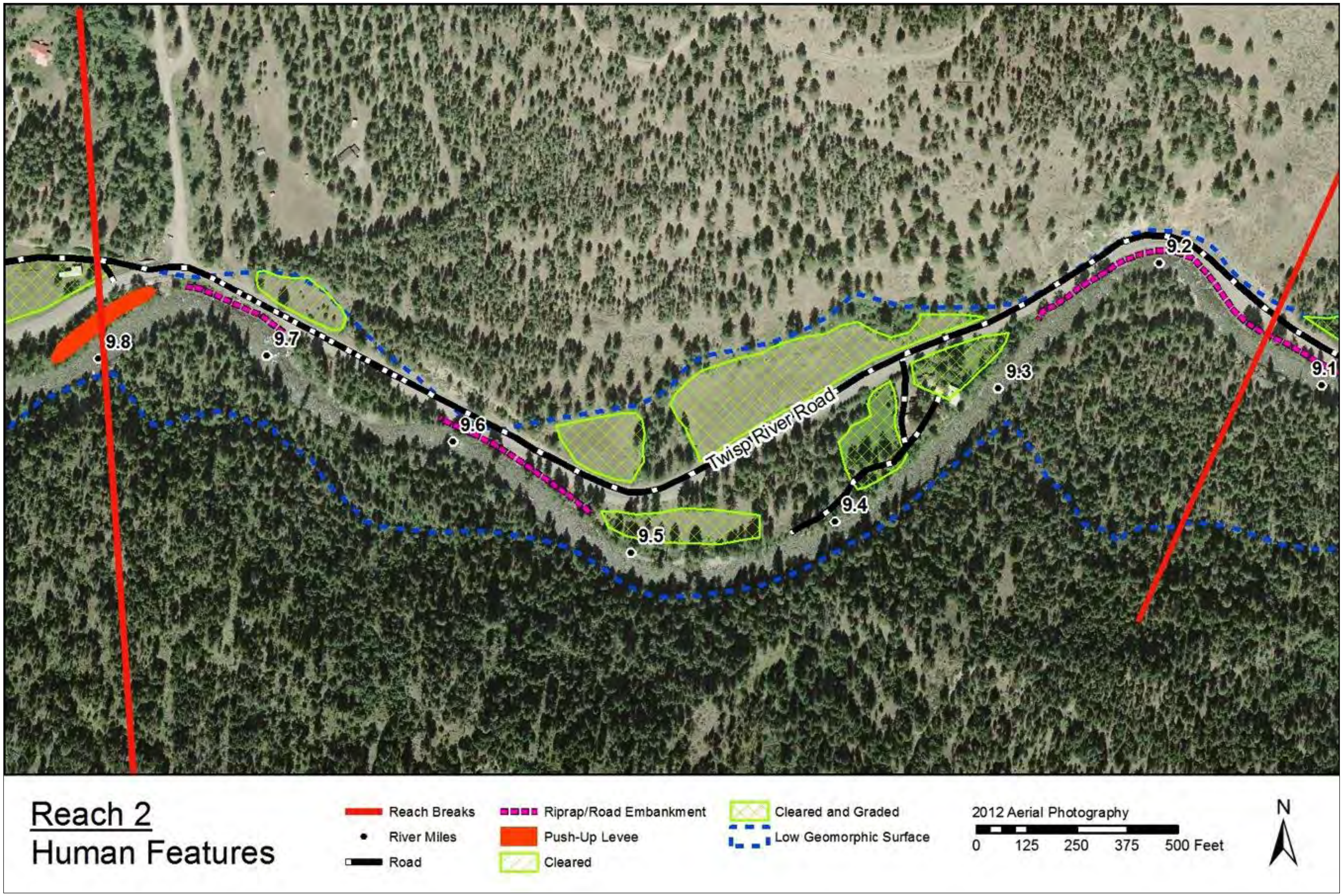

Figure 35. Human features in Reach 2.

Figure 36 The road embankment at RM 9.15 looking upstream.

Significant Riparian Impairment

There are significant impacts to riparian vegetation as a result of River Road along the north side of the channel. Clearing for residential and agricultural uses also impairs riparian function throughout the reach.

Figure 34 shows that a majority of the vegetation is less than 50 feet tall, with patches of trees up to 100 feet tall. There are several areas along the north side of the channel where the riparian corridor is very narrow and clearing has occurred up to the channel's edge. There are some fallen conifers in this reach, but wood recruitment is much lower than would be expected under undisturbed conditions. Past removal of riparian vegetation impacts biological and physical processes. The lack of a dense vegetative canopy reduces the amount of shade provided to the stream, increasing summer water temperatures and decreasing winter water temperatures. The removal of vegetation from the system has reduced the amount of wood available for future recruitment.

3.3 REACH 3

3.3.1 Reach Overview

Reach 3 corresponds to the downstream portion of USBR Reach T5 and extends from River Mile 9.79 (Little Bridge Creek confluence) to 12.22 for a total length of 2.43 miles. The gradient is lower than the downstream reaches and the road no longer directly abuts the channel. This reach is riffle dominated and the surface is primarily cobble. The sinuosity and complexity of the channel increases compared to Reaches 1 and 2, with increased floodplain inundation. However, there has been a reduction in floodplain connectivity (inundation frequency) and lateral channel dynamics since historical conditions, which is likely the result of past floodplain filling, grading, and development in the downstream half of the reach along river-left. These impacts may have contributed to channel incision and disconnection of the channel upstream, where the broad left-bank oxbow is now abandoned. This area, located at RM 11.3 – 11.87, may provide great opportunities to reconnect expansive off-channel salmonid rearing habitat. The ownership in this reach is predominately private, with RM 11.5 to 11.8 within the Okanogan National Forest on both sides of the river (Figure 38).

Figure 37. A representative photo of Reach 3 at RM 11.8.

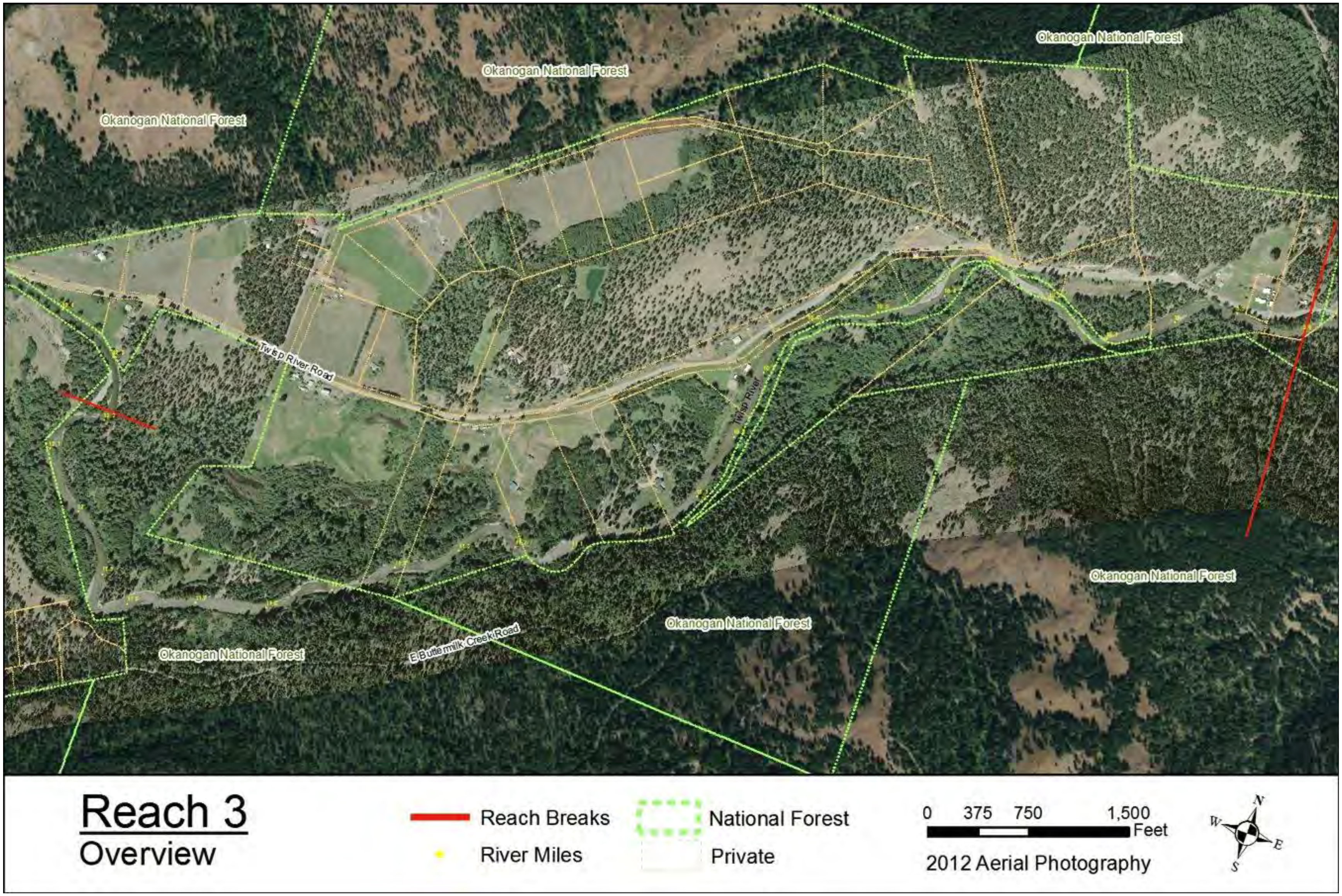

Figure 38. An overview of Reach 3 with landownership.

Table 12. Key descriptive and geomorphic metrics for Reach 3.

Metric	Value
Reach Length	2.43 Miles
River Miles	9.79 – 12.22
Valley Gradient	0.85%
Stream Gradient	0.57%
Sinuosity	1.43
Dominant Channel Type	Pool-Riffle
Avg Bankful Width	102.2 ft
Average Floodplain Width	>300 ft
Dominant Substrate	Cobble

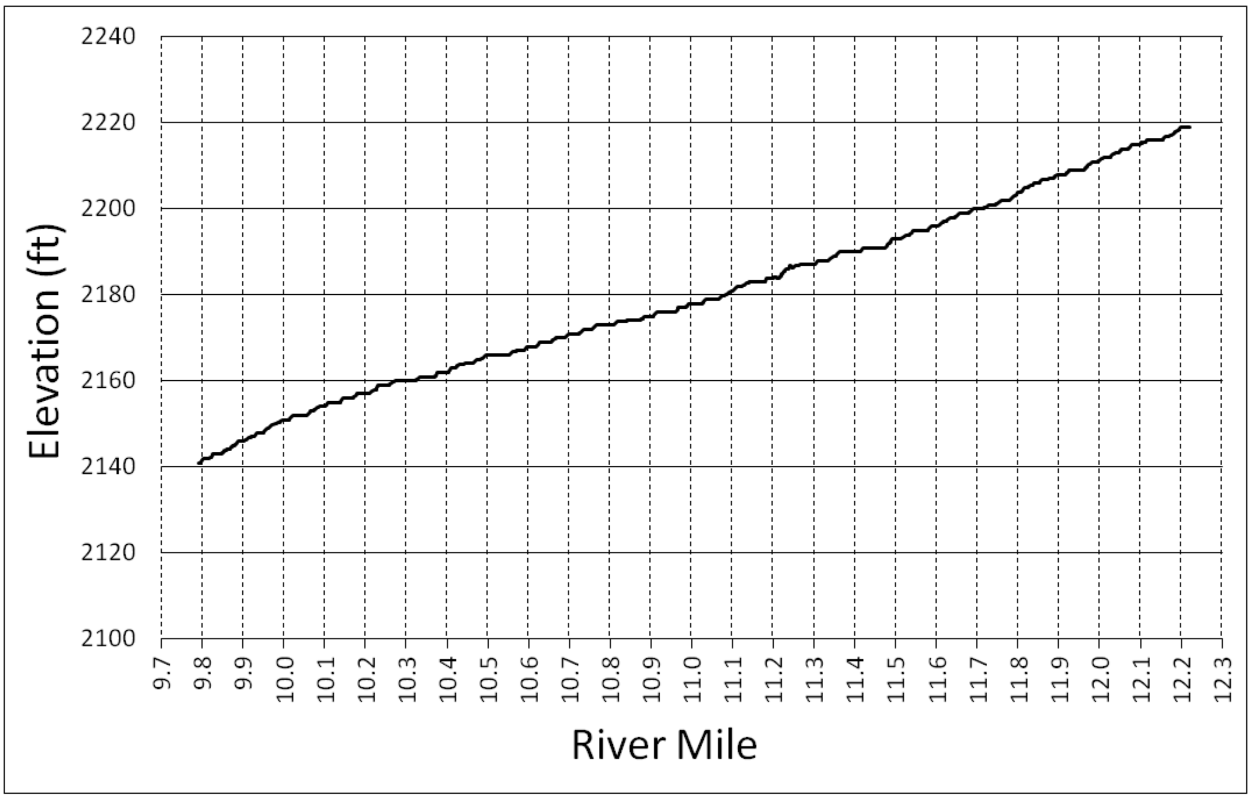

Figure 39. Longitudinal profile of Reach 3. Elevation data is derived from the 2006 LiDAR data and so represents water surface at the time of the LiDAR flight.

3.3.2 River Morphology and Geomorphic Processes

Geology and Landforms

This reach has a much wider and more well-connected floodplain than the downstream reaches. It is bounded on both sides primarily by glacial till deposits. The channel has eroded into this material, resulting in landslide deposits along valley-left in the upstream half of the reach. Channel gradient is 0.57%, compared to the much steeper 1.16% in Reach 2. The channel remains dominated by fast-water reaches (69% riffles), but there is greater lateral dynamics and higher quality habitat. There are three side channels within the reach, which account for 2% of the habitat unit area.

Hydrology

There are no significant tributary inputs in this reach. There is subsurface flow contributed from the modern alluvial floodplain along the left-bank that was observed during field surveys (near RM 11.47). Hyporheic flow is assumed to occur throughout the reach in low gradient alluvial sections with higher sinuosity and the presence of gravel bars.

Floodplain and Channel Migration Zone

The floodplain in Reach 3 is several hundred feet wide and is inundated semi-regularly (Figure 40). Channel sinuosity, complexity, and floodplain inundation are higher than in downstream reaches. In the upstream half of the reach, the river is against the south valley wall and there is a broad floodplain on the north side that is comprised of an extensive network of remnant oxbows that represent former channel locations. The channel migration zone in this location, at least historically, was very large. This surface has likely seen a reduction in floodplain inundation (and migration) due to channel incision caused by downstream floodplain development and channel constriction. This is described in more detail in the Human Alterations section. In the downstream half of the reach, the river runs primarily along the north side of the valley and there is a distinctive abandoned oxbow in the river-right floodplain near RM 10.5. This surface remains relatively well-connected to flood flows.

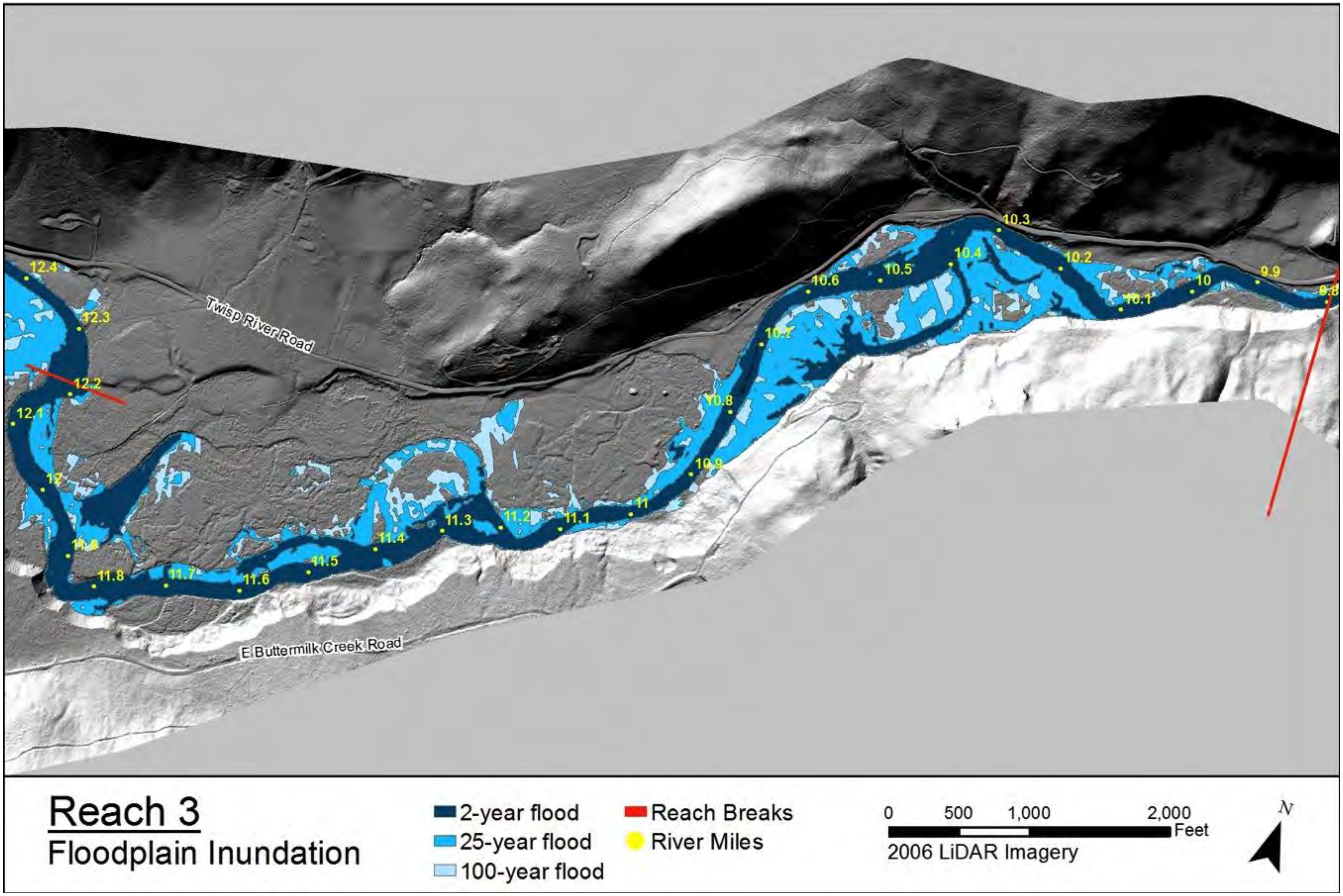

Figure 40 Extents of floodplain inundation for selected flood recurrence intervals in Reach 3. Flood inundations developed using HEC-GeoRAS based on the LiDAR surface.

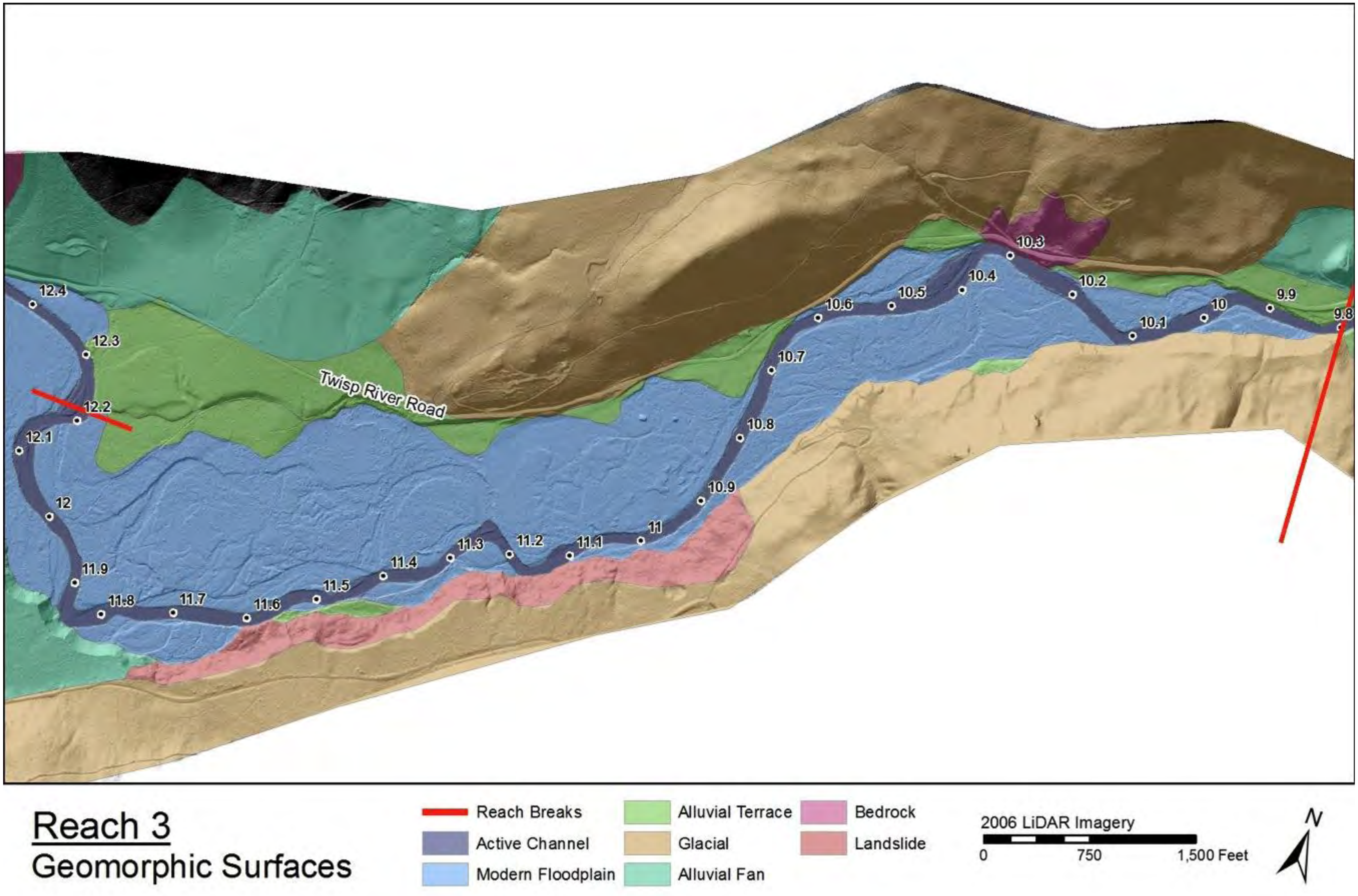

Figure 41. Geomorphic surfaces for Reach 3.

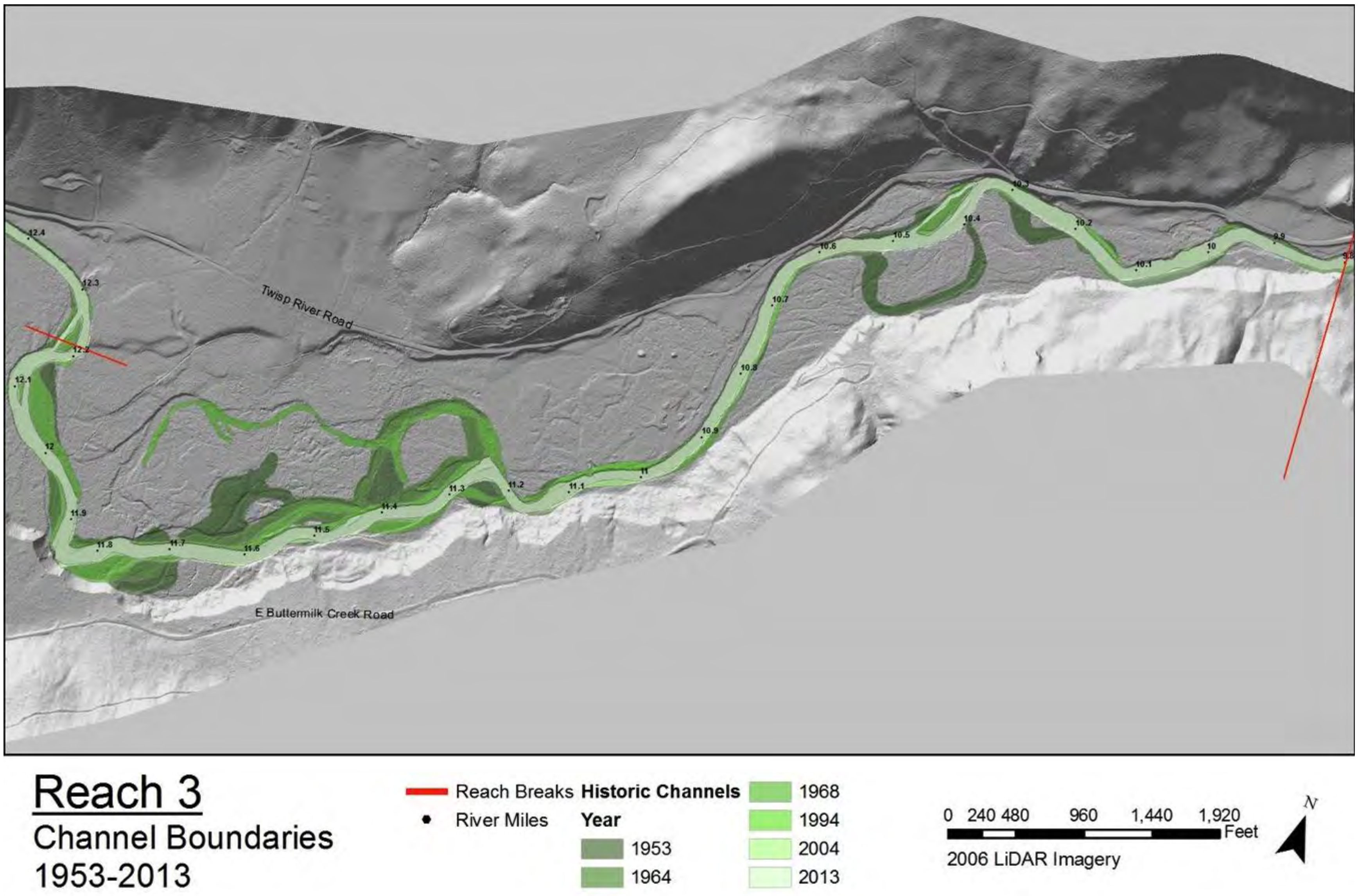

Figure 42. Historical channel boundaries for Reach 3.

Sediment

Reach 3 is primarily a response reach, although human alterations have likely increased transport conditions. The quantity of boulders present in Reach 3 is less than the downstream sections, but the channel substrate remains primarily cobble (69%; Habitat assessment, Appendix A). Material is sourced from bank erosion into contemporary floodplain surfaces (Figure 43) but also from erosion into tributary fan and glacial deposits on valley-right in the upstream half of the reach. Unconsolidated cobble and gravel are entering the system in this reach, providing a good source for spawning gravel recruitment downstream.

The presence of gravel cobble bars and apex log jams, which result in sediment deposition, indicate that this reach is acting primarily as a response reach (Figure 44). Several bars were observed throughout this reach; some were a result of large wood and boulders creating deposition zones, whereas others were well-established point bars. The size of the material that is accumulating on the exposed mid-channel bars is finer than what was observed in the downstream reaches.

Figure 43. The high eroding banks with natural alluvium protecting the toe of the bank at RM 11.77 are acting as a source of fine sediment to the system.

Figure 44. Gravel/cobble bar at RM 9.96 looking upstream, just out of the photo is a large boulder at the upstream side of the bar.

Large Wood

Large wood in Reach 3 averaged 54 pieces/mile, almost half of the study area average (96 pieces/mile). Historically, this reach would have been expected to have a high frequency of large wood and log jams throughout. Active recruitment of large wood to the channel was noted, primarily along river-left, but due to the channel's pattern of lateral migration and the high density of large conifers along the banks, the quantity of wood observed in the channel is lower than expected given the conditions. Two apex log jams were noted within the reach (Habitat Assessment, Appendix A). Higher wood frequencies would have existed historically as a result of recruitment by bank erosion and avulsions, which have been reduced. Riparian clearing along river-left has further reduced large wood recruitment potential. An increase in large stable log jams would help to improve lateral and vertical channel dynamics.

Vegetation

Reach 3 had a highly variable riparian corridor. Grassland/forbs, and small trees accounted for 29% of the reach; large trees, sapling/pole, and shrub/seedling each accounted for 14% of the riparian corridor (Habitat Assessment, Appendix A). The image created from the LiDAR first return data

(Figure 45) shows that the vegetation canopy heights were dominated by trees ranging from 10 to 50 feet tall, with a few patches of vegetation over 100 feet tall. The overstory was primarily composed of cottonwoods and Douglas fir, but also contained ponderosa pine. The understory was dominated by alder with some dogwood noted in the Habitat Assessment report (Appendix A).

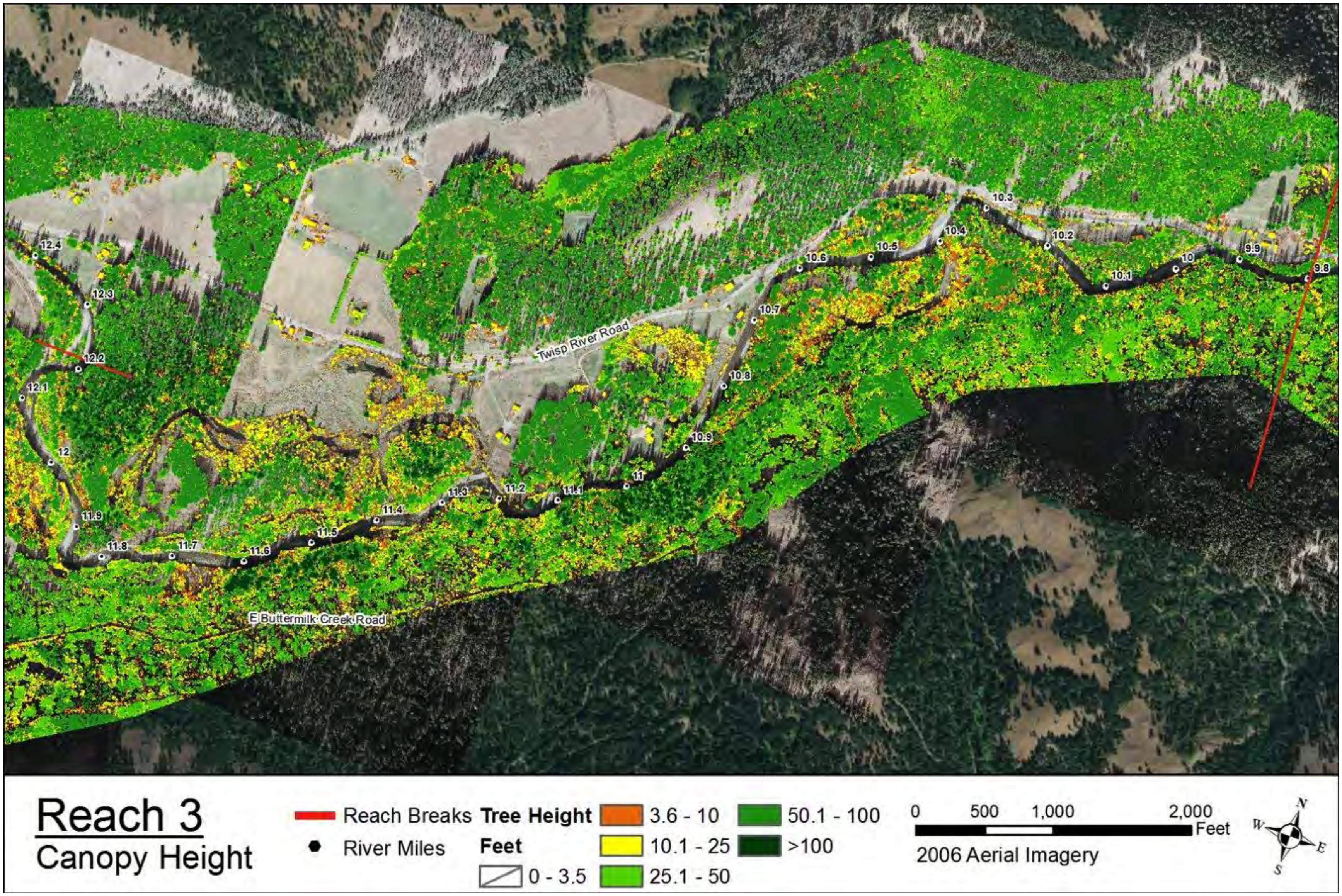

Figure 45. LiDAR first return (highest hit) data for Reach 3. These data show vegetation canopy heights. Buildings and other human infrastructure are also included in this data.

3.3.3 Human Alterations

Floodplain Filling, Grading, and Channel Constriction

Floodplain filling, grading, and channel constriction have occurred in the river-left floodplain in the middle portion of the reach between RM 10.8 and ll.3. This surface has been filled and graded to support residential and agricultural uses. Along the left-bank at RM 11.2, there is bank armoring and a levee that constrain the channel. It is likely that these practices have resulted in channel downcutting that continued upstream. The localized as well as upstream channel incision has reduced floodplain inundation and has decreased lateral channel dynamics. The loss of large wood and log jams has likely contributed to these impacts. The effects of these practices extends at least up to the upstream end of the reach near RM 12. Aerial photos pre-1960 and topographic evidence suggest that historically, this area was characterized by a more sinuous channel planform, multi-thread channel segments, and well-connected floodplains. Large abandoned oxbows in the river-left floodplain at RM 11.3 and 11.8 are evidence of this. This reach historically would have functioned more like Reach 5 given the width of the low surface, valley gradient, and lack of lateral controls on the channel. It currently has much less complex habitat.

Loss of Instream Habitat Complexity

Historically, this reach would have been expected to have a high frequency of large wood and log jams. Jams would have been recruited by bank erosion and avulsions, which have been reduced. Riparian clearing has further reduced recruitment potential. Large stable log jams would help to increase lateral and vertical channel dynamics.

Riparian Impairment

There are several areas where there has been significant riparian and floodplain clearing. Most of these are located along the river-left bank between RM 10.6 and 11.3, which is also where the greatest floodplain impairment has occurred as described above. Additional areas include on the river-left near RM 11.7-11.8 and on river-right near 10.5-10.6. The road embankment on river-left at RM 10.3 also impairs riparian function and channel margin habitat (Figure 46). Riparian alterations in Reach 3 have reduced floodplain hydraulic roughness and have reduced the availability of large wood for recruitment.

Figure 46. RM 10.27 river left, the road embankment and large angular riprap installed at the bank toe.

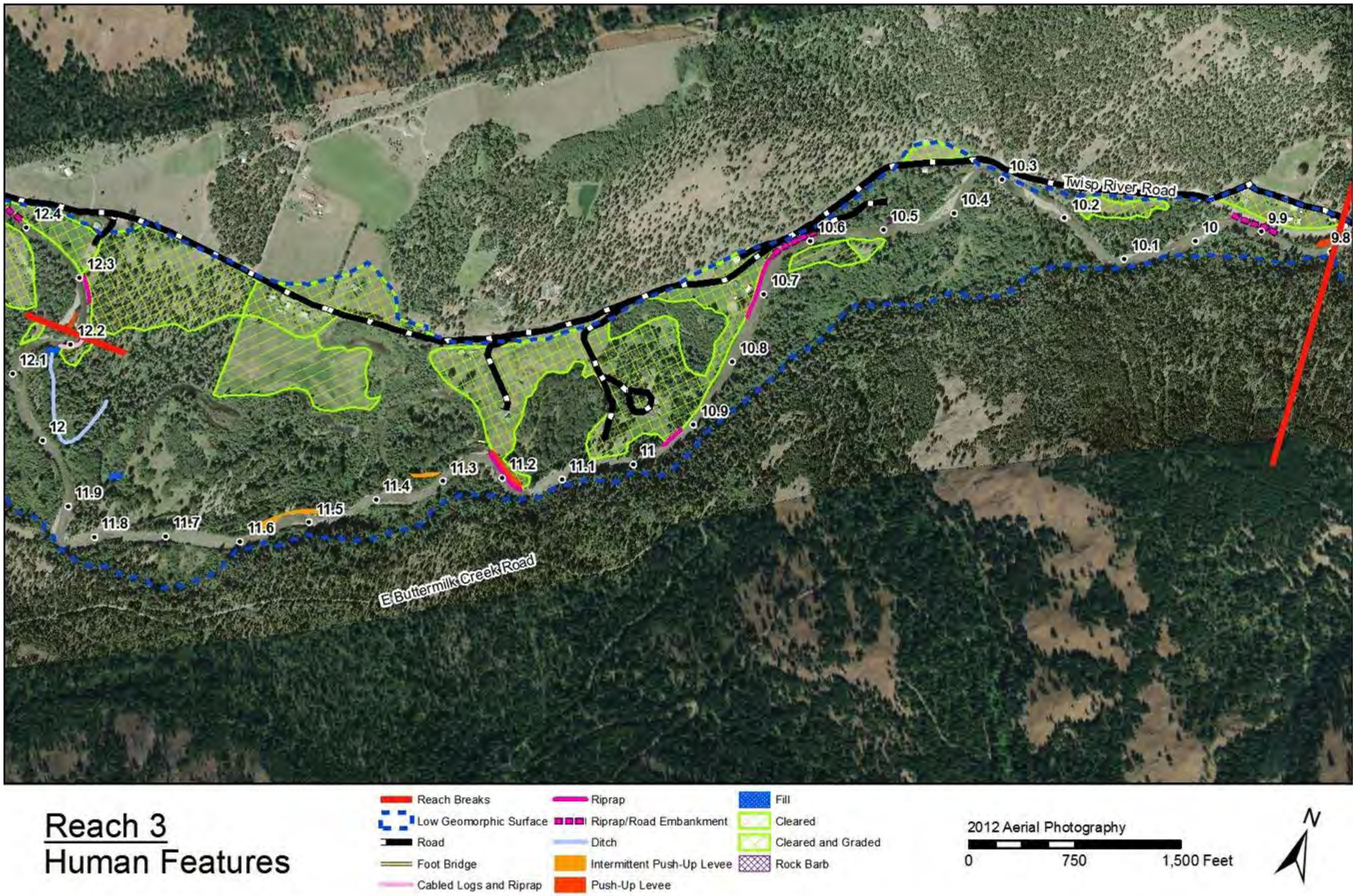

Figure 47 Human features in Reach 3.

3.4 REACH 4

3.4.1 Reach Overview

Reach 4 extends from RM 12.22 to 13.60 (the confluence with Buttermilk Creek) for a total distance of 1.38 miles. A representative photo is provided in Figure 48 and an overview map is included as Figure 49. The reach is semi-confined by glacial terraces, hillslope contacts, and tributary fans and has a moderately steep gradient (1.21%). It is the most sinuous reach in the study area but this is not a result of extensive meander development or high planform diversity. The high sinuosity (1.49) is due to a long arcing bend through much of the reach, which is governed primarily by the influence of the Buttermilk Creek alluvial fan encroaching into the Twisp River valley from the south. There has been relatively little change in channel location over the historical photo record (back to 1953) due largely to natural confinement; however, clearing and grading associated with agricultural uses may be a contributing factor. Despite the overall lack of planform diversity, there are 3 short sections of split flow around small stable islands, and some alcove development in a few locations. Off-channel and side-channel habitat is otherwise very limited. The channel units are dominated by riffle habitat (69%), which reflects the moderately high gradient and lateral controls on the channel. Landownership is predominately private, with the exception of RM 12.4 to 12.5 on river-left and RM 13.4 to 13.5 on river-right, which are National Forest. Agricultural uses, primarily pastures for livestock grazing, dominate portions of the floodplain and riparian areas.

Figure 48. A representative section of Reach 4 at RM 12.8.

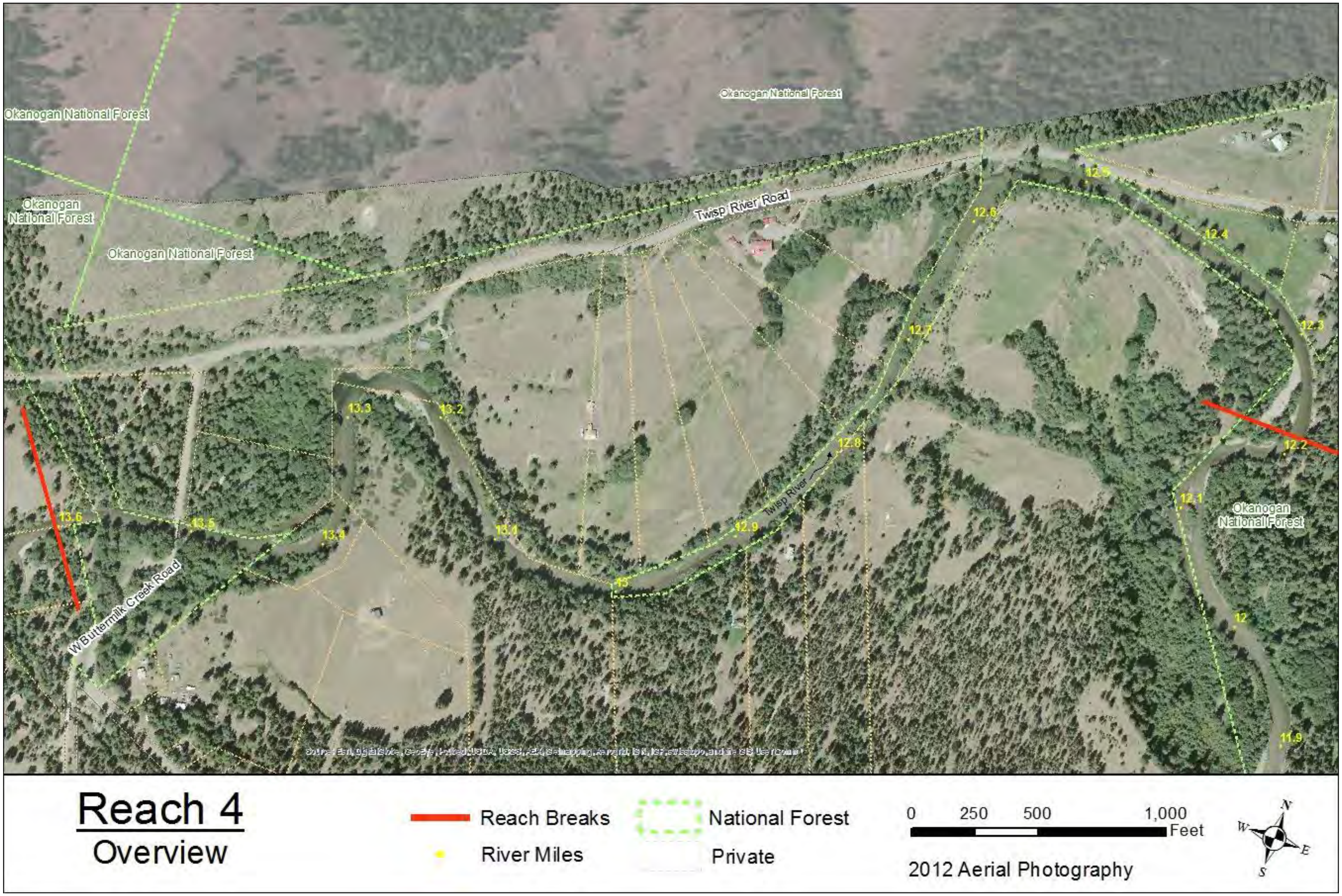

Figure 49. Overview map of Reach 4 showing landownership.

Table 13. Key descriptive and geomorphic metrics for Reach 4.

Metric	Value
Reach Length	1.38 miles
River miles	12.22 to 13.60
Valley gradient	0.72%
Stream gradient	1.21%
Sinuosity	1.49
Dominant channel type	Plane-bed
Avg bankfull width	79.5 ft
Avg floodprone width	120.75 ft
Dominant substrate	Cobble

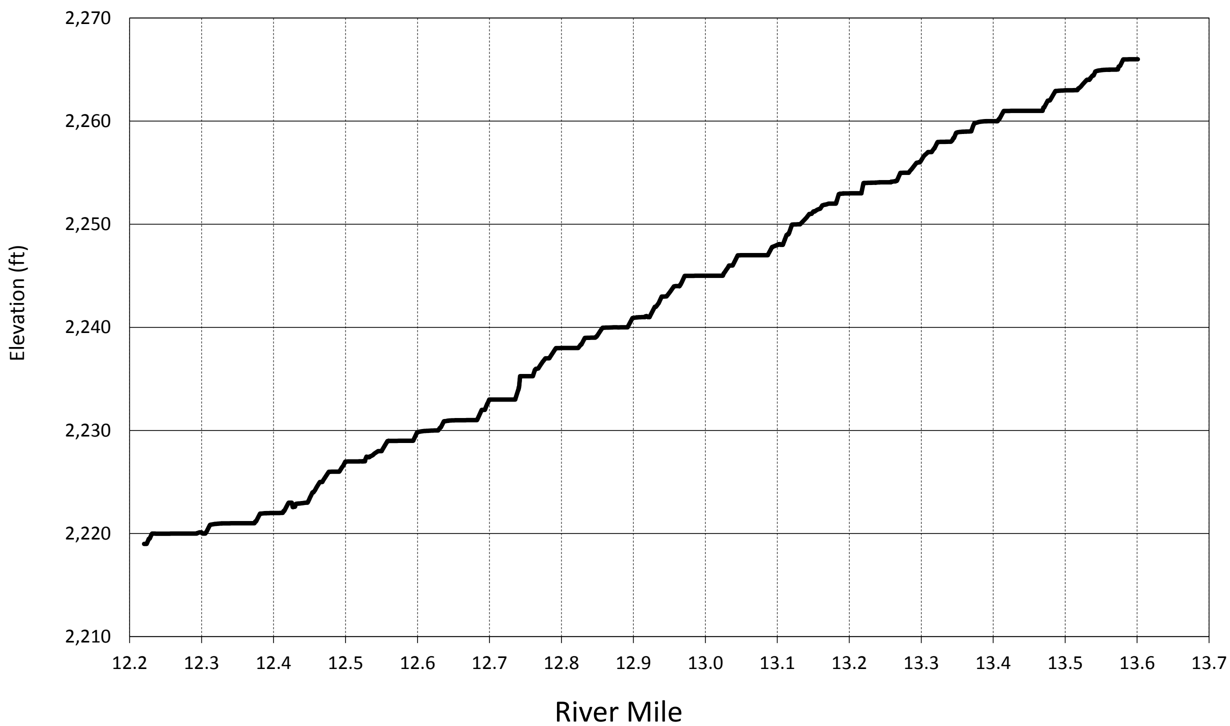

Figure 50. Longitudinal profile of Reach 4. Elevation data is derived from the 2006 LiDAR data and so represents water surface at the time of the LiDAR flight.

3.4.2 River Morphology and Geomorphic Processes

Geology and Landforms

Alluvial fan deposits provide the primary lateral controls on the channel. Hillslope contacts and glacial terraces are also present along the reach (Figure 52). The large Buttermilk Creek alluvial fan occupies much of the southern side of the valley in this reach and creates the long arcing northern bend in the river. The fan deposits have been eroded to various degrees as the channel has widened following past incision. At the downstream end of the reach, there is a series of intermediate terraces that appear to have formed following erosion into the Buttermilk Creek fan (Figure 51). These surfaces are likely comprised of glacial outwash material that formed during and immediately following the last glaciation period. The smaller modern channel has incised into these surfaces and has created a new lower floodplain surface, abandoning these higher terraces.

The influence of the Buttermilk Creek alluvial fan has resulted in the semi-confined nature of this reach, with the modern extent of active floodplain largely controlled by its presence. Erosion into this material via channel scrolling has created the modern floodplain surface. More recent contributions of alluvial material from Buttermilk and Canyon Creeks have a large influence on these erosion processes. The influx of material fuels the cycle of bedload deposition, lateral erosion, subsequent downriver deposition, etc.

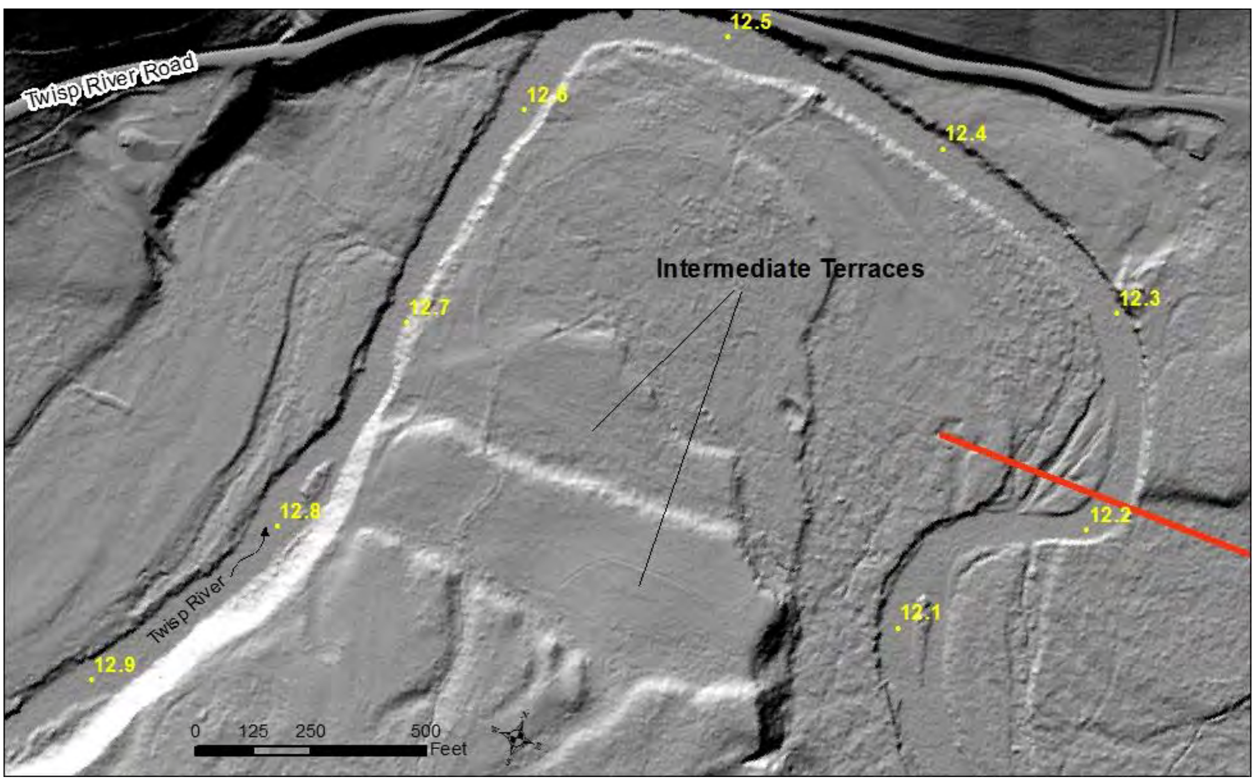

Figure 51. Location of glacial outwash terrace deposits formed during or immediately following the period of last glaciation.

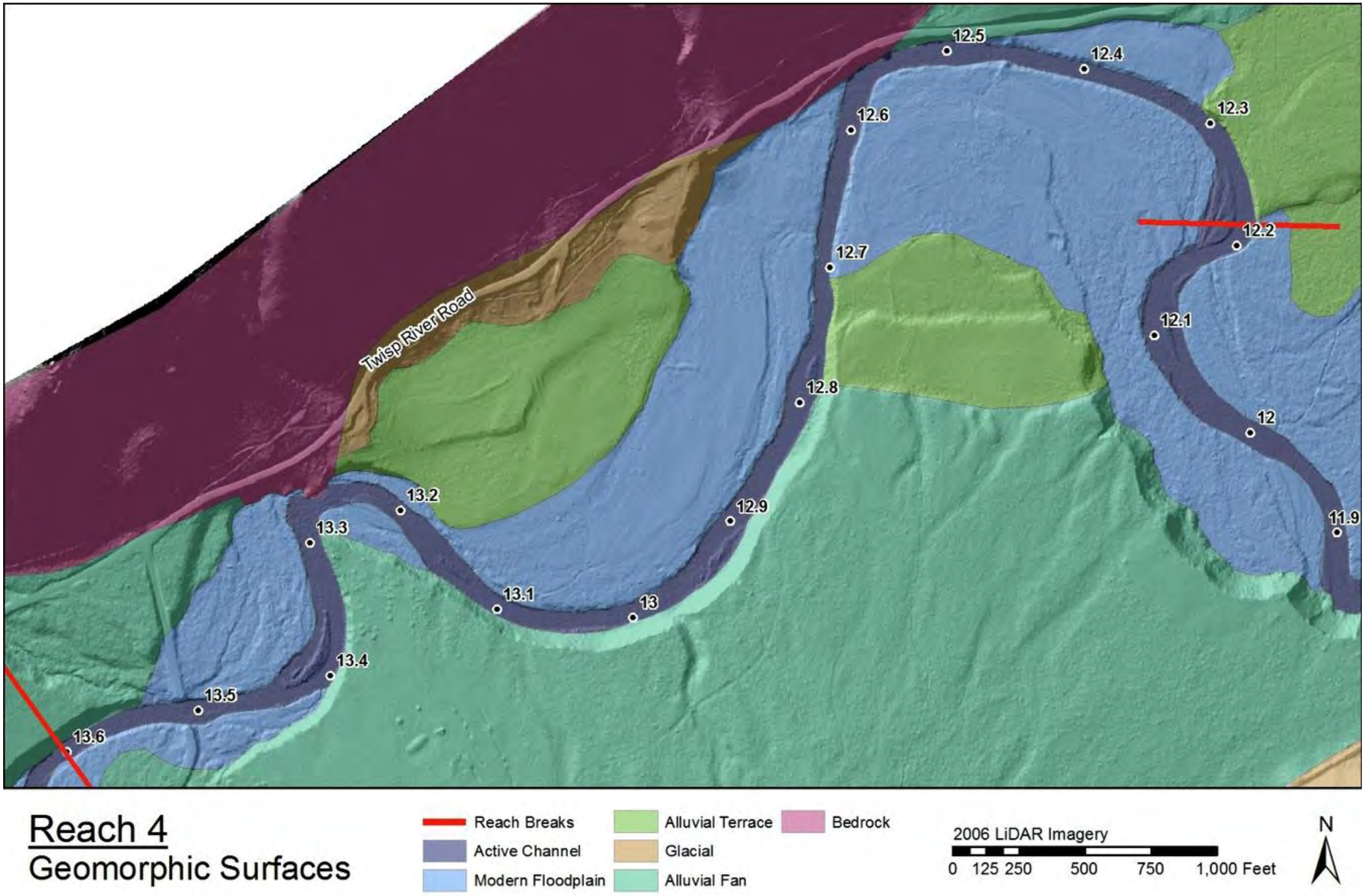

Figure 52. Geomorphic surfaces in Reach 4.

Hydrology

There are two tributaries that enter the reach at the upstream end: Buttermilk Creek and Canyon Creek. Buttermilk Creek, which enters from the south, is a significant contributor of flow. Buttermilk Creek adds approximately 20% of the flow to the Twisp River at this location. The contemporary Buttermilk Creek channel is located along the upstream edge of the fan. It has been in this location at least since the period of the earliest aerial photo records (1953). Canyon Creek is smaller, but is steep and contributes large material to the Twisp River channel (Figure 53).

Figure 53. Mouth of Canyon Creek showing large cobble and boulder material contributed to the mainstem Twisp.

Floodplain and Channel Migration Zone

Although this is the most sinuous reach in the study area, it has only moderate floodplain availability due to the semi-confined nature of the channel. The floodplain inundation map from HEC-RAS modeling using the LiDAR-derived surface is provided in Figure 54. Alluvial fan deposits naturally limit lateral channel migration and floodplain formation through this reach, resulting in relatively high lateral stability. LiDAR provides evidence that the channel has experienced multiple historical incision episodes based on sequences of abandoned terraces on the distal end of the Buttermilk Creek alluvial fan as well as on the north side of the valley near RM 13.1 – 13.2. There is also more recent evidence of incision on the terrace on river-left in the middle of the reach where alluvial processes (scour) are visible on the now abandoned terrace (see Figure 52).

There is greater floodplain connectivity and evidence of more recent active channel migration at the upstream and downstream ends of the reach. The floodplain is relatively well-connected at the upstream end where the river has re-worked bedload material contributed from Buttermilk and Canyon Creeks. The floodplain is also relatively well-connected at the downstream end (river-right) where the channel has scrolled to the north and has left a low floodplain surface to the south.

Channel changes since the earliest available aerial photos were mapped and are presented in Figure 54. This analysis shows that the channel has been mostly stable since 1953. There are no aerial photos that pre-date the flood of record in 1948, when channel adjustments would likely have occurred.

The Buttermilk Creek Road Bridge at the upstream end of the reach, and the private bridge at RM 12.46, provide some floodplain and CMZ impacts. These are discussed in greater detail in the Human Alterations section below.

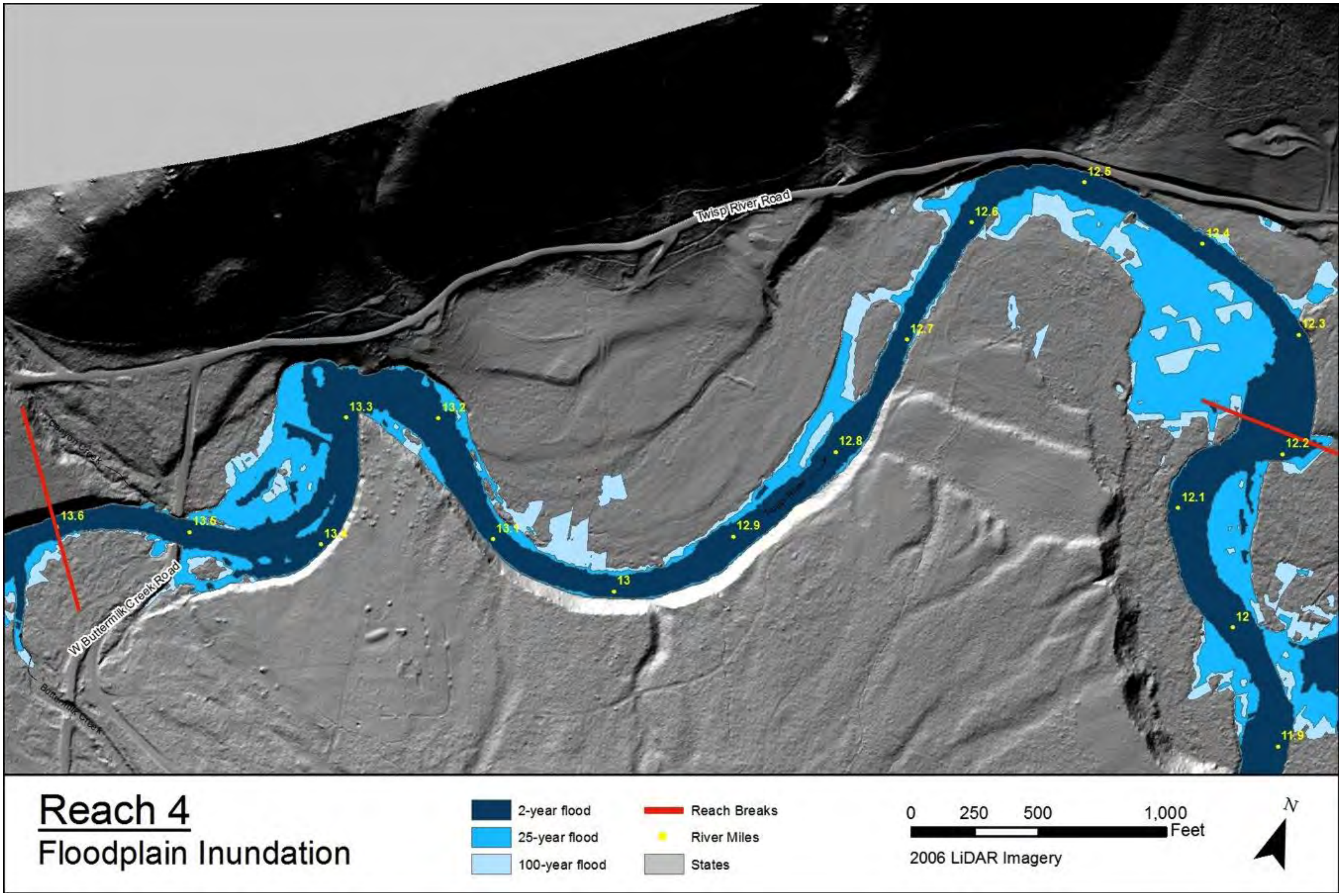

Figure 54. Extents of floodplain inundation for selected flood recurrence intervals in Reach 4. Flood inundations developed using HEC-GeoRAS based on the LiDAR surface.

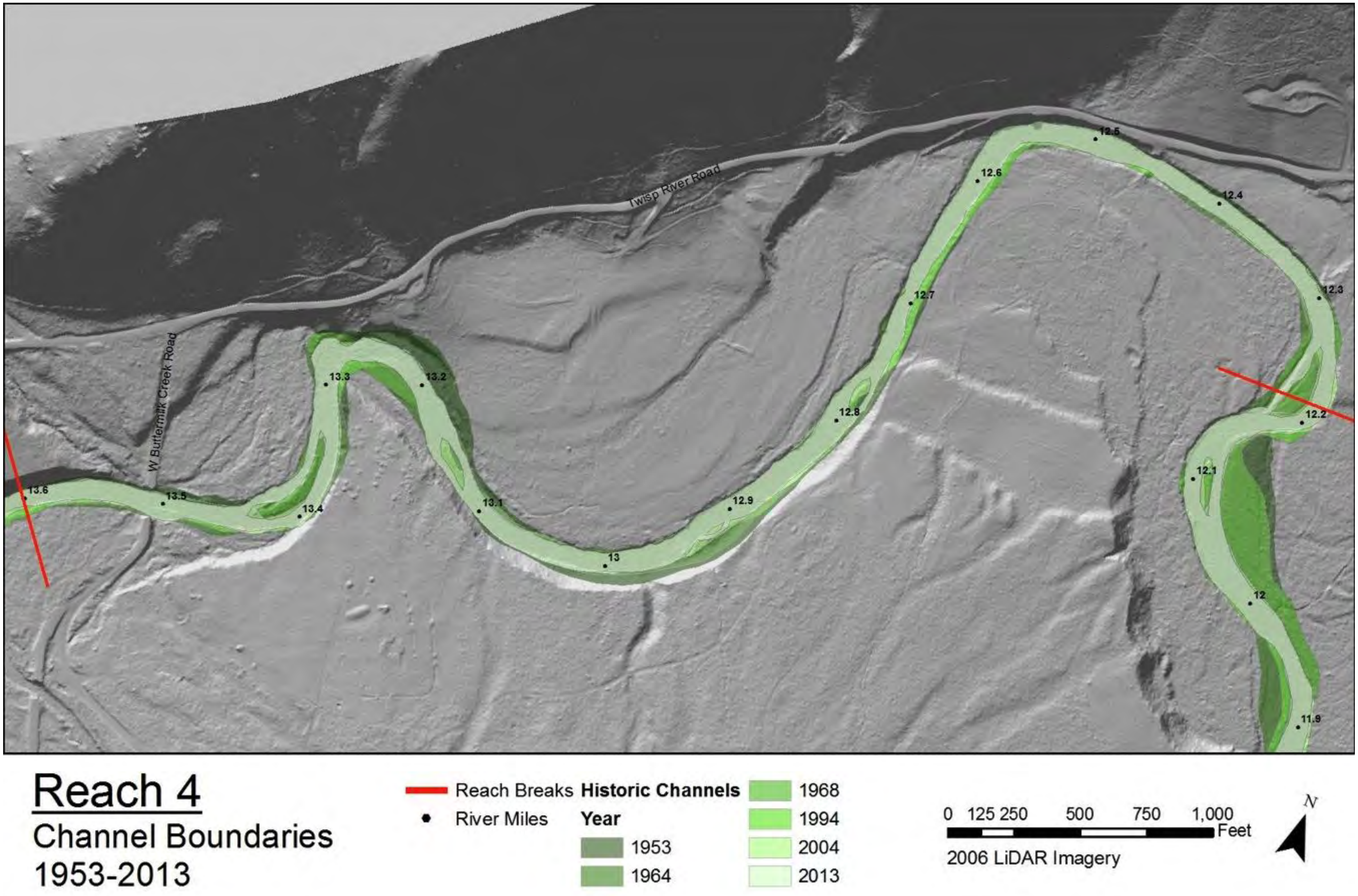

Figure 55. Historical Channel Boundaries

Sediment

The reach is primarily transport dominated, with occasional areas of deposition ('response'), which are mostly located in the upstream and downstream portions of the reach where the river has developed a wider active channel migration zone and gradient is less. Plane-bed riffle and glide channel units prevail, with only occasional pools. Bed substrate is dominated by cobbles (56%), with gravels subdominant (31%). There are few gravel bars (Figure 56). There are not many fines, although fine sediment accumulation was observed on the channel bed at the downstream end of the reach where the gradient lessens.

There are several sediment sources in this reach including older fan deposits that the river has eroded into, more recent tributary inputs, and bank erosion from modern alluvial surfaces. Topographic evidence indicates that the channel has been eroding towards the river-right into the large Buttermilk Creek alluvial fan; however, the channel has been relatively stable over the last 60 years (available air photo record). Contemporary active erosion into more recent alluvial surfaces occurs in various locations. Near RM 12.9, there is active erosion along the river-left bank, resulting in gravel recruitment to the channel. Another sediment source occurs just downstream of RM 13 where large alluvial fan material output from the abandoned alluvial fan channel has resulted in a large accumulation of boulders approximately 12 to 15 feet above the water surface elevation. The cobble and boulder bar located just downstream is also likely sourced from this channel.

Buttermilk Creek and Canyon Creek enter the reach at the upstream end and contribute sediment during floods. The 1953 aerial photo shows evidence of a recent debris flow in Buttermilk Creek, which likely contributed a significant amount of sediment, including bedload, to the Twisp River (Figure 57). It is possible the debris flow occurred during the 1948 regional flood event.

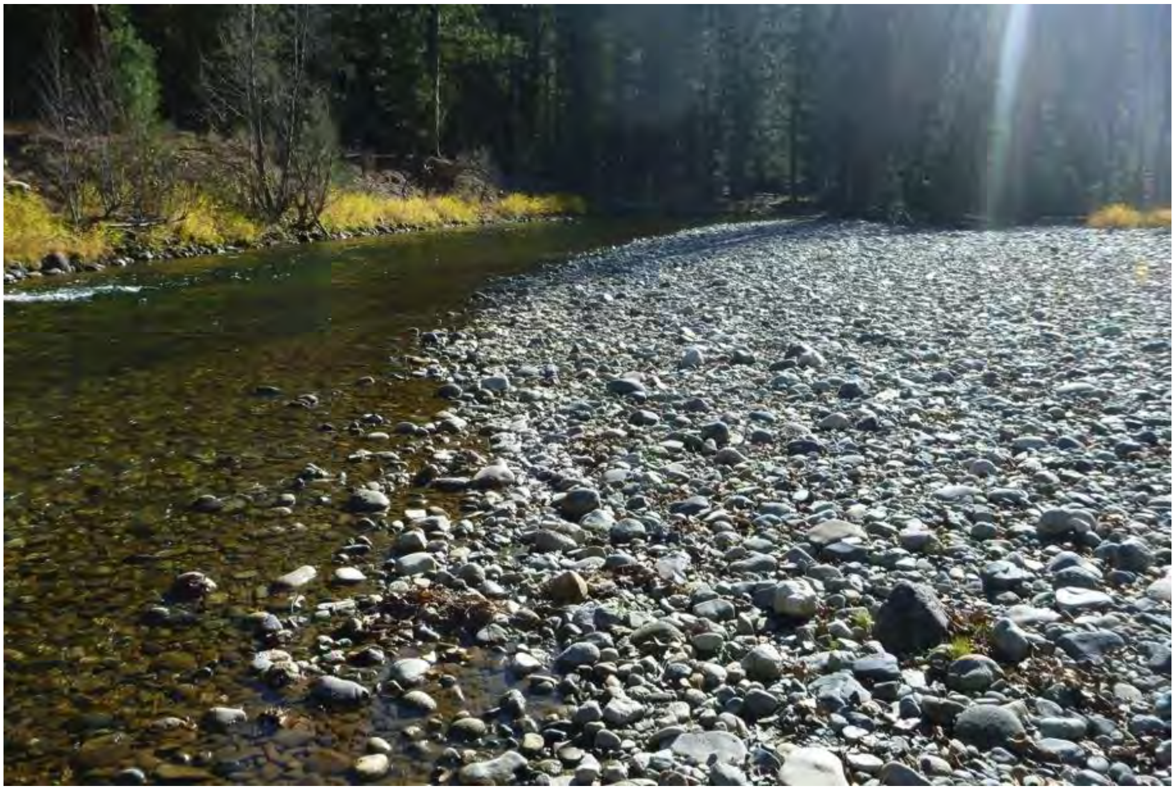

Figure 56. One of the few cobble bars in Reach 4. This one is located on river-right near RM 12.3.

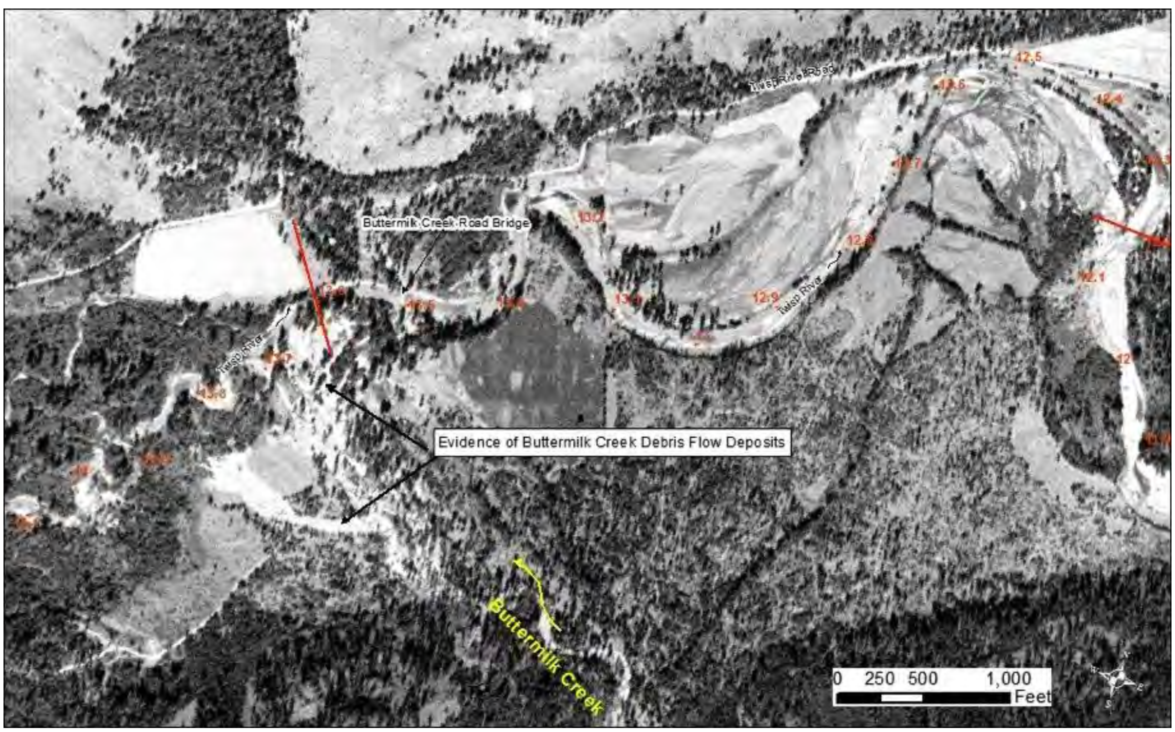

Figure 57. 1953 aerial photo of Reach 4 and downstream portion of Reach 5 showing evidence of Buttermilk Creek debris flow deposits. The red lines are the reach breaks.

Large Wood

Reach 4 had the lowest frequency of medium and large wood in the study area (9.4 medium and large pieces per mile), but had relatively abundant small wood and 2 bar apex log jams. The jams were comprised primarily of small material. The existing in-channel complexity that does exist in this reach is largely a result of the islands and log jams that are driving split flow. The islands that were observed in this reach had established alders providing stability and protection from erosion. The islands also act as a strainer for wood being transported downstream.

Figure 58. Bar apex log jam near RM 12.8 in Reach 4. This is one of only two log jams in the reach. Both jams were comprised primarily of the 'small' size class of large wood.

Vegetation

Vegetation conditions in Reach 4 consist of a variable width riparian buffer comprised of both conifers (primarily Douglas fir) and deciduous species (primarily cottonwood and alder). Canopy heights are depicted in Figure 59, which demonstrates the relatively young and sparse riparian and floodplain vegetation conditions. Of the 5 measured habitat units in the habitat survey, dominant overstory vegetation was 'small tree' for 3 of them, 'grass/forb' for 1, and 'no vegetation' for 1.

Riparian and floodplain vegetation in Reach 4 play a lesser role in channel form and dynamics compared to the more alluvial reaches (i.e. Reaches 3, 5, and 6) in the study area where there is a greater degree of floodplain connectivity and riparian trees are more readily recruited to the channel. Recruitment of riparian trees does still occur in Reach 4, but it is primarily from natural tree mortality, with only a few areas where there is active recruitment from bank erosion. Riparian vegetation does, however, play an important role in providing bank integrity and stream shade.

Under historical conditions, vegetation would have played a larger role in channel form and process in the reach. This would have been the result of large trees that could be recruited to the channel as stable “key pieces” of LW. The resulting log jams would then create additional lateral dynamics, with more recruitment of LW, and the cycle would continue. There also would have been large shade-producing conifers that would have helped control water temperatures.

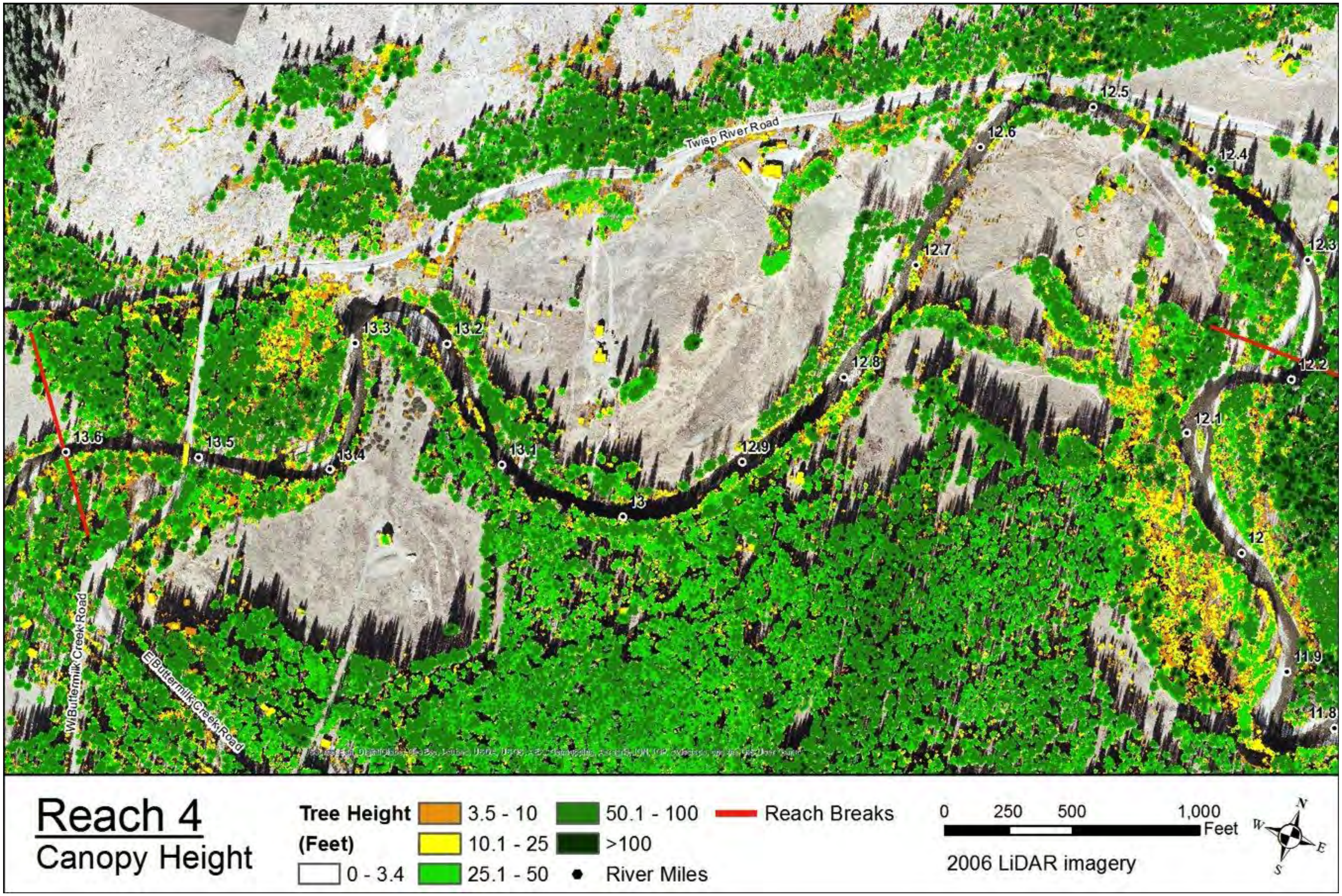

Figure 59. LiDAR first return (highest hit) data for Reach 4. These data show vegetation canopy heights. Buildings and other human infrastructure are also included in this data but there are only a few occurrences in the reach.

3.4.3 Human Alterations

The already limited amount of floodplain inundation and channel migration potential has been altered by bridges, levees, floodplain grading, and bank armoring. There are two bridges in this reach contributing to floodplain discontinuity and inhibiting lateral migration. Much of the floodplain has been cleared and graded for agricultural, residential, and recreational uses. Push-up levees, oftentimes intermittent, are located along much of this reach, with impacts on floodplain inundation rates. Cleared riparian areas dominate much of the reach with impacts to channel stability, shade, and large wood recruitment. Large wood and log jam numbers are significantly reduced from what would be expected under historical conditions. A map of human features in the reach is provided in Figure 62.

Bridges

One of the primary human alterations to Reach 4 are the two bridges that cross the Twisp River. The downstream bridge (RM 12.46) has associated riprap upstream and downstream along both banks that affects floodplain inundation along river-right (Figure 60). The effect is less on river-left due to the proximity of the hillslope. The bridge appears to be low and narrow and is acting as a channel constriction under high flows. Gullying was noted on the left bank along the roadway around RM 12.55, with the potential for fine sediments entering the system. There are multiple large trees leaning over the channel in this area that are potential sources of large woody debris and could enhance in-channel habitat and provide cover for fish.

There is a second bridge at RM 13.5 (Figure 61). The bridge and associated riprap disconnect natural fluvial processes; the road prism disconnects floodplain continuity and the riprap prevents channel migration. The right bank has large gravel deposits extending from the center bridge pillar to the bank abutment. This deposit is composed of material similar to the channel bed materials, indicating the potential for mobilization during high flow events. There is fill associated with the roadway on the north and south approaches to the bridge. These block floodplain continuity in the river-left and river-right floodplains. The hydraulic modeling results indicate that this human alteration has resulted in floodplain discontinuity, particularly on river-right, as a result of road embankment construction.

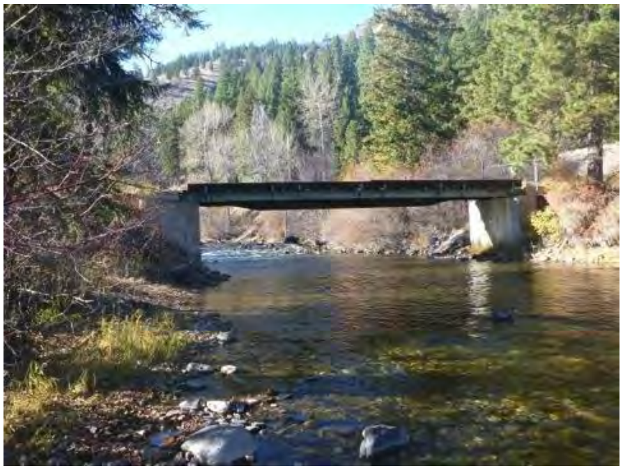

Figure 60. A small single lane bridge with abutments on the channel margin at RM 12.46.

Figure 61. Bridge at RM 13.5 looking upstream.

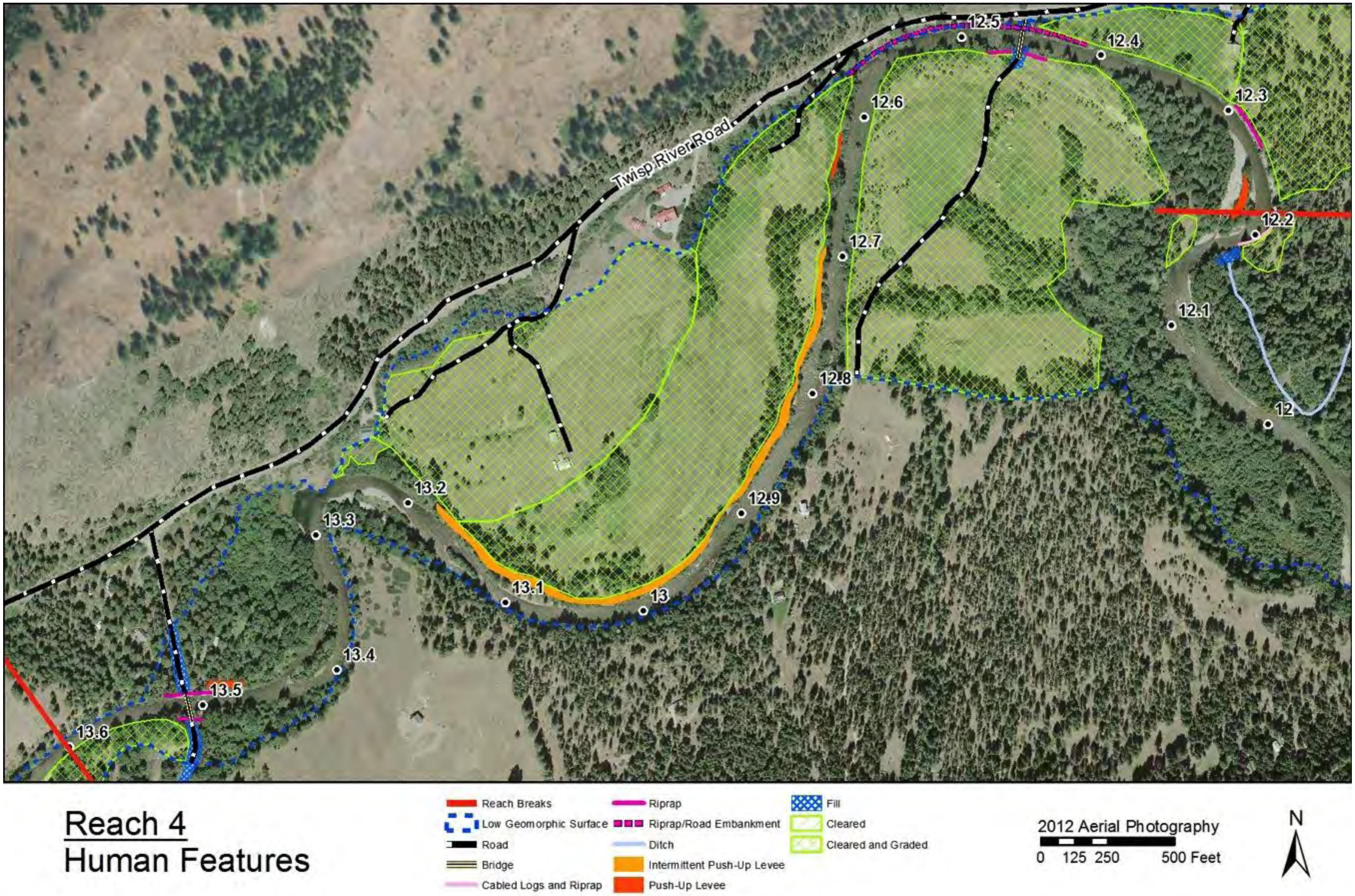

Figure 62. Human features in Reach 4.

Floodplain Grading, Levees, and Bridges

Much of the floodplain has been cleared and graded for agricultural, residential, and recreational uses. Push-up levees, oftentimes intermittent, are located along much of the reach, with impacts on floodplain inundation rates. Clearing and grading has taken place along river-left from RM 12.3 to 13.15 in the modern alluvial terrace as well as the 100-year floodplain. Bank erosion was noted at several locations throughout the reach (e.g. right bank at RM 12.6) likely a result of riparian vegetation clearing to the water's edge. There is a push-up levee on river-left at RM 12.81 with fallen alders on it that was potentially constructed to prevent flow into the high flow channel on the left-bank. There is also a push up levee along the right-bank on the interior of the channel bend at RM 12.24, but it does not appear to be disconnecting hydraulic connectivity of the annually active high flow channel on the interior of the levee. Two bridges, and their associated approach fills, contribute to floodplain disconnection and inhibit lateral migration.

Loss of Instream Habitat Complexity

Due to the transport dominated character of the reach and general lack of planform complexity, large wood would not be expected to play as large of a role in Reach 4 compared to Reaches 3 or 5. However, large wood jams would nevertheless have been expected to form under historical conditions when wood loading and wood sizes were greater. These contributions would likely have increased complexity and dynamics (e.g. split flow, channel migration) in the reach compared to historical conditions. The lack of wood in recent decades may help explain the relatively static location of the channel over the past 60 years.

Significant Riparian Impairment

Riparian and floodplain vegetation conditions in Reach 4 have been heavily impacted by human uses including the Twisp River Road, agricultural clearing, and clearing associated with rural residences. The canopy height figure (Figure 59) shows the degree of impact on riparian vegetation in the reach. This figure demonstrates that the riparian buffer is rarely greater than 100 feet wide and that riparian vegetation is mostly comprised of trees less than 100 feet tall. There are several areas with little to no riparian corridor where there is clearing up to or very near the channel.

Impaired riparian conditions have affected several biological and physical processes in the reach. The potential for LW loading has been reduced, and is likely at least partially responsible for the low LW and log jam numbers. Some of the bank erosion occurring in the reach, particularly around RM 12.9 appears to be related to lack of riparian vegetation needed to provide bank integrity. Lack of riparian canopy also affects water temperature in this reach. Beyond the riparian areas, floodplain areas are also heavily cleared, particularly on the river-left in the middle section of the reach and within the river-right floodplain at the downstream end of the reach. These reductions in floodplain vegetation can have negative impacts on floodplain refuge habitat, rates of channel migration/avulsion, off-channel habitat development, and LW recruitment during avulsion or channel migration events.

Figure 63. View of river-left bank near RM 12.65 showing evidence of active clearing of riparian and floodplain vegetation.

3.5 REACH 5

3.5.1 Reach Overview

Reach 5 corresponds to the downstream portion of T6a from the USBR Methow Subbasin Geomorphic Assessment and extends 2.59 miles from RM 13.6 (confluence of Buttermilk Creek) to RM 16.19. Reach 5 is a dynamic, lower gradient braided reach (Figure 64). This portion of the study area provides analog conditions as much of the reach has a dynamic, multi-thread channel, with active lateral channel dynamics, abundant off-channel habitats, and high large wood and log jam numbers. There is a large levee/pond complex in the upstream portion of the reach along river-left, reducing available habitat and limiting lateral migration to the north in this area. This reach exhibits rapid channel repositioning via bank erosion and avulsions. Significant channel changes occur on the order of every 10 to 15 years. This degree of change, although good for creation of new habitats, may be greater than under historical conditions when larger riparian trees, larger downed trees in the channel and floodplain, and large stable log jams would have created a greater degree of stability. The more active contemporary channel could potentially be a redd scour and sedimentation issue.

Landownership in Reach 5 is primarily private, with the exception of a small portion of the active floodplain on both sides of the channel from approximately RM 14 to 14.2 and along river-right from RM 15.1 to 15.3 and 14.2 to 14.4, which is National Forest land (Figure 65).

Figure 64. A representative section of Reach 5 at RM 14.1.

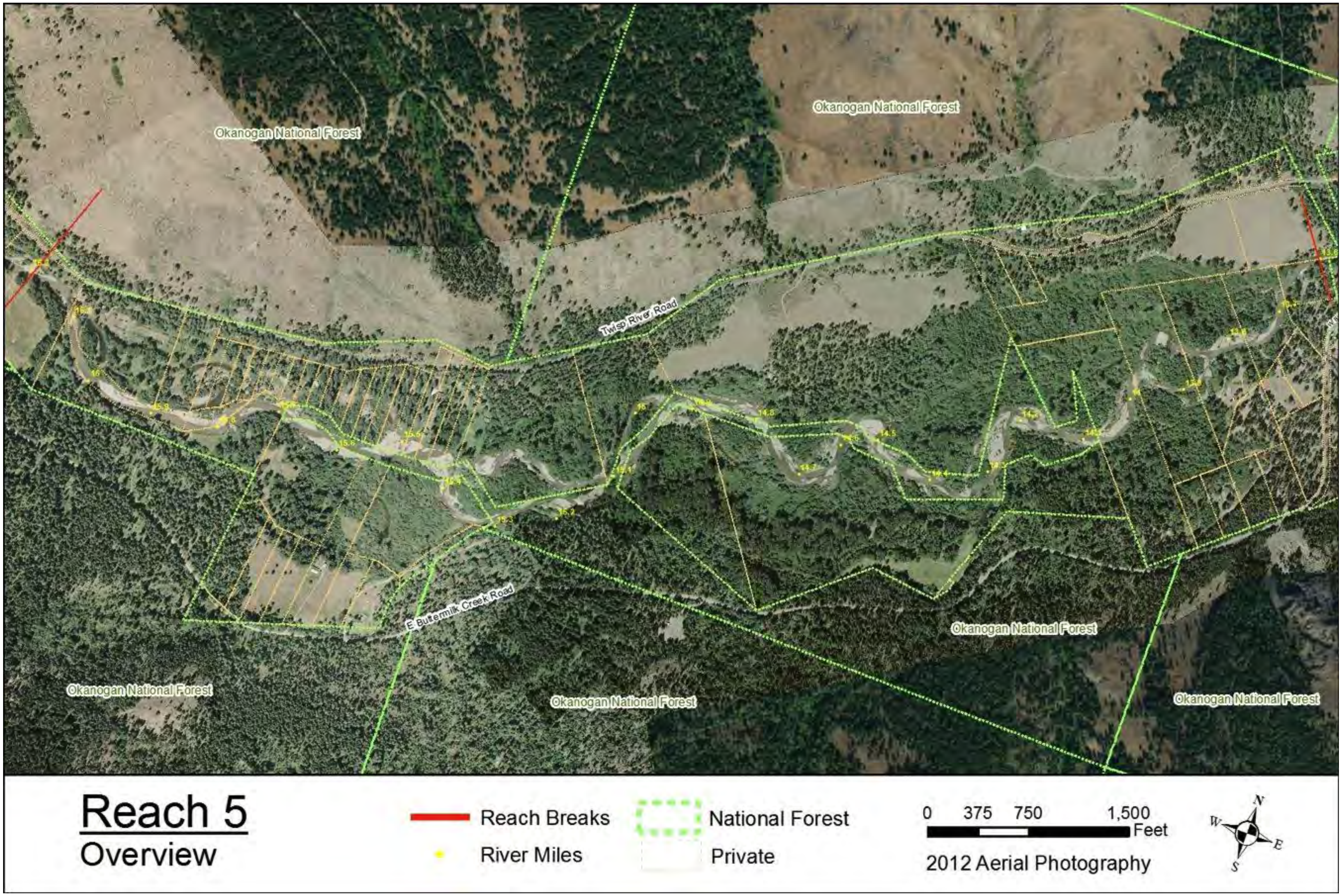

Figure 65. Overview map of Reach 5 showing landownership.

Table 14. Key descriptive and geomorphic metrics for Reach 5.

Metric	Value
Reach Length	2.59 miles
River miles	13.6 to 16.19
Valley gradient	0.84%
Stream gradient	0.59%
Sinuosity	1.34
Dominant Channel Type	Pool-riffle
Avg bankfull width	92.6 ft
Avg floodplain width	393 ft
Dominant substrate	Gravel/cobble

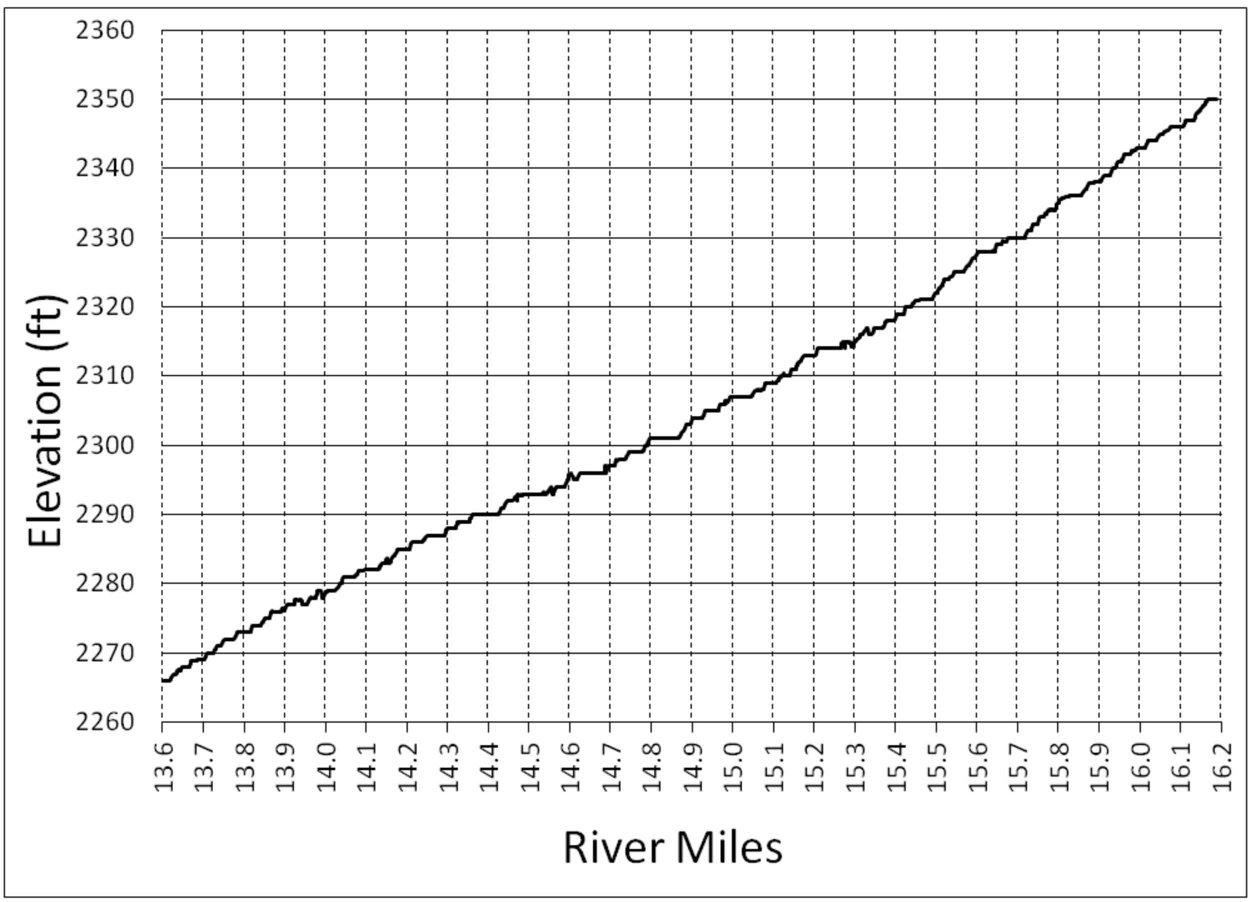

Figure 66. Longitudinal profile of Reach 5. Elevation data is derived from the 2006 LiDAR data and so represents water surface at the time of the LiDAR flight.

3.5.2 River Morphology and Geomorphic Processes

Geology and Landforms

Reach 5 has a complex, multi-thread channel, with active lateral channel dynamics and abundant off-channel habitats. The mainstem has a relatively even makeup of glides, riffles and pools (Appendix A). The dynamic braided system is largely due to the channel's low gradient (0.59%; Figure 66) and lack of confinement along the channel margins, with alluvial fans primarily forming the margins along the north and south valley walls.

Hydrology

There are two primary tributaries that enter this reach. At the upstream end, Scaffold Camp Creek enters from river-right. The Scaffold Creek alluvial fan has a large effect on channel morphology in this area. At the downstream end of the reach, Buttermilk Creek enters from river-right. Buttermilk Creek contributes approximately 20% of the flow to the Twisp River. Other drainages include Lime Creek and numerous smaller unnamed tributaries.

Floodplain and Channel Migration Zone

The floodplain in Reach 5 was the widest and most active within the study area (Figure 72). Based on results from the hydraulics analysis, nearly the entire valley floor is inundated at the 100-year flood and many of the off-channel habitat features are active at more frequent flows (Figure 71). The braided nature of the channel results in frequent active high-flow channels and point and mid-channel bars that are active during regular high flow events (e.g. Q1 to Q5; Figure 71). This portion of the study reach had extensive side channel networks with dense vegetative cover in some locations, providing excellent habitat. This portion of the study area provides a good analog for the active nature and frequent floodplain inundation that would be expected to be found in Reaches 3 and 6 in the absence of human alterations.

The dynamic nature of the channel in this reach has resulted in channel migration as recently as 2012, with an avulsion and channel abandonment that took place at RM 14.5 (Figure 68). The previous channel is primarily exposed gravel deposits with high flow channels throughout the area. Based on the historical aerial photo record, the channel has actively migrated throughout the low surface over the past several decades (Figure 72). As discussed below under the Large Wood section, the rate of channel adjustment may be greater now due to a reduction in sizes for both instream wood and riparian trees. This may have a detrimental effect on habitat conditions through redd scour.

Reach 5 has the largest amount of side channels within the study area, with the 19 measured side channels accounting for 18% of the habitat area in the reach (Habitat Assessment, Appendix A). The largest side channel was 4,956-feet long with significant amounts of wood accumulation that provides a tremendous amount of rearing habitat as well as spawning potential (Figure 69). The side-channels and backwater alcoves throughout the floodplain provide high flow refugia (Figure 70).

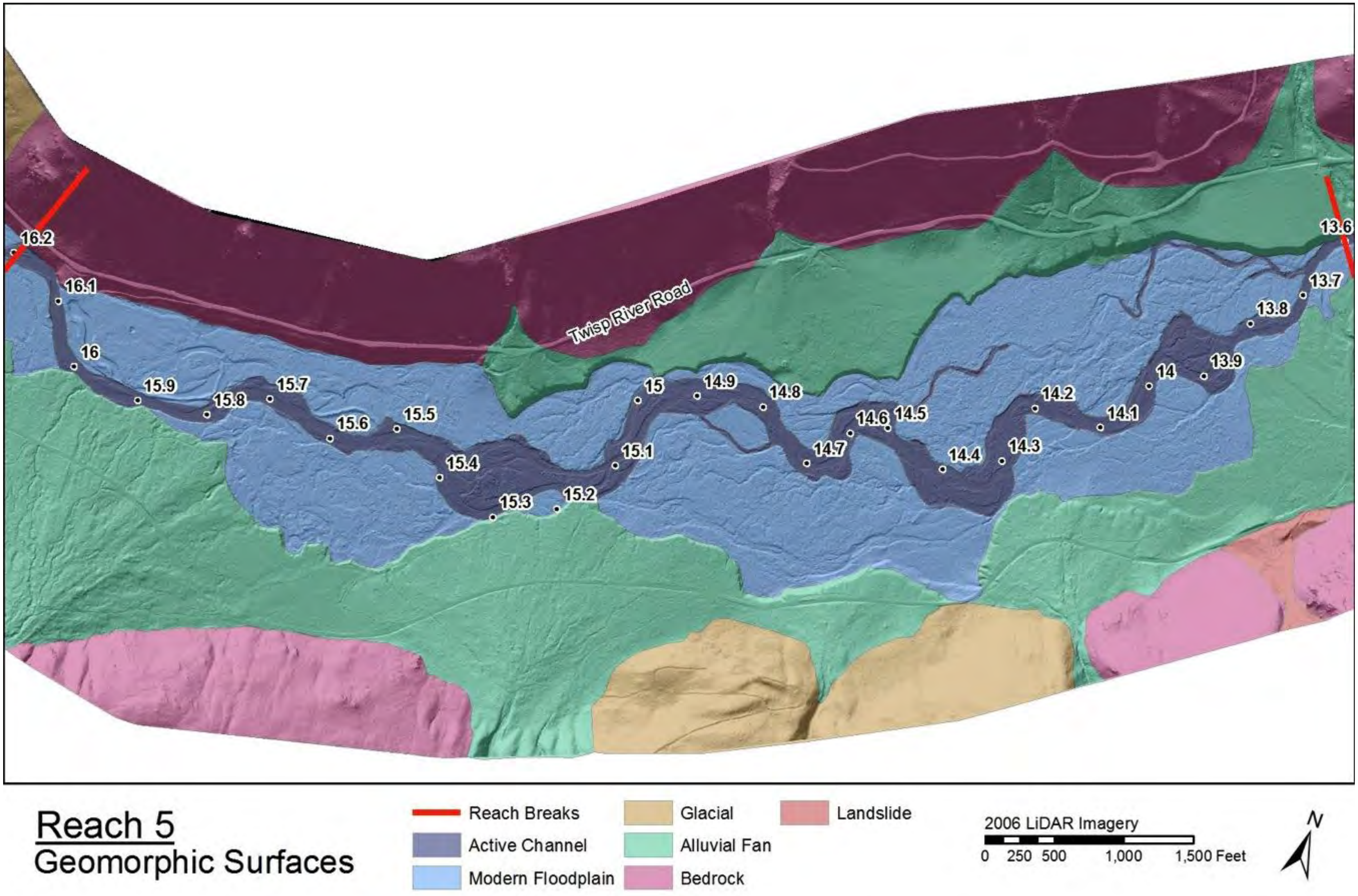

Figure 67. Geomorphic surfaces in Reach 5.

Figure 68. Channel avulsion occurred at RM 14.5 and a large gravel deposit remains on river-left in the previous main channel with evidence of high flow scour

Figure 69. A representative photo from the 4,956 foot long side channel.

Figure 70. River right at RM 14.4 there is a beaver dam creating a backwater alcove.

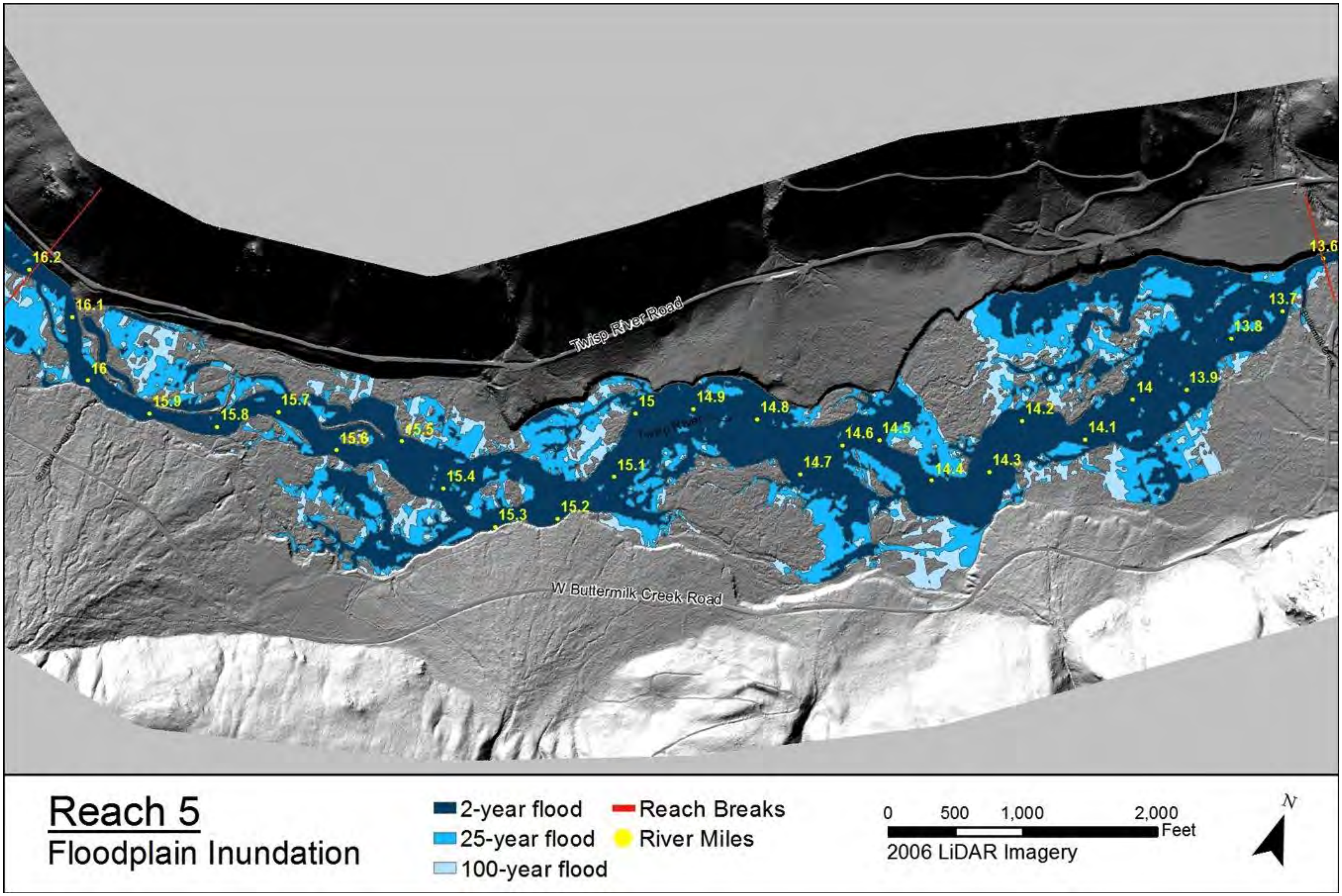

Figure 71. Extents of floodplain inundation for selected flood recurrence intervals in Reach 4. Flood inundations developed using HEC-GeoRAS based on the LiDAR surface.

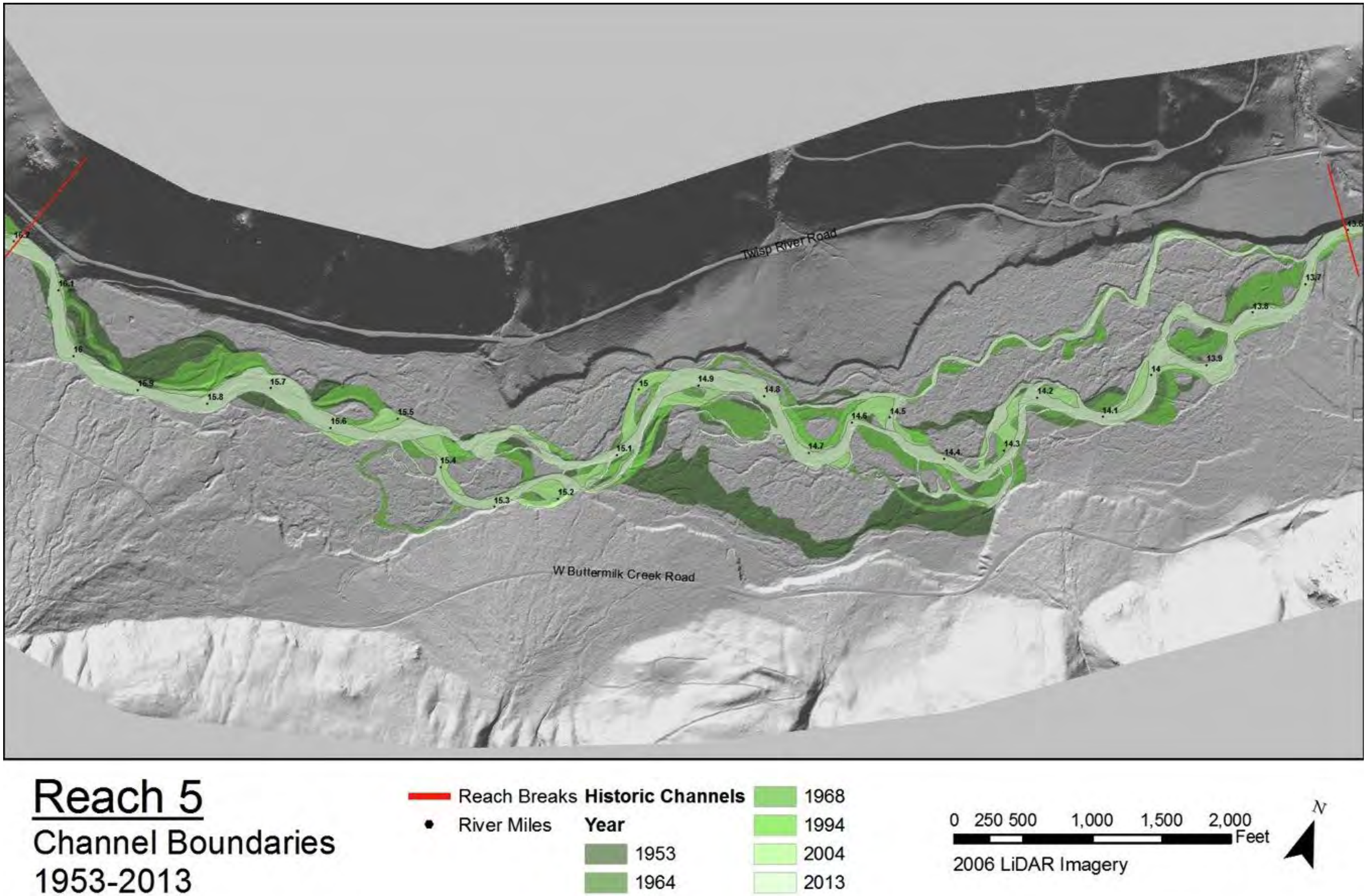

Figure 72. Historical channel boundaries for Reach 5.

Sediment

The sediment measured on the channel bed in this reach was equal parts gravel and cobble, and is the finest observed in the study area. The finer composition of the bed surface is likely a result of the low gradient depositional channel type. Bars observed in this reach were primarily gravel and sand, and lacked established vegetation on these surfaces, indicating that they are scoured and filled regularly.

This reach is very much a response reach and may be on a trend of aggradation based on the frequent bar deposition and frequent planform adjustment. Material is sourced almost exclusively from erosion of the modern floodplain surface, with only a few areas where the channel currently abuts terrace deposits (primarily alluvial fan in origin). Thus, the bed sediments lack the coarse input from colluvial sources relative to other reaches.

Large Wood

Reach 5 had high quantities of large wood and log jams when compared to the remainder of the study area. This reach had 537 pieces of wood, for 207 pieces per mile. A significant portion of the wood (27%, or 145 pieces) were found in the over 15,000 feet of side channel habitat (Appendix A). Although this reach had a significant amount of total wood, only a fraction of the pieces (34 pieces) were considered “large” pieces (>20 inches diameter; >35 feet long). There was also a lot of smaller wood that was smaller than the minimum length required for a qualifying piece, and therefore was not counted. A total of ten log jams were observed in Reach 5, comprising 155 pieces of wood (Appendix A). Significant quantities of cut wood were found near RM 15.4 that appeared to have been cut just upstream. Large wood was observed to typically accumulate at bar apexes and along low-angle gravel bars (Figure 73 and Figure 74). Wood is an important catalyst for rapid channel repositioning via bank erosion and avulsions. The frequency of channel adjustment may actually be greater now compared to historical conditions due to the relatively small size of the wood that is in the channel and that is available to be recruited. Historically, large wood would serve as key pieces that would form large jams that would persist for many years or even decades. In the current condition, there are smaller jams that are more transient and allow for more frequent channel adjustment. This poses a potential risk to salmonids via increased potential for redd scour or burial.

Figure 73. Large amounts of LWD have accumulated throughout this reach especially in the areas highlighted in red boxes.

Figure 74. Rm 13.85 wood deposition on the gravel bars throughout the channel.

Vegetation

The riparian corridor is relatively young with 43% shrub/seedling; 29% sapling/pole; 21% small trees; and 7% having no vegetation. The lack of mature vegetation is likely due to the dynamic nature of the channel that results in a re-setting of the vegetation trajectory relatively frequently (Figure 75). There are patches of large cottonwoods, and some large conifers, that are evident in the floodplain, but the channel is not currently eroding into these areas.

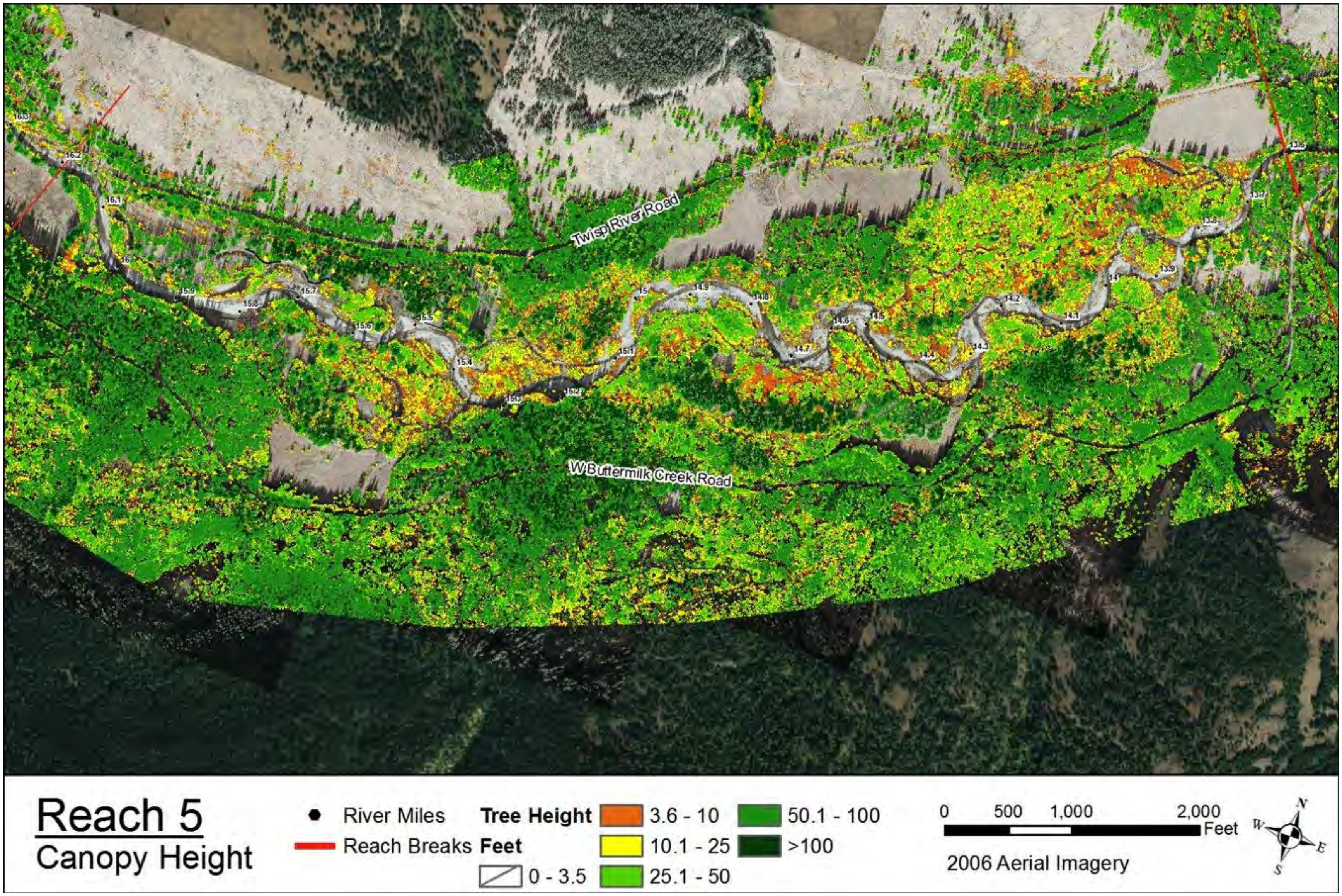

Figure 75. LiDAR first return (highest hit) data for Reach 5. These data show vegetation canopy heights. Buildings and other human infrastructure are also included in this data but there are only a few occurrences in the reach.

3.5.3 Human Alterations

Much of the reach length is largely unaffected by contemporary human hydromodifications. However, at the upstream and downstream ends of the reach there are some significant impairments. The greatest impairments occur at the upstream end of the reach in the river-left floodplain, where there is a levee and excavated pond complex that degrades floodplain function and off-channel connectivity. At the downstream end of the reach, on river-right, there are several areas of bank armoring that impair channel migration and riparian function. Past riparian timber harvest, combined with the probable past removal of large wood from the channel, has reduced riparian and in-channel structure, which has likely contributed to the extremely dynamic condition of this reach.

Figure 76. RM 13.8 riprap with large posts and a constructed footbridge constructed along river right opening to a gravel clearing.

Figure 77. RM 13.85 Significant riprap has been placed along river right of this this residential clearing with recreational elements up to the bank's edge.

Floodplain Fill, Grading, Levees, and Bank Armoring

There are two main areas where floodplain filling, grading, levees, and bank armoring have occurred: 1) downstream end on river-right from RM 13.6 to 13.9, and 2) upstream end on river-left from RM 15.45 to 16.1.

At the downstream end, clearing and grading have occurred within the 100-year floodplain related to recreational and residential uses (Figure 76 and Figure 77). There are also several areas of riprap along the channel banks and the construction of a small footbridge (RM 13.8). There is also a gabion wall that lines the lower end of Buttermilk Creek, near the confluence.

At the upstream end, there is a levee and excavated pond complex that impairs floodplain function, channel migration, and off-channel connectivity in this area. The levee complex limits lateral channel migration, reduces floodplain inundation, and disconnects the open water ponds and floodplain features from the mainstem Twisp River (Figure 79 and Figure 80). There is a gabion wall at the inlet to this levee complex (RM 16.1; Figure 78). A culvert provides an inflow to the pond complex under annual high flows with an outflow location at the levee breach at RM 15.91. The gabion walls prevent lateral channel migration. The culvert allows high flows to enter the pond complex, but does not allow for fish to access the area, except for at very high flows. The near channel pond at RM 15.8 has no low flow connectivity to the main channel, but is connected under high flows. The pond is approximately 4 feet deep and has fine sediment accumulation and submerged vegetation; tthere was no evidence of fish present in the pond complex. Just downstream of the primary levee and pond complex, there are a few areas were bank armoring (primarily riprap) is protecting houses within the floodplain and channel migration zone.

Figure 78. Gabion wall and culvert located at the upstream end of the large pond complex along river left at RM 16.1.

Figure 79. Pushup levee at RM 15.9 along river-left with established conifers

Figure 80. The near channel pond at RM 15.75 has no low flow connectivity to the main channel

Riparian Impairment

Riparian clearing has occurred primarily in the areas described above at the upstream and downstream ends of the reach. Clearing of riparian vegetation has reduced shading, the potential for large wood input, and bank stability.

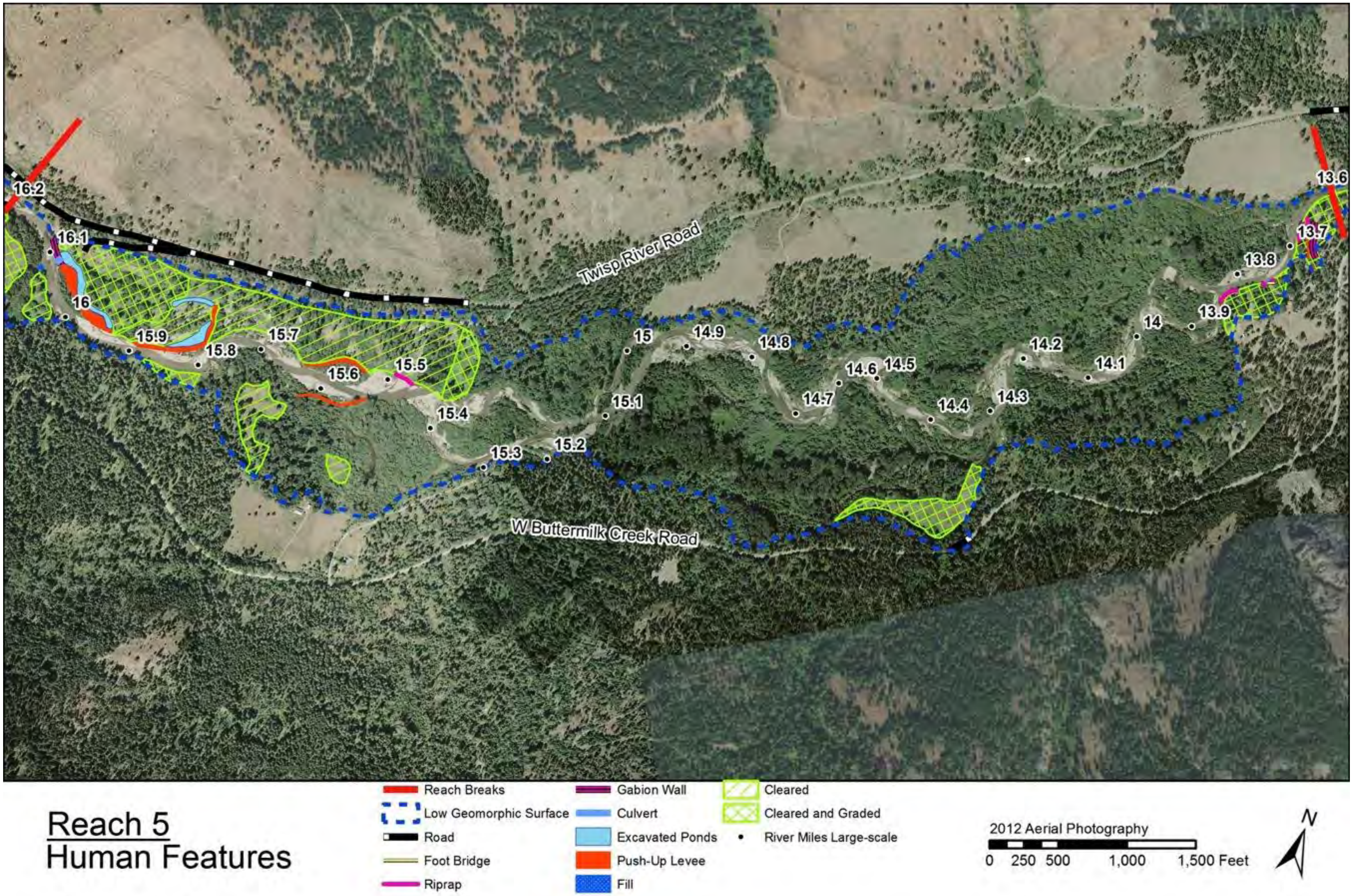

Figure 81. Human features in Reach 5.

3.6 REACH 6

3.6.1 Reach Overview

Reach 6 corresponds to Reach T6b from the Methow Subbasin Geomorphic Assessment (USBR 2008). Reach 6 is 1.93 miles long and extends from RM 16.19 to 18.12 (the upstream extent of this study; Figure 82). This reach is mostly unconfined but has a relatively steep gradient. There are different processes occurring throughout the reach; the upstream portion is fan dominated, the middle portion is naturally confined, and the lower portion of the reach is unconfined and dynamic. The fan dominated upper reach has overflow channels in the river-left floodplain. It is possible that there has been moderate disconnection of the floodplain in this portion of the reach due to the upstream bridge and floodplain fill effects. The bridge constricts the channel and the approach fills interrupt floodplain flows. The confined middle portion of the channel is a transport reach with some fallen conifers providing recruitment. The dynamic lower area has seen a recent avulsion (estimated following the 2012 floods) and is in an early successional channel state. In general, beneficial dynamic processes are occurring in this reach. This reach is predominately within the Okanogan National Forest with the exception of the downstream portion of the reach (Figure 83).

Figure 82. A representative section of Reach 6 at RM 17.6.

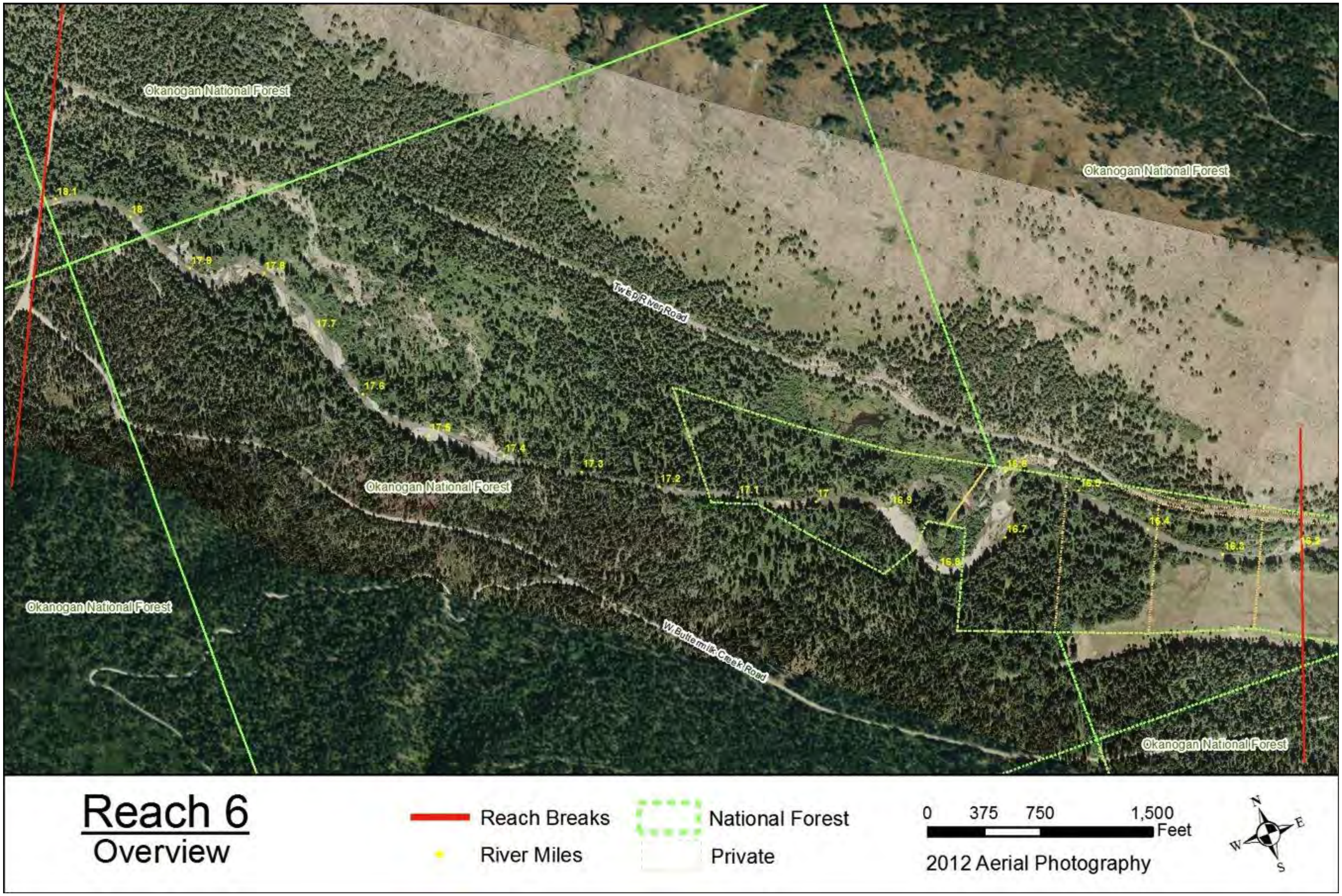

Figure 83: Overview map of Reach 6 showing landownership.

Table 15. Key descriptive and geomorphic metrics for Reach 6.

Metric	Value
Reach Length	1.93 miles
River Miles	16.19 to 18.12
Valley Gradient	1.08%
Stream Gradient	0.95%
Sinuosity	1.11
Dominant Channel Type	Pool-riffle
Avg Bankfull Width	72 ft
Avg floodplain Width	260 ft
Dominant Substrate	Cobble/ gravel

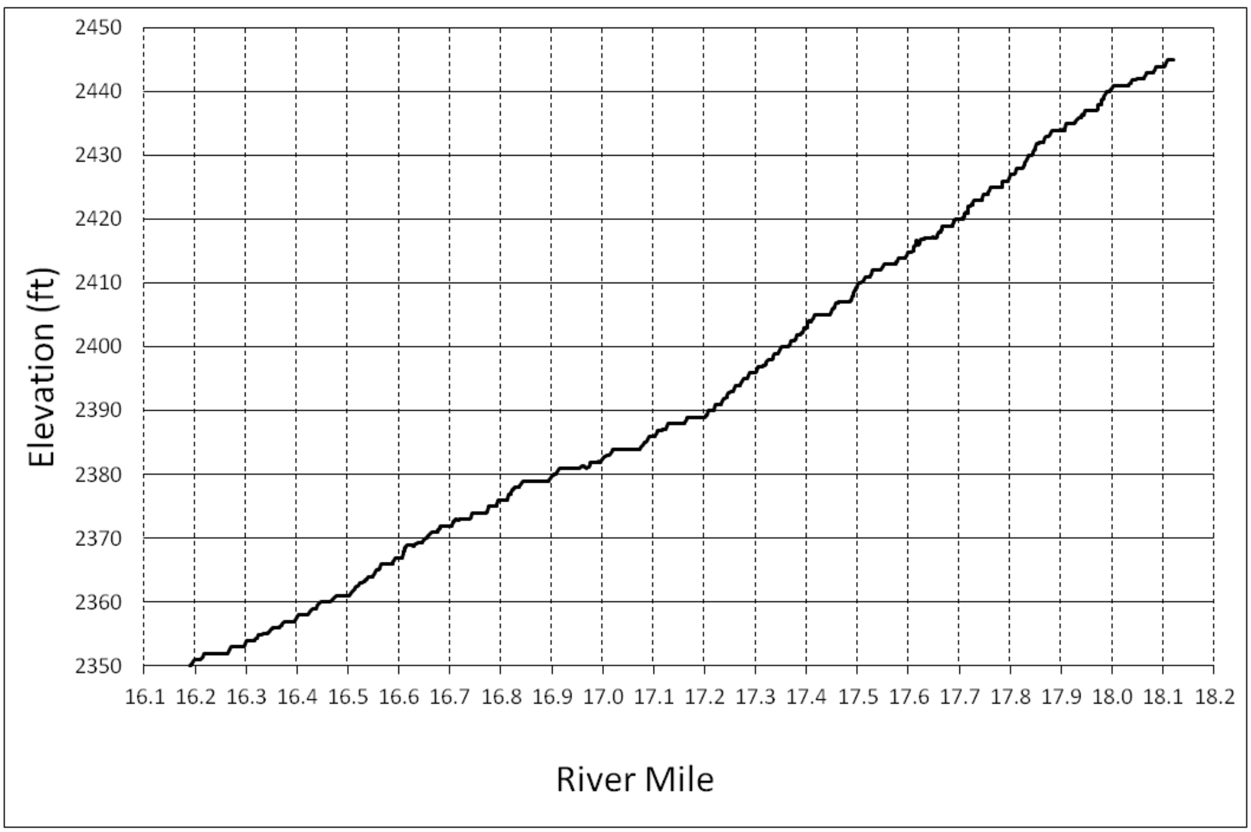

Figure 84. Longitudinal profile of Reach 6. Elevation data is derived from the 2006 LiDAR data and so represents water surface at the time of the LiDAR flight.

3.6.2 River Morphology and Geomorphic Processes

Geology and Landforms

Reach 6 is bounded on the river-right (south side of the study area) by the War Creek and Eagle Creek alluvial fans. Glacial, tributary fan, and alluvial terrace deposits form the north side of the valley. On river-left at the upstream end of the reach there is a broad floodplain that was occupied by the river as recently as the late 1980s. Reach 6 is high gradient in the middle, low gradient in the lower portion, and moderate gradient in the upper portion. Overall gradient is 0.95%. The reach has relatively low sinuosity (1.11). The channel units observed within this reach are primarily fast water units (69% riffles).

Hydrology

Two tributaries enter the mainstem in Reach 6, one of which was active under low flows and the other was ephemeral. The active tributary enters the mainstem along river-right at RM 17.11 (Eagle Creek). The steep, cobble-gravel channel had a step-pool planform and accounts for 15% of the flows observed in the mainstem directly downstream of this location. The second tributary was a large well-defined ephemeral tributary upstream on river-left at RM 17.22. It is primarily dry at low flows with some groundwater noted in the topographical depressions near the mouth. It appears to receive infrequent scouring flows and is composed of large cobble and small boulders with multiple pieces of large wood across the channel. War Creek enters the reach at the upstream end on river-right.

Floodplain and Channel Migration Zone

The channel is currently located adjacent to the alluvial fans on river right, with a large floodplain on river left for a majority of the reach. The river left floodplain pinches out with very little active floodplain development at the transition between Reach 5 and 6 (RM 16.2) where there are visible bedrock outcrops on the left bank channel margin. The maximum floodplain width is approximately 500 meters, making it one of the largest floodplains in the study area (Figure 87). Regular (i.e. Q1, Q2) floodplain inundation and scouring have created complex geomorphic features throughout the reach. Side-channels and backwater alcoves created through scour and fill alluviation provide high flow refugia throughout the reach (Figure 86).

Based on the results of the hydraulic analysis, portions of the entire valley floor are inundated during the 100-year flood and many of the off-channel habitat features are active at more frequent flows (i.e. Q2; Figure 87). In the upstream portion of the reach, the former mainstem once occupied what is currently the river-left floodplain (Figure 88). This channel is currently a high flow channel and is approximately 4 feet above the current elevation of the channel bed. There is evidence of scouring flows on this surface.

There is a wetland complex along valley-left at RM 16.6, which are old channel scars and were 3 to 4 feet deep at the time of the survey (Figure 86). The water surface elevation is controlled by beaver dams and natural earth berms. The outflow location does not appear to have low flow surface connectivity and there is an existing groundwater-fed outflow that is stopped approximately 80 feet from the mainstem by debris and floodplain deposits. This area is likely inaccessible to fish and lacks cover, but appears to be a properly functioning wetland.

There was a mainstem avulsion caused by a large log jam and upstream sediment accumulation, which forced a levee breach at RM 16.8. The new channel is now located to the north of the old channel. The new channel is still actively responding to this event, with new channel erosion resulting in large gravel bars and wood recruitment along the new meander. This area remains very dynamic and unstable.

The historical channel boundaries, shown in Figure 88, illustrate the dynamic nature of the channel and the previous channel avulsions that have taken place.

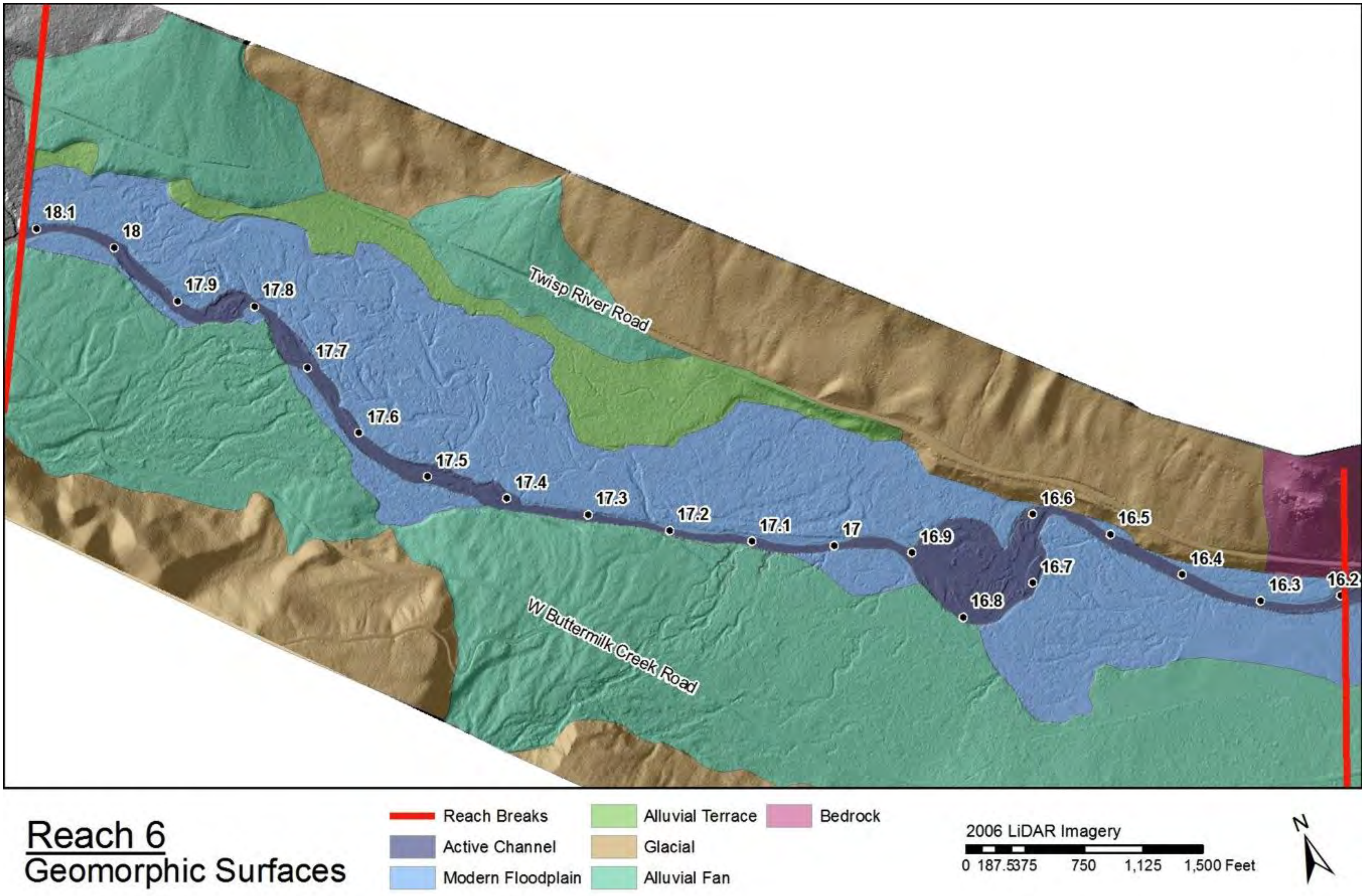

Figure 85. Geomorphic surfaces for Reach 6.

Figure 86. Wetland complex along river-left at RM 16.6.

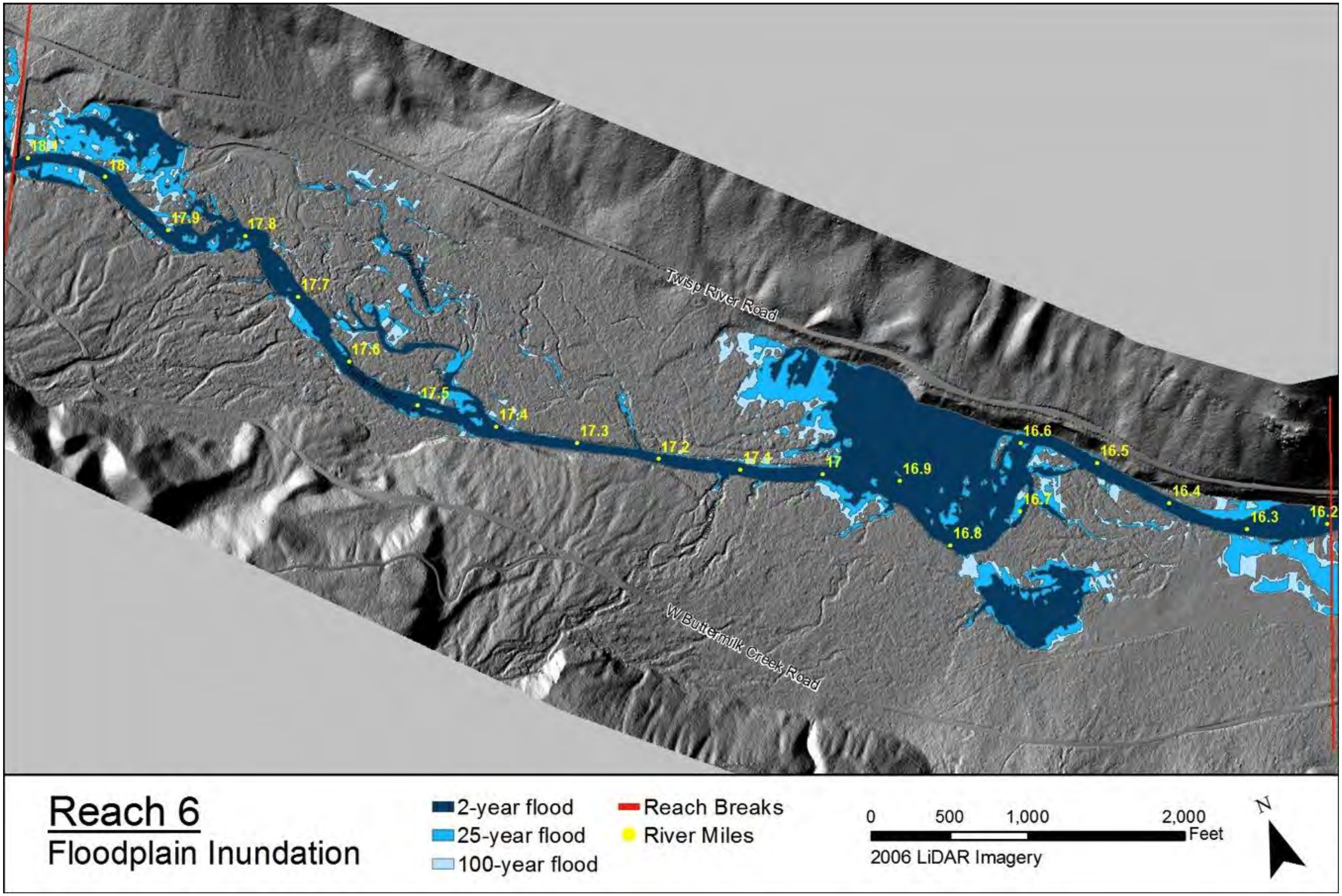

Figure 87. Floodplain inundation mapping for Reach 6.

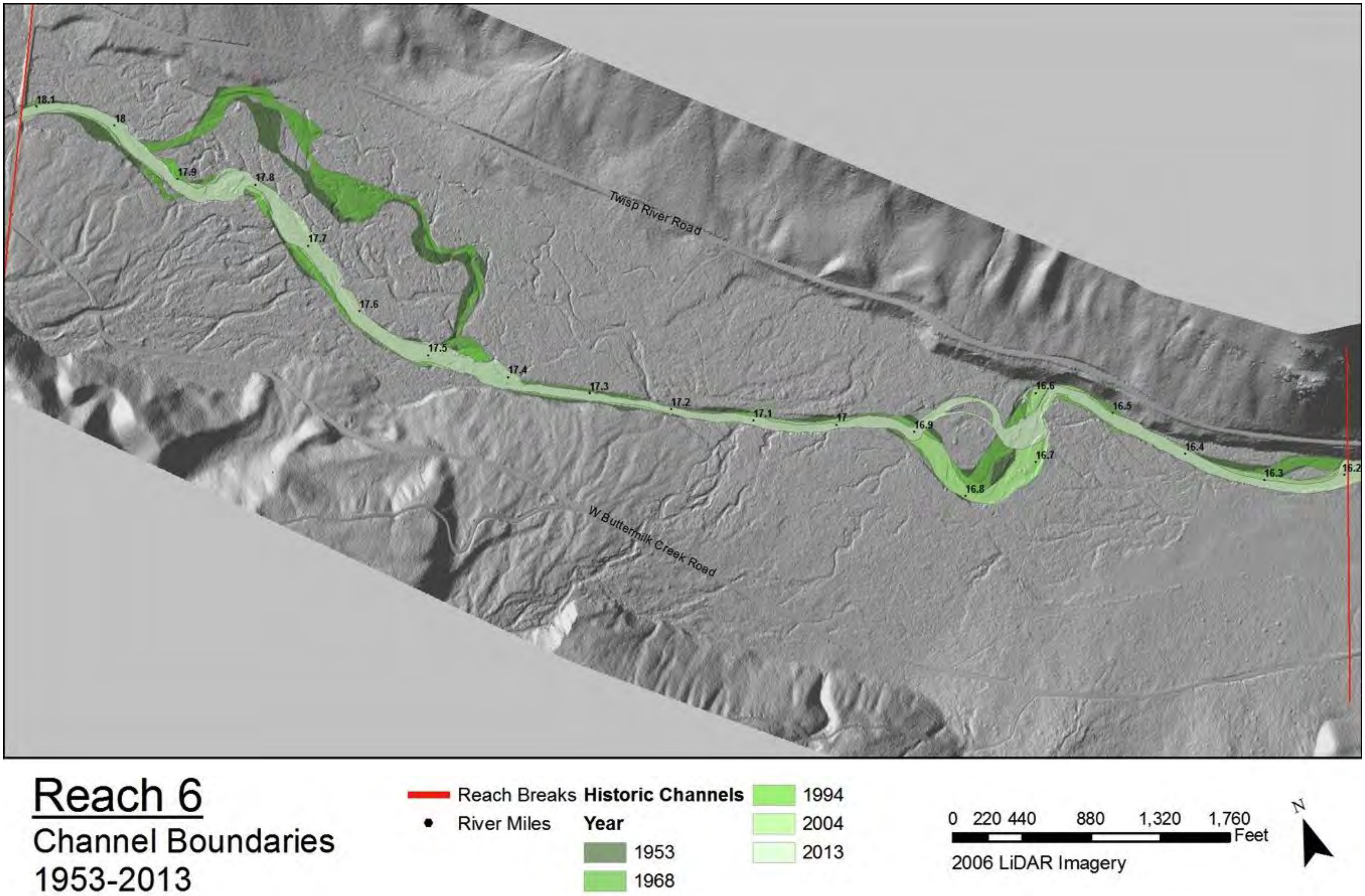

Figure 88. Historical channel boundaries for Reach 6.

Sediment

Bed substrate is dominated by cobble (55%), with gravel subdominant at 38%. Sources of sediment include War Creek and Eagle Creek, which periodically contribute debris flow deposits. Much of the material is derived from the modern floodplain surfaces along river-left, which are regularly eroded into through natural channel adjustment processes. During debris flows from river-right, these surfaces are rapidly eroded due to the influx of larger debris flow deposits from valley-right. Another source of sediment is the erosion into glacial deposits along river-left near RM 16.5. This erosion recruits large boulders that add complexity to in-stream habitat. The mid-channel bars are primarily composed of gravel and sand with little established vegetation on the exposed surfaces, indicating frequent scour (Figure 89).

Figure 89. Looking upstream at RM 16.6, the highly dynamic nature of this portion of the reach is evidenced by the exposed gravels and high flow channels.

Large Wood

Reach 6 had significantly more large wood than most of the other reaches, with the second highest count of large wood in the study area (169 pieces distributed at 88 pieces/mile) and the second highest log jam count (three log jams totaling 30 logs; Habitat Assessment, Appendix A). Although mature conifers along river-right offer a high potential for woody debris recruitment to the channel, the amount of wood is estimated to be much lower than what would be expected historically given the depositional nature and geomorphic complexity of this reach. Large wood would have played a major role, especially in the upstream and downstream ends of the reach in the less confined areas. The wood would have likely accumulated at the apexes of islands, throughout side channels, and on the outside of meander bends. The difference between the observed, present-day conditions and the historical conditions is likely due to the removal of large wood that took place during the 1970s. The amount of wood available for recruitment in the immediate future is also lower than historical conditions. This is a result of floodplain and riparian forests that are in early or mid-successional stages.

Figure 90. RM 17.25 looking upstream. Channel spanning woody debris and highly vegetated banks that have the potential for future recruitment.

Vegetation

The riparian corridor consists of relatively young vegetation, with 63% small trees; 25% shrub/seedling; and 12% of the measured units being dominated by no vegetation. The canopy height map (Figure 91) shows the pattern of riparian and floodplain vegetation. There is a lack of vegetation at the upstream end on river-left, possibly related both to high flow scouring flows as well as clearing associated with the nearby campground. At the downstream end on river-right, there is a cleared pasture where riparian and floodplain vegetation is highly degraded. In other areas, such as in the middle portion of the reach, there are stands of trees in excess of 100 feet tall.

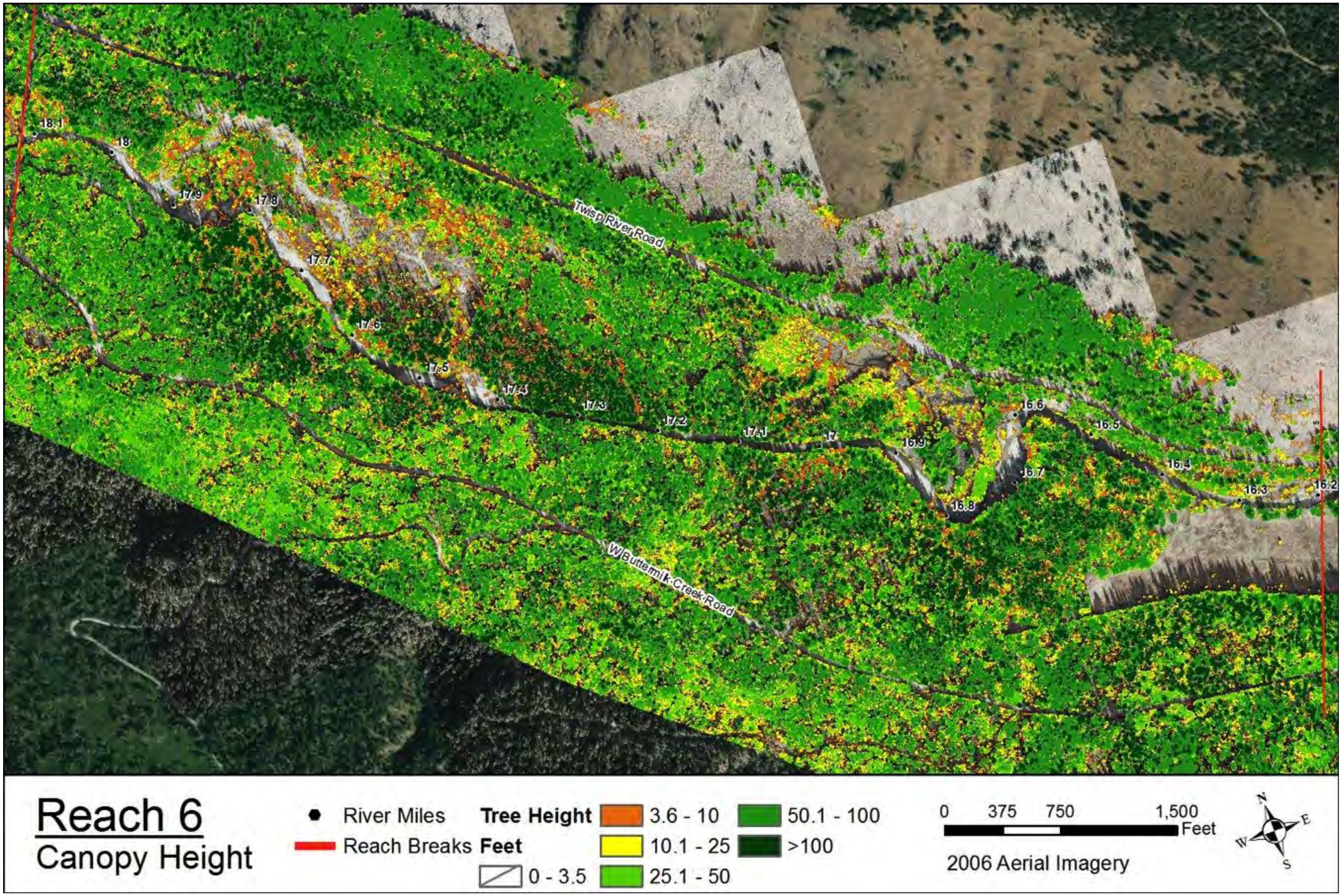

Figure 91. LiDAR first return (highest hit) data for Reach 6. These data show vegetation canopy heights. Buildings and other human infrastructure are also included in this data but there are only a few occurrences in this reach.

3.6.3 Human Alterations

Bridge Constriction at Upstream End

The bridge at the upstream end of the reach affects floodplain function and channel migration (Figure 92). The primary impact on floodplain function is the fill associated with the north approach, which bisects the floodplain. There is a single undersized culvert under the road fill, but the upstream intake was unidentifiable and did not appear to be conveying flows effectively. High flows are currently routed along the upstream edge of the fill back into the channel at the bridge. The bridge also restricts channel migration and prevents natural planform adjustment. In addition to altering flow and channel migration patterns, the bridge and associated roadway is acting as a fine sediment input along river-right, with evidence of scouring flows in this location.

Figure 92. Channel spanning bridge at RM 18.12, the upstream extent of this geomorphic study.

Floodplain Grading and Riparian Clearing

The primary area of impact from floodplain grading and clearing is at the downstream end of the reach on river-right where the land has been cleared and graded for agricultural uses. This area has a very narrow, or non-existent, riparian buffer. The bank is actively eroding and channel margin complexity is low.

In the upstream portion of the reach in the river-left floodplain (from approximately RM 17.8 to 18), there has been clearing and grading for a gravel roadway (Figure 94). There is riprap along the toe to prevent erosion. This does not have a significant impact on channel or floodplain processes as it is located at the outside edge of the 100-year floodplain. Near RM 16.8, there is the remnant of a push-up levee. The push-up levee was breached during the channel avulsion at this location.

Figure 93. The push-up levee on river left at RM 16.8 is composed of cobbles and sands.

Figure 94. Gravel road and clearing and grading along river left corresponding to RM 17.8 to 18.0

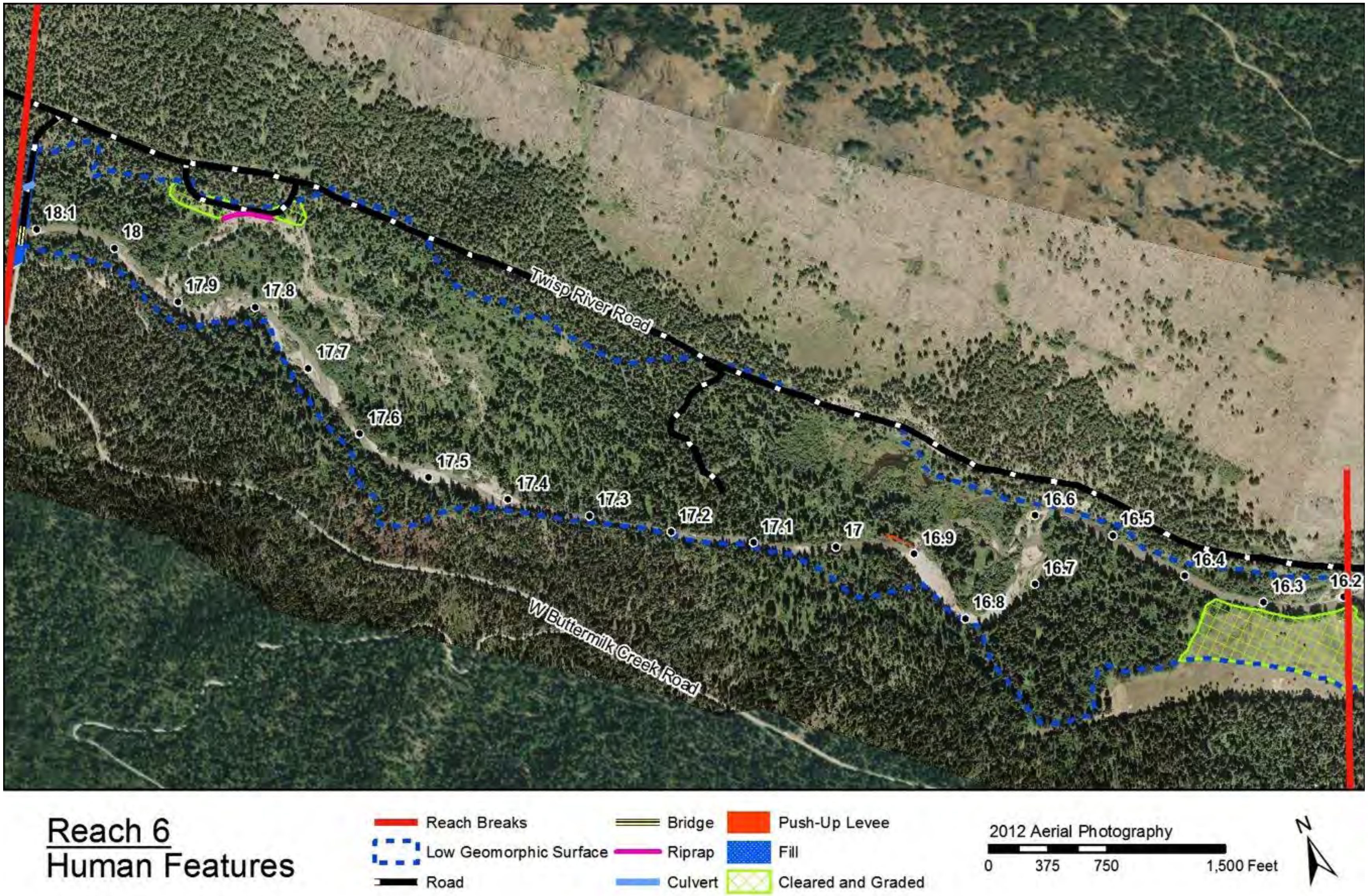

Figure 95. Human features in Reach 6

4 Restoration Strategy

4.1 INTRODUCTION

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

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

Project opportunities are linked to their respective action type(s) in the tables in Section 0 and are described in greater detail in Appendix C. The projects listed in Appendix C represent an initial step in identifying projects that fit the action types for each reach.

4.2 EXISTING AND TARGET HABITAT CONDITIONS

One of the primary tools for identifying action types and projects is a comparison of existing and target habitat conditions. This highlights habitat deficiencies and helps to develop restoration strategies. For each reach, existing and target habitat conditions are presented for a suite of habitat and geomorphic categories (Section 0 tables). Existing conditions were developed based directly on analyses and surveys performed as part of this Reach Assessment. Existing conditions information draws heavily from the habitat survey data (Appendix A) and also from the hydraulics and geomorphology assessments.

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

4.3 RESTORATION ACTION TYPES

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

4.3.1 Protection

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

Examples:

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

4.3.2 Riparian Restoration

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

Examples:

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

4.3.3 Habitat Reconnection via Infrastructure Modification

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

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

Examples:

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

4.3.4 Placement of Structural Habitat Elements

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

Examples:

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

4.3.5 Off-Channel Habitat Enhancement

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

Examples:

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

4.4 RESTORATION STRATEGY OVERVIEW

The restoration strategy for the study area includes a variety of approaches depending on existing limiting factors, the potential for biological and physical habitat improvements, and site-specific opportunities observed during field surveys. These strategies, and the technical basis for them, are presented in detail at the reach-scale in Section 0. Table 16 provides a snapshot of the restoration strategy at the study area scale. This table includes just the key summary points regarding existing conditions and restoration opportunities. This same information is repeated in map form in Appendix C.

Table 16. Overview of restoration strategy at the study area scale.

Reach	Overview of conditions	Overview of restoration strategy
Reach 1	Natural confinement Loss of the already limited floodplain function Significant riparian impacts Loss of streambank complexity	Limited Restoration Potential Newby to Bridge Project – Riparian restoration, limited off-channel enhancement, large wood to enhance streambank complexity
Reach 2	Natural confinement Loss of streambank complexity Significant riparian impacts	Limited Restoration Potential Newby to Bridge Project – Riparian restoration, large wood to enhance streambank complexity
Reach 3	Moderately confined to unconfined channel with good potential habitat Floodplain filling, grading, and channel constriction Reduced lateral channel dynamics via armoring Loss of instream habitat complexity Riparian impairment	High restoration potential Newby Narrows Project – enhance instream complexity, enhance off-channel rearing areas and connectivity, riparian restoration Horseshoe Side-Channel Project – remove bank armoring and levees to restore channel migration. Address incision impacts through enhancing connections with off-channels, enhance instream complexity, riparian restoration.
Reach 4	Natural moderate confinement Floodplain grading, levees, and bridges Loss of instream habitat complexity Significant riparian impairment	Moderate restoration potential Buttermilk Fan Project – levee removal, bank armoring modification, off-channel enhancement, instream complexity, riparian enhancement
Reach 5	Generally high quality conditions in downstream portion Floodplain Fill, Grading, Levees, and Bank Armoring in upstream portion Riparian impairment	High restoration and preservation potential Buttermilk Bends Project – Preservation plus whole tree placement for key pieces Scaffold Camp Project – levee removal, bank armoring removal, floodplain re-grading, off-channel enhancement, riparian enhancement
Reach 6	Natural moderate confinement Dynamic areas at upstream and downstream ends of reach Bridge constriction and associated floodplain impacts Floodplain grading Riparian clearing	Moderate restoration potential Scaffold Camp Project – only a small portion of this project is within this reach. Includes off-channel enhancement, streambank complexity, riparian planting. Eagle Project – whole tree placement, potential for enhancing connectivity to floodplain wetlands War Project – address impacts related to upstream bridge, instream complexity, potential off-channel enhancement.

REACH-SCALE STRATEGIES

4.4.1 Reach 1

There is limited restoration potential in Reach 1 due to natural confinement and the high degree of human infrastructure adjacent to the channel. Only one project, the "Newby to Bridge" project, is located within this reach; it also includes Reach 2. The main restoration focus is riparian restoration, including re-establishing the native riparian vegetation community in numerous locations throughout the reach. This will be challenging, as many of these locations are cleared areas maintained for rural residential or small-scale agricultural uses. In addition to riparian restoration, there is one location where there is an opportunity for creation and enhancement of off-channel habitat. This area is located along the river-left bank near RM 8.3. There may also be areas throughout the reach where channel margin habitat could be enhanced via the placement of large wood along the channel boundaries. However, these projects would likely be opportunistic (i.e. where there are willing landowners), small-scale, and isolated; and so may not provide sufficient habitat benefits given the cost and planning efforts required for implementation.

Reach 1 Restoration Strategy

Table 17. Reach 1 Restoration Strategy Table.

Reach 1 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Riparian condition	<50% species composition, seral stage, and structural complexity are consistent with potential native community. 25% small tree 75% grassland 0% medium-large trees 30% canopy cover Human disturbance is located within approximately 70% of the riparian zone. 43.1% of the 100 ft riparian buffer has been cleared. Disturbance includes a road and associated riprap at RM 8.1, clearing and grading on both sides of the channel for houses and lawns, and a push-up levee along river-right at the downstream portion of the reach.	At least a 100 ft riparian buffer with: > 80% mature trees, or consistent with potential native community < 20% riparian disturbance (human) > 80% canopy closure in the riparian zone. [REI]	Riparian restoration	Newby to Bridge Project
Floodplain Connectivity	Reach is naturally confined throughout most of its length. Where floodplains exist, there is reduced connectivity of the	Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions,	Off-channel habitat enhancement	Newby to Bridge Project

Reach 1 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
	floodplain to the main channel. Roadways and push-up levees have a moderate impact on floodplain inundation rates in a few locations. 3.45 mi/mi^2 of road in the floodplain.	riparian vegetation and succession. Minimal human disturbance of the floodplain <2mi/mi^2 road density in the floodplain [adapted from REI]		
Bank condition / Channel migration	Many of the streambanks in the reach are affected by bank armoring, mostly riprap along the road embankment or used to protect residential property. However, the reach is naturally laterally constricted by terraces and hillslopes on both sides of the channel throughout much of the reach.	Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion. [adapted from REI]	Placement of structural habitat elements	Newby to Bridge Project
Vertical channel stability	Floodplain alterations and channelization have likely resulted in some degree of vertical incision. Incision is likely limited by coarse substrate, including lag from glacial and tributary fan sources.	No measurable trend of human-induced aggradation or incision [adapted from REI]	No actions identified	
Pools	Pools have inadequate cover and there are few large pools (> 3 ft deep) in the reach. Pools per mile = 3.7 12% pool habitat	~4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Many large pools >3 ft deep with good fish	Placement of structural habitat elements	Newby to Bridge Project

Reach 1 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
	1 pool > 3 ft deep	cover. [REI]		
Large wood and logjams	12 M-L pieces / mi 0 jams /mi	> 42.5 pieces/mi (>12 diam; > 35 ft long) [from Fox 2001] ≥ 3 logjams/mi [based on conditions in Reach 5]	Placement of structural habitat elements	Newby to Bridge Project
Off-Channel Habitat	2% side-channel habitat. The only side channel observed in this reach is a fast moving 348' channel located at the beginning of the reach with little cover offered. The natural extent of potential off-channel habitat is constrained by the effects of the roadway and residential development on lateral channel migration and floodplain connectivity, which are necessary for long-term creation and maintenance of adequate off-channel habitat. A lack of logjams also limits off-channel development.	Reach has ponds, oxbows, backwaters, side-channels, and other off-channel areas with cover that are consistent with natural conditions. No manmade barriers are present that prevent access to off-channel areas. [adapted from REI]	Off-channel habitat enhancement	Newby to Bridge Project

4.4.2 Reach 2

The restoration strategy in Reach 2 is similar to Reach 1; however, Reach 2 has even greater natural confinement and very limited opportunity for meaningful restoration. The only project identified for Reach 2 is the "Newby to Bridge" project, which also encompasses Reach 1. Riparian restoration is the primary strategy, but this will be challenging due to private rural residential uses. The Twisp River Road also has a significant impact on riparian vegetation along much of the river-left side of the reach. Addressing riparian impairments associated with the roadway will also be challenging. As with Reach 1, there may be some limited opportunity for enhancing channel margin habitat using large wood placements, but these projects would be isolated, opportunistic, and may provide questionable fish benefits given the level of coordination that could be required.

Reach 2 Restoration Strategy

Table 18. Reach 2 Restoration Strategy Table.

Reach 2 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Riparian condition	<50% species composition, seral stage, and structural complexity are consistent with potential native community. 100% small tree 40% canopy cover Human disturbance is located within approximately 60% of the riparian zone. 11.6% of the 100 ft riparian buffer has been cleared. Disturbance includes roads and associated riprap, lawns, and houses.	At least a 100 ft riparian buffer with: > 80% mature trees, or consistent with potential native community < 20% riparian disturbance (human) > 80% canopy closure in the riparian zone. [REI]	Riparian restoration	Newby to Bridge Project
Floodplain Connectivity	The channel is naturally confined by glacial terraces and alluvial fan deposits. The modeled flows (2-100 year event) were confined to the main channel and no floodplain or side channels were observed in this reach, which is additionally constrained by the road and residential alterations.	Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession. Minimal human disturbance of the floodplain [adapted from REI] $<2 mi/mi^2$ road density in the floodplain	No actions identified	

Reach 2 Attribute	**Existing Condition (from assessment)**	**Target Condition [source]**	**Action Type**	**Potential Projects**
	0 mi/mi^2 of road in the floodplain.			
Bank condition / Channel migration	Much of the river-left channel margin is affected by road embankments comprised of fill and riprap. There are also houses with access roads along the river and vegetation impacts up to the top of bank.	Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion. [adapted from REI]	Placement of structural habitat elements	Newby to Bridge Project
Vertical channel stability	Channel substrate is primarily cobble/gravel/boulder. There is no clear evidence of channel incision. The large material may be helping to limit channel incision. Natural confinement limits the impacts of bank armoring on vertical stability.	No measurable trend of human-induced aggradation or incision [adapted from REI]	No actions identified	
Pools	Pools have inadequate cover and there are few large pools (> 3 ft deep) in the reach. Pools per mile = 1.54 1% pool habitat 0 pools > 3 ft deep	~4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Many large pools >3 ft deep with good fish cover. [REI]	Placement of structural habitat elements	Newby to Bridge Project
Large wood and logjams	11 M-L pieces / mi 0 jams /mi	> 42.5 pieces/mi (>12 diam; > 35 ft long) [from Fox 2001] ≥ 3 logjams/mi [based on conditions in Reach 5]	Placement of structural habitat elements	Newby to Bridge Project
Off-Channel	0% side-channel habitat.	Reach has ponds, oxbows, backwaters, side-channels,	No actions identified	

Reach 2 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Habitat	The naturally confined valley morphology limits the formation of side channels and other off-channel habitat. Much of the habitat complexity in this reach is created by large boulders and cobbles.	and other off-channel areas with cover that are consistent with natural conditions. No manmade barriers are present that prevent access to off-channel areas. [adapted from REI]		

4.4.3 Reach 3

Reach 3 has some of the best restoration potential in the study area. This is due to a combination of factors, including the natural geomorphic character, the degree of human impacts (and resulting limiting factors), and site specific opportunities. In contrast to the downstream reaches (Reaches 1 and 2), Reach 3 is less confined, meandering, and dynamic, with the potential to provide high quality in-channel and off-channel spawning and rearing habitat. However, human influence has had significant impact on the reach in some areas, including bank armoring, levees, riparian clearing, and channel simplification. These impacts have reduced habitat quantity and quality, and in some cases, limit the ability of the system to effectively create and maintain high quality habitat into the future. Impaired processes and habitat, however, are generally recoverable due to land use patterns and site specific opportunities. There are two projects that were identified in Reach 3, the "Newby Narrows" project and the "Horseshoe Side-Channel" project. The Newby Narrows project is located near the downstream end of the reach. The primary element of the Newby Narrows project would create and enhance off-channel rearing habitat within a disconnected floodplain channel scar network on river-right. There is also opportunity to enhance off-channel habitat on river-left and to enhance mainstem habitat complexity through large wood and log jam placements. The other project in Reach 3 is the Horseshoe Side-Channel project, which is located at the upstream end of the reach. This project offers one of the best potential restoration opportunities in the study area. It has also been investigated previously as a potential project area by the US Bureau of Reclamation (USBR 2006), and the project opportunities discussed in this Reach Assessment build off of those prior investigations and concepts. The site consists of an extensive floodplain wetland and abandoned oxbow complex on river-left. The main channel in this area has experienced incision due to downstream channel confinement and floodplain fill. These impacts have reduced the hydrologic and fish passage connectivity between the main channel and floodplain. There are numerous opportunities within this project area to enhance connectivity to existing floodplain wetlands, increase the quantity of off-channel areas, promote channel migration, increase floodplain inundation rates, and increase mainstem channel complexity.

Reach 3 Restoration Strategy

Table 19. Reach 3 Restoration Strategy Table.

Reach 3 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Riparian condition	50-80% species composition, seral stage, and structural complexity are consistent with potential native community. 29% small tree 29% grassland/forb 14% shrub/seedling 14% sapling/pole 14% medium-large trees 50% canopy cover Human disturbance is located within approximately 50% of the riparian zone. 12.9% of the 100 ft riparian buffer has been cleared. Disturbance includes roads and associated riprap, lawns, and houses.	At least a 100 ft riparian buffer with: > 80% mature trees, or consistent with potential native community < 20% riparian disturbance (human) > 80% canopy closure in the riparian zone. [REI]	Riparian restoration	Newby Narrows Project Horseshoe Side-Channel Project
Floodplain Connectivity	Reduced floodplain connectivity due to roads, bank armoring, and push-up levees. There has also been fill and grading in the floodplain, particularly in the upstream portion of the reach.	Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession. Minimal human disturbance of the floodplain [adapted from REI]	Habitat reconnection via infrastructure modification Off-channel habitat enhancement Placement of structural habitat elements	Newby Narrows Project Horseshoe Side-Channel Project

Reach 3 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
	1.80 mi/mi^2 of road in the floodplain	<2mi/mi^2 road density in the floodplain		
Bank condition / Channel migration	Portions of the reach are affected by bank armoring, which impairs streambank complexity and reduces natural rates of channel migration. Push-up levees and riprap are present intermittently along river-left. Clearing and grading for residential and recreational uses has taken place in the active floodplain.	Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion. [adapted from REI]	Habitat reconnection via infrastructure modification Placement of structural habitat elements	Newby Narrows Project Horseshoe Side-Channel Project
Vertical channel stability	There are signs of vertical instability based on abandoned floodplain surfaces. Channelization and floodplain filling and grading appear to have caused incision in several locations, especially in the Horseshoe Side-Channel project area. Limited presence of gravel bars, even in very unconfined portions of the channel, suggest a general trend of incision.	No measurable trend of human-induced aggradation or incision [adapted from REI]	Habitat reconnection via infrastructure modification Placement of structural habitat elements	Newby Narrows Project Horseshoe Side-Channel Project
Pools	Pools have inadequate cover and there are few large pools (> 3 ft deep) in the reach. Pools per mile = 4.5 14% pool habitat	~4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Many large pools >3 ft deep with good fish cover.	Placement of structural habitat elements	Newby Narrows Project Horseshoe Side-Channel Project

Reach 3 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
	3 pools > 3 ft deep	[REI]		
Large wood and logjams	18 M-L pieces / mi 0.82 jams /mi	> 42.5 pieces/mi (>12 diam; > 35 ft long) [from Fox 2001] ≥ 3 logjams/mi [based on conditions in Reach 5]	Placement of structural habitat elements	Newby Narrows Project Horseshoe Side-Channel Project
Off-Channel Habitat	2% side-channel habitat. Three side channels with minimal amounts of woody debris. There is extensive off-channel wetland habitat in the Horseshoe Side-Channel Project area but most of it is not connected to the mainstem except at very high flows.	Reach has ponds, oxbows, backwaters, side-channels, and other off-channel areas with cover that are consistent with natural conditions. No manmade barriers are present that prevent access to off-channel areas. [adapted from REI]	Habitat reconnection via infrastructure modification Off-channel habitat enhancement	Newby Narrows Project Horseshoe Side-Channel Project

4.4.4 Reach 4

Reach 4 has moderate restoration potential. Most of the reach is moderately confined by tributary fans and these constraints limit the future habitat potential to some degree. Channels are more naturally plane-bed and simplified, so their ability to provide abundant salmonid spawning and rearing habitats are naturally limited. There are, however, areas where human impacts have resulted in habitat and process impairments and where meaningful restoration work could nevertheless improve conditions. These areas tend to be spread out across the entire reach and span multiple property owners and impairment types. Restoration therefore risks being somewhat piecemeal and opportunistic. The reach is entirely encompassed by the "Buttermilk Fan" project, which also extends upstream into the downstream portion of Reach 5. This project includes multiple potential elements, including removing push-up levees, removing/modifying bank armoring, creating/enhancing off-channel habitat, riparian restoration, and instream complexity using large wood. One of the primary elements of this project is addressing floodplain disconnection caused by the long push-up levee in the middle of the reach along river-left. Although intermittent, this levee, and other impacts, have likely contributed to stream channel incision that has further affected floodplain connectivity and the ability of the channel to freely migrate and create off-channel habitats over time. Removing the levee, performing selective off-channel excavation, riparian restoration, and targeted log jam placement could help to reconnect the floodplain and off-channel habitats. Overall, infrastructure (e.g. bridges) and land-use constraints (e.g. agricultural uses) will affect what can reasonably be accomplished in this reach.

Reach 4 Restoration Strategy

Table 20. Reach 4 Restoration Strategy Table.

Reach 4 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Riparian condition	50-80% species composition, seral stage, and structural complexity are consistent with potential native community. 60% small tree 20% grassland/forb 20% no vegetation 20% canopy cover Human disturbance is located within approximately 80% of the riparian zone. 54.1% of the 100 ft riparian buffer has been cleared. Disturbance includes roads and associated riprap, lawns, and houses.	At least a 100 ft riparian buffer with: > 80% mature trees, or consistent with potential native community < 20% riparian disturbance (human) > 80% canopy closure in the riparian zone. [REI]	Riparian restoration	Buttermilk Fan Project
Floodplain Connectivity	Floodplain connectivity is reduced by the two bridge crossings and associated fill on the approaches. There are also intermittent push-up levees and moderate amounts of past floodplain filling and grading. 2.88 mi/mi^2 of road in the	Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession. Minimal human disturbance of the floodplain [adapted from REI] <2mi/mi^2 road density in the floodplain	Habitat reconnection via infrastructure modification Off-channel habitat enhancement Placement of structural habitat elements	Buttermilk Fan Project

Reach 4 Attribute	**Existing Condition (from assessment)**	**Target Condition [source]**	**Action Type**	**Potential Projects**
	floodplain			
Bank condition / Channel migration	There is bank armoring associated with the two bridges but otherwise not extensive armoring. Floodplain grading and push-up levees have some impact on channel migration, as does the approach road fills at the two bridge crossings.	Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion. [adapted from REI]	Habitat reconnection via infrastructure modification Placement of structural habitat elements	Buttermilk Fan Project
Vertical channel stability	The two bridge crossings create constrictions that have likely resulted in channel incision. Push-up levees and floodplain fill and grading have likely contributed to downcutting. Flood scars on the now-abandoned surface on river-left (mid-reach) suggests channel incision.	No measurable trend of human-induced aggradation or incision [adapted from REI]	Habitat reconnection via infrastructure modification	Buttermilk Fan Project
Pools	Pools have inadequate cover and there are few large pools (> 3 ft deep) in the reach. Pools per mile = 4.3 14% pool habitat 2 pools > 3 ft deep	~4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Many large pools >3 ft deep with good fish cover. [REI]	Placement of structural habitat elements	Buttermilk Fan Project
Large wood and logjams	9 M-L pieces / mi 1.45 jams /mi	> 42.5 pieces/mi (>12 diam; > 35 ft long) [from Fox 2001] ≥ 3 logjams/mi [based on conditions in Reach 5]	Placement of structural habitat elements	Buttermilk Fan Project
Off-Channel	2% side-channel habitat.	Reach has ponds, oxbows,	Off-channel habitat	Buttermilk Fan Project

Reach 4 Attribute	**Existing Condition (from assessment)**	**Target Condition [source]**	**Action Type**	**Potential Projects**
Habitat	Four side channels with little woody debris were identified. Log jams within two of the side channels and one small off-channel wetland also contribute to off-channel habitat complexity.	backwaters, side-channels, and other off-channel areas with cover that are consistent with natural conditions. No manmade barriers are present that prevent access to off-channel areas. [adapted from REI]	enhancement Habitat reconnection via infrastructure modification	

4.4.5 Reach 5

The restoration strategy for Reach 5 has two primary components depending on location. These two components are represented by the upstream “Scaffold Camp” project and the downstream “Buttermilk Bends” project. The Buttermilk Bends project encompasses most of the reach. This project area is the most intact (i.e. least human impact) of the entire study area and the strategy here is primarily focused on preservation as opposed to restoration. However, there may be some limited restoration work that could provide some important benefits and would support the existing intact processes. In this segment, the floodplain and channel migration zone is wide, unconfined, and actively migrating. There is wood recruitment and regular planform adjustment, which creates new habitats on a 1-2 year basis. Although this active dynamism is beneficial, and reflects a lack of artificial constraints on the channel, there may be concerns with dramatic planform adjustments that occur on a very frequent timescale, more frequent than would be expected prior to removal of the historical large structure provided by large wood jams (with large key pieces) and riparian forests with large trees. Remnant large cottonwood stands, and some large conifer stands, give evidence of past conditions. As a result of the lack of large structure in the contemporary channel and floodplain, lateral (planform) and vertical (profile) adjustments occur regularly and may pose risks to salmonids in the form of redd scour. The potential treatment approach that has therefore been identified is the placement of large whole trees in the channel at numerous locations. To limit disturbance to existing vegetation, these trees would ideally be placed by helicopter or by machines via carefully placed access points. Whole trees would provide the large structure that is missing from this area and would serve as key pieces to create and maintain naturally-formed log jams over time.

In contrast to the Buttermilk Bends project, the Scaffold Camp project, which is located near the upstream end of the reach, has significant human-related impairments that provide some of the greatest restoration opportunity in the study area. The primary impairments are related to a levee and floodplain pond complex on river-left. These features restrict lateral channel migration, affect floodplain inundation rates and patterns, and affect riparian and floodplain forest succession. The origin of these features is unknown, but they do not appear to be protecting any significant built infrastructure and aerial photo analysis suggests that must of this floodplain area could be reconnected. The specifics of the approach will require further investigation, but the general strategy would include removal of levees, removal of bank armoring, re-grading of ponds to create off-channel and side-channel habitat, large wood placement, and the restoration of riparian and floodplain forest vegetation. This project also extends upstream into Reach 6, where there is additional opportunity to enhance off-channel connectivity, instream complexity, and riparian conditions.

Reach 5 Restoration Strategy

Table 21. Reach 5 Restoration Strategy Table.

Reach 5 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Riparian condition	50-80% species composition, seral stage, and structural complexity are consistent with potential native community. 21% small tree 43% shrub/seedling 29% sapling/pole 7% no vegetation 70% canopy cover Human disturbance is located within approximately 30% of the riparian zone. 6.4% of the 100 ft riparian buffer has been cleared. Disturbance includes roads and associated riprap, lawns, and houses.	At least a 100 ft riparian buffer with: > 80% mature trees, or consistent with potential native community < 20% riparian disturbance (human) > 80% canopy closure in the riparian zone. [REI]	Riparian restoration	Scaffold Camp Project
Floodplain Connectivity	Floodplain connectivity is high in the downstream half of the reach but is affected by levees, fill, and excavated ponds on river-left in the upstream half. These features reduce the extent, frequency, and patterns of floodplain inundation.	Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession. Minimal human disturbance of the floodplain [adapted from REI] <2mi/mi^2 road density in the	Habitat reconnection via infrastructure modification Off-channel habitat enhancement Placement of structural habitat elements	Scaffold Camp Project

Reach 5 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
	1.33 mi/mi^2 of road in the floodplain	floodplain		
Bank condition / Channel migration	There are a few areas of riprap protecting houses and private property. These occur at the upstream end on river-left and at the downstream end on river-right. Bank migration is impaired at these locations. Much of the remainder of the reach is migrating near (or slightly above) natural rates.	Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion. [adapted from REI]	Habitat reconnection via infrastructure modification Placement of structural habitat elements	Scaffold Camp Project
Vertical channel stability	Due to its low gradient and wide floodprone width, this reach provides relatively high sediment storage capacity. It is highly dynamic, likely more than historical conditions due to loss of large trees in riparian areas and in log jams.	No measurable trend of human-induced aggradation or incision [adapted from REI]	Placement of structural habitat elements	Scaffold Camp Project Buttermilk Bends Project
Pools	Pools have good cover with only a minor reduction in pool volume from fine sediment and there are many large pools (> 3 ft deep) in the reach. Pools per mile = 13.2 23% pool habitat 14 pools > 3 ft deep	~4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Many large pools >3 ft deep with good fish cover. [REI]	Placement of structural habitat elements Habitat reconnection via infrastructure modification	Scaffold Camp Project Buttermilk Bends Project

Reach 5 Attribute	**Existing Condition (from assessment)**	**Target Condition [source]**	**Action Type**	**Potential Projects**
Large wood and logjams	54 M-L pieces / mi 3.86 jams /mi	> 42.5 pieces/mi (>12 diam; > 35 ft long) [from Fox 2001] ≥ 3 logjams/mi [based on conditions in Reach 5]	Placement of structural habitat elements	Scaffold Camp Project Buttermilk Bends Project
Off-Channel Habitat	18% side-channel habitat. Nineteen side channels were identified, one almost a mile long and with moderate amounts of LWM that met the standards. Four off-channel wetlands were also identified, comprising roughly 12,000 square feet and including numerous beaver dams and log jams.	Reach has ponds, oxbows, backwaters, side-channels, and other off-channel areas with cover that are consistent with natural conditions. No manmade barriers are present that prevent access to off-channel areas. [adapted from REI]	Off-channel habitat enhancement	Scaffold Camp Project

4.4.6 Reach 6

Reach 6 has moderate restoration potential that is focused in two primary locations. These include the upstream “War” project and the downstream “Eagle” project. The Eagle project area is a highly dynamic area where a recent stream channel avulsion has altered the planform pattern for approximately 1,000 feet. Due to the recent avulsion, this area is in an early successional geomorphic and riparian vegetation condition and adjustments will be expected to continue to occur in response to the avulsion. Under historical conditions, this type of channel change would be expected to recruit large trees that would serve as key pieces and form large stable jams. However, under current conditions, the large wood recruited during the avulsion is smaller and less stable, and therefore more mobile over time. The treatment strategy here is to place large whole trees at select locations that will provide the large structure that is missing and to serve as key pieces. There may also be the potential for enhancing connectivity to the existing floodplain wetland complex along the river-left valley wall toe.

The other restoration area in Reach 6 is the War project, which is located at the upstream end of the reach adjacent to the War Creek fan on valley-right. This project has multiple elements, including addressing floodplain disconnection caused by the upstream bridge (and associated approach fills), increasing instream channel complexity using large wood, and enhancing connectivity to the river-left floodplain area. This area, however, is dynamic, and there is evidence of scour across the left bank floodplain that may provide some uncertainty with the potential effectiveness of off-channel work in this area. These conditions warrant further investigation.

Reach 6 Restoration Strategy

Table 22. Reach 6 Restoration Strategy Table.

Reach 6 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Riparian condition	50-80% species composition, seral stage, and structural complexity are consistent with potential native community. 63% small tree 25% shrub/seedling 12% no vegetation 50% canopy cover Human disturbance is located within approximately 40% of the riparian zone. 4.2% of the 100 ft riparian buffer has been cleared. Disturbance includes roads and associated riprap, lawns, and houses.	At least a 100 ft riparian buffer with: > 80% mature trees, or consistent with potential native community < 20% riparian disturbance (human) > 80% canopy closure in the riparian zone. [REI]	Riparian restoration	War Project Eagle Project
Floodplain Connectivity	The bridge and approach fills at the upstream end impair floodplain inundation rates and patterns. On river-right at the downstream end, floodplain grading has impaired floodplain inundation patterns. Floodplains are relatively well-connected throughout the remainder of the reach.	Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession. Minimal human disturbance of the floodplain [adapted from REI] $<2 mi/mi^2$ road density in the floodplain	Habitat reconnection via infrastructure modification Off-channel habitat enhancement Placement of structural habitat elements	War Project Eagle Project

Reach 6 Attribute	**Existing Condition (from assessment)**	**Target Condition [source]**	**Action Type**	**Potential Projects**
	0.62 mi/mi^2 of road in the floodplain			
Bank condition / Channel migration	The bridge at the upstream end of the reach has some impact on bank migration, but overall, there are minimal impacts on bank stability and channel migration processes.	Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion. [adapted from REI]	No actions identified	
Vertical channel stability	There is vertical instability at the upstream bridge crossing, which creates a constriction that has resulted in channel incision. The remainder of the reach is near the natural range of vertical stability.	No measurable trend of human-induced aggradation or incision [adapted from REI]	No actions identified	
Pools	Pools either have inadequate cover or there are few large pools (> 3 ft deep) in the reach. Pools per mile = 7.7 15% pool habitat 2 pools > 3 ft deep	~4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Many large pools >3 ft deep with good fish cover. [REI]	Placement of structural habitat elements	War Project Eagle Project
Large wood and logjams	35.8 M-L pieces / mi 1.55 jams /mi	> 42.5 pieces/mi (>12 diam; > 35 ft long) [from Fox 2001] ≥ 3 logjams/mi [based on conditions in Reach 5]	Placement of structural habitat elements	War Project Eagle Project
Off-Channel Habitat	1% side-channel habitat. Two slow-moving side-	Reach has ponds, oxbows, backwaters, side-channels, and	Off-channel habitat enhancement	War Project Eagle Project

Reach 6 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
	channels with minimal LWM were identified in this reach.	other off-channel areas with cover that are consistent with natural conditions. No manmade barriers are present that prevent access to off-channel areas. [adapted from REI]		

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Appendix A

Stream Habitat Assessment

Middle Twisp River (RM 7.8 – 18.12)

Survey: October 2013

Contents

1 Introduction & Background

The Twisp River is located on the east slopes of the Cascade Mountains in Okanogan County, Washington. It flows into the Methow River near the town of Twisp, Washington. A study of the Middle Twisp River was conducted on October 22 – October 29, 2013 from RM 7.8 – RM 18.12. The study follows a 2009 Stream Habitat Assessment of the Lower Twisp River (Inter-Fluve 2010). Stream flow was measured on October 29, 2013 at the beginning and end point of study area. Stream flow measured 96 cfs at RM 7.8 (beginning of study area) and measured 62 cfs at RM 17.85. According to the USGS gauging station located at RM 1.6 of the Twisp River, near Twisp, WA (gage number 12448998), stream flow during the time of the survey measured from 96 – 127 cubic feet per second (cfs)

The objective of the Habitat Assessment is to characterize the habitat quantity and quality for salmonid species native to the Twisp River and the Upper Columbia River basin by quantifying in-channel morphologic features and qualitatively describing riparian conditions that influence aquatic habitat. This information is used to inform potential restoration/preservation actions, and will provide a baseline for evaluating future habitat trends and for measuring the effectiveness of restoration efforts. To our knowledge, this is the first comprehensive stream habitat assessment on this section of the Twisp River since a 2001 Stream Survey Report was conducted by the Methow Valley Ranger District of the Okanogan-Wenatchee National Forest and the Pacific Watershed Institute (PWI).

Spring Chinook and steelhead utilize the Twisp River from RM 0 – 15 for migration, spawning, and juvenile rearing. Bull trout also present in the Twisp River, utilizing it for foraging, migration, and over-wintering. Most of the spring Chinook and all of the bull spawning occurs between RM 12 – 27 (USBR, 2008).

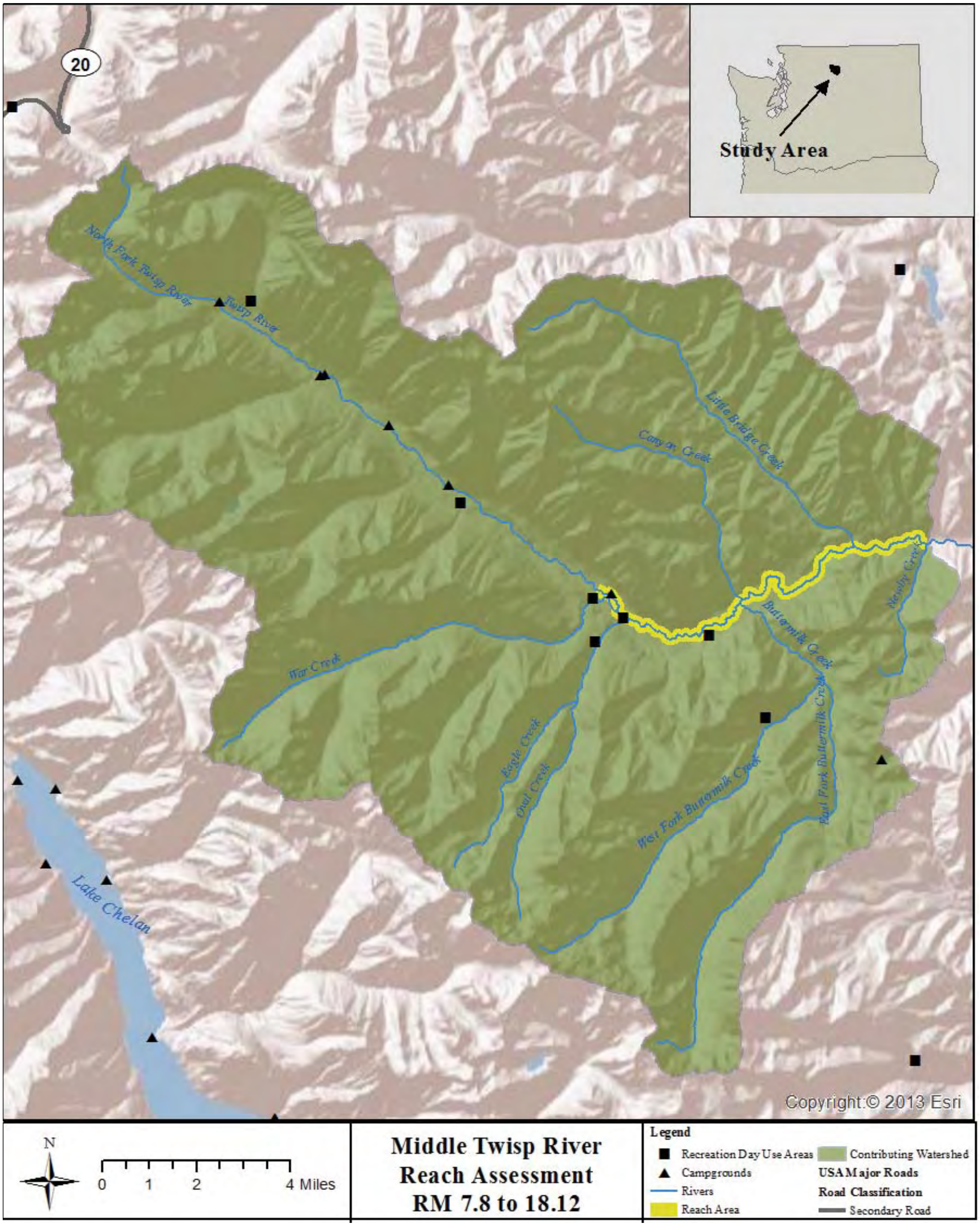


Figure 1. Overview of Middle Twisp study area from RM 7.8 to 18.12.

2 Methods

Six geomorphic reaches were delineated in this stream assessment. The same reach delineations were used for both the stream assessment and the geomorphology assessment to maintain consistency.

Field methods for the habitat survey used the USFS Region 6 Level I & II Stream Inventory Handbook, Version 2.12 (USDA Forest Service 2012). All protocols and most forest options were observed during the survey due to favorable wading depths and conditions. Flow rates were slightly above average, ranging from 96 – 127 cfs (median averages for these dates range from 52 – 68 cfs) according to USGS Twisp River gauge 12448998.

All reach-scale metrics were calculated using GIS measurements as opposed to reach lengths measured in the field by tape. We chose GIS measurements because GIS provides a more accurate measurement at a reach scale.

The measured n^{th} unit measurement frequency was 20%, or 1 unit measured in every 5. This choice was made to ensure that enough n^{th} unit measurements would be made. At nth units, ocular wet width measurements were estimated by the observer and then measured by the recorder with a 100′ tape. The average difference between the actual measured width and ocular values was 0.3 feet. Floodprone widths were only measured in the field when accurate measurements were possible. Others were measured in the office using LIDAR images.

Two pebble counts were performed in each of the six reaches. To maintain consistency, the first pebble count of each reach was performed around the first 25% of the entire length of the reach; the second pebble count was performed at approximately 75% of the entire length the reach. For example, if a reach was one mile long, we tried to perform a pebble count at 0.25 miles and 0.75 miles. A gravelometer was used to measure pebble counts. When more than one person was taking measurements, a survey rod was used to measure pebble size. In addition to pebble count, visual (ocular) measurements of bed sediment (considered a “forest option” in the USFS protocol), were recorded at every n^{th} unit.

Depths of pools, riffles and glides were measured using a 9-foot graduated survey rod carried by the observer. Where water velocity or depth appeared unsafe, the observer either estimated depths or measured outside the thalweg.

Off-channel marshland was measured and recorded when connected to the main river. At times, marshland and side channel backwaters were challenging to differentiate. In these instances, vegetation was used as the primary indicator.

Side channels units were identified when the main channel split to form a stable island with soil or fine sediment deposits and vegetation older than 2 to 3 years old. Each side channel was determined to be fast or slow, and its average width and length measured. Length was recorded as wetted length, with a second column measuring total length (including dry channel length). Where side channels were either too long (one side channel measured just short of 1 mile), or too thick with downed wood, GIS was used to measure side channel length. LWD was counted for each side channel.

Floodprone width (FPW) is defined as the width of the floodplain at twice the max bankfull depth. Survey crews measured floodprone width in the field where it was possible to achieve accurate measurements. Where the floodplain was excessively wide, FPW was calculated in the office using LIDAR combined with n^{th} unit measurements.

Reach 5 and some of Reach 6 are highly complex, low gradient, sinuous reaches. Within these reaches, several channel units were designated as “braided” when there was a series of three or more roughly parallel channels structured during bankfull flow and separated from each other by unstable islands. In these units, channel width was recorded as the *average* wetted channel widths for each of the multiple channels with flowing water. This is a deviation from the handbook, which suggests using the *sum* of the wetted channel widths. Due to the highly complex nature of these reaches, it is likely that several more of the channel units could be designated as braided.

LWD was counted using the USFS Stream Inventory Guidebook guidelines. In the case of log jams, only wood that conformed to Guidebook guidelines was counted.

3 Summary of Results

This section summarizes the results of the habitat assessment for all six reaches. Detailed reach summaries with reach-specific results are included in Appendix A.

3.1 CHANNEL MORPHOLOGY

Channel bed substrate consisted primarily of cobble, gravel, and boulder in reaches 1 and 2, and cobble and gravel in reaches 3 through 6. Bedrock and sand occurred infrequently.

Bankfull widths throughout the study area were not highly variable in reaches 1,2, 4, and 6 (Table 1). Reach 3 and 5 had moderately variable bankfull widths, ranging from 61 – 180 feet wide (Reach 3) and 48 – 200 feet wide (Reach 5). The average bankfull width throughout the study area was 87.3 feet (stdev 34.6). Average bankfull depths for each reach ranged from 2 – 5 feet (Table 2). The average bankfull depth throughout the entire study area was 3.2 (stdev 1.3). Floodprone widths varied considerably throughout the Middle Twisp River. Floodprone widths averages varied from 121 feet in Reach 4, to 393 feet in Reach 5, with an average standard deviation of 247. The floodprone width averaged 269 feet throughout the entire project area.

Table 1. Max, Min, and mean bankfull widths for reaches 1 – 6 in feet.

Bankfull Widths (feet)						
	Reach 1	**Reach 2**	**Reach 3**	**Reach 4**	**Reach 5**	**Reach 6**
Min	66	75	61	68	48	56
Max	91	107	180	90	200	90
Mean	81.6	91	102.2	79.5	92.6	72
St Dev	13.7	22.6	48	9	49.5	13.3

Table 2. Max, Min, and mean bankfull depths for reaches 1-6 in feet. Mean values are an average of the three individual measurements taken at multiple nth units in each reach.

Bankfull Depths (feet)						
	Reach 1	**Reach 2**	**Reach 3**	**Reach 4**	**Reach 5**	**Reach 6**
Min	3.3	3	2.5	2.3	0.2	1.2
Max	5	6.4	4.5	4.9	4.5	3.3
Mean	4.3	5.0	3.7	4.0	2.3	2.0
St Dev	0.5	1.2	0.5	0.9	1.1	0.6

Table 3. Max, min, and mean floodprone depths for reaches 1- 6 (in feet). Mean values are an average of all measurements taken in each reach at nth units. Where floodprone width could not be calculated in the field, it was estimated using LIDAR.

Floodprone Width (feet)						
	Reach 1	**Reach 2**	**Reach 3**	**Reach 4**	**Reach 5**	**Reach 6**
Min	100	100	210	98	110	63
Max	195	135	375	160	900	865
Mean	170	118	320	121	393	261
St Dev	61	25	69	29	338	340

3.2 HABITAT UNIT COMPOSITION

Riffles were by far the dominant habitat area in the study area, with lesser percentages of glide and pool. (60%, 20%, and 15% respectively). The remaining 5% of habitat area was composed by side channel (Figure 2). Less than 1% of braided channel habitat was measured in the study area as well. At the reach level, Reach 5 was the most unique reach with nearly equal proportions of side channels, glides, riffles, pools (Figure 3).

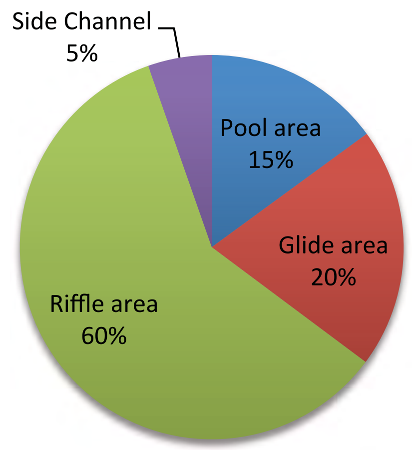


Figure 2. Habitat area composition of Reaches 1-6 in the Middle Twisp River.

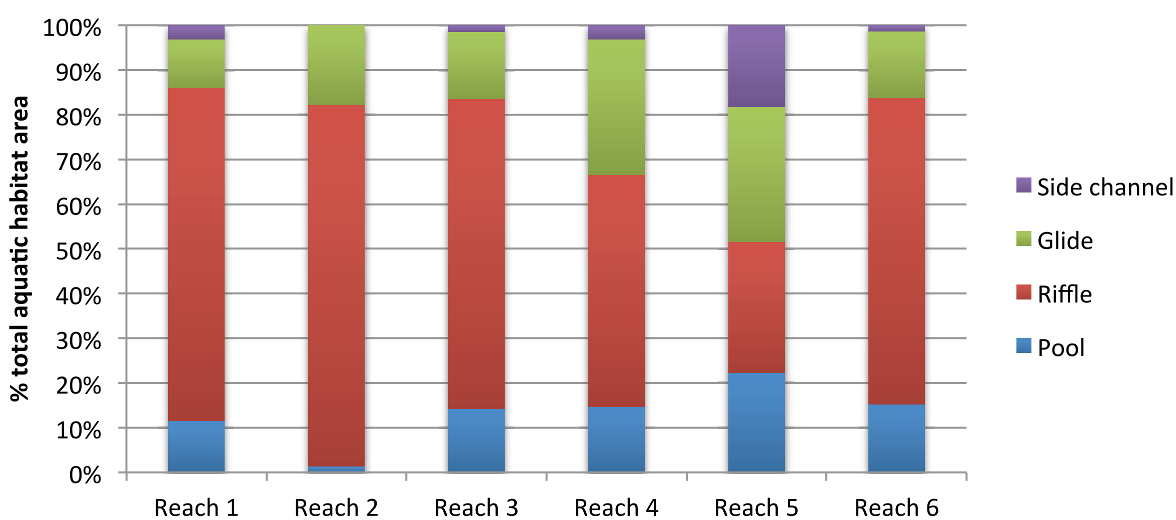


Figure 3. Habitat unit composition of Reach 1-6 in the Middle Twisp River.

Pool frequency ranged from 1.53 pools/mile (Reach 2) to 13.12 pools/mile (Reach 5), with a mean frequency of 6.88 pools/mile. Frequency was calculated as the number of pools divided by the length of the reach in miles. Pool spacing values were calculated by using the frequency (f) to determine spacing over a mile, then normalizing those distances using the average bankfull width (W_{bf}):

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

Reach 5 had the great proportion of pool area habitat (23%) while Reach 2 had the least (1%) (Figure 3). Mean pool spacing was 15.4 bankful widths. Spacing ranged from 4.2 at the most closely space (Reach 5), to 36.8 in Reach 2. Reaches 3 and 5 had the greatest pool area in the study area (Figure 4) with 34% and 26% of the habitat area, respectively. Average residual pool depth was 2.84, with a range of between 2.1 feet for the most shallow residual pool depth in Reach 6, to 2.95 feet for the deepest residual pool depth in Reach 4. The deep residual pool depth measured was 8 feet.

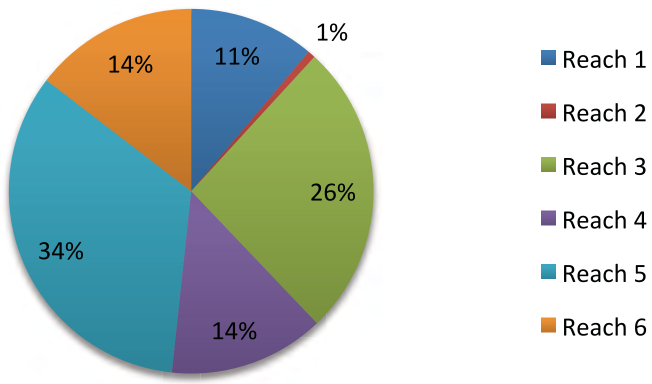


Figure 4. Percent of total area (square feet) of pools in each reach of the 10.32 mile study area.

Mean wetted pool width was 43.6 feet (StDev of 16 feet). Reach 5 had both the widest pool at 100 feet, and narrowest pool at 22 feet. The average pool length in the study area was 140 feet (StDev of 63 feet). Reach 2 had the shortest average pool length at 78 feet (only one pool was measured in Reach 2). Reach 4 had the longest average pool length at 194 feet.

3.3 OFF-CHANNEL HABITAT

Side channel habitat units accounted for 5% of habitat area in the study reach. A total of 28 side channel units were counted during the survey. Of the 28 side channels, 23 were slow, and 5 were fast-moving. Reach 5 had the most side channel habitat area of all reaches in the study area (Figure 5), accounting for 73% of the side channel habitat area in the study area. Except Reach 2, all reaches had side channel habitat. The mean side channel length was 670 feet (StDev 989), with a maximum side channel length measuring 4,956 feet (Reach 5) and minimum observed length of 20 feet (Reach 5). Mean side channel width was 11.0 feet (StDev 10.3), ranging from 2-40 feet.

In addition to side channels, the study area had five marshes ranging from small ponds to large connecting backwater ponds. These off channel marshlands contain food sources (invertebrates), LWD, refuge, and rearing habitat for fish and wildlife species. One off channel marsh was identified in Reach 4, the remaining five were identified in Reach 5.

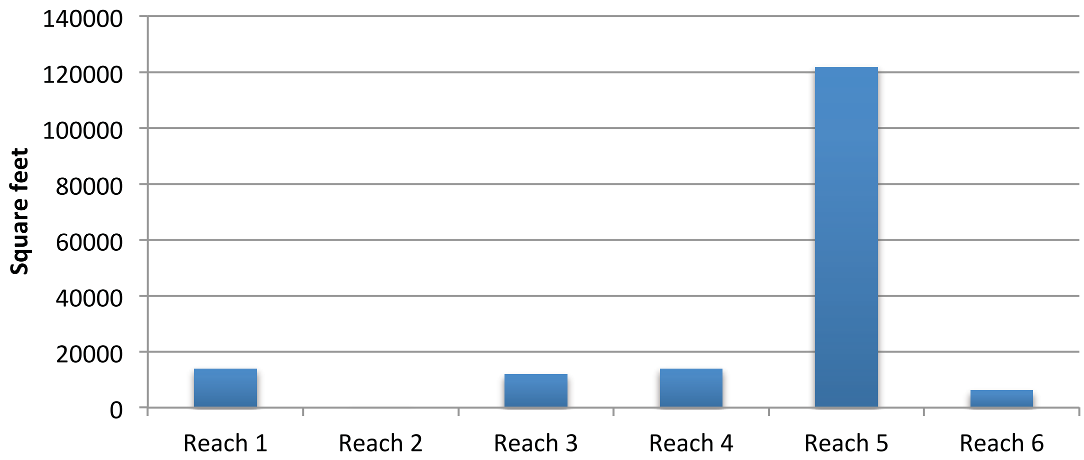


Figure 5. Side channel habitat area by reach. Reach 5 accounted for 73% of the side channel habitat area.

3.4 LARGE WOOD

An average of 96 pieces of LWD/mile was counted in the study area; 71% was "small" wood, measuring between 6 – 12 inches in diameter with lengths greater than 20 feet (Figure 6). Medium and large wood, measuring more than 12" diameter and more than 35' long), accounted for the remaining 29% of wood in the study area. Wood counts varied from as low as 28 pieces of small, medium and large wood per mile (Reach 2), to as high as 207 pieces per mile in Reach 5. Reach 5 also had the most wood overall with 54% of the total wood count. A total of 17 log jams were counted throughout the study area. Log jams are defined as having 10 or more pieces of contiguous LWD. Rates of log jams ranged from 0 log jams/mile for reaches 1 and 2, to a max of 3.86 log jams/mile in Reach 5. Wood counts in log jams ranged from a minimum of 10 pieces to a max of 35 pieces. Side channels account for 17% of the entire wood count (167 pieces of the 991 total pieces counted).

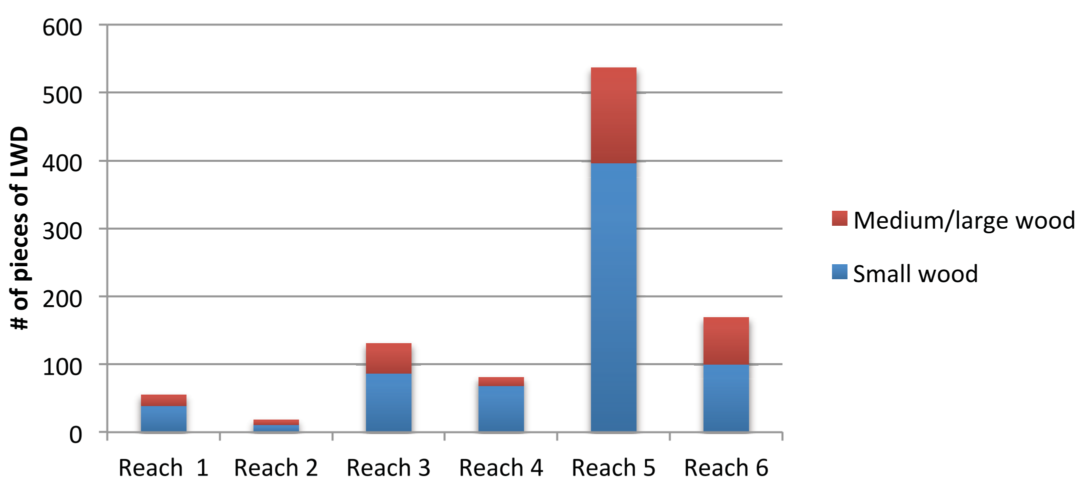


Figure 6. Small (6 – 12" diameter, >20 ' long) and medium/large wood (>12" diameter, >35' long) counts by reach.

3.5 SUBSTRATE & FINE SEDIMENT

Bed substrate and fine sediment measurements are based on pebble count (two in each reach) (Figure 8) and ocular measurements (Figure 7) conducted at each measured habitat unit throughout the study area. In general, substrate increased in coarseness going downstream. Cobble was the dominant substrate in all six reaches except Reach 5, where cobble and gravel were of equal proportions.

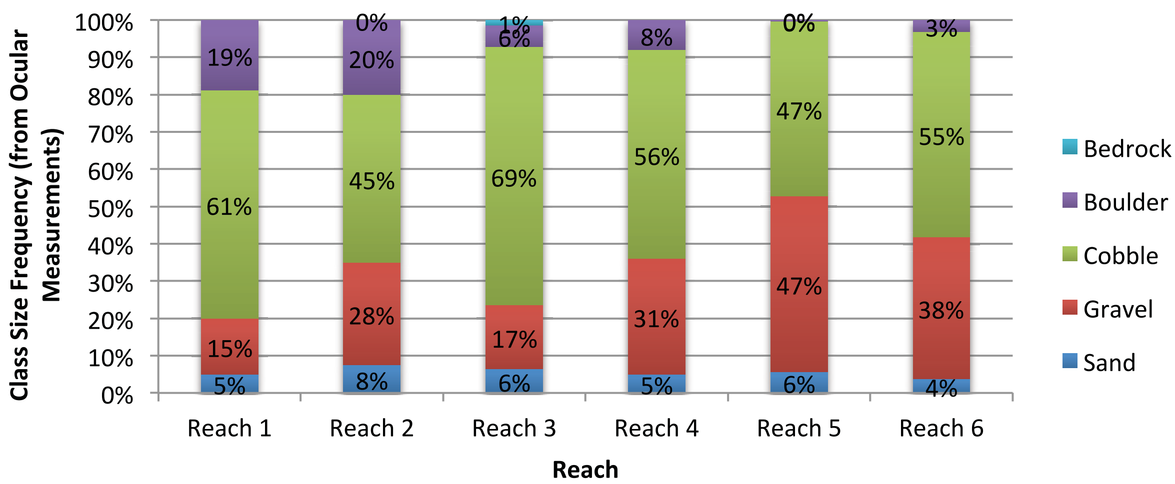


Figure 7. Ocular estimates of substrate by reach for the 10.32 mile study area of the Middle Twisp River.

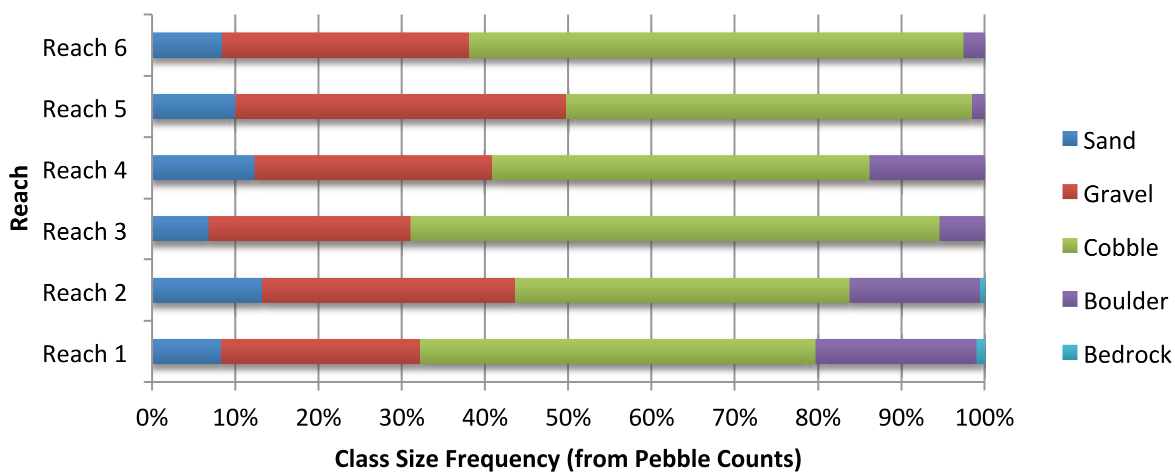


Figure 8. Pebble count classification of substrate by Reach for the MIddle Twisp River. Pebble counts percent composition were averaged between the two pebble counts from each reach.

Pebble counts show similar results in the distribution of sediments. Average sand counts ranges from 8% - 13%. The highest average sand count (<2mm) in the pebble count was 13% composition in Reach 2 compared to 8% in the ocular measurements.

3.6 INSTABILITY & DISTURBANCE

All reaches had significant human impacts, including residential development on the floodplain, channelization, roads, and agriculture clearing adjacent to the river and riparian areas. There was more significant human alteration at the lower half of the study area. Twisp River Road is adjacent to lower reaches, deviating away from the river at the start of Reach 5 where the valley widens.

Anthropogenically-caused bank erosion was minimal throughout the entire study area. In total, 285 linear feet of bank erosion was identified at n^{th} unit measurement in the lower four reaches. No anthropogenically caused bank erosion was identified in reaches 5 and 6.

3.7 FISH PASSAGE BARRIERS

There were no anthropogenic fish passage barriers in the study area. Access to some off-channel habitat may be limited in low-flow, low-water years, and may impact adult fish passage.

3.8 RIPARIAN CORRIDOR

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

In total, 40 nth-unit measurements were completed within the six reaches of the study area. Riparian measurements identified small trees measuring 9.0 – 20.9 inches in diameter as the dominant size class (40%). The remainder of the riparian zone measured was dominated by shrub/seedling cover measuring 1.0 – 4.9 inches in diameter (23%); grassland/forb (15%); sapling/pole measuring 5.0 – 8.9 inches in diameter (12%); and large trees measuring 21 – 31.9 inches in diameter (2%). Figure 9). The riparian overstory measured was dominated by Douglas fir (42%) as well as cottonwood (35%), alder (15%), and ponderosa (8%)(Figure 10). Understory was dominated by alder (63%). Other species included (in order of frequency) dogwood, cottonwood, other/unknown, Douglas fir, and willow.

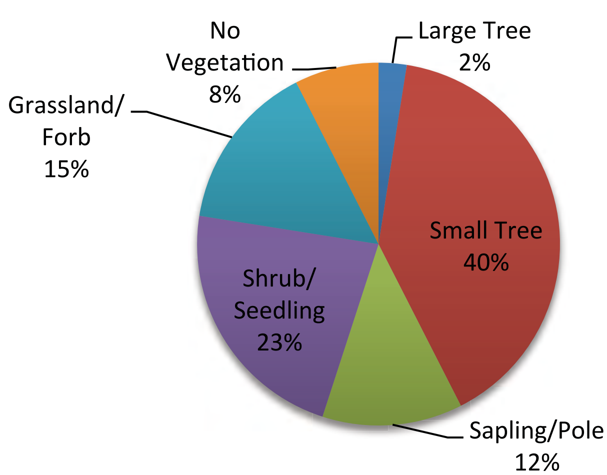


Figure 9. Distribution of the dominant size class category of vegetation observed within the 40 n^{th} units measured throughout the study area..

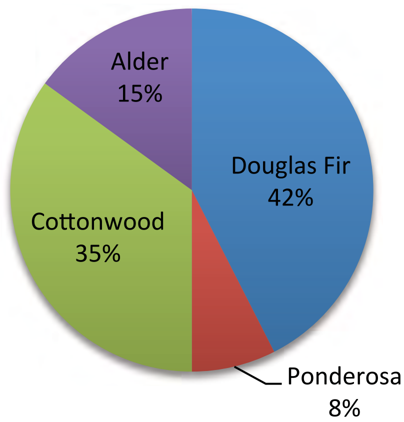


Figure 10. Proportions of vegetation cover observed in the overstory of the riparian zone within the 40 n[th] units measured throughout the study area.

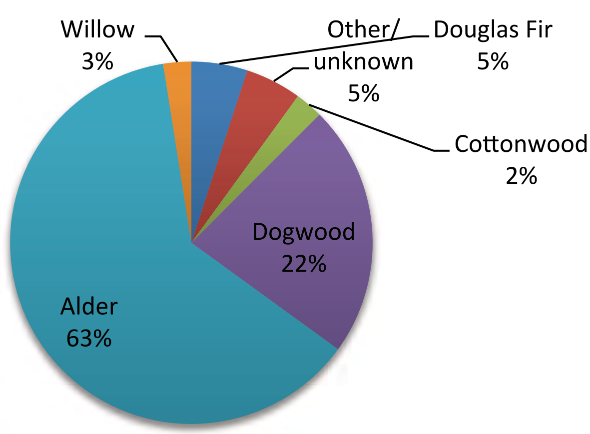


Figure 11. Proportions of vegetation cover observed in the understory of the riparian zone within the 40 n[th] units measured throughout the study area.

Table 4. Middle Twisp Reach Data Summary. RM 7.8 – 18.12.

		Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	TOTAL
Reach Mileage Boundaries		7.8-9.14	9.14 – 9.79	9.79 – 12.22	12.22 – 13.60	13.60 – 16.19	16.19 – 18.12	7.8 – 18.12
Wetted Width (ft)								
All Habitat Types(Main Channel)								
	Mean	65.1	62.7	65.1	59.3	41.1	41.8	51
	StDev	8.7	10.6	12.5	12	13.8	13.2	16.6
Pool								
	Mean	57.8	40.0	58.5	56.7	37.4	37.1	43.6
	StDev	9.5	n=1	13.6	15.4	14.2	11.8	16.1
Glide								
	Mean	63.3	40.3	64.8	57.4	45.8	46.0	53.1
	StDev	8.3	5.8	12.9	10.2	12.2	12.0	13.5
Riffle								
	Mean	69.5	68.3	69.8	62.1	43.2	43.3	55.9
	StDev	6.0	7.5	9.9	11.8	13.2	14.4	16.8
Side Channel								
	Mean	40	N/A	14	15	8.4	5.5	11.0
	StDev	n=1	N/A	10.1	15.7	6.3	0.7	10.3
Water Depth (ft)								
Pool Maximum Depth								
	Mean	3.8	4.2	3.9	4.2	4.1	3.3	3.9
	StDev	0.9	n=1	1.5	2.6	1.3	1	1.4
Pool Residual Depth								
	Mean	2.4	2.7	2.8	3	2.9	2.1	2.7
	StDev	0.7	n=1	1.5	2.7	1.3	0.9	1.4
Glide Maximum Depth								
	Mean	2.6	2.8	1.9	2	2.2	1.8	2.1
	StDev	0.3	0.3	0.4	0.6	0.8	0.5	0.6
Glide Average Depth								
	Mean	1.8	1.8	1.3	1.4	1.3	1.2	1.4
	StDev	0	0.2	0.4	0.3	0.6	0.3	0.4
Riffle Maximum Depth								
	Mean	2.6	2.5	2	1.6	1.5	1.7	1.9
	StDev	0.4	0.9	0.5	0.4	0.6	0.7	0.6
Side Channel								

	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	TOTAL
Maximum Depth							
Mean	2.8	0	1.7	2.2	2.2	1.5	2.1
StDev	n=1	0	0.6	1.8	1.1	1.4	1.1
Bankful Characteristics							
Width (ft)							
Mean	81.7	91	102.2	79.5	92.6	72	87.3
StDev	13.7	22.6	48	9	49.5	13.3	34.6
Average Depth (ft)							
Mean	4.3	5	3.7	3.8	2.3	2	3.2
StDev	0.5	1.2	0.5	0.9	1.1	0.6	1.2
Maximum Depth (ft)							
Mean	4.9	6	4.3	4.6	3.2	2.7	3.9
StDev	0.3	0.7	0.3	0.3	1.1	0.7	1.2
Width: Depth Ratio							
Mean	19.2	18.2	27.4	20.1	39.7	35.3	20.2
StDev	2.4	7.7	11.5	4	87	14	49.4
Floodprone Width							
Mean	170	118	320	121	393	260	269
StDev	61	25	69	29	338	340	247
Habitat Area %							
Pool	12%	1%	14%	14%	23%	15%	15%
Glide	11%	18%	15%	15%	29%	15%	59%
Riffle	74%	81%	69%	69%	21%	69%	20%
Side Channel	3%	0	2%	2%	18%	1%	6%
Pools							
Pools Per Mile	3.7	1.5	4.5	4.3	13.1	7.8	7
Residual Depth (% of pools)							
Pools < 3 ft	40%	0%	18%	67%	26%	53%	35%
Pools 3-6 ft	60%	100%	73%	17%	71%	47%	61%
Pools 6-9 ft	0%	0%	9%	17%	3%	0%	4%
Pools 9-12 ft	0%	0%	0%	0%	0%	0%	0%
Riffle: Pool Ratio							
Riffle: Pool Ratio	6.4	59.7	4.9	3.5	1.3	4.5	4
Riffle & Glide: Pool Ratio	7.4	72.9	5.9	5.6	2.7	5.5	5.3
Mean Pool Spacing (Bankfull Channel Widths Per Pool)	15.8	36.8	10.5	15.7	4.2	9.2	15.4

	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	TOTAL
Large Wood							
Total Number Pieces							
Total	55	18	131	81	537	169	991
Large (20 in by 35 ft)	4	4	17	1	47	35	108
Medium (12 in by 35 ft)	12	3	27	12	94	34	182
Large and Medium	16	7	44	13	141	69	290
Small (6 in x 20 ft)	39	11	87	68	396	100	701
Number of Pieces/Mile							
Total	41.0	27.7	53.9	58.7	207.3	87.6	96
Large (20 in by 35 ft)	3.0	6.2	7.0	0.7	18.1	18.1	10
Medium (12 in by 35 ft)	9.0	4.6	11.1	8.7	36.3	17.6	18
Large and Medium	11.9	10.8	18.1	9.4	54.4	35.8	28
Small (6 in x 20 ft)	29.1	16.9	35.8	49.3	152.9	51.8	68
Log Jams							
Total	0	0	2	2	10	3	17
Log Jams Per Mile	0	0	0.8	1.4	3.9	1.6	1.6
Bank Erosion							
Total % Bank Erosion	1%	1%	<1%	<1%	0	0	<1%
Substrate (ocular estimates)							
Total							
% Sand	5%	8%	6%	5%	6%	4%	5%
% Gravel	15%	28%	17%	31%	47%	38%	34%
% Cobble	61%	45%	69%	56%	47%	55%	55%
% Boulder	19%	20%	6%	8%	0%	3%	6%
% Bedrock	0%	0%	1%	0%	0%	0%	0%
Fast Water Units							
% Sand	5%	8%	8%	4%	4%	3%	5%
% Gravel	15%	28%	20%	23%	42%	36%	30%
% Cobble	60%	45%	66%	65%	53%	56%	58%
% Boulder	20%	20%	6%	9%	1%	5%	7%
% Bedrock	0%	0%	0%	0%	0%	0%	0%
Slow Water Units							
% Sand	5%	0%	3%	10%	8%	5%	6%

	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	TOTAL
% Gravel	15%	0%	10%	65%	54%	42%	42%
% Cobble	62%	0%	78%	20%	38%	53%	48%
% Boulder	14%	0%	5%	5%	0%	0%	2%
% Bedrock	0%	0%	5%	0%	0%	0%	1%
Vegetation (% of sampled units)							
Riparian zone (100-foot-wide zone averaged between both banks)							
Dominant Overstory Size Class							
Mature Tree (*32 in.)*	0%	0%	0%	0%	0%	0%	0%
Large Tree (*21 – 31.9 in.)*	0%	0%	14%	0%	0%	0%	3%
Small Tree (*9 – 20.9 in.)*	25%	100%	29%	60%	21%	63%	40%
Sapling/Pole *(5.0 – 8.9 in.)*	0%	0%	14%	0%	29%	0%	13%
Shrub/Seedling (*1-4.9 in.)*	0%	0%	14%	0%	43%	25%	23%
Grassland/Forb	75%	0%	29%	20%	0%	0%	15%
No Vegetation	0%	0%	0%	20%	7%	12%	8%
Overstory Species Composition							
Conifer (Undifferentiated)	0%	0%	0%	0%	0%	0%	0%
Douglas Fir	50%	100%	43%	20%	21%	75%	43%
Ponderosa Pine	25%	0%	14%	20%	0%	0%	8%
Cedar	0%	0%	0%	0%	0%	0%	0%
Spruce	0%	0%	0%	0%	0%	0%	0%
Hardwood (Undifferentiated)	0%	0%	0%	0%	0%	0%	0%
Cottonwood	25%	0%	43%	60%	43%	13%	35%
Alder	0%	0%	0%	0%	36%	13%	15%
Understory Species Composition							
Conifer (Undifferentiated)	0%	0%	0%	0%	0%	0%	0%
Douglas Fir	50%	0%	0%	0%	0%	0%	5%
Ponderosa Pine	0%	0%	0%	0%	0%	0%	0%
Cedar	0%	0%	0%	0%	0%	0%	0%
Spruce	0%	0%	0%	0%	0%	0%	0%
Other/unknown	25%	50%	0%	0%	0%	0%	5%
Cottonwood, ash, poplar	0%	0%	0%	0%	7%	0%	3%

	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	TOTAL
Dogwood	0%	0%	14%	0%	36%	38%	23%
Alder	0%	50%	86%	100%	57%	63%	63%
Willow	25%	0%	0%	0%	0%	0%	3%

4 Comparison to 1994 USFWS Survey

The Methow Valley Ranger District of the Okanogan-Wenatchee National Forest and the Pacific Watershed Institute (PWI), a non-profit watershed restoration organization, conducted a stream survey of the Twisp River in 2001. A total of 30.4 miles of the Twisp River was surveyed, beginning at the mouth, and ending at the confluence of the North and South forks of the Twisp River. The Twisp River was also surveyed by the USFS in 1993.

Comparisons to previous surveys allow us to detect trends in habitat characteristics over time. Because reach breaks from the 2013 Inter-Fluve survey do not exactly coincide with reach breaks in the 2001 and 1993 surveys (Table 5), exact comparisons between the 1993, 2001, and 2013 surveys is not possible. While reach breaks in the 2001 survey are similar to the 2013 survey for the entire study area, only two of three reach breaks in 2001 can be compared to the much coarser 1993 survey. Protocol between survey years were also different (see Table 7 summary below for differences in protocol for surveying pools), as well as conditions on the river. Water levels during the 2001 survey were extremely low as compared to 2013 water levels, which were slightly high.

In an attempt to standardize data, we lumped comparable reaches from the 2013 survey together so they could be compared to the 2001 and 1993 results. In general, the 1993 and 2001 survey reaches were longer. Reach 6 of the 2001 survey includes both Reach 1 (T4a) and Reach 2 (T4b) of the 2013 survey. Reach 7 of the 2001 survey includes both Reach 3 (T5a) and Reach 4 (T5b) of the 2013 survey. Reach 8, however, is approximately 0.27 miles shorter than the combined length of both Reach 5 (T6) and Reach 6 (T7) from the 2013 survey. Comparisons between the 2001 survey and 2013 survey should be accessed with understanding of this discrepancy.

4.1 SUMMARY

It is possible to document general trends for the entire study area between the 2013 and 2001 surveys, and for the later four reaches of the 2013 study with the 1993 survey. Pool and side channel habitat area slightly decreased between 2001 and 2013, while fast water slightly increased between 2001 and 2013.

Pool characteristics identified between surveys are likely unreliable due to the differences in protocol. The 2001 survey identified pools in side channels as well as pools that were greater than half the channel width, whereas the 2013 survey didn’t identify pools in side channels and identified pools as needing to be at least one channel width long. This discrepancy likely resulted in the elevated numbers of pools in the 2001 survey.

LWD per mile in general trended upward between the 1993, 2001, and 2013. Small LWD saw the largest gains in the number of pieces of LWD, with nearly three times more small wood per mile in 2013 than 1993. Medium and large wood per mile generally trended upwards as well.

Bankful widths and width/depth ratios weren’t as consistent in trends. While 2013 reaches 3 and 4 saw an increase in bankfull width, reaches 5 and 6 decreased. The width/depth ratio identifies a high point in 2001 for reaches 3, 4, 5, and 6.

Table 5. Equivalent reaches and associated river miles for 2001 and 2013 surveys.

Reach Comparisons			
2001 Survey Reach	**2001 Survey Description**	**2013 Survey Reach**	**2013 Survey Description**
Reach 6	RM 8.04 (Newby Creek) – RM 9.96 (Little Bridge Creek) **[1.92 miles total]**	Reach 1 (T4a) Reach 2 (T4b)	RM 7.8 (Newby Creek) – RM 9.14 **[1.34 miles]** RM 9.14 – RM 9.79 (Little Bridge Creek) **[0.65 miles]** **[1.99 miles total]**
Reach 7	RM 9.96 (Little Bridge Creek) – RM 13.72 (Buttermilk Creek) **[3.76 miles total]**	Reach 3 (T5a) Reach 4 (T5b)	RM 9.79 (Little Bridge Creek) – RM 12.22 **[2.43 miles]** RM 12.22 – RM 13.6 (Buttermilk Creek) **[1.38 miles]** **[3.81 miles total]**
Reach 8	RM 13.72 (Buttermilk Creek) – RM 17.6 (War Creek Campground) **[3.88 miles total]**	Reach 5 (T6) Reach 6 (T7)	RM 13.6 (Buttermilk Creek) – 16.19 **[2.59 miles]** RM 16.19 – RM 17.85[1] **[1.93 miles]** **[4.52 miles total]**

[1] Reach 6 (T7) of the 2013 survey ends 0.27 miles beyond Reach 8 of the 2001 survey.

Table 6. Comparison of percent habitat areas for habitat units measured in 2001 and 2013.

Habitat Unit Area Composition							
2001 Survey Reach	**2013 Survey Reaches**	**% Pool Area**		**% Fast Water Area[2]**		**% Side Channel Area**	
		2001	**2013**	**2001**	**2013**	**2001**	**2013**
Reach 6	Reach 1, 2	11.2%	8%	86%	90%	2.8%	2%
Reach 7	Reach 3, 4	23.6%	14%	73.4%	84%	3.0%	2%
Reach 8[1]	Reach 5, 6	30.2%	19%	58.9%	69%	10.9%	12%

[1] Reach 6 (T7) of the 2013 survey ends approximately 0.27 miles beyond Reach 8 of the 2001 survey.
[2] The 2001 survey did not separate out fast water units into glides and riffles.

Table 6 compares habitat unit area measured in 2001 and 2013 (1993 habitat area not available). Pool area decreased in all reaches in the 2013 survey results. Conversely, fast water frequency increased in 2013 survey results. Side channel habitat area had less change, with slight increases in the 2013 reaches 1-4, and a slight decrease in 2013 reaches 5 and 6.

Table 7. Comparison of pools between 1993, 2001, and 2013. Note that 1993 statistics for pools > 3 ft deep, and average pool residual depth are not available.

Pool Characteristics									
1993 Survey Reach	**2001 Survey Reach**	**2013 Survey Reaches**	**1993 Pools per Mile**	**2001 Pools per Mile**	**2013 Pools per Mile**	**2001 Stream Survey Pools >3' Deep/Mile**	**2013 Stream Survey Pools >3' Deep/Mile**	**Average Pool Residual Depth 2001**	**Average Pool Residual Depth 2013**
N/A	Reach 6	Reach 1, 2	N/A[2]	5.7	3.0	5.2	0.5	1.75	2.5
Reach 2	Reach 7	Reach 3, 4	5.0	7.4	4.5	4.8	1.3	2.54	2.8
Reach 2, 3	Reach 8[1]	Reach 5, 6	11.6	14.7	10.8	9.8	3.5	2.69	2.7

[1] Reach 6 (T7) of the 2013 survey ends approximately 0.27 miles beyond Reach 8 of the 2001 survey.
[2] 1993 reach breaks for Reach 1 do not coincide with 2001 and 2013 reach breaks.

Table 7 provides a summary comparison of pool characteristics between 1993, 2001, and 2013. Data is not available for 1993 regarding pools more than 3 ft deep/mile, and average residual depth. The data shows a slight decrease in pools per mile, far fewer pools more than 3 ft deep/mile, and a slight increase in the average residual depth of pools. While pools per mile have overall decreased between the 1993 and 2013 survey, the 2001 survey identified the highest ratio of pools/mile, specifically in reaches 5 and 6 where there were 14.7 pools/mile. The greatest disparity in data between the 2001 and 2013 surveys was found in comparing pools more than 3 ft deep/mile. The data show a decrease by approximately 75% between 2001 and 2013 in pools more than 3 ft deep/mile. The most dramatic decrease was seen in the lower reaches (2013 reaches 1 and 2) of the 2013 study area, where pools more than 3 ft deep/mile decreased by over 90%. Conversely, the average residual depth in pools increased between 2001 and 2013 between 0.1 ft – 0.75 ft.

One reason for the rather disparate pool data in Table 6 and Table 7 is likely related to a difference in survey protocol for measuring pools. Survey protocol in 2001 called for identifying pools “that span at least half the channel and are at least 3 feet deep at low flow, or at least 1.5 deep with 40% or better hiding cover,” whereas the 2013 survey only identified pools that spanned an entire channel width. Additionally, the 2001 protocol also appears to have identified pools in the side channels. The 2013 survey did not identify side channel pools. Because of this difference it survey protocol, it is likely that 2001 data are inflated in comparison to 2013 data, and that pool data cannot be accurately compared between the two surveys.

Table 8. LWD per mile compared between reaches in 1993, 2001, and 2013. All LWD is in-channel wood (does not include side channels). The 1993 and 2001 surveys had leaning and standing trees removed from the count.

LWD Per Mile														
1993 Survey Reaches	2001 Survey Reaches[2]	2013 Survey Reaches	Small (>20' L) (6 – 12" D)			Medium (>35' L) (12'- 20" D)			Large (>35'L) (>20"D)			Medium & Large		
			1993	2001	2013	1993	2001	2013	1991	2001	2013	1991	2001	2013
N/A[3]	Reach 6	Reach 1, 2	N/A[2]	20.0	23.1	N/A	1.7	67.0	N/A	1.5	4.0	N/A	3.2	11.1
Reach 2	Reach 7	Reach 3, 4	7.2	15.9	20.4	1.6	5.5	4.6	1.6	0.5	3.9	3.2	6.0	8.6
Reach 2, 3	Reach 8	Reach 5, 6	19.6	57.2	57.3	10.3	22.6	14.4	8.2	8.2	10.4	18.5	30.8	24.8

[1]Reach 6 (T7) of the 2013 survey ends approximately 0.27 miles beyond Reach 8 of the 2001 survey.
[2]Corresponds to the metric "Hankin Reeves: In-Channel Only (no standing trees, no side channels)" from the 2001 survey.
[3] 1993 reach breaks for Reach 1 do not coincide with 2001 and 2013 reach breaks.

Table 8 compares LWD between 1993, 2001, and 2013. In general, LWD per mile increased between 1993 and 2013 in all reaches. Small LWD had the most dramatic increases with nearly three times more small LWD in reaches 1-4 in 2013 than 1993. Medium LWD increased in 2001 and slightly decreased in 2013. Large LWD trended up on a whole, but decreased in 2013 reaches 3 and 4 before increased in 2013.

Table 9. Bankful width averages, and average width/depth ratios compared between 1993, 2001, and 2013.

Width and Width/Depth Ratio								
1993 Survey Reaches	2001 Survey Reaches2	2013 Survey Reaches	Bankfull Width			Width/Depth Ratio		
			1993	2001	2013	1993	2001	2013
N/A[2]	Reach 6	Reach 1, 2	N/A[2]	81.3	85.4	N/A[2]	28.5	18.1
Reach 2	Reach 7	Reach 3, 4	75.5	90.0	92.1	21.4	35.4	24.5
Reach 2, 3	Reach 8[1]	Reach 5, 6	101.2	96.0	84.7	39.7	49.2	38.1

[1]Reach 6 (T7) of the 2013 survey ends approximately 0.27 miles beyond Reach 8 of the 2001 survey.
[2] 1993 reach breaks for Reach 1 do not coincide with 2001 and 2013 reach breaks.

Table 9 compares bankfull width and the width/depth ratio between 1993, 2001, and 2013. Overall, bankfull widths did not have a consistent trend between 1993 and 2013. Reaches 1 and 2 decreased over time; reaches 3 and 4 increased; and reaches 5 and 6 decreased. Width/depth ratios, similarly, did not consistently trend between 1993 and 2013. Reaches 1 and 2 trended upward; reaches 3, 4, 5, and 6 peaked in 2001 and then decreased in 2013.

5 Stream Habitat Reach Reports

5.1 REACH 1

Location: River mile 7.8 - 9.14 (1.34 miles). From the confluence of Newby Creek to RM 9.14. This reach corresponds to the downstream portion of Reach T4 from the Methow Subbasin Geomorphic Assessment (USBR 2008).

Survey Date: 10/22/2013

Survey Crew: Jonathan Graca, Ben Gardner, Gardner Johnston

Figure 12. Representative view of a Reach 1 riffle. Riffles composed 74% of the reach.

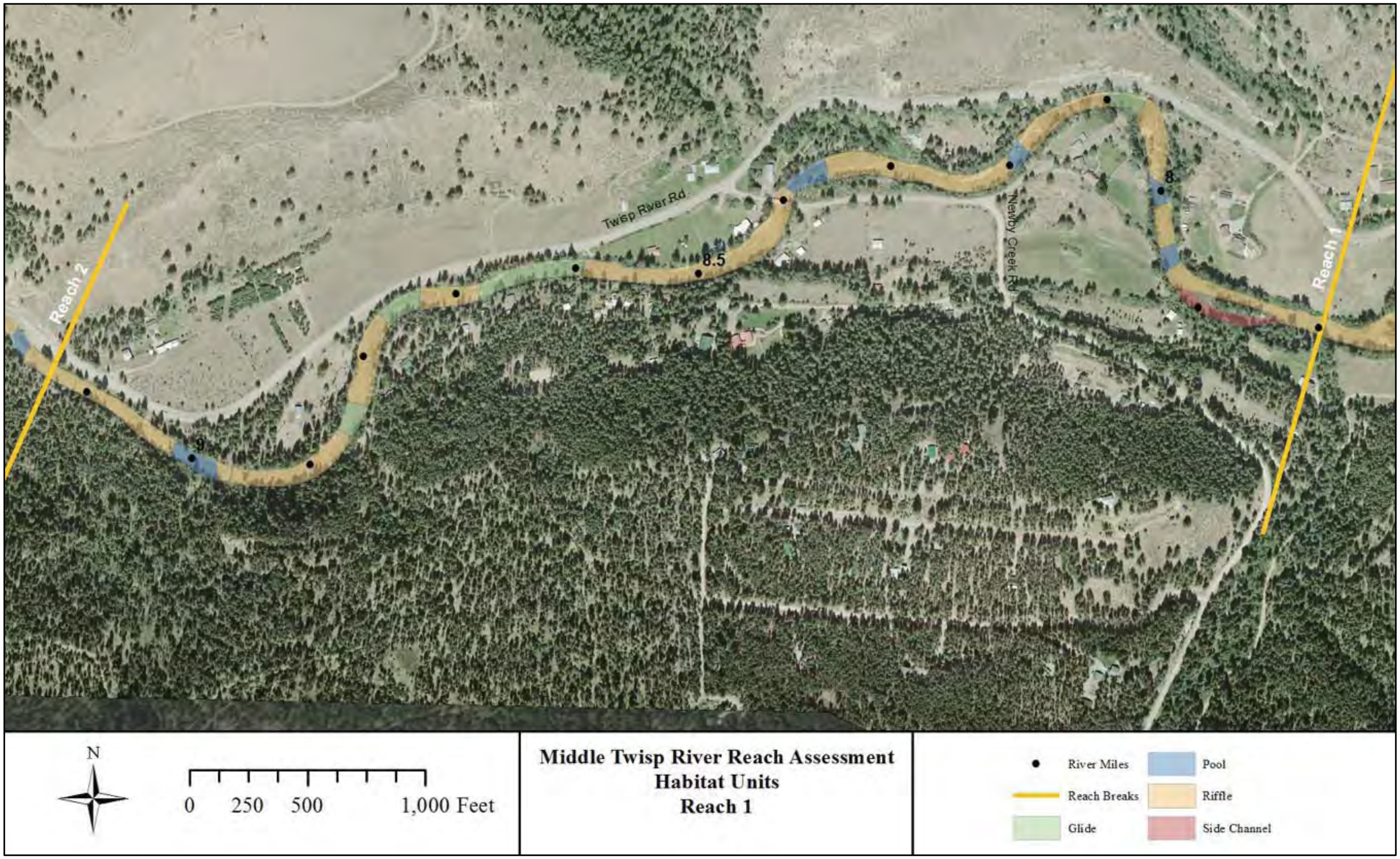


Figure 13. Reach 1 locator and habitat unit composition map.

5.1.1 Habitat Unit Composition

Relative to upper reaches in the study area, Reach 1 was high-gradient with fast water units (glides and riffles) comprising 85% of the area of reach (Figure 14). Five pools accounted for 12% area of reach. Reach 1 was relatively uniform with no braided channels and only one side channel that accounts for 3% of the habitat area in the reach.

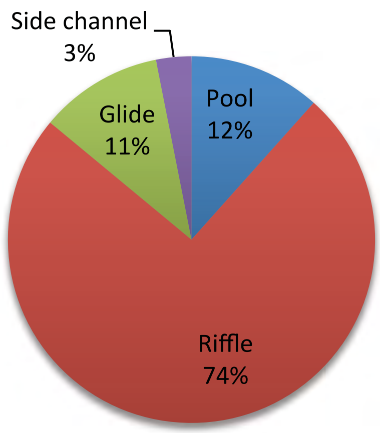


Figure 14. Habitat area composition for Reach 1.

5.1.2 Pools

Five pools were observed in Reach 1, composing 12% of the habitat area (Figure 14) and averaging 3.7 pools/mile (the entire study area averages 7 pools/mile). None had high-quality habitat. All had substrate that is relatively large and 80% had residual depths of under 3 feet (Figure 16). Eighty percent of the pools do have large woody material in the channel to provide complexity and cover. Pools occur at a mean spacing of 15.8 bankfull channel widths/pool in Reach 1 – nearly the same as the study area average of 15.4 bankful channel widths/pool. Average residual pool depth was 2.4 feet with a maximum residual depth of 3.2 ft.

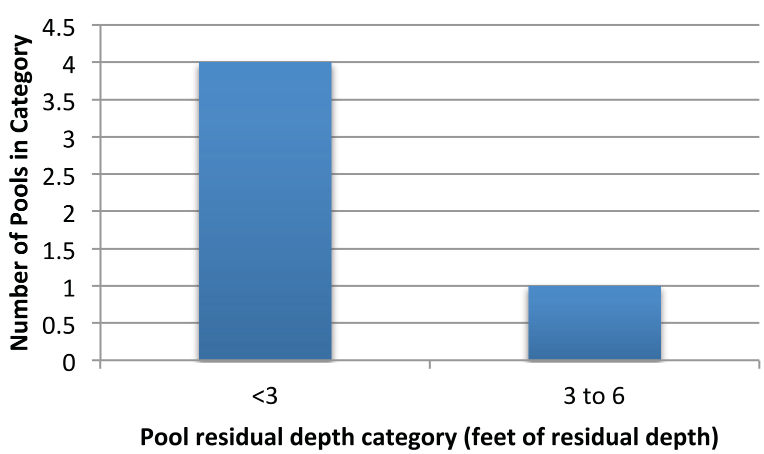


Figure 15. Reach 1 residual pool depth and count of total pools in the reach.

Figure 16. One of five pools in Reach 1 at RM 7.95 (left). Measuring bankful width (right).

5.1.3 Side Channels

Reach 1 had little side channel habitat area relative to other reaches in the study area. The only side channel observed in this study area was a 348-foot-long fast-moving channel located between RM 7.8 to 7.9 that was well connected to the main channel (Table 10). Four small and one medium pieces of wood were observed in the side channel. No off-channel wetland was identified in Reach 1.

Table 10. Side channels identified in Reach 1.

Location	Length (feet)	Dominant unit type	Wood count
RM 7.9	348	Fast water	5

5.1.4 Large Woody Material

Large wood quantities in Reach 1 were the second lowest amongst the six reaches in the study area for both average wood per mile (40) and total wood count (55). The average throughout the study reach was 96 pieces/mile. Of the 55 pieces of wood counted, 71% were small; 22% were medium, and 7% were large. No log jams were present. Most of the woody material in the reach was found in fast moving water (85% of woody material).

Table 11. Large woody material quantities in Reach 1 (1.38 miles).

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in x 35 ft)	Total
Number of Pieces	39	12	4	55
Number of Pieces/Mile	29	9	3	41
Num. of medium/large pieces	16			
Num. of medium/large pieces/mi	11.9/mile			
Number of jams/mile	0 jams/mile			
Number of Jams*	0			

Jams consist of at least 10 qualifying pieces of wood whose numbers are reflected in the total wood count.

5.1.5 Substrate and Fine Sediment

Bed substrate was primarily cobble (61%) with smaller portions of boulder, gravel, and sand (19%, 15%, and 5% respectively). Percent fines (<2mm) were low, ranging from 5-9% based on the ocular estimates (Figure 17) and pebble counts (Figure 18 and Figure 19).

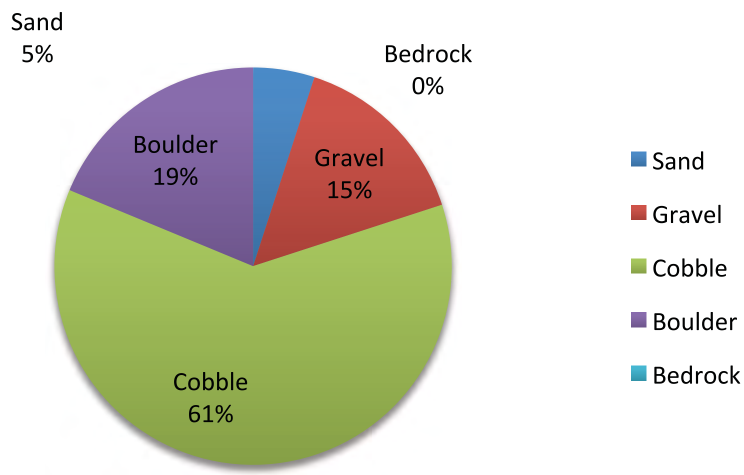
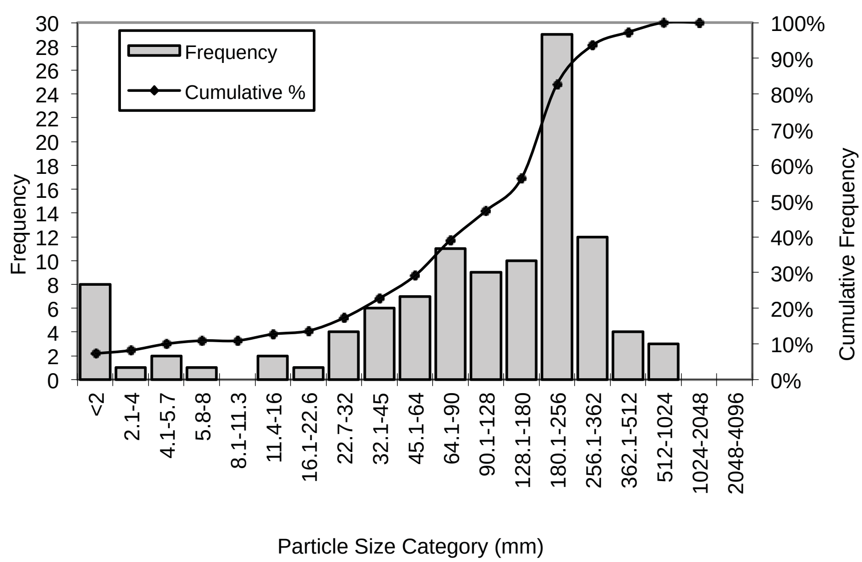


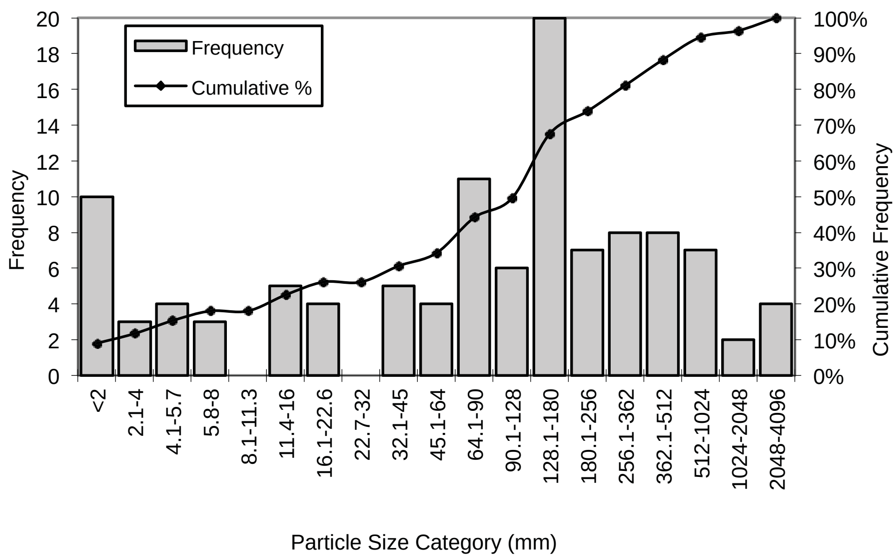
Figure 17. Percent composition of bed substrate based on ocular estimates, Reach 1.



Material	Percent Composition
Sand	7%
Gravel	22%
Cobble	54%
Boulder	17%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	1
D16	29
D50	141
D84	338
D95	418

Figure 18. Grain size distribution and particle size classes from pebble count taken at RM 8.07, Reach 1.



Material	Percent Composition
Sand	9%
Gravel	25%
Cobble	40%
Boulder	21%
Bedrock	2%

Size Class	Size percent finer than (mm)
D5	1
D16	6
D50	131
D84	423
D95	1057

Figure 19. Grain size distribution and particle size classes from pebble count taken at RM 8.65, Reach 1.

5.1.6 Riparian Corridor

Reach 1 had a variable riparian corridor with significant cleared areas for roads and residential yards. The majority of the riparian clearing was prevalent on the south side of the river for the first half of the reach, and on the north side of the river for the second half of the reach. The four n^{th} units measured in Reach 1 classified 25% of the riparian area within 100 feet of the measurement as small trees measuring 9 – 20.9 in. diameter; the remaining 75% measured was classified as grassland/forbes. Understory species composition was variable with a majority of species identified as Hawthorne, dogwood, and willow. The overstory was largely composed of cottonwood, Douglas fir, and ponderosa pine.

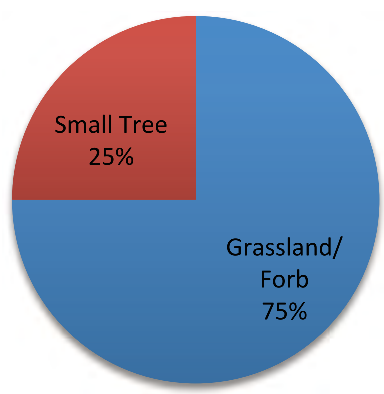


Figure 21. Dominant riparian vegetation identified within 100 feet of river by ocular estimates, Reach 1.

Figure 20. Reach 1 is bordered on the north by the Twisp River Rd and on the south by several residences. The reach is relatively fast moving with little wood retention. Both images taken at RM 8.1.

5.2 REACH 2

Location: River mile 9.14 – 9.79 (Confluence with Little Bridge Creek) (0.65 miles).

Survey Date: 10/22/2013

Survey Crew: Jonathan Graca, Ben Gardner, Gardner Johnston

Figure 22. Downstream view of a riffle in Reach 2 with high percentages of boulders.

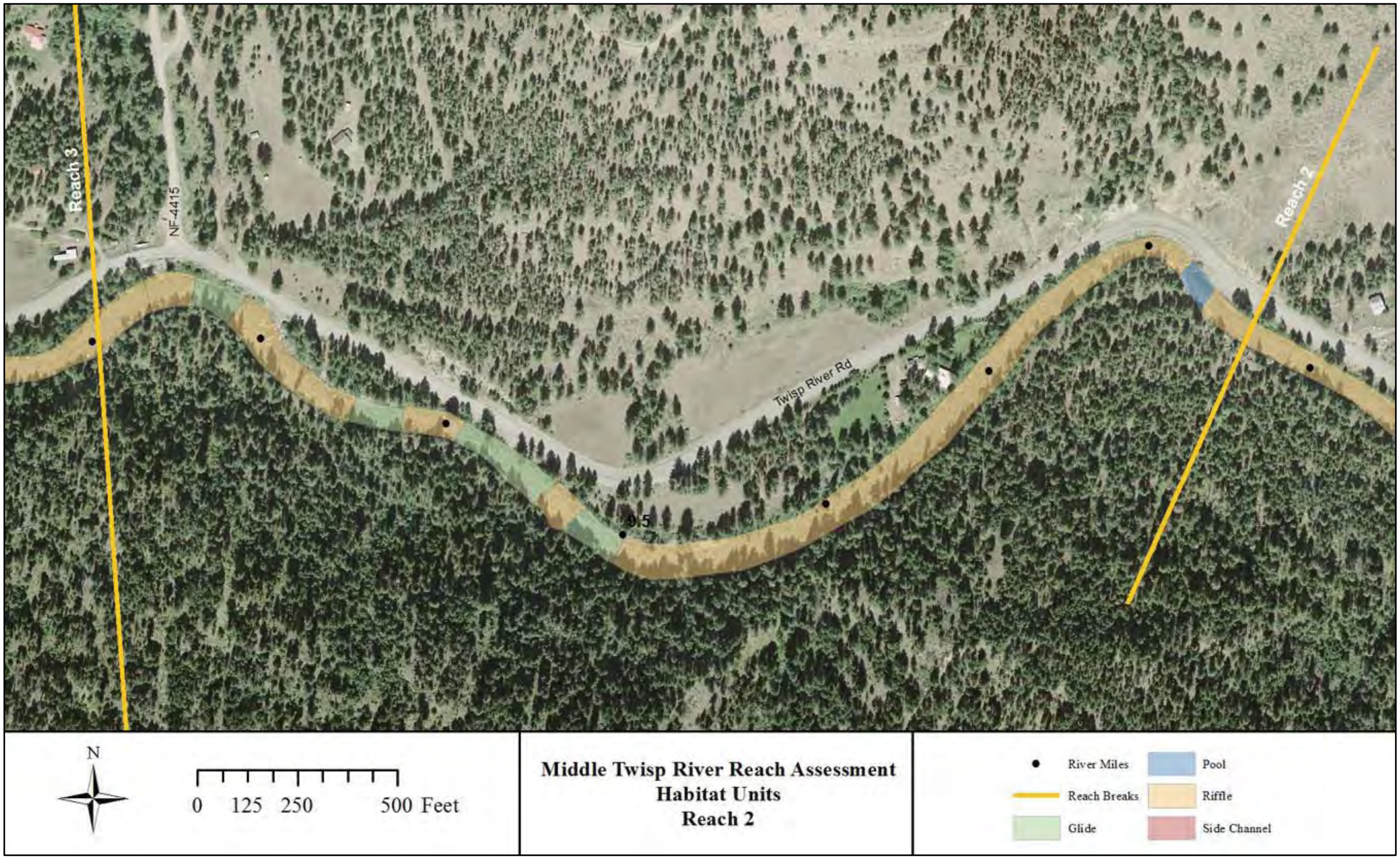


Figure 23. Reach 2 locator and habitat unit composition map.

5.2.1 Habitat Unit Composition

Reach 2 was the shortest reach in the study area. It is a high gradient reach, largely constrained by road on the north (left side of photo in Figure 22) and residential housing with push-up leeves and rip-rap on the south side of the river. Fast water units (glides and riffles) comprised 99% of the reach area habitat (Figure 24). Only one pool was identified in the Reach, accounting for 1% of the reach area. No side channels were present in this reach.

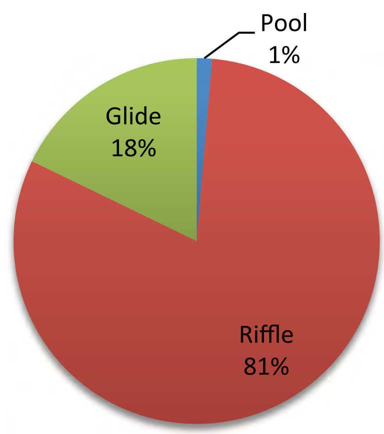


Figure 24. Habitat Composition for Reach 2.

5.2.2 Pools

One pool was identified in Reach 2, equating to a pool frequency of 1.54 pools per mile (compared to a study area average of 7 pools/mile). While the pool did have a residual depth of 2.7, it was not exemplary of good salmon habitat (Figure 26) due to fast current, large substrate, and no wood or significant cover. Reach 2 had a frequency of 36.8 channel widths/pool (verses the average of 15.4 channel width/pool observed within the study area).

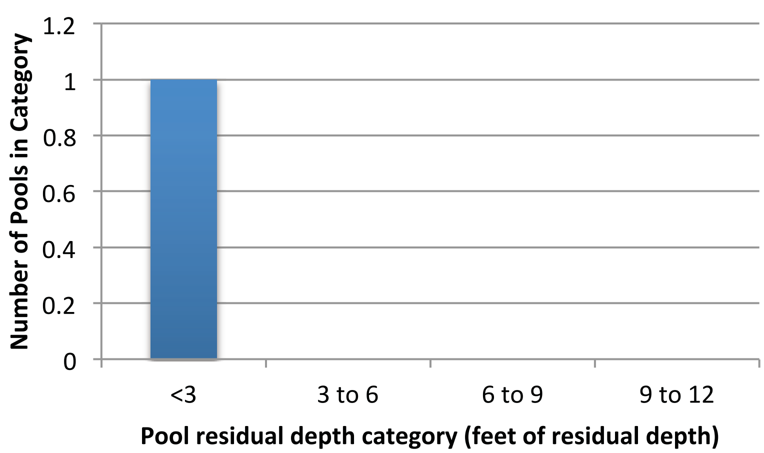


Figure 25. Residual pool depth and total count of pools in reach 2.

Figure 26. A relatively high-gradient reach, only one pool was identified in Reach 2. While the residual depth qualified this unit as a pool, due to fast current, large substrate, and no wood or cover, this pool is not representative of good habitat.

5.2.3 Side Channels

No side channels or off-channel wetland were identified in Reach 2.

5.2.4 Large Woody Material

Reach 2 had the lowest wood counts of the study area, with 27 pieces of wood per mile, and 18 total pieces of wood counted. No jams were present in the reach. LWD included 61% small wood; 17% medium wood; and 22% large wood. All wood counted in Reach 2 was located in riffles or glides, which composed 98% of this higher gradient reach.

Table 12. Large woody material quantities in Reach 2 (0.65 miles).

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in x 35 ft)	Total
Number of Pieces	11	3	4	18
Number of Pieces/Mile	17	5	6	28
Num. of medium/large pieces	7			
Number of medium/large pieces/mile	10.8			
Number of jams/mile	0 jams/mile			
Number of Jams*	0			

* Jams consist of at least 10 qualifying pieces of wood whose numbers are reflected in the total wood count.

5.2.5 Substrate and Fine Sediment

Bed substrate was primarily cobble (45%), with smaller yet significant portions of gravel and boulders (28% and 20% respectively). Percent fines (<2mm) were low to moderate, ranging from 7% (ocular measurements) (Figure 27), to 14% and 15% based on two pebble counts in Reach 2 (Figure 28, and Figure 29).

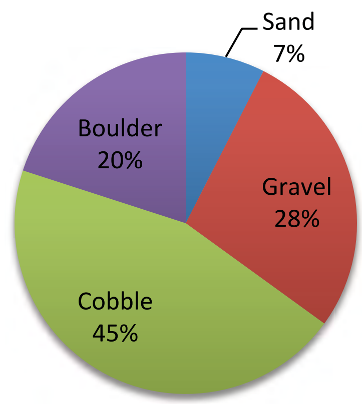
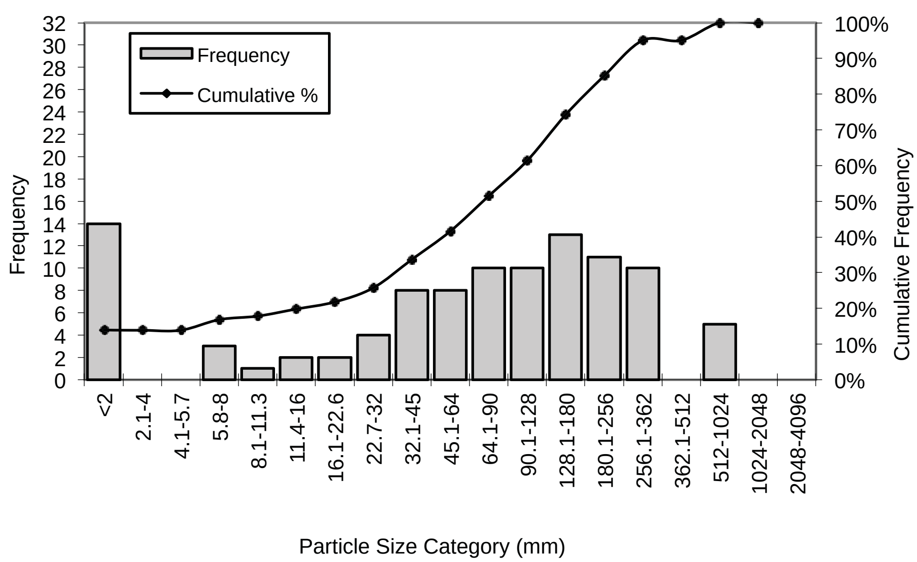


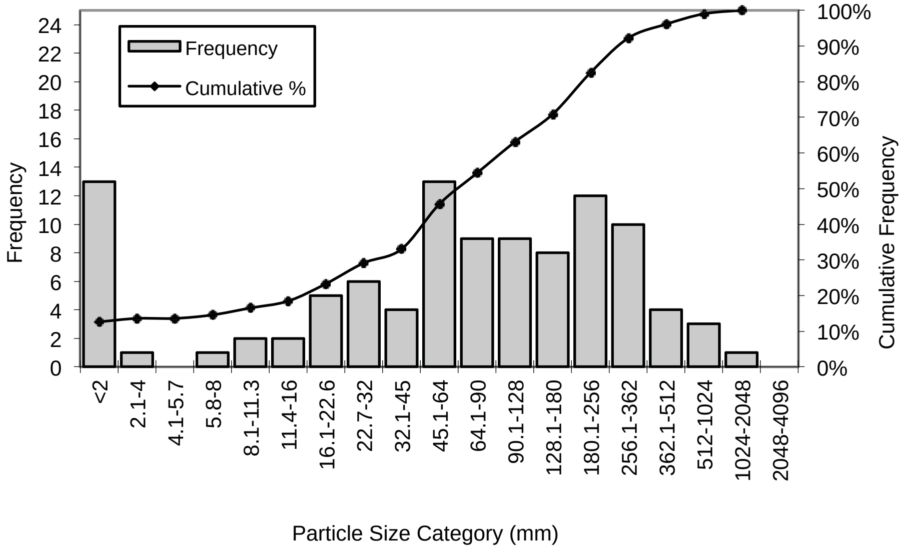
Figure 27. Percent composition of bed substrate based on ocular estimates, Reach 2.



Material	Percent Composition
Sand	14%
Gravel	28%
Cobble	44%
Boulder	15%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	1
D16	7
D50	86
D84	248
D95	361

Figure 28. Grain size distribution and particle size classes from pebble count taken at RM 9.5 in Reach 2.



Material	Percent Composition
Sand	13%
Gravel	33%
Cobble	37%
Boulder	17%
Bedrock	1%

Size Class	Size percent finer than (mm)
D5	1
D16	10
D50	77
D84	272
D95	569

Figure 29. Grain size distribution and particle size classes from pebble count taken at RM 9.69, Reach 2.

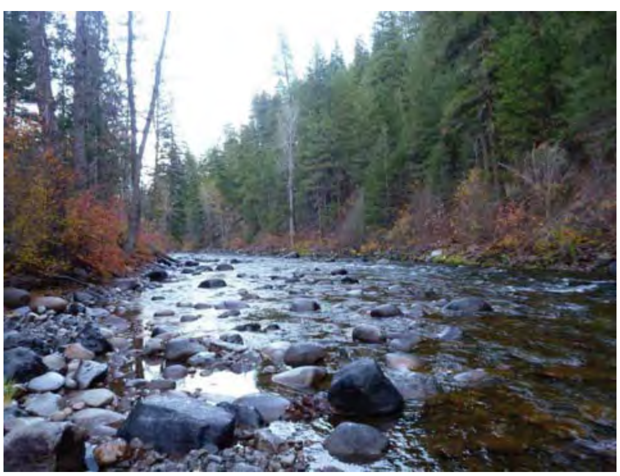


Figure 30. Upstream and downstream photos at RM 9.33 show large cobbles and boulders.

5.2.6 Riparian Corridor

Riparian vegetation within the two n^{th} units measured in Reach 2 was dominated by small trees measuring 9 – 20.9 in. diam. The overstory species distribution within the two units was comprised of Douglas fir trees (100%). Understory was 50% unknown softwoods and 50% alder. The level of stream shade along the southern edge of the river was robust throughout Reach 2, providing valuable shaded river habitat. The north side of the reach was often impacted by the road, limiting shade. About 75 feet of unstable bank was identified during an nth unit measurement at RM 9.65 on river left.

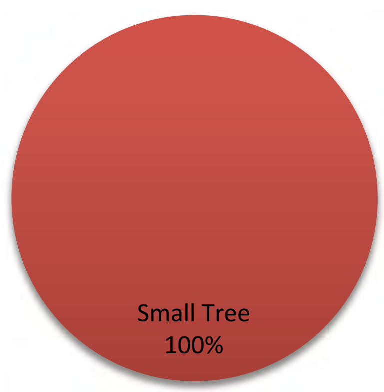


Figure 31. Dominant riparian vegetation identified within 100 feet of river by ocular estimates, Reach 2.

5.3 REACH 3

Location: River mile 9.79 (Little Bridge Creek confluence) - 12.22 (2.43 miles)

Survey Date: 10/23/2013

Survey Crew: Jonathan Graca, Ben Gardner, Gardner Johnston

Figure 32. Representative view of a Reach 3 glide.

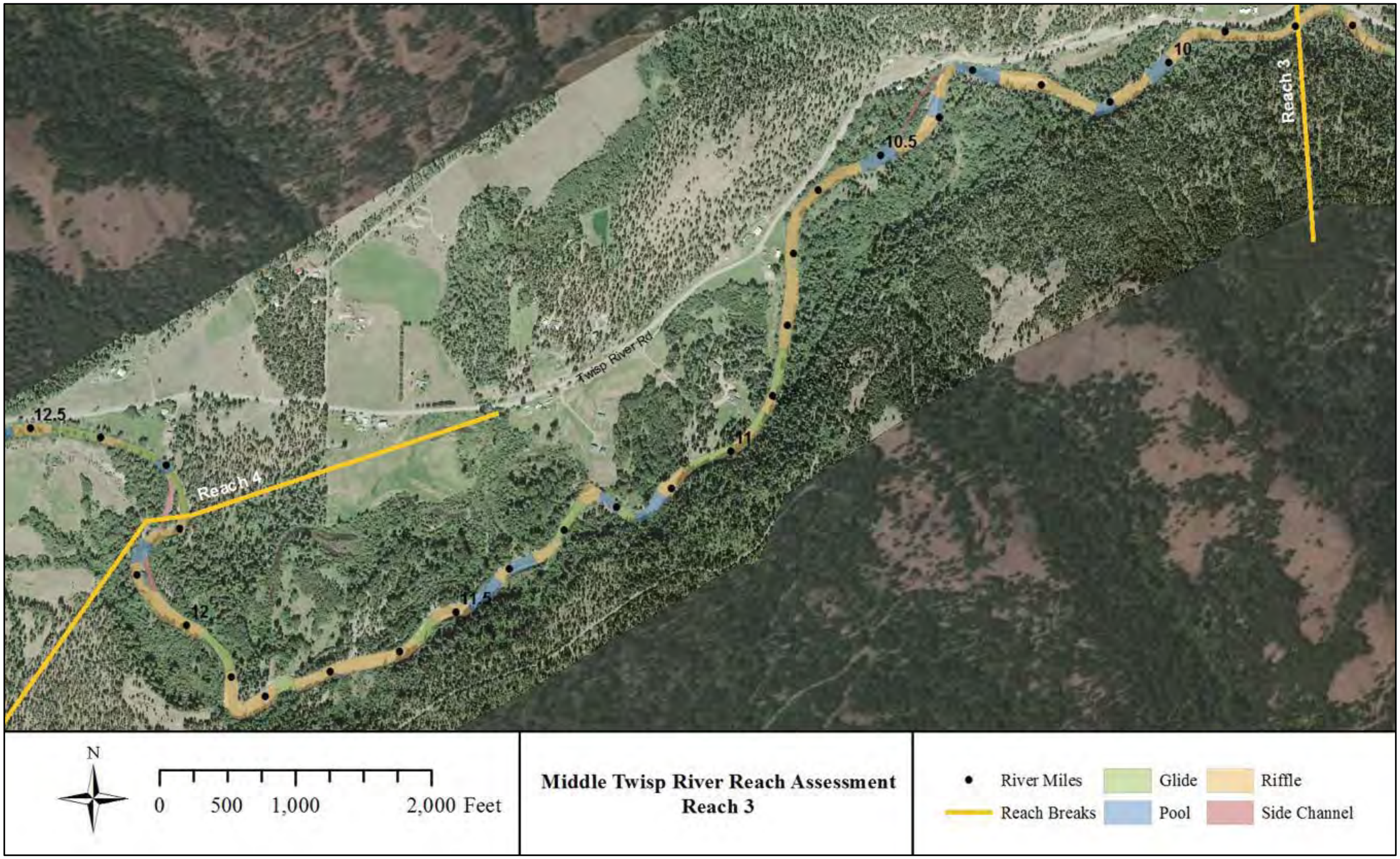


Figure 33. Reach 3 locator and habitat unit composition map.

5.3.1 Habitat Unit Composition

Reach 3 habitat area was slightly more diverse in comparison to downstream reaches as gradient decreased and the road moved away from the river. Fast-water units dominated the reach with riffles accounting for 84% of the reach area (glides accounted for 15%, and riffles for 69%). Pools accounted for 14% or habitat area, and side channels for 2% (Figure 34).

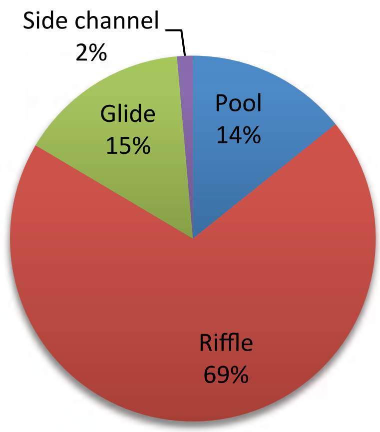


Figure 34. Habitat unit composition Reach 3.

5.3.2 Pools

Reach 3 had 11 pools (Figure 35), and a pool frequency of 4.5 pools/mile. Pool habitat comprised 15% of the reach area (Figure 35), with 73% of the pools having residuals depths of under 3 feet. Two pools had residual depths of 3 – 6 feet, and one pool had a residual depth of six feet. Reach three had a frequency of 10.5 channel widths/pool, compared to the study average of 15.4 channel widths/pool. Fifteen pieces of LWD were counted in the 11 pools.

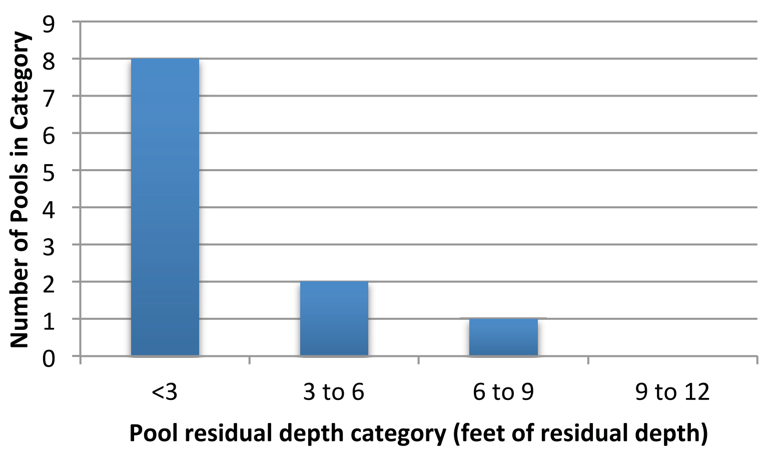


Figure 35. Reach 1 residual pool depth and count of total pools in the reach.

5.3.3 Side Channels

Reach 3 had three side channels (two slow-moving, one fast), accounting for 2% of the habitat area of the reach (Figure 34). Total wood count in the side channels was 7 (Figure 36). No off-channel wetland was identified in Reach 3.

Location	Length (feet)	Dominant unit type	Wood count
RM 10.72	505	Slow water	3
RM 12.1	225	Fast water	0
RM 12.25	35	Slow water	4
TOTAL	**765**		**7**

Figure 36. Side channels identified in Reach 3.

Figure 37. Reach 3 had 765 feet of side channel. Above is an image a 505-ft-long side channel that enters the Twisp River at RM 10.35

5.3.4 Large Woody Material

Large wood in Reach 3 averaged 54 pieces/mile (compared to the study area average of 96 pieces/mile). Small wood was the most prevalent, composing 66% of the total wood count and 35 pieces per mile (Table 13). Reach 3 had two log jams present, both apex log jams. Together, the two jams composed 37% of the wood found in the Reach. Approximately 12% of the wood was in pools.

Table 13. Large woody material quantities in Reach 3 (2.43 miles).

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in x 35 ft)	Total
Number of Pieces	87	27	17	131
Number of Pieces/Mile	35	11	7	54
Num. of medium/large pieces	44			
Num. of medium/large pieces/mile	18.1			
Number of jams/mile	.82 jams/mile			
Number of Jams*	2			

* Jams consist of at least 10 qualifying pieces of wood whose numbers are reflected in the total wood count.

Figure 38. Two log jams were present in Reach 3. This apex log jam at RM 12.1 had 10 medium and 25 small pieces of wood.

5.3.5 Substrate and Fine Sediment

Bed substrate in Reach 3 was primarily cobble (69%) with 17% gravel, 6% boulder, and 1% bedrock (Figure 39). While cobble counts were relatively similar to downstream reaches, the boulder count was significantly lower than Reach 1 and 2 (19% and 20% respectively).

Percent fines (<2m) were low and relatively consistent between the ocular measurements and pebble counts. Ocular measurements estimate 7% sand (Figure 39). The two pebble counts in Reach 3 estimate 9% and 5% (Figure 40 and Figure 41).

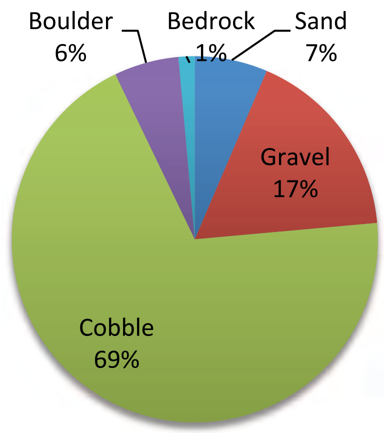
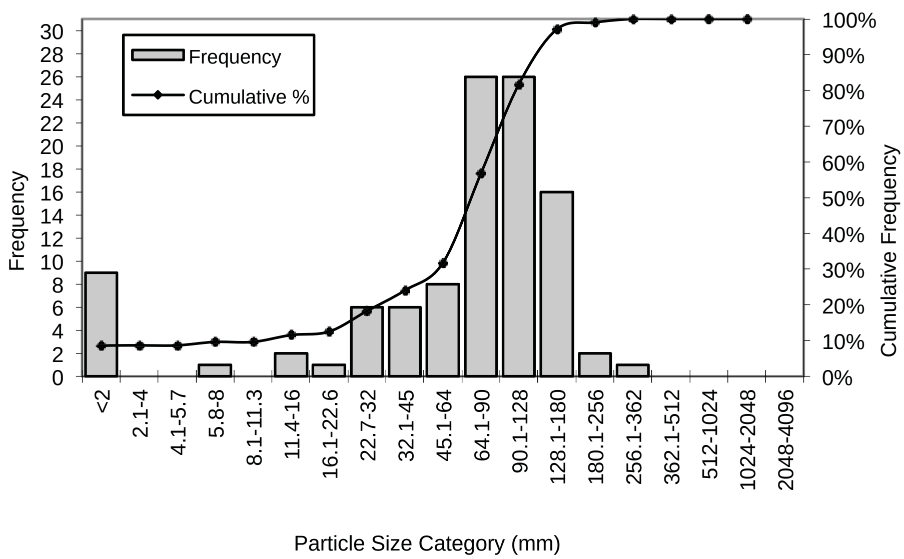


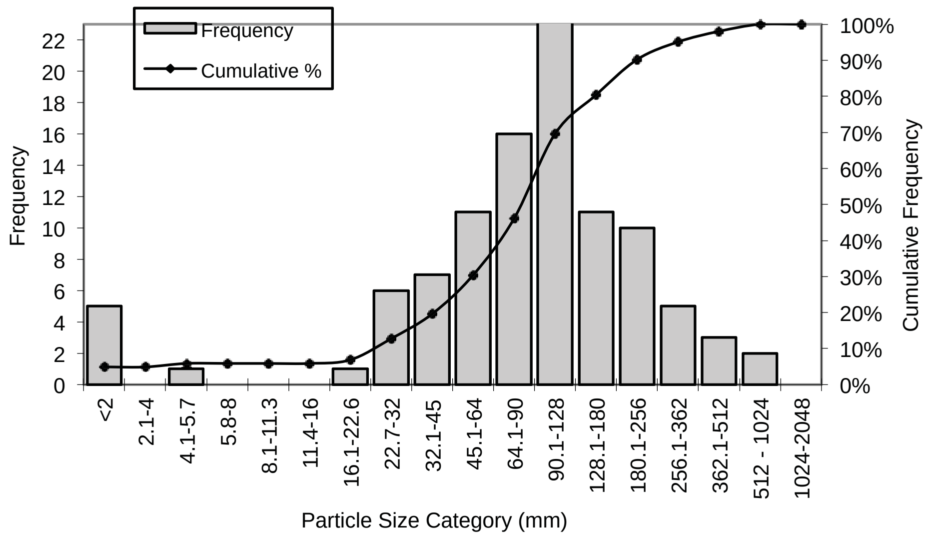
Figure 39. Percent composition of bed substrate based on ocular estimates, Reach 3.



Material	Percent Composition
Sand	9%
Gravel	23%
Cobble	67%
Boulder	1%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	1
D16	28
D50	83
D84	136
D95	173

Figure 40. Grain size distribution and particle size classes from pebble count observed at RM 10.15, Reach 3.



Material	Percent Composition
Sand	5%
Gravel	25%
Cobble	60%
Boulder	10%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	1
D16	25
D50	99
D84	208
D95	360

Figure 41. Grain size distribution and particle size classes from pebble count taken at RM 11.18, Reach 3.

5.3.6 Riparian Corridor

Reach 3 had a highly variable riparian corridor. Five n^{th} unit measurements in the reach measured 29% grassland/forbs, and 29% small trees measuring 9 – 20.9 in. diam.; large trees measuring 21 – 31.9 in. diam., sapling/pole measuring 5 – 8.9 in diam, and shrub/seedling measuring 1 – 4.9 in diam. each accounted for 14% of the riparian corridor (Figure 42). The overstory was also variable, mostly composed of cottonwoods and Douglas fir, but also containing some ponderosa. Understory was dominated by alder with some dogwood.

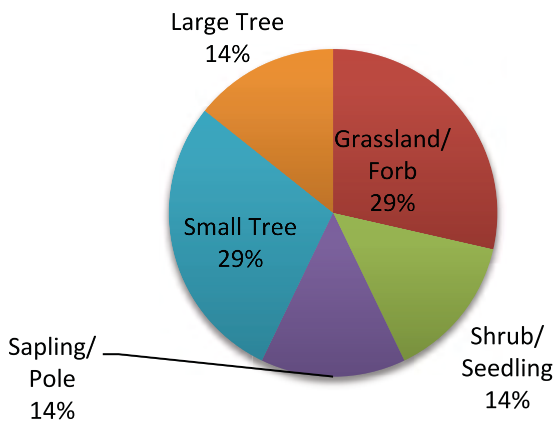


Figure 42. Dominant riparian vegetation identified within 100 feet of river by ocular estimates, Reach 3.

5.4 REACH 4

Location: River mile 12.22 – 13.60 (confluence with Buttermilk Creek) (1.38 miles)

Survey Date: 10/24/2013

Survey Crew: Jonathan Graca, Ben Gardner

Figure 43. Looking upstream at a 9-foot-deep pool at RM 12.55 in Reach 4.

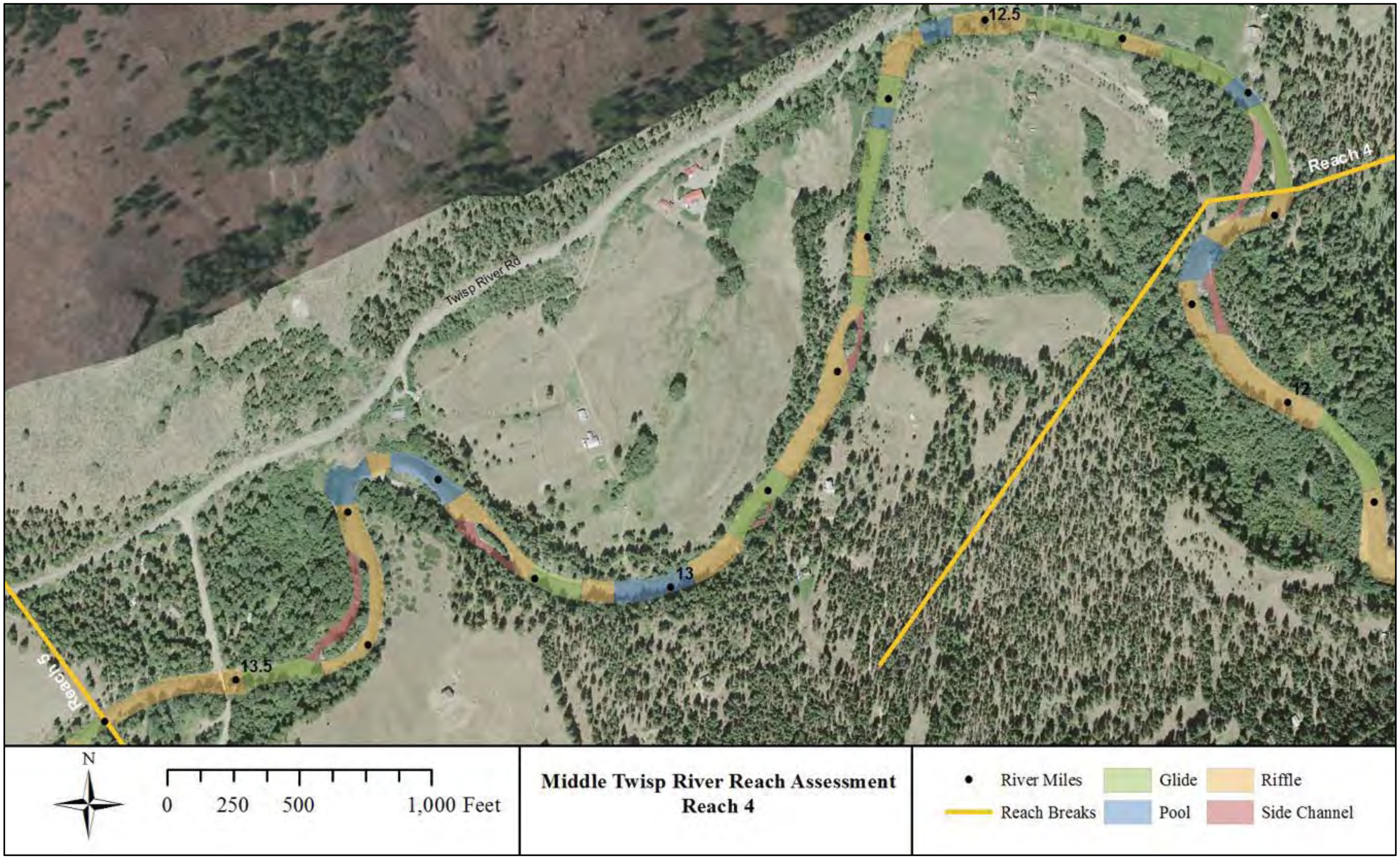


Figure 44. Reach 4 locator and habitat unit composition map.

5.4.1 Habitat Unit Composition

Habitat composition of Reach 4 was similar to that of Reach 3 with fast water reaches accounting for 84% of the habitat area, 14% of the habitat area as pool, and 2% side channel (Figure 45).

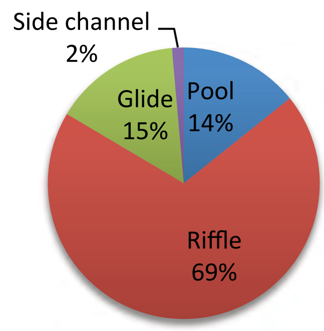


Figure 45. Habitat Composition for Reach 1.

5.4.2 Pools

Reach 4 had a pool frequency of 4.3 pools per mile compared to an average of 7 pools/mile for the entire study area (Figure 45). Pool frequency was measured at 15.7 channel widths/pool, compared to an average of 15.6 channel widths/pool throughout the study area. A total of 6 pools were recorded, including four under 3 feet residual depth, one between 3 – 6 feet residual depth, and one between 6 – 9 feet residual depth (Figure 46). All pools but one had wood in them.

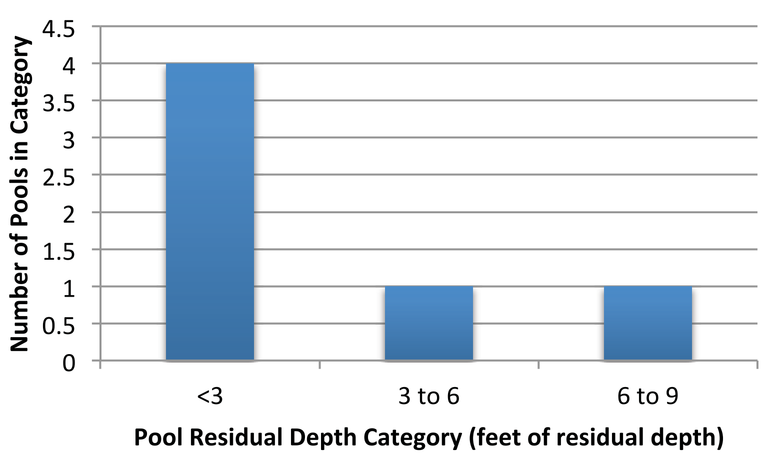


Figure 46. Reach 4 residual pool depth and count of total pools in the reach.

5.4.3 Side Channels

Side channels in Reach 4 accounted for 2% of the habitat area of the reach. A total of four side channels were identified with 5 pieces of wood total. An apex log jam was identified at the upstream end of the RM 12.77 side channel (Figure 48). The RM 13.4 side channel also had a log jam at its upstream end, creating a split-flow condition around a stable, well-vegetated island. One small off channel wetland was identified in Reach 4 that measured approximately 25 feet by 25 feet.

Location	Length (feet)	Dominant unit type	Wood count
RM 12.77	130	Slow water	1
RM 12.91	140	Fast water	0
RM 13.15	200	Fast water	3
RM 13.4	310	Fast water	1
TOTAL	**780**		**5**

Figure 47. Side channels identified in Reach 4.

Figure 48. Slow-moving side channel at RM 12.77 with apex log jam at the upstream end.

5.4.4 Large Woody Material

Reach 4 averaged 59 pieces of wood per mile (compared to the study average of 96 pieces/mile) (Table 14). The frequency of wood is largely due to the high number of small wood found in the reach. Total wood count was 81, with 84% small, 15% medium, and 1% large. Two log jams were present, both apex log jams. One jam had 5 medium logs and 15 small qualifying logs; the other had 1 medium and 9 small. Together, the log jams composed 34% of large wood.

Table 14. Large woody material quantities in Reach 4 (1.38 miles)

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in x 35 ft)	Total
Number of Pieces	68	12	1	81
Number of Pieces/Mile	49	9	1	59
Num. of medium/large pieces	13			
Num. of medium/large pieces/mile	9.4			
Number of jams/mile	2.17 jams/mile			
Number of Jams*	2			

* Jams consist of at least 10 qualifying pieces of wood whose numbers are reflected in the total wood count.

5.4.5 Substrate and Fine Sediment

Based on ocular estimates, Reach 4 bed substrate was primarily cobble (58%) with gravel and boulder subdominant (31% and 8% respectively) (Figure 49). Boulder counts were significantly lower than Reaches 1 and 2, which had boulder counts of 19% and 20%, respectively.

Percent fines (<2mm) were low to moderate with moderate consistency. Ocular measurements estimated 5% sand (Figure 49) whereas pebble counts estimate fines at 13% and 12% (Figure 49, and Figure 50).

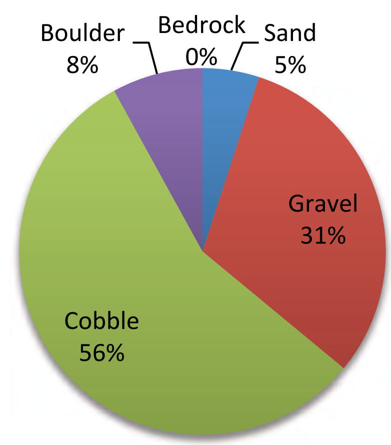
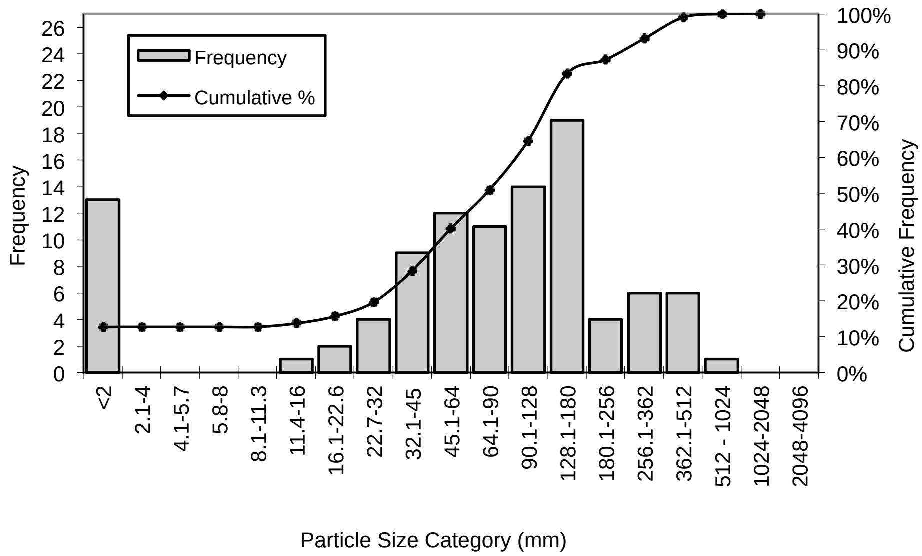


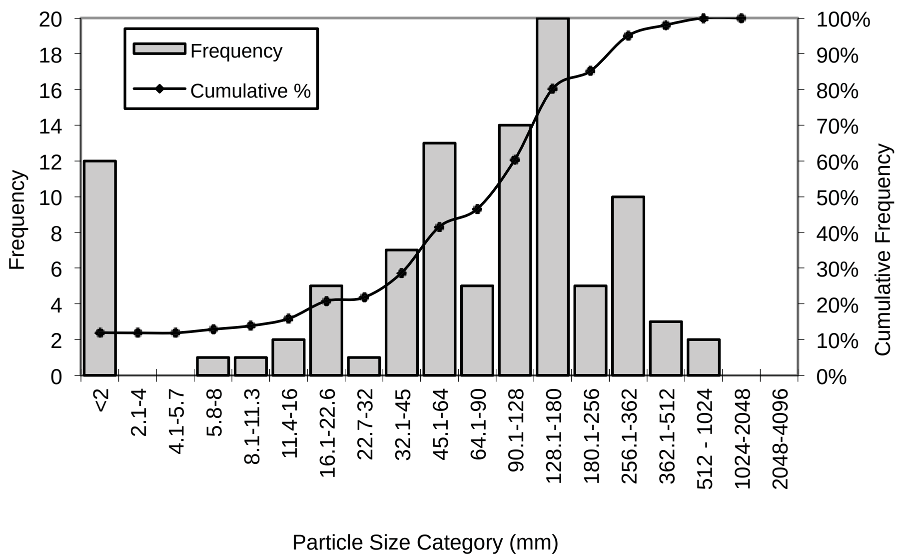
Figure 49. Percent composition of bed substrate based on ocular estimates, Reach 4.



Material	Percent Composition
Sand	13%
Gravel	27%
Cobble	47%
Boulder	13%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	1
D16	24
D50	88
D84	193
D95	410

Figure 50. Grain size distribution and particle size classes from pebble count taken at RM 12.45, Reach 4.



Material	Percent Composition
Sand	12%
Gravel	30%
Cobble	44%
Boulder	15%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	1
D16	16
D50	40
D84	190
D95	407

Figure 51. Grain size distribution and particle size classes from pebble count taken at RM 13.05, Reach 4.

5.4.6 Riparian Corridor

Reach 4 has a narrow riparian corridor, with significant human impacts near the river from residences, farming practices, and roads on both the north and south sides of the river

Four n^{th} unit measurements were performed in Reach 4. Within the four units, 20% of the riparian corridor was identified as having no vegetation, 20% as grassland/forb, and 60% as small trees measuring 9.0 – 20.9 in. diam. (Figure 52). The overstory is dominated by cottonwoods, with additional units of ponderosa and Douglas fir. The understory was dominated by alder.

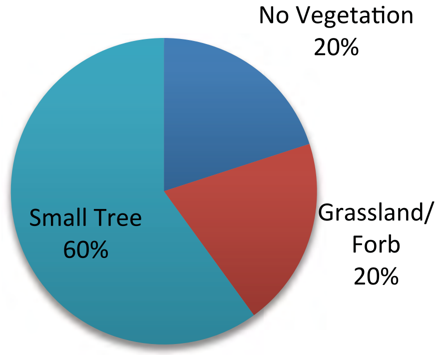


Figure 52. Dominant riparian vegetation identified within 100 feet of river by ocular estimates, Reach 4.

5.5 REACH 5

Location: River mile 13.60 (confluence with Buttermilk Creek) – 16.19 (2.59 miles)

Survey Date: 10/25/2013 – 10/28/2013

Survey Crew: Jonathan Graca, Ben Gardner

Figure 53. Reach 5 is a lower gradient, highly braided reach with vastly improved habitat characteristics compared to lower reaches in this study area.

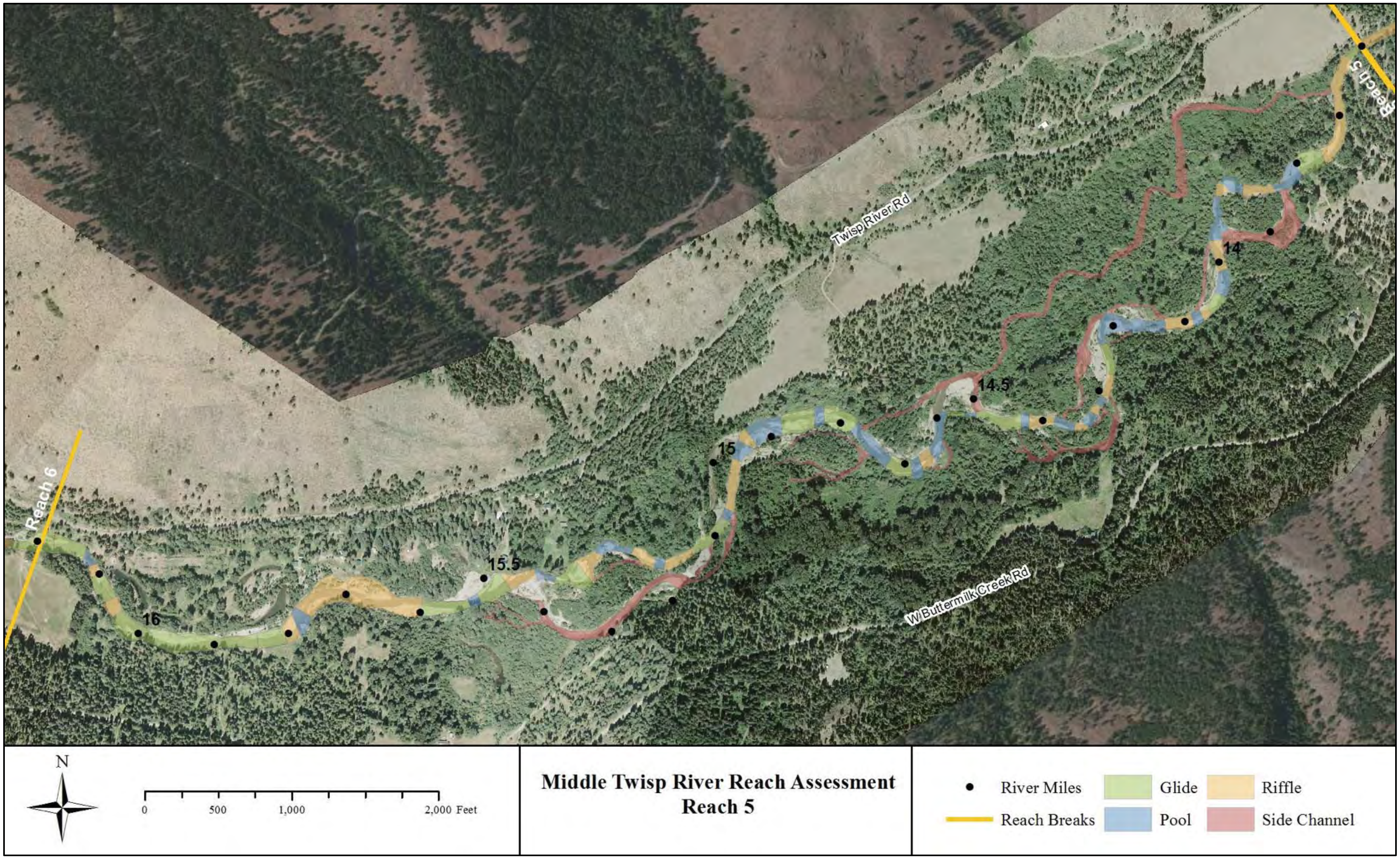


Figure 54. Reach 5 locator and habitat unit composition map.

5.5.1 Habitat Unit Composition

Reach 5 is a dynamic, lower gradient, braided reach with excellent habitat. Habitat area composition was relatively equal amongst the four habitat characteristics: Fast-moving water accounted for the majority of the habitat area with 30% glides and 29% riffles. The 19 side channels within the reach accounted for 18% of the habitat area of the reach, and 34 pools accounted for 23% of the habitat area. This is the highest percentage of both side channels and pools within the study area (Figure 55).

Four habitat units were designated “braided” where three or more roughly parallel channels were structured during bankfull flow and separated from each other by unstable islands. While only the four units were designated as braided, much of the reach could potentially be considered braided because of its highly sinuous nature and significant number of side channels that wind in and out of the main channel. More channel units were not designated as braided during the study because of the complexities in identification of braided streams. Specifically, it was difficult to accurately identify bankfull flow indicators within this low gradient, meandering reach.

Figure 55. Habitat Composition for Reach 5.

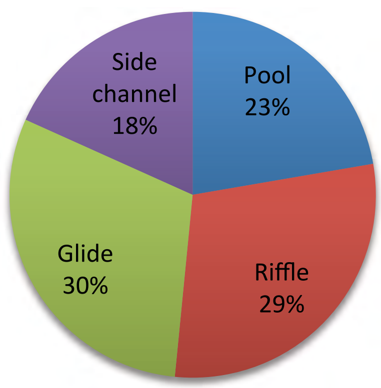


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Figure 56. Bankful widths varied from 48 – 200 feet in Reach 5. The above photo is taken near RM 15.4 where the bankfull width was recorded at 200 feet.

5.5.2 Pools

There is significant high-quality pool habitat throughout Reach 5, including 20 pools with 1-3 feet of residual depth and 14 pools of 3-6 feet residual depth. Pool frequency is 13.12 pools/mile (compared to the study area average of 7 pools/mile) (Figure 57) and 4.2 channel widths/pool – the lowest frequency in the study area. Unlike downstream reaches, many of the pools are formed in a back-to-back sequence, with short (non-qualifying) riffles or glides between them. Dozens of salmon redds were observed in marked and unmarked areas throughout the reach.

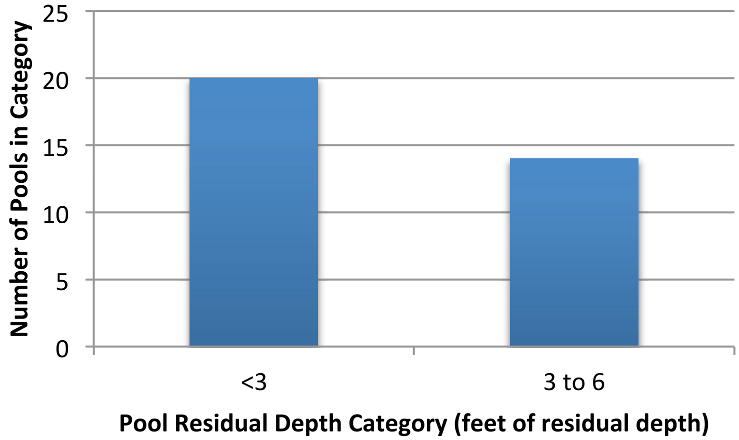


Figure 57. Reach 1 residual pool depth and count of total pools in the reach.

Figure 58. Looking downstream at a six-foot deep pool at RM 14.35. Note side channel entering on river right.

5.5.3 Side Channels

Reach 5 had the most side channel habitat area within the study area. Nineteen side channels were identified, accounting for 18% of the habitat area (Figure 55) within the reach. In total, side channels measured 3 linear miles. Of the 19 side channels, 18 were slow-water side channels and 1 was a fast-water side channel. Reach 5 had the longest side channel, measuring nearly a mile (4956 feet). While this channel had significant wood accumulation throughout the channel, only a fraction of the wood (34 pieces) quantified as LWD. Much of the wood was slightly shorter than the minimum length for a small piece of LWD and thus was not counted.

Four off-channel wetlands were also identified in Reach 5, ranging in size from 150 square feet to approximately 8000 square feet. In total, the off-channel wetlands identified comprised 12,050 square feet.

Location	Length (feet)	Dominant unit type	Wood count
RM 13.65	4956	Slow water	34
Enters RM 13.65 side channel	120	Slow water	4
RM 14.16	775	Slow water	5
RM 14.05	400	Slow water	4
RM 14.14	375	Slow water	9
RM 14.15	110	Slow water	0
RM 14.21	820	Slow water	11
RM 14.31	1255	Slow water	13
RM 14.32	100	Slow water	3
RM 14.65	750	Slow water	14
RM 14.74	1900	Slow water	9
RM 15.07	900	Slow water	6
RM 15.43	2156	Slow water	22
RM 15.12	273	Slow water	3
RM 15.18	20	Fast water	0
RM 15.24	400	Slow water	7
RM 15.46	100	Slow water	0
RM 15.4	350	Slow water	2
TOTAL	**15760**		**146**

Figure 59. Side channels identified in Reach 5.

Figure 60. Downstream end of 4956-foot side channel that exits at RM 13.65. While there was significant wood throughout the channel (see left of photo), most of the wood was not long enough to quantify as small wood. As a result, only 34 pieces of wood quantified as LWD.

5.5.4 Large Woody Material

Reach 5 had the most wood in the reach with 537 pieces distributed at a rate of 207 pieces per mile– the highest wood count and wood per mile in the study area (Table 15). Small wood comprised 74% of the wood count; medium accounted for 18% of the wood count; and large accounted for 8%. This low-gradient reach was heavily braided and sinuous, encouraging large wood to accumulate at apex points and along low-angle gravel bars. With over 15,000 feet of side channel in Reach 5, the side channels accounted for 27% (145 pieces) of the total wood count for the reach. In total, they comprised 155 pieces of wood in Reach 5. Ten log jams were present in the reach, measuring 3.9 jams/mile, also the high rate with the study area.

While the reach had excellent habitat overall, a significant amount of wood was observed in the river near RM 15.4, including a log jam in SO 181, that appeared to have been cut instream just upriver.

Figure 61. Significant portions of wood were observed in SO 181 that appeared to have been cut instream just upstream of where this photo was captured.

Table 15. Large woody material quantities in Reach 5 (2.59 miles).

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in x 35 ft)	Total
Number of Pieces	396	94	47	537
Number of Pieces/Mile	153	36	18	207
Num. of medium/large pieces	141			
Num. of medium/large pieces/mile	54.4			
Number of jams/mile	3.86 jams/mile			
Number of Jams*	10			

* Jams consist of at least 10 qualifying pieces of wood whose numbers are reflected in the total wood count.

5.5.5 Substrate and Fine Sediment

Ocular estimates for substrate in reach 5 varied significantly from downstream channels. Cobble and Gravel both accounted for 47%. Boulder and bedrock were not observed in our ocular estimates. Percent fines (<2mm) were low, and relatively consistent amongst measurement techniques. Ocular observations estimated 6% sand (Figure 62). Both pebble counts estimate 10% sand (Figure 63, and Figure 64). This relatively low observed distribution of fines was consistent with the observed lower gradient of the reach and improved spawning potential observed throughout Reach 5.

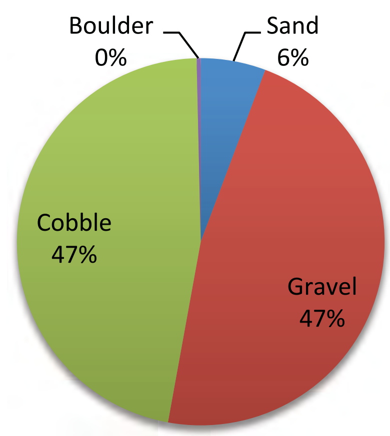
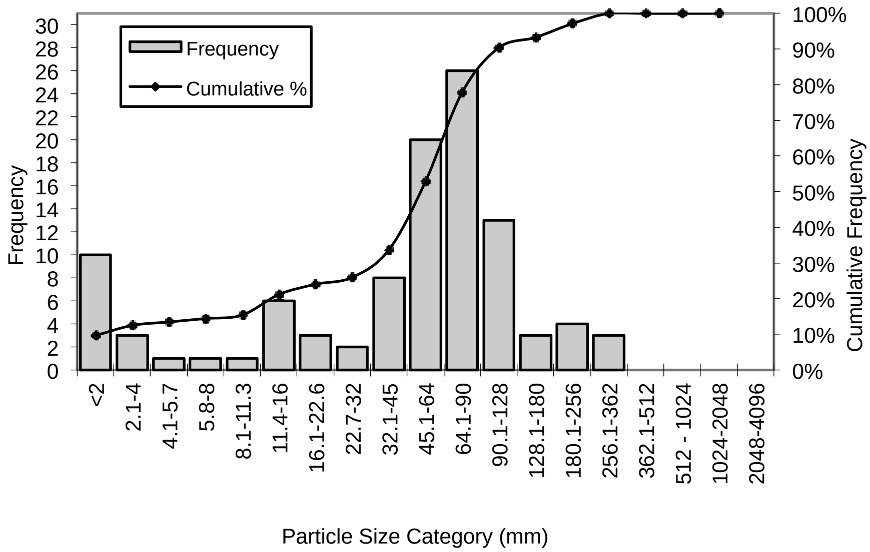


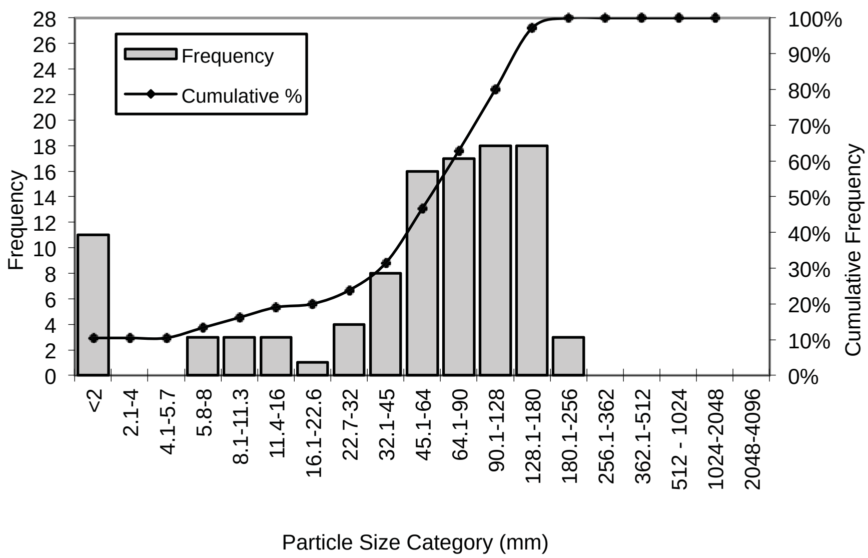
Figure 62. Percent composition of bed substrate based on ocular estimates, Reach 5.



Material	Percent Composition
Sand	10%
Gravel	43%
Cobble	44%
Boulder	3%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	1
D16	15
D50	61
D84	109
D95	214

Figure 63. Grain size distribution and particle size classes from pebble count taken at RM13.65, Reach 5.



Material	Percent Composition
Sand	10%
Gravel	36%
Cobble	53%
Boulder	0%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	1
D16	11
D50	69
D84	140
D95	174

Figure 64. Grain size distribution and particle size classes from pebble count taken at RM 16.86, Reach 5.

5.5.6 Riparian Corridor

Reach 5 had a variable but relatively young riparian corridor. With the road 1,000 feet or more from the river along most of the reach, the riparian buffer along Reach 5 is much wider on average than downstream reaches where the road is often within 50 – 100 feet of the river.

In total, 14 n^{th} unit measurements were performed along Reach 5. Shrub/seedling measuring 1 – 4.9 in. diam. accounted for 43% of the riparian habitat measured ; 29% sapling/pole measuring 5 – 8.9 in. diam.; 21% small trees measuring 9 – 20.9 in. diam.; and 7% having no vegetation. Overstory was composed of primarily cottonwoods and alders. Understory was primarily alder and dogwood with one unit of cottonwood understory. No human-caused unstable banks were observed within within n^{th} unit measurements.

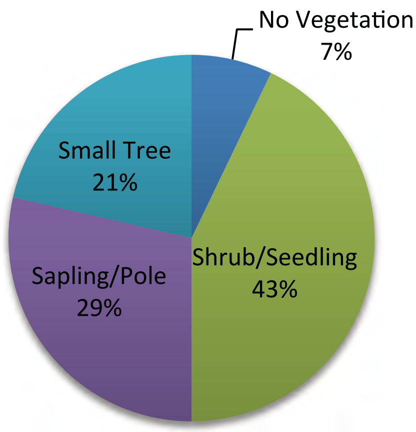


Figure 65. Dominant riparian vegetation identified within 100 feet of river by ocular estimates, Reach 5.

5.6 REACH 6

Location: River mile 16.19 – 18.12 (1.93 miles)

Survey Date: 10/28/2013 – 10/29/2013

Survey Crew: Jonathan Graca, Ben Gardner

Figure 66. Reach 6 had 15 pools translating into 7.7 pools per mile. While pools were prevalent, they were relatively short in length, many only slightly longer than the channel width. Note the pool/glide/pool sequence at RM 16.9.

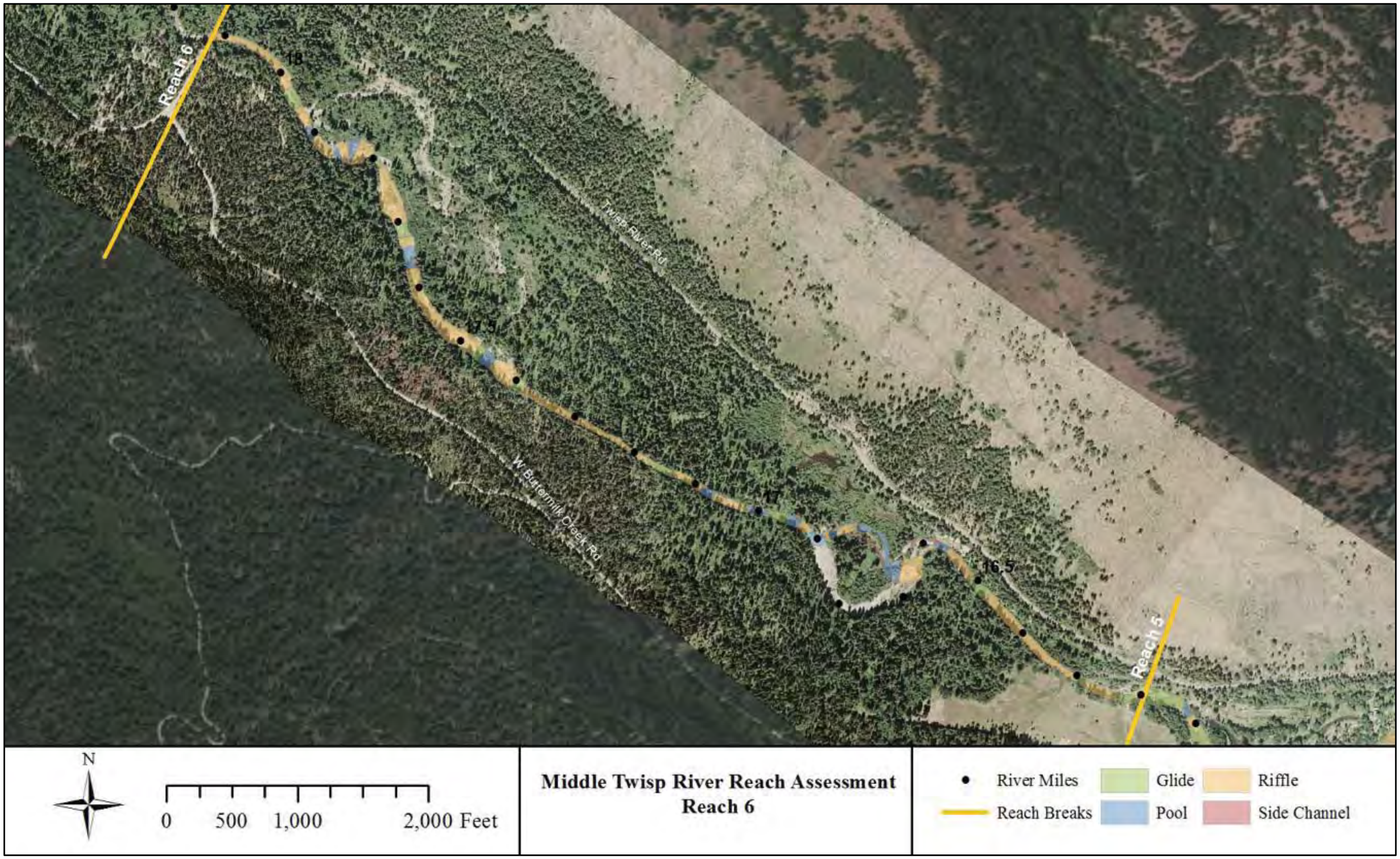


Figure 67. Reach 6 locator and habitat unit composition map

5.6.1 Habitat Unit Composition

While Reach 6 riffles and glides together composed 84% of the habitat area (69% and 15% respectively), there was a high pool frequency as well (7.7 pools/mile), which accounted for 15% of the habitat area. Side channels composed only 1% of the habitat area (Figure 68).

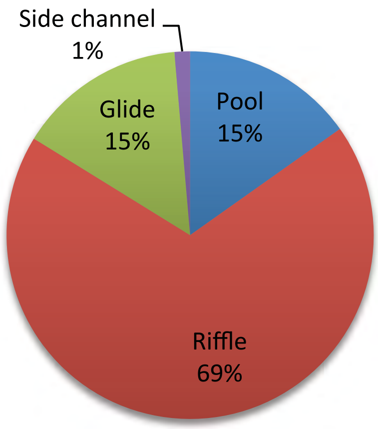


Figure 68. Habitat Composition for Reach 6.

5.6.2 Pools

High quality pool habitat was prevalent in Reach 6. Fifteen pools were identified, translating into a pool frequency of 7.7 pools/mile – the second highest frequency in the study area – and a frequency of 9.2 channel widths/pool. Of the 15 pools, 13 have residual depths of 1 – 3 feet and 2 have residual depths of 3 – 6 feet. Reach 6, more than others, is composed of long spans of fast water punctuated by high densities of relatively short pools in between.

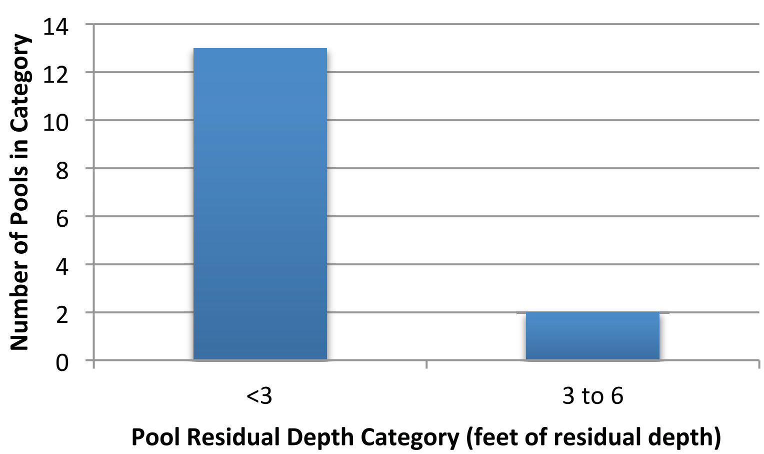


Figure 69. Residual pool depth and count of total pools in Reach 6.

5.6.3 Side Channels

Two side channels totaling 1,125 feet were identified in Reach 6 (Table 16), accounting for 1% of the habitat area of the reach (Figure 68). Both are slow moving side channels totaling 5 pieces of LWD.

Table 16. Side channels identified in Reach 6.

Location	Length (feet)	Dominant unit type	Wood count
RM 16.59	625	Slow water	2
RM 16.65	500	Slow water	3

5.6.4 Large Woody Material

Reach 6 had the second highest count of large wood in the study area with 169 pieces distributed at 88 pieces/mile (Table 17). Reach 6 had significantly more large wood than other reaches in the study area. Small wood accounted for 59% of the total wood count; medium wood accounted for 20% of the total wood count; and large wood accounted for 21% of the total wood count. Reach 6 had the second highest log jam count, with three jams totaling 30 logs.

Table 17. Large woody material quantities in Reach 6.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in x 35 ft)	Total
Number of pieces	100	34	35	169
Number of pieces/mile	52	18	18	88
Num. of medium/large pieces	36			
Num. of medium/large pieces per mile	18.7			
Number of jams/mile	1.56 jams/mile			
Number of jams*	3			

* Jams consist of at least 10 qualifying pieces of wood whose numbers are reflected in the total wood count.

5.6.5 Substrate and Fine Sediment

Ocular observations estimated a majority of the substrate was cobble (55%) with gravel subdominant (38%). Boulders account for an additional 3%. Percent fines (<2mm) is low to moderate, ranging from 4% in ocular observations, to 13% and 4% observed in the two pebble counts (Figure 70, and Figure 71).

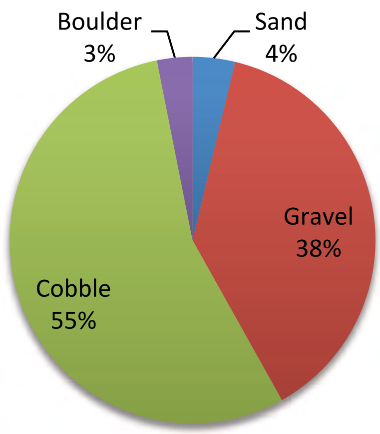
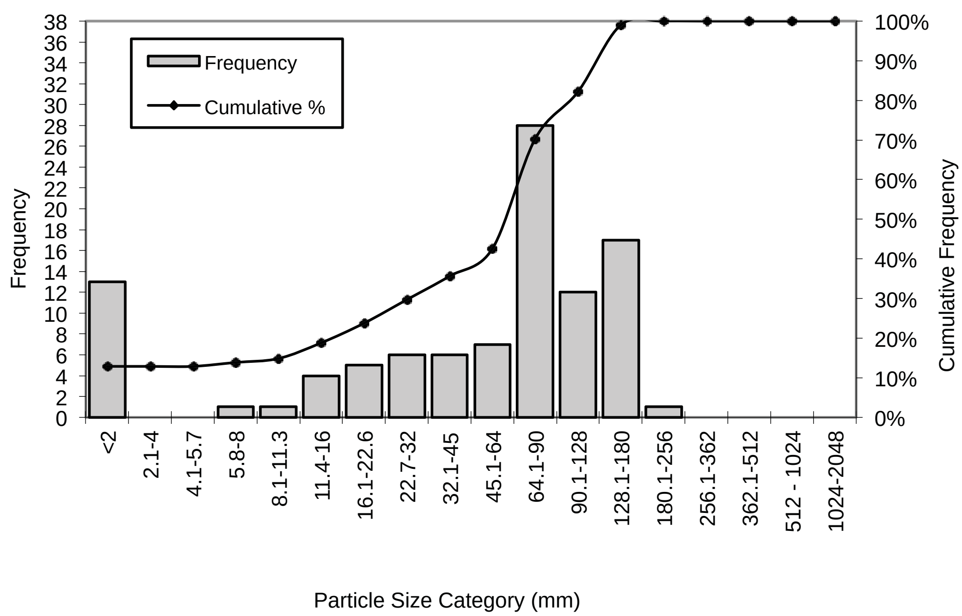


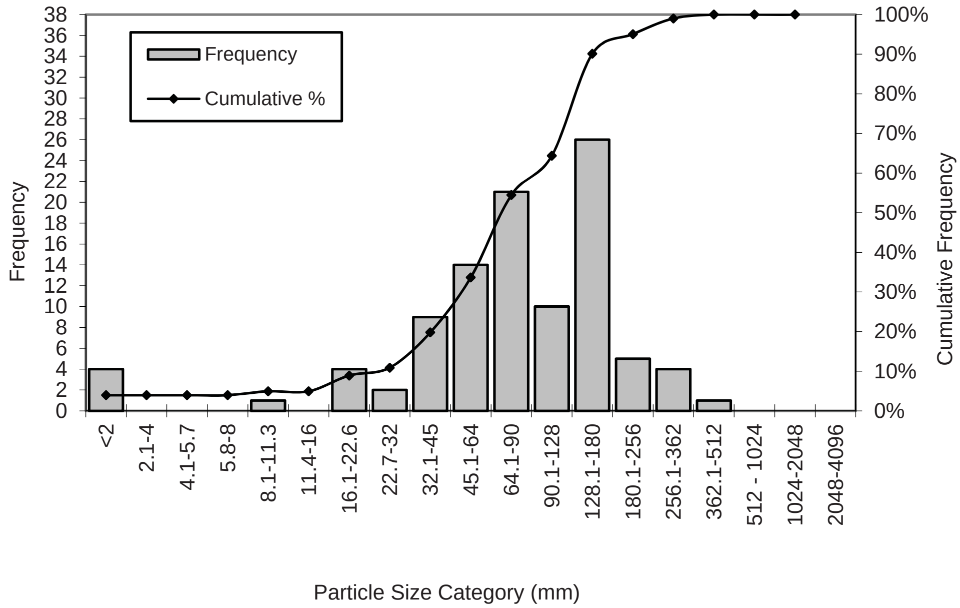
Figure 70. Percent composition of bed substrate based on ocular estimates, Reach 6.



Material	Percent Composition
Sand	13%
Gravel	30%
Cobble	57%
Boulder	0%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	1
D16	13
D50	29
D84	134
D95	168

Figure 71. Grain size distribution and particle size classes from pebble count taken at RM 16.94, Reach 6.



Material	Percent Composition
Sand	4%
Gravel	30%
Cobble	61%
Boulder	5%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	11
D16	39
D50	84
D84	168
D95	255

Figure 72. Grain size distribution and particle size classes from pebble count taken at RM 18.11, Reach 6.

5.6.6 Riparian Corridor

Eight nth unit measurements were completed in Reach 6. The riparian corridor observed in these units consisted of largely younger vegetation with 63% small trees measuring 9 – 20.9 in. diam.; 25% shrub/seedling measuring 1 – 4.9 in. diam.; and 12% identified as having no vegetation. The young vegetation is primarily a result of recent flood disturbance to the riparian areas sampled.

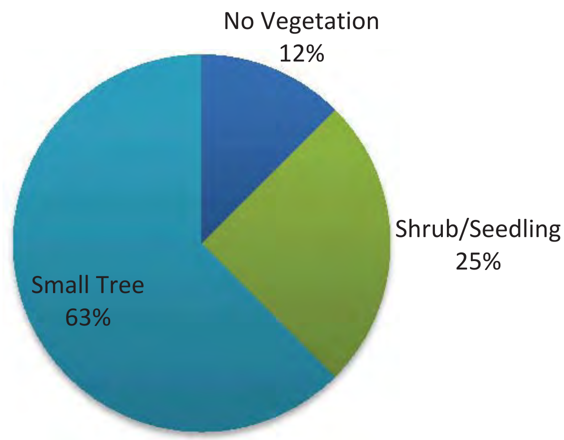


Figure 73. Dominant riparian vegetation identified within 100 feet of river by ocular estimates, Reach 6.

6 References

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Appendix B

Reach-Based Ecosystem Indicators (REI)

Middle Twisp River (RM 7.8 – 18.12)

Contents

1 Introduction

1.1 BACKGROUND

The REI provides a consistent means of evaluating biological and physical conditions of a watershed in relation to regional standards and known habitat requirements for aquatic biota. These indicators, along with other scientific evaluations, describe the current quality of stream biophysical conditions and can help inform restoration targets and actions. The REI indicators used in this assessment are adaptations from previous efforts including the NMFS matrix of pathways and indicators (NMFS 1996) and the USFWS (1998). With a few exceptions, the REI are based on the USBR's latest adaptations and use of these indicators (USBR 2012).

The REI evaluation for the Middle Twisp River was conducted using field data, observations, previous studies, and available data for the study area. In particular, the rankings were developed based on: 1) quantitative inventory information from the Habitat Assessment performed as part of the Reach Assessment using USFS (2010) protocols, 2) assessment of geomorphic patterns and processes and how they have deviated, if at all, from historical conditions, and 3) analysis of existing watershed assessments and data (e.g. available ArcMap layers and shapefiles). Functional ratings include **adequate**, **at risk**, or **unacceptable**. The REI analysis helps to summarize habitat impairments and to distill the impairments down to a consistent value that can be compared among reaches.

1.2 SUMMARY OF RESULTS

Reaches in the downstream portion of the study area (Reaches 1-4) were the most impacted reaches, having the highest number of **at risk** and **unacceptable** ratings. Although Reach 4 has the highest at ten out of eleven indicators rated either **at risk** or **unacceptable**, Reach 2 is the least functional reach in the study area due to six **unacceptable** ratings (and two **at risk** ratings). Reaches 1 and 3 are close behind, each having 9 **unacceptable** or **at risk** ratings out of 11 categories. LWM was rated **unacceptable** in all reaches except Reach 5, in which the highest number of LWM was measured and from which the criteria for jams/mile was determined. The downstream reaches have more naturally confined channels, which results in less LWM retention throughout these reaches. Reaches 5 and 6 in the upstream portion of the study area were generally more functional overall. Reach 5 had no **unacceptable** ratings and Reach 6 had only one. For the study area as a whole, **at risk** was the most common rating (34), followed by **unacceptable** (16), then **adequate** (16).

2 Metrics & Indicators

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
Watershed Scale					
Watershed Condition	Effective Drainage Network and Watershed Road Density	Increase in Drainage Network/Road Density	Zero or minimum increases in active channel length correlated with human caused disturbance. Road density <1 miles/miles2.	Low to moderate increase in active channel length correlated with human caused disturbances. Road density 1-2.4 miles/miles2.	Greater than moderate increase in active channel length correlated with human caused disturbances. Road density >2.4 miles/miles2.
	Disturbance Regime	Natural/Human Caused	Environmental disturbance is short-lived; predictable hydrograph, high quality habitat and watershed complexity providing refuge and rearing space for all life stages or multiple life-history forms. Natural processes are stable.	Scour events, debris torrents, or catastrophic fires are localized events that occur in several minor parts of the watershed. Resiliency of habitat to recover from environmental disturbances is moderate.	Frequent flood or drought producing highly variable and unpredictable flows, scour events, debris torrents, or high probability of catastrophic fire exists throughout a major portion of the watershed. The channel is simplified, providing little hydraulic complexity in the form of pools or side channels. Natural processes are unstable.
Flow/Hydrology	Streamflow	Change in Peak/Base Flows	Magnitude, timing, duration, and frequency of peak flows within a watershed are not altered relative to natural conditions of an undisturbed watershed of similar size, geology, and geography.	Some evidence of altered magnitude, timing, duration and/or frequency of peak flows relative to natural conditions of 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 of an undisturbed watershed of similar size, geology, and geography.
Water Quality	Temperature	Daily maximum and 7-day mean maximum temperatures	Bull Trout: Incubation 2-5°C, rearing 4-10°C, spawning 1-9°C. Salmon and Steelhead: June-Sept 15°C, Sept-May 12°C, rearing 15°C, migration 15°C, adult holding 15°C. OR 7-day daily maximum temperature performance standards: Salmon spawning 13°C, core summer salmonid habitat 16°C. Salmonid spawning, rearing and migration 17.5°C. Salmonid rearing and migration only 17.5°C.	MWMT in reach during the following life history stages: Incubation <2°C or <6°C; rearing <4°C or >13-15°C; spawning <4°C or >10°C. Temperatures in areas used by adults during the local spawning migration sometimes exceed 15°C. OR 7-day average daily maximum temperature standards are exceeded by ≤15%.	MWMT in reach during the following life history stages: Incubation <1°C or <6°C; rearing >15°C; spawning <4°C or >10°C. Temperatures in areas used by adults during the local spawning migration sometimes exceed 15°C. OR 7-day average daily maximum temperature standards are exceeded by ≤15%.
	Turbidity	Turbidity NTU's	Performance Standard: Acute <70 NTU, Chronic <50 NTU. For streams that naturally exceed these standards: Turbidity should not exceed natural baseline levels at the 95% CL <15% exceedance. OR Turbidity shall not exceed: 5 NTU over background when the background is 50 NTU or less; or a 10% increase in turbidity when the background turbidity is more than 50 NTU (WDOE 173-201A-200)	15-50% exceedance.	>50% exceedance.
	Chemical Contamination/ Nutrients	Metals/Pollutants, pH, DO, Nitrogen, Phosphorus	Low levels of chemical contamination from landuse sources, no excessive nutrients, no CWA 303d designated reaches. OR Washington State Department of Ecology standards 173-201A-200.	Moderate levels of chemical contamination from landuse sources, some excess nutrients, one CWA 303d designated reach.	High levels of chemical contamination from landuse sources, high levels of excess nutrients, more than one DWA 303d designated reach.

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
Reach Scale					
Habitat Access	Physical Barriers	Main Channel Barriers	No man-made barriers present in the mainstem that limit upstream or downstream migration at any flow.	Man-made barriers present in the mainstem that prevent upstream or downstream migration at some flows that are biologically significant.	Man-made barriers present in the mainstem that prevent upstream or downstream migration at multiple or all flows.
Habitat Quality	Substrate	Dominant Substrate/Fine Sediment	Gravels or small cobbles make up >50% of the bed materials in spawning areas. ≤12%fines/sand (<2 mm) in spawning gravel.	Gravels or small cobbles make up 30-50% of the bed materials in spawning areas. 12-17% fines (<2 mm) in spawning gravel.	Gravels or small cobbles make up <30% of the bed materials in spawning areas. >17% fines (<2 mm) in spawning gravel.
	LWM	Pieces per Mile at Bankfull	>42.5 pieces/mile >12" diameter and >35 ft long (based on data from Fox and Bolton 2007); adequate sources of woody debris available for both long- and short-term recruitment. And, at least 3 jams/mile based on Reach 5 as a reference reach for jam quantities.	Current levels are able to maintain the minimum requirements for an "adequate" rating, but potential sources for long-term woody debris recruitment are lacking in order to maintain these current levels. And less than 3 jams/mile.	Current levels are not at meeting the minimum requirements for an "adequate" rating, and potential sources of woody debris for short- and/or long-term recruitment are lacking as well. And no jams/mile.
	Pools	Pool Frequency and Quality; presence of large pools.	Pool frequency: Number of pools/mile for a given channel width: Channel width of 65-100 ft = 4 pools/mile. Pools have good cover and cool water with only a minor reduction in pool volume from fine sediment. Each reach has many large pools >1 m (3 ft) deep with good fish cover.	Pool frequency is similar to the values for the "adequate" rating, but pools have inadequate cover/temperature and/or there has been a moderate reduction of pool volume by fine sediment. Reaches have few large pools (>1 m deep) present with good fish cover.	Pool frequency is considerably lower than the values for the "adequate" rating. Pools also have inadequate cover/temperature and there has been a major reduction of pool volume by fine sediment. Reaches have no large pools (>1 m deep) with good fish cover.
	Off-Channel Habitat	Connectivity with Main Channel	Reach has many ponds, oxbows, backwaters, and other off-channel areas with cover. Side channels are low energy areas. No man-made barriers present along the mainstem that prevent access to off-channel areas.	Reach has some ponds, oxbows, backwaters, and other off-channel areas with cover. Side channels are high energy areas. Man-made barriers are present that prevent access of off-channel habitat at some flows that are biologically significant.	Reach has few or no ponds, oxbows, backwaters, and other off-channel areas. Man-made barriers are present that prevent access to off-channel habitat at multiple or all flows.
Channel	Dynamics	Floodplain Connectivity	Floodplain areas are hydrologically linked to main channel within the context of the local process domain; overbank flows occur and maintain wetland functions, and riparian vegetation and succession. Naturally confined channels are considered adequate.	Reduced linkage of wetland, floodplains and riparian areas to main channel in reaches with historically strong connectivity; overbank flows are reduced relative to historic frequency, as evidenced by moderate degradation of wetland function and riparian vegetation/succession.	Severe reduction in hydrologic connectivity between off-channel, wetland, floodplain, and riparian areas relative to historical connectivity; wetland extent drastically reduced and riparian vegetation/succession is altered significantly.
		Bank Stability/Channel Migration	Channel is migrating at or near natural rates.	Limited amount of channel migration is occurring at a faster/slower rate relative to natural rates, but significant change in channel width or planform is not detectable; large woody debris is still being recruited.	Little or no channel migration is occurring because of human actions preventing reworking of the floodplain and large woody debris recruitment; or channel migration is occurring at an accelerated rate such that channel width has at least doubled, possibly resulting in a channel planform change, and sediment supply has noticeably increased from bank erosion.
		Vertical Channel Stability	No measurable trend of aggradation or incision and	Measurable trend of aggradation of incision that has the potential to, but has not yet caused,	Enough incision has occurred that the floodplain and off-channel habitat areas have been

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
			no visible change in channel planform.	disconnection of the floodplain or a visible change in channel planform (e.g. single thread to braided.)	disconnected; or enough aggradation has occurred to create a visible change in channel planform (e.g. single thread to braided.)
Riparian Vegetation	Condition	Structure	>80% species composition, seral stage, and structural complexity are consistent with potential native community.	50-80% species composition, seral stage, and structural complexity are consistent with potential native community.	<50% species composition, seral stage, and structural complexity are consistent with potential native community.
		Disturbance (Human)	>80% mature trees (medium-large) in the riparian buffer zone (defined as a 30 m belt along each bank) that are available for recruitment by the river via channel migration; <20% disturbance in the floodplain (e.g. agriculture, residential, roads, etc.); <2 miles/miles2 road density in the floodplain.	50-80% mature trees (medium-large) in the riparian buffer zone (defined as a 30 m belt along each bank) that are available for recruitment by the river via channel migration; 20-50% disturbance in the floodplain (e.g. agriculture, residential, roads, etc.); 2-3 miles/miles2 road density in the floodplain.	<50% mature trees (medium-large) in the riparian buffer zone (defined as a 30 m belt along each bank) that are available for recruitment by the river via channel migration; >50% disturbance in the floodplain (e.g. agriculture, residential, roads, etc.); >3 miles/miles2 road density in the floodplain.
		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.

3 REI Ratings

This section discusses the results for each indicator, rated at either the reach-scale or watershed-scale for all six reaches.

3.1 WATERSHED-SCALE RATINGS

General Characteristics	General Indicators	Specific Indicators	Rating	Discussion
Watershed Scale				
Watershed Condition	Effective Drainage Network and Watershed Road Density	Increase in Drainage Network/Road Density	At Risk Condition	Road density was calculated using USFS roads and Chelan County roads shapefiles. Road density was calculated for the watershed area contributing to the study area as determined in the Streamstats online mapper application (USGS 2014). Areas of overlap in the data sets were removed to eliminate over overestimation of road density. Road density for the contributing watershed was 1.54 miles/mile2, which puts the study area within the At Risk category.
	Disturbance Regime	Natural/Human Caused	At Risk Condition	This disturbance history rating reflects historical accounts of riparian and hillslope timber harvest, mining, grazing, agriculture and roads and residential development. These activities have been shown to create channel instability and decrease the ability of the system to respond to natural disturbance regimes such as fire or flood. The watershed has a naturally frequent fire regime, annual snowmelt flooding and infrequent rain-on-snow floods, and active tributary alluvial fans. The channel has reduced complexity and floodplain connection, and is shown to be incising in some areas and aggrading in others. Furthermore, fire suppression within the basin has elevated the risk of potential catastrophic disturbance (e.g. stand-replacing fire) to the study area. These alterations include past human disturbance to which the system is still recovering from, or on-going "press" disturbances that have a persistent and long-lasting impact. Based on this information, the Twisp receives a rating of At Risk.
Flow/Hydrology	Streamflow	Change in Peak/Base Flows	At Risk Condition	The hydrology of the watershed contributing to the Middle Twisp study area on the Twisp River is driven by a combination of precipitation and snowmelt. Annual snowmelt flooding in the spring and early summer, with infrequent rain-on-snow floods dominates the season streamflow pattern in the basin. Snowmelt runoff is primarily driven by changes in ambient air temperature, snowpack mass, and the elevation distribution of the season's snowpack. Peak runoff usually occurs from April through July, with the highest rates typically in late June. The Twisp River typically returns to baseflow by late August. Many of the land-use activities and channel alterations affecting the Twisp River have been shown to change one or all of the above-mentioned attributes of peak flows in other basins. Climate change models indicate that rainfall is expected to increase one to two percent by 2040, and four percent by 2080 (e.g. Mote and Salanthe 2009) and likely result in an increase in winter stream flows, earlier and lower peak runoff, and lower summer baseflows. These analyses suggest that human-induced climate change is likely to have an effect on the magnitude, timing, duration, and frequency of streamflows. Based on the effects of past watershed management, and the potential effects of climate change, this indicator is rated At Risk for the middle Twisp River.
Water Quality	Temperature	Daily maximum and 7-day mean daily maximum temperatures	Unacceptable Risk Condition	Two excursions above temperature threshold limits in 1989 resulted in the original listing of the Twisp River on the 1996 Washington state 303(d) list (Andonaegui 2000). As of 2012, the Twisp River (measured at RM 26.096-28.154) is listed as a "waters of concern" by the Department of Ecology for temperature excursions beyond the criterion from measurements collected in 1999 at station 'Twisp River at War Creek CG'. Additional recent measurements show that the Lower Twisp River continues to have high temperatures throughout the summer months. Near the mouth of the Twisp the highest 7-day average daily maximum temperature recorded during the summer exceeded 16°C by about 26% in 2001 and 30% in 2005. Threshold criterion were also exceeded by over 15% at two other locations in those years (USBR 2008 App I). Temperature data from 2008 and 2009 show 7-day average daily maximum temperatures with over 15% exceedance of 16°C consistently from mid-July through mid-September. No more recent temperature data is available for the Middle Twisp study area at this time, although it is worth noting there are several natural springs around RM 16-18 and potentially RM 7-9.6 that contribute localized cooling and cool water recharge for the Middle Twisp River.
	Turbidity	Turbidity NTU's	N/A	Data was unavailable.
	Chemical Contamination/ Nutrients	Metals/Pollutants, pH, DO, Nitrogen, Phosphorus	N/A	Data was unavailable.

3.2 REACH-SCALE RATINGS

Pathway	General Indicators	Specific Indicators	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Habitat Access	Physical Barriers	Main Channel Barriers	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate
			There are no anthropogenic barriers in the main channel in Reach 1.	There are no anthropogenic barriers in the main channel in Reach 2.	There are no anthropogenic barriers in the main channel in Reach 3.	There are no anthropogenic barriers in the main channel in Reach 4.	There are no anthropogenic barriers in the main channel in Reach 5.	There are no anthropogenic barriers in the main channel in Reach 6.
Habitat Quality	Substrate	Dominant Substrate/ Fine Sediment	Adequate	At Risk	Adequate	At Risk	Adequate	At Risk
			Two pebble counts: Gravel+Cobble: 76% + 65% Sand: 7% + 9% Ocular Average Gravel+Cobble: 76% Sand: 5%	Two pebble counts: Gravel+Cobble = 72% + 70% Sand = 14% + 13% Ocular Average Gravel+Cobble = 73% Sand = 7%	Two pebble counts: Gravel+Cobble = 90% + 85% Sand = 9% + 5% Ocular Average Gravel+Cobble = 86% Sand = 7%	Two pebble counts: Gravel+Cobble = 74% + 74% Sand = 13% + 12% Ocular Average Gravel+Cobble = 87% Sand = 5%	Two pebble counts: Gravel+Cobble = 87% + 90% Sand = 10% + 10% Ocular Average Gravel+Cobble = 94% Sand = 6%	Two pebble counts: Gravel+Cobble = 87% + 91% Sand = 13% + 4% Ocular Average Gravel+Cobble = 93% Sand = 4%
	LWM	Pieces per Mile at Bankfull	Unacceptable	Unacceptable	Unacceptable	Unacceptable	Adequate	Unacceptable
			Total pieces = 55 M+L pieces/mi = 12 Jams/mi = 0 Limited availability of large wood for future recruitment.	Total pieces = 18 M+L pieces/mi = 11 Jams/mi = 0 Limited availability of large wood for future recruitment.	Total pieces = 131 M+L pieces/mi = 18 Jams/mi = 0.82 Minimal availability of large wood for future recruitment.	Total pieces = 89 M+L pieces/mi = 9 Jams/mi = 1.45 Minimal availability of large wood for future recruitment.	Total pieces = 537 M+L pieces/mi = 54 Jams/mi = 3.86 Only moderate large wood available for future recruitment due to the young seral stage of the riparian vegetation.	Total pieces = 169 M+L pieces/mi = 36 Jams/mi = 1.55 Moderate availability of large wood for future recruitment.
	Pools	Pool Frequency and Quality; presence of large pools.	At Risk	Unacceptable	At Risk	At Risk	Adequate	At Risk
			Total Pools = 5 Pools/mi = 3.7 Pools > 3 ft = 1 Pools had moderate cover	Total Pools = 1 Pools/mi = 1.54 Pools > 3 ft = 0	Total Pools = 11 Pools/mi = 4.5 Pools > 3 ft = 3 Only 3 pools deeper than 3 ft with less than adequate cover	Total Pools = 6 Pools/mi = 4.3 Pools > 3 ft = 2 Only two pools deeper than 3 ft with moderate cover	Total Pools = 34 Pools/mi = 13.2 Pools > 3 ft = 14 Pools had moderate cover	Total Pools = 15 Pools/mi = 7.7 Pools > 3 ft = 2 Only two pools deeper than 3 ft with moderate cover
	Off-Channel Habitat	Connectivity with Main Channel	At Risk	Adequate	At Risk	At Risk	Adequate	At Risk
			Total SC = 1 Fast water = 1 Slow water = N/A Cover = limited Is mostly a naturally	Total SC = 0 Fast water = N/A Slow water = N/A Cover = N/A Is a naturally confined	Total SC = 2 Fast water = N/A Slow water = 2 Cover = limited SC total 2% of the reach	Total SC = 4 Fast water = 3 Slow water = 1 Cover = limited SC total 2% of the reach	Total SC = 19 Fast water = 1 Slow water = 18 Cover = moderate-adequate	Total SC = 2 Fast water = N/A Slow water = 2 Cover = moderate

Pathway	General Indicators	Specific Indicators	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
			confined channel, therefore would expect to have some, but not substantially greater amounts off-channel habitat.	channel . Would not expect to have off-channel habitat.	length. Historically more side channels would be expected in this reach.	length. Historically more side channels would be expected in this reach.	One side channel was approximately 1 mile long. Total length of side channels was 18% of the reach length.	SC total 1% of the reach length. Historically more side channels would be expected in this reach.
Riparian Vegetation	Condition	Structure	Unacceptable	Unacceptable	At risk	Unacceptable	At Risk	At Risk
			25% small tree 75% grass/forb Seral stage = should see more patches of mature trees Species composition is adequate Structural complexity is lacking 43.1% of 100 ft riparian buffer is cleared	100% small tree Seral stage = should see more patches of mature trees Species composition should be more varied coniferous over story and hardwood understory species Structural complexity is completely lacking 11.6% of 100 ft riparian buffer is cleared	29% small tree 29% grass/forb 14% shrub/seedlg 14% sapling/pole 14% M+L trees Seral stage = should see more patches of mature Cottonwoods, Douglas Fir, and Ponderosa Pine. Species composition is adequate Structural complexity is adequate 12.9% of 100 ft riparian buffer is cleared	60% small tree 20% grass/forb 20% no vegetation Seral stage = should see more patches of mature Cottonwoods, Douglas Fir, and Ponderosa Pine, which would contribute to a healthier structural complexity as well. Species composition is lacking 54.1% of 100 ft riparian buffer is cleared	21% small tree 7% no vegetation 43% shrub/seedlg 29% sapling/pole Seral stage = should see more patches of mature trees closer to the channel, since larger, older trees are present within reach, but outside of the 100 ft riparian buffer. This would contribute to a healthier structural complexity. Species composition is adequate 6.4% of 100 ft riparian buffer is cleared	63% small tree 12% no vegetation 25% shrub/seedlg Seral stage = should see slightly more patches of mature Cottonwoods, Douglas Fir, and Ponderosa Pine, which would contribute to a healthier structural complexity. Species composition is adequate. 4.2% of 100 ft riparian buffer is cleared
		Disturbance (Human)	Unacceptable	Unacceptable	At Risk	Unacceptable	At Risk	At Risk
			Disturbed floodplain = 70% Road Density = 3.45 miles/miles2 Very few medium-large trees within the riparian buffer available for recruitment of the river via channel migration	Disturbed floodplain = 60% Road Density = 0 miles/miles2 Very few medium-large trees in the riparian buffer available for recruitment of the river via channel migration	Disturbed floodplain = 50% Road Density = 1.80 miles/miles2 Moderate amounts of medium-large trees in the riparian buffer available for recruitment of the river via channel migration	Disturbed floodplain = 80% Road Density = 2.88 miles/miles2 Minimal amounts of medium-large trees in the riparian buffer available for recruitment of the river via channel migration	Disturbed floodplain = 30% Road Density = 1.33 miles/miles2 Moderate-to-high amounts of medium trees in the riparian buffer available for recruitment of the river via channel migration	Disturbed floodplain = 40% Road Density = 0.62 miles/miles2 Adequate amounts of medium-large trees in the riparian buffer available for recruitment of the river via channel migration

Pathway	General Indicators	Specific Indicators	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
		Canopy Cover	Unacceptable	Unacceptable	Unacceptable	Unacceptable	At Risk	At Risk
			Canopy Cover = 30% Thermal Shading = minimal Banks visible in patches in aerial photography.	Canopy Cover = 40% Thermal Shading = minimal Banks visible in patches in aerial photography.	Canopy Cover = 50% Thermal Shading = moderate Reach has some large expanses of development with no canopy cover at all. Banks visible at all times in aerial photography.	Canopy Cover = 20% Thermal Shading = minimal Stream and banks highly visible at several portions of the reach.	Canopy Cover = 70% Thermal Shading = moderate (patchy) Young-Middle age trees primarily provide thermal shading. Bank area and stream surface only visible in patches due to recent channel migrations.	Canopy Cover = 50% Thermal Shading = moderate (patchy) Lower portions of reach have highly visible stream surface and banks while upper portions are much more shaded with larger trees.
Channel	Dynamics	Floodplain Connectivity	At Risk	Adequate	At Risk	At Risk	At Risk	Adequate
			Reach is naturally confined throughout most of its length. Where floodplains exist, there is reduced connectivity of the floodplain to the main channel. Roadways and push-up levees have a moderate impact on floodplain inundation rates in a few locations. Floodplain Road Density = 3.45 miles/miles^2 Given only an At Risk rating due to high natural confinement.	The channel is naturally confined by glacial terraces and alluvial fan deposits. The modeled flows (2-100 year event) were confined to the main channel and no floodplain or side channels were observed in this reach, which is additionally constrained by the road and residential alterations. Floodplain Road Density = 0 miles/miles^2 Given an Adequate rating due to natural confinement.	Reduced floodplain connectivity due to roads, bank armoring, and push-up levees. There has also been fill and grading in the floodplain, particularly in the upstream portion of the reach. Floodplain Road Density = 1.80 miles/miles^2	Floodplain connectivity is reduced by the two bridge crossings and associated fill on the approaches. There are also intermittent push-up levees and moderate amounts of past floodplain filling and grading. Floodplain Road Density = 2.88 miles/miles^2	Floodplain connectivity is high in the downstream half of the reach but is affected by levees, fill, and excavated ponds on river-left in the upstream half. These features reduce the extent, frequency, and patterns of floodplain inundation. Floodplain Road Density = 1.33 miles/miles^2	The bridge and approach fills at the upstream end impair floodplain inundation rates and patterns. On river-right at the downstream end, floodplain grading has impaired floodplain inundation patterns. Floodplains are relatively well-connected throughout the remainder of the reach. Floodplain Road Density = 0.62 miles/miles^2

Pathway	General Indicators	Specific Indicators	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
		Bank Stability/ Channel Migration	At Risk	At Risk	At Risk	At Risk	At Risk	Adequate
			Many of the streambanks in the reach are affected by bank armoring, mostly riprap along the road embankment or used to protect residential property. However, the reach is naturally laterally constricted by terraces and hillslopes on both sides of the channel throughout much of the reach. Given only an At Risk rating due to high natural confinement.	Much of the river-left channel margin is affected by road embankments comprised of fill and riprap. There are also houses with access roads along the river and vegetation impacts up to the top of bank. Given only an At Risk rating due to high natural confinement.	Portions of the reach are affected by bank armoring, which impairs streambank complexity and reduces natural rates of channel migration. Push-up levees and riprap are present intermittently along river-left. Clearing and grading for residential and recreational uses has taken place in the active floodplain.	There is bank armoring associated with the two bridges but otherwise not extensive armoring. Floodplain grading and push-up levees have some impact on channel migration, as does the approach road fills at the two bridge crossings.	There are a few areas of riprap protecting houses and private property. These occur at the upstream end on river-left and at the downstream end on river-right. Bank migration is impaired at these locations. Much of the remainder of the reach is migrating near (or slightly above) natural rates.	The bridge at the upstream end of the reach has some impact on bank migration, but overall, there are minimal impacts on bank stability and channel migration processes.
		Vertical Channel Stability	At Risk	Adequate	At Risk	At Risk	At Risk	At Risk
			Floodplain alterations and channelization have likely resulted in some degree of vertical incision. Incision is likely limited by coarse substrate, including lag from glacial and tributary fan sources.	The channel is a single-thread boulder-step bed with a cobble/gravel/boulder substrate that limits vertical incision and provides vertical stability.	There are signs of vertical instability based on abandoned floodplain surfaces. Channelization and floodplain filling and grading appear to have caused incision in several locations, especially in the Jennings project area. Limited presence of gravel bars, even in very unconfined portions of the channel, suggest a general trend of incision.	The two bridge crossings create constrictions that have likely resulted in channel incision. Push-up levees and floodplain fill and grading have likely contributed to downcutting. Flood scars on the now-abandoned surface on river-left (mid-reach) suggests channel incision.	Due to its low gradient and wide floodprone width, this reach provides relatively high sediment storage capacity. It is highly dynamic, likely more than historical conditions due to loss of large trees in riparian areas and in log jams.	There is vertical instability at the upstream bridge crossing, which creates a constriction that has resulted in channel incision. The remainder of the reach is near the natural range of vertical stability.

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Appendix C

Project Opportunities

Middle Twisp River (RM 7.8 – 18.12)

This table describes project opportunities by project area. Locator maps of the project opportunities are included below the table.

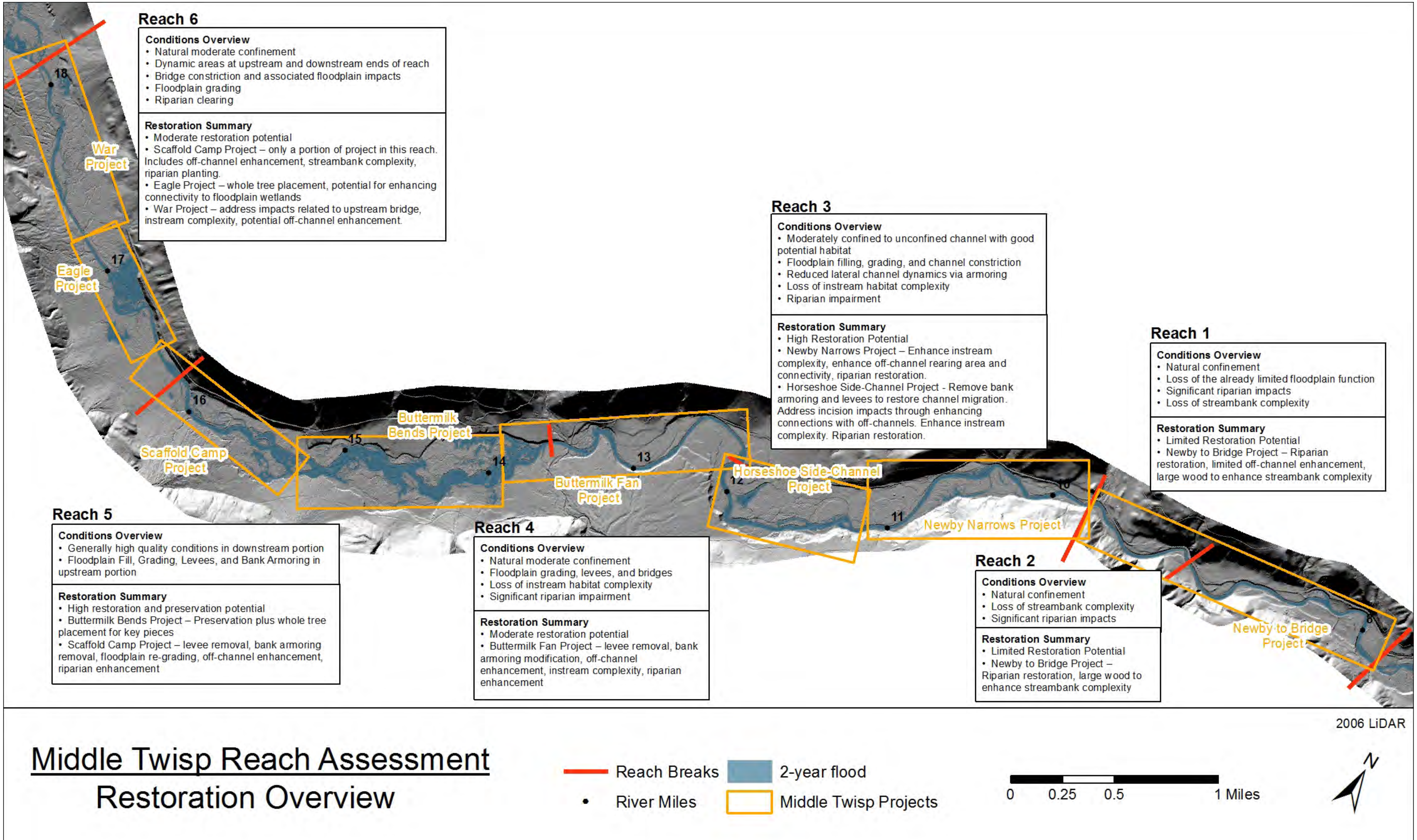
Reach	Project RM	Project Name	Project Elements	Considerations
6	17.2 – 18.2	War Creek	Address floodplain disconnection at 4430 Road bridge and fill. • Perforations (culverts, bridge) through the road fill in east floodplain could provide upstream and downstream floodplain flow connectivity. RM 18.05 left bank side-channel. • A side-channel could be created in the river-left floodplain downstream of the road fill that utilizes old channel scars. This could also be created as a flow-through side-channel through a new culvert under the road fill. Alternatively, a groundwater channel could be created. RM 18.0 right bank alcove. • In river-right (west) floodplain downstream of bridge, seepage indicates that groundwater-fed alcove habitat could be created in old channel scars.Enhance connection to1985 (left bank) side-channel • Apex jam at head of channel inlet (RM 17.95) • Apex jams and select excavation at head of secondary inlet (RM 17.65) • Log jams within main channel will increase roughness RM 17.23 left bank alcove. • On river-left there is an existing floodplain channel depression that could be excavated to increase fish access at low flows and to increase rearing capacity. There may be the potential for a groundwater-fed alcove at this location. Wood placements in mainstem. • Apex jams to induce lateral channel dynamics, multi-thread channels • Margin placements to enhance local cover and complexity • Place whole trees (large key members) in channel at numerous apex and meander bend locations where wood would naturally accumulate in order to capture fluvially-transported wood. Alternatively, pilings could be driven at select locations to serve this same purpose.	LW numbers in this area are likely close to “adequate” (based on REI) Some lateral channel dynamics occurring – major channel shift between 1985 and 1994.
6	16.4 – 17.2	Eagle Creek	Pull existing whole trees into channel RM 17.0 – 17.1. • There are 2 very large downed trees above top of bank on the river-right bank. Pull these into channel. RM 16.6 – 17.0 left bank side-channel reconnection. • Enhance connectivity to existing left-bank floodplain wetlands via select excavation. Large wood placement in mainstem. • Add whole trees or pilings to encourage log jam development and lateral dynamics within the newly avulsed channel segment between RM 16.6 and 16.9. RM 16.65 river-right side-channel. • Apex log jam and side channel excavation to encourage flow through a future potential avulsion path that would move the river away from the hillslope/roadway impacts.	Lateral dynamics occurring. Recent channel shift post 2012. New early successional channel will continue to adjust Some large key members are located in channel and may serve to build jams over time.

Reach	Project RM	Project Name	Project Elements	Considerations
5-6	15.3 – 16.4	Scaffold Camp	RM 16.2 – 16.4 right bank log jams and riparian restoration. • Small log jams and riparian planting on river-right at eroding bank adjacent to field. Add jams for initial stability until riparian veg matures. • Riparian replanting of cleared riparian and floodplain area. RM 16.2 – 16.3 left bank side-channel connection. • Add log jam and use select excavation to activate left bank side-channels. RM 16 – 16.18 right bank alcove/groundwater channels. • One potential flow-through side-channel from RM 16.05 to near 16.18 • Reconnection of alcove/wall-based channel at RM 16. Might be good groundwater flow channel. Investigate groundwater flow potential. • Riparian restoration in cleared areas near these channels. RM 15.9 – 16.1 left bank floodplain and side-channel reconnection . • Remove levee, gabion wall, and culvert and create active side-channel within footprint of disconnected pond (re-grade). • Riparian work at cleared areas inboard of levee. RM 15.8 – 15.9 right bank margin jams and riparian restoration. • This is a cleared riparian area along the right bank with a rapidly eroding bank. Small margin log jams would provide interim stability until riparian vegetation can mature. RM 15.75 – 15.9 left bank floodplain and side-channel reconnection. • Remove all or part of levee to reconnect side-channel and floodplain. Regrade ponds as necessary to provide side-channel habitat. • Riparian restoration inboard of levee. Full levee removal may require added protection of houses downstream. RM 15.53 – 15.65 left bank floodplain and side-channel reconnection. • Remove levee to reconnect off-channel and floodplain. Apex jams to activate side-channels RM 15.35 – 15.63 right bank push-up levee removal and side-channel reconnection. • Remove push up levee near RM 15.6 and use select excavation to reconnect side channel through right bank floodplain. Mainstem wood placements. • Throughout the project area as well as in newly created off-channel habitats, place whole trees or potentially pilings to serve as key members to collect fluvially-transported wood and build log jams.	Pasture land use at upstream right bank may hinder riparian restoration Private property and infrastructure throughout Origin and use of ponds and push-up levees on left bank are unknown. Houses on river-left at downstream end would need risk assessment and potential protection with levee removal scenarios.
5	13.9 – 15.3	Buttermilk Bends	Mostly analog. Whole tree placement. • Helicopter placement of a whole trees for key pieces to form log jams There is a lack of very large pieces but numerous smaller pieces that would form racking members.	Ideally would be done via helicopter placements to limit disturbance.

Reach	Project RM	Project Name	Project Elements	Considerations
4-5	12.2 – 13.9	Buttermilk Fan	RM 13.85 left bank side-channel or main channel shift. • Encourage side-channel or even mainstem flow to the north (e.g. in old 1953 alignment) via select excavation and log jam placement in mainstem. The idea is to shift the mainstem away from riprap and residential development on right bank just downstream. RM 13.76 and 13.84 river-right riprap modification. • Modify/replace riprap on right bank at two locations. RM 13.65 – 13.7 modify fill and bank armoring on river-right. • To the extent possible, modify/replace bank armoring and fill at the mouth and the lower end of Buttermilk Creek to enhance this potentially highly diverse area (river-right). RM 13.5 left bank levee and riprap removal. • Remove push-up levee and a portion of the riprap on river-left just downstream of the bridge to enhance floodplain connectivity. RM 13.4 river-right backwater alcove. • Create backwater alcove (likely groundwater-fed) on river-right downstream of the bridge. RM 13.28 river-left backwater alcove. • There is an existing backwater cove at this location. Create larger backwater alcove channel that extends back into the floodplain. RM 12.6 – 13.2 left bank push up levee removal. • Remove left bank push-up levees to reconnect 100-year floodplain. In particular, removal of push-up levee at high flow channel entrance on leftbank at RM 12.85 would allow for more frequent inudation of the high flow channel extending down to RM 12.68. RM 12.6 – RM 12.9 complexity wood placements. • There is the potential for small habitat cover and complexity log jams within glides in this area. This work could extent beyond just these RMs and could occur throughout the project area. RM 12.57 river-left off-channel/alcove creation. • Excavate off-channel habitat on the left bank at road/hillslope toe at. A narrow outflow channel would be required to avoid mature cottonwoods and conifers. There is the potential to excavate large habitat beyond the stand of trees. The existing gravel cobble bar at the outflow location suggests the potential for sediment accumulation. The left bank of the outflow is the toe of the road embankment that contains riprap and bedrock. RM 12.25 to 12.3 left bank riprap removal and log jams. • Remove riprap, place meander bend log jams to achieve interim stability. • Riparian revegetation. • Potential apex jam at island at 12.25 Riparian and floodplain revegetation throughout reach. • Create a forested riparian buffer, particularly along river-left where there is pasture land and along river-right near the downstream end of the reach.	Semi-confined channel. Removal of push-up levees will not significantly increase floodplain inundation; only at very high flows. Private lands with potentially active grazing.

Reach	Project RM	Project Name	Project Elements	Considerations
3	11.1 – 12.2	Horseshoe Side-Channel	RM 11.98 – 12.15 river-left side-channel. • Apex jam and select excavation to activate river-left side-channel. RM 11.86 – 11.96 river-right side-channel. • Potential for river-right apex jam and select side-channel excavation. RM 11.25 – RM 11.8 valley-left wetland and side-channel complex reconnection. • Numerous possibilities for side-channel and off-channel reconnection in the expansive abandoned oxbow wetland complex on valley-left. This would be accomplished via select excavation to connect up remnant oxbow wetlands. • Removal of road crossings (fill) and artificial berms/dikes that have been built in the area. • Wood cover would be added to off-channel habitat. RM 11.25 – 11.6 river-left side-channels and levee removals. • Numerous possibilities for apex jams and flow-through side-channel activation via select excavation closer to the river on river-left. • Numerous push-up levees throughout this area could be removed to restore natural floodplain inundation patterns. RM 11.3 – 11.45 river-right side-channels. • Two possibilities for apex jams and select excavation for flow-through side-channel activation on river-right.The upstream one begins at RM 11.3 and the other one begins at RM 11.45 RM 11.2 riprap and fill removal. • The riprap bank and floodplain fill at RM 11.2 on left bank is not protecting infrastructure and could be removed • Place log jams for interim stability until restored riparian vegetation can become established. • Reforestation of streambanks and cleared riparian area. Riparian restoration. • Numerous areas with past and on-going vegetation clearing could be targeted for riparian and floodplain vegetation restoration throughout this project area.	USBR developed a preliminary suite of restoration alternatives for this site in 2006 (USBR 2006). Private lands with some residential uses.
3	9.8 – 11.1	Newby Narrows	RM 10.66 – 10.95 margin complexity. • Add margin complexity wood, primarily on river-right bank but also potentially on river-left. RM 10.65 – 11.07 riparian reforestation. • Riparian reforestation on river-left from where the riparian and floodplain areas have been cleared for agriculture and residential uses. RM 10.4 to 10.75 river-right old oxbow reconnection. • Old oxbow in river-right floodplain. Excavate downstream connection for fish access and to increase low flow rearing area. There is also the potential for excavation to connect as a flow-through side-channel from upstream end near RM 10.75. Groundwater-fed channels connecting to the oxbow are possible, but need further investigation. RM 10.4-10.57 left-bank side-channel. • In river-left floodplain there is the potential for creation of a side-channel that would connect up to the existing low flow side-channel. • Place apex jam at side-channel inlet. RM 10.27 – 10.43 apex log jams. • There are two places for apex jams on existing bars to enhance split flow conditions and island development. One at RM 10.43 and one at RM 10.27. RM 10.4 – 10.56 river-right margin complexity. • Place margin complexity wood on river-right bank where it has been cleared. RM 10.5 – 10.6 river-right riparian restoration. • Riparian and floodplain revegetation on river-right, primarily between RM 10.5 – 10.6. RM 10.2 right bank backwater alcove. • Potential excavation of backwater alcove channel that outlets on right bank near RM 10.2. RM 9.96 – 10.1 apex log jams. • There is the potential for 2-3 bar apex jams in this overwidened section that has some existing bar formation. One of the apex jams could be built at RM 10.05 upon an existing car-sized mid-channel boulder. The jam would also add wood complexity to existing pool formed behind the boulder. Another jam or jams could be built downstream along the bar complex. RM 9.97 to 10.08 river-left off-channel. • In the river-left floodplain, a side-channel or groundwater-fed alcove could be excavated utilizing an existing flood swale.	Groundwater flow potential needs further investigation. Private lands. Houses nearby in river-left floodplain. During field survey, saw real estate for sale sign on river-right parcel near RM 10.56 (Clingan Property?).

Reach	Project RM	Project Name	Project Elements	Considerations
1-2	7.8 – 9.8	Newby to Bridge	Not much opportunity due to high gradient, confinement, lots of development, the nearby roadway, and flood protection infrastructure. Riparian restoration • Work with willing landowners to perform riparian reforestation where possible. RM 8.3 river-left alcove habitat. • There is the potential for creation of off-channel alcove habitat in river-left floodplain. This would be a small project but a good one with limited impacts to existing vegetation. There is very little off-channel rearing habitat in upstream or downstream areas, which means this could provide good “stepping stone” habitat to bridge the gap between other higher quality rearing areas. Enhance channel margin complexity • Where possible, enhance channel margin complexity via large wood placements. In some areas, it may be possible to enhance habitat along existing riprap banks via large wood placements for margin complexity and cover.	Private residences, development, the nearby roadway, and flood protection infrastructure will limit the ability to do work in this area.


Reach 6
Conditions Overview
• Natural moderate confinement
• Dynamic areas at upstream and downstream ends of reach
• Bridge constriction and associated floodplain impacts
• Floodplain grading
• Riparian clearing
Restoration Summary
• Moderate restoration potential
• Scaffold Camp Project – only a portion of project in this reach. Includes off-channel enhancement, streambank complexity, riparian planting.
• Eagle Project – whole tree placement, potential for enhancing connectivity to floodplain wetlands
• War Project – address impacts related to upstream bridge, instream complexity, potential off-channel enhancement.
Reach 3
Conditions Overview
• Moderately confined to unconfined channel with good potential habitat
• Floodplain filling, grading, and channel constriction
• Reduced lateral channel dynamics via armoring
• Loss of instream habitat complexity
• Riparian impairment
Restoration Summary
• High Restoration Potential
• Newby Narrows Project – Enhance instream complexity, enhance off-channel rearing area and connectivity, riparian restoration.
• Horseshoe Side-Channel Project - Remove bank armoring and levees to restore channel migration. Address incision impacts through enhancing connections with off-channels. Enhance instream complexity. Riparian restoration.
Reach 1
Conditions Overview
• Natural confinement
• Loss of the already limited floodplain function
• Significant riparian impacts
• Loss of streambank complexity
Restoration Summary
• Limited Restoration Potential
• Newby to Bridge Project – Riparian restoration, limited off-channel enhancement, large wood to enhance streambank complexity
Reach 5
Conditions Overview
• Generally high quality conditions in downstream portion
• Floodplain Fill, Grading, Levees, and Bank Armoring in upstream portion
Restoration Summary
• High restoration and preservation potential
• Buttermilk Bends Project – Preservation plus whole tree placement for key pieces
• Scaffold Camp Project – levee removal, bank armoring removal, floodplain re-grading, off-channel enhancement, riparian enhancement
Reach 4
Conditions Overview
• Natural moderate confinement
• Floodplain grading, levees, and bridges
• Loss of instream habitat complexity
• Significant riparian impairment
Restoration Summary
• Moderate restoration potential
• Buttermilk Fan Project – levee removal, bank armoring modification, off-channel enhancement, instream complexity, riparian enhancement
Reach 2
Conditions Overview
• Natural confinement
• Loss of streambank complexity
• Significant riparian impacts
Restoration Summary
• Limited Restoration Potential
• Newby to Bridge Project – Riparian restoration, large wood to enhance streambank complexity
War Project
Eagle Project
Scaffold Camp Project
Buttermilk Bends Project
Buttermilk Fan Project
Horseshoe Side-Channel Project
Newby Narrows Project
Newby to Bridge Project
18
17
16
15
14
13
12
11
10
8
2006 LiDAR
Middle Twisp Reach Assessment
Restoration Overview
Reach Breaks
River Miles
2-year flood
Middle Twisp Projects
0
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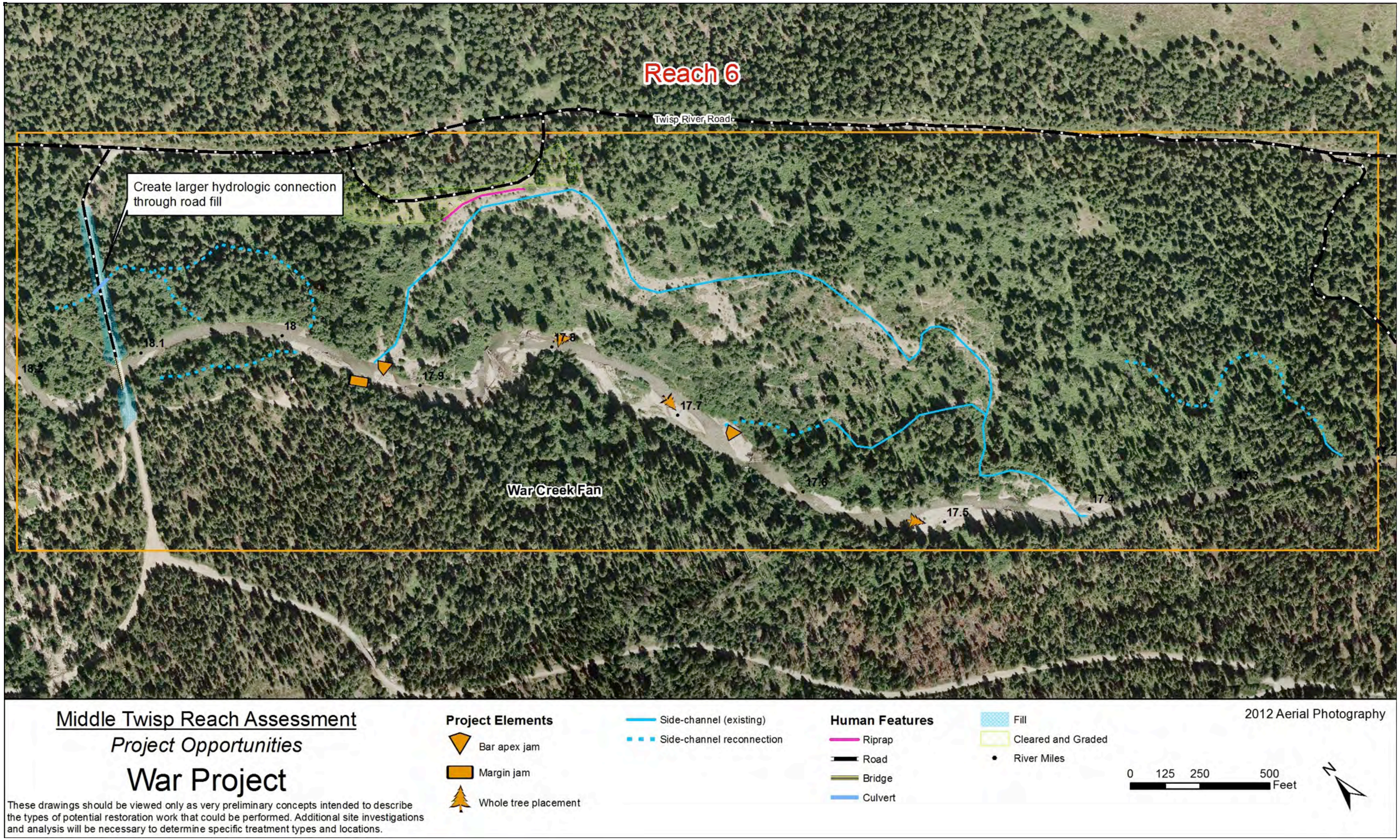
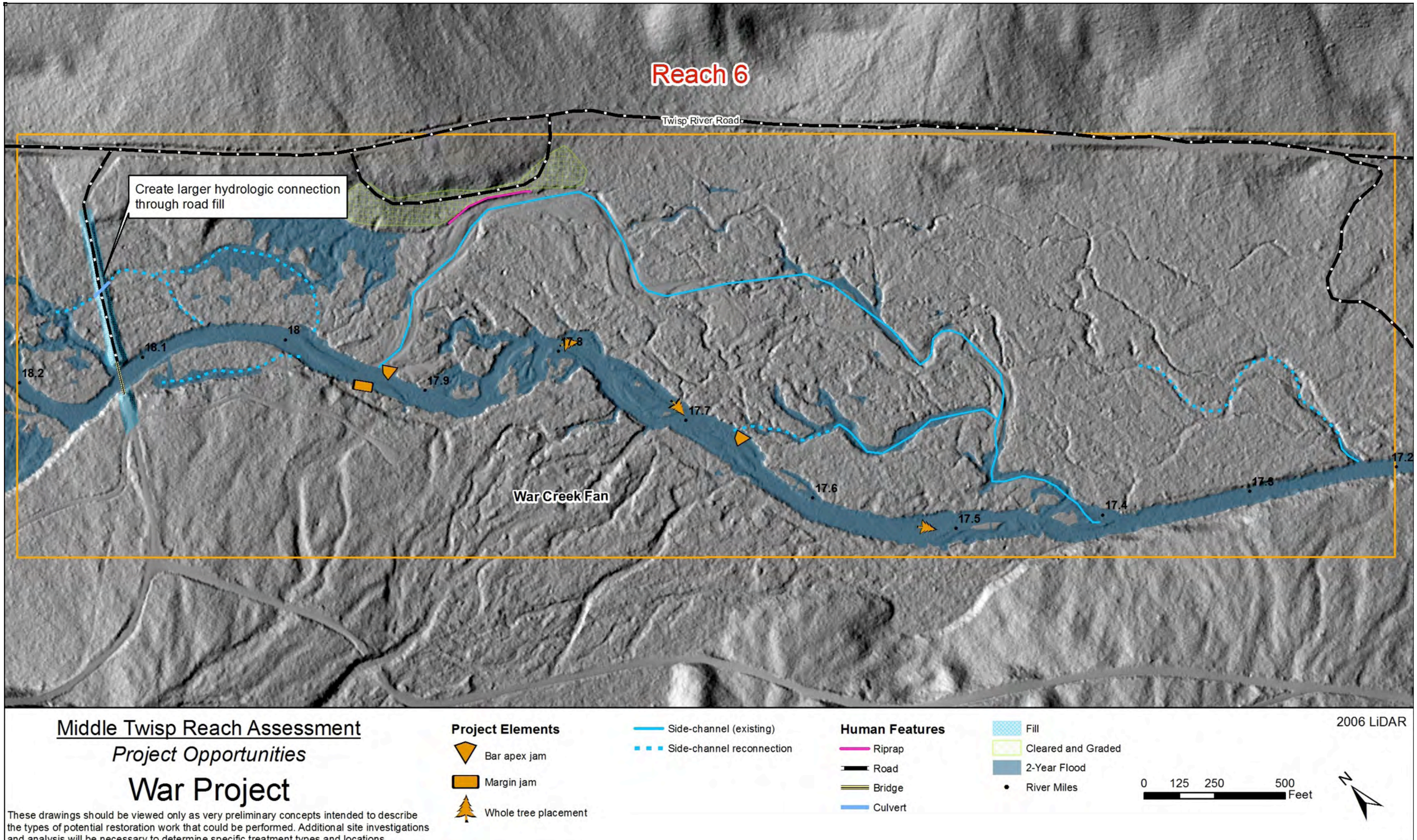
0.5
1 Miles
N


Reach 6
Twisp River Road
Create larger hydrologic connection through road fill
18.2
18.1
18
17.9
17.8
17.7
17.6
17.5
17.4
War Creek Fan
Middle Twisp Reach Assessment
Project Opportunities
War Project
These drawings should be viewed only as very preliminary concepts intended to describe the types of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations.
Project Elements
Bar apex jam
Margin jam
Whole tree placement
Side-channel (existing)
Side-channel reconnection
Human Features
Riprap
Road
Bridge
Culvert
Fill
Cleared and Graded
River Miles
2012 Aerial Photography
0 125 250 500
Feet
N


Reach 6
Twisp River Road
Create larger hydrologic connection through road fill
18.2
18.1
18
17.9
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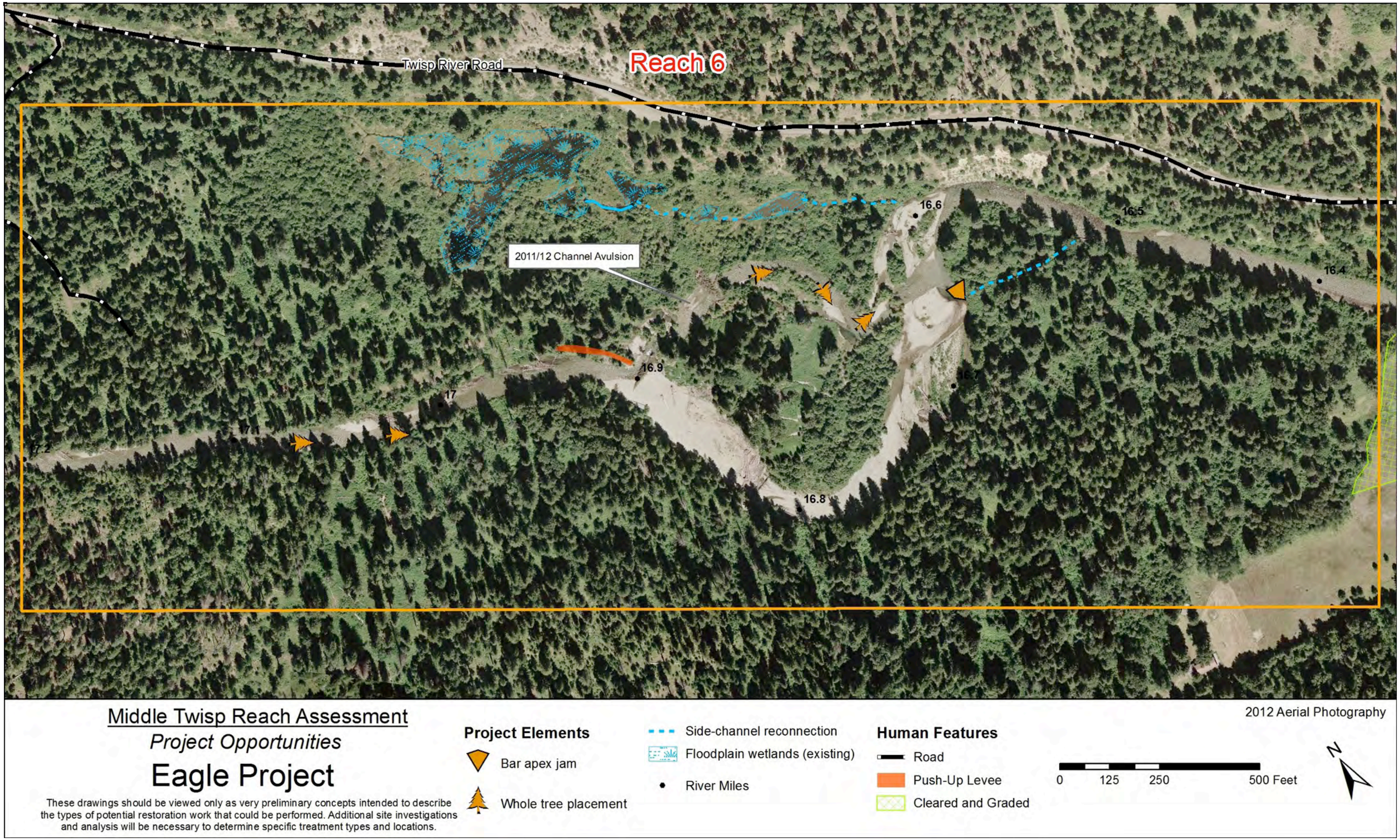
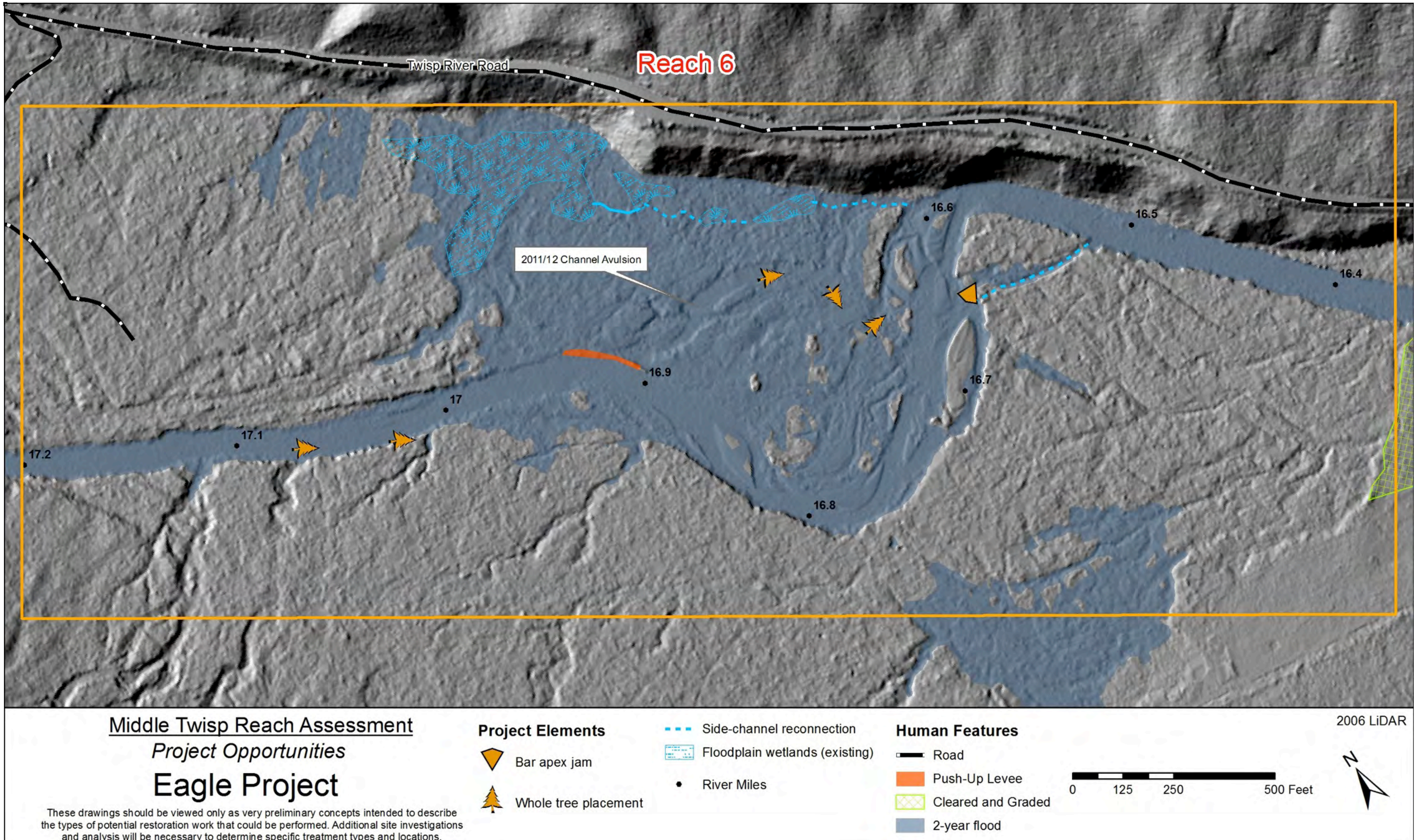
17.4
17.3
17.2
War Creek Fan
Middle Twisp Reach Assessment
Project Opportunities
War Project
These drawings should be viewed only as very preliminary concepts intended to describe the types of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations.
Project Elements
Bar apex jam
Margin jam
Whole tree placement
Side-channel (existing)
Side-channel reconnection
Human Features
Riprap
Road
Bridge
Culvert
Fill
Cleared and Graded
2-Year Flood
River Miles
2006 LiDAR
0 125 250 500
Feet
N


Twisp River Road
Reach 6
2011/12 Channel Avulsion
16.6
16.5
16.4
16.9
16.7
17
17.1
17.2
16.8
Middle Twisp Reach Assessment
Project Opportunities
Eagle Project
These drawings should be viewed only as very preliminary concepts intended to describe the types of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations.
Project Elements
Bar apex jam
Whole tree placement
Side-channel reconnection
Floodplain wetlands (existing)
River Miles
Human Features
Road
Push-Up Levee
Cleared and Graded
2012 Aerial Photography
0
125
250
500 Feet
N


Twisp River Road
Reach 6
2011/12 Channel Avulsion
16.4
16.5
16.6
16.7
16.8
16.9
17
17.1
17.2
Middle Twisp Reach Assessment
Project Opportunities
Eagle Project
These drawings should be viewed only as very preliminary concepts intended to describe the types of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations.
Project Elements
Bar apex jam
Whole tree placement
Side-channel reconnection
Floodplain wetlands (existing)
River Miles
Human Features
Road
Push-Up Levee
Cleared and Graded
2-year flood
2006 LiDAR
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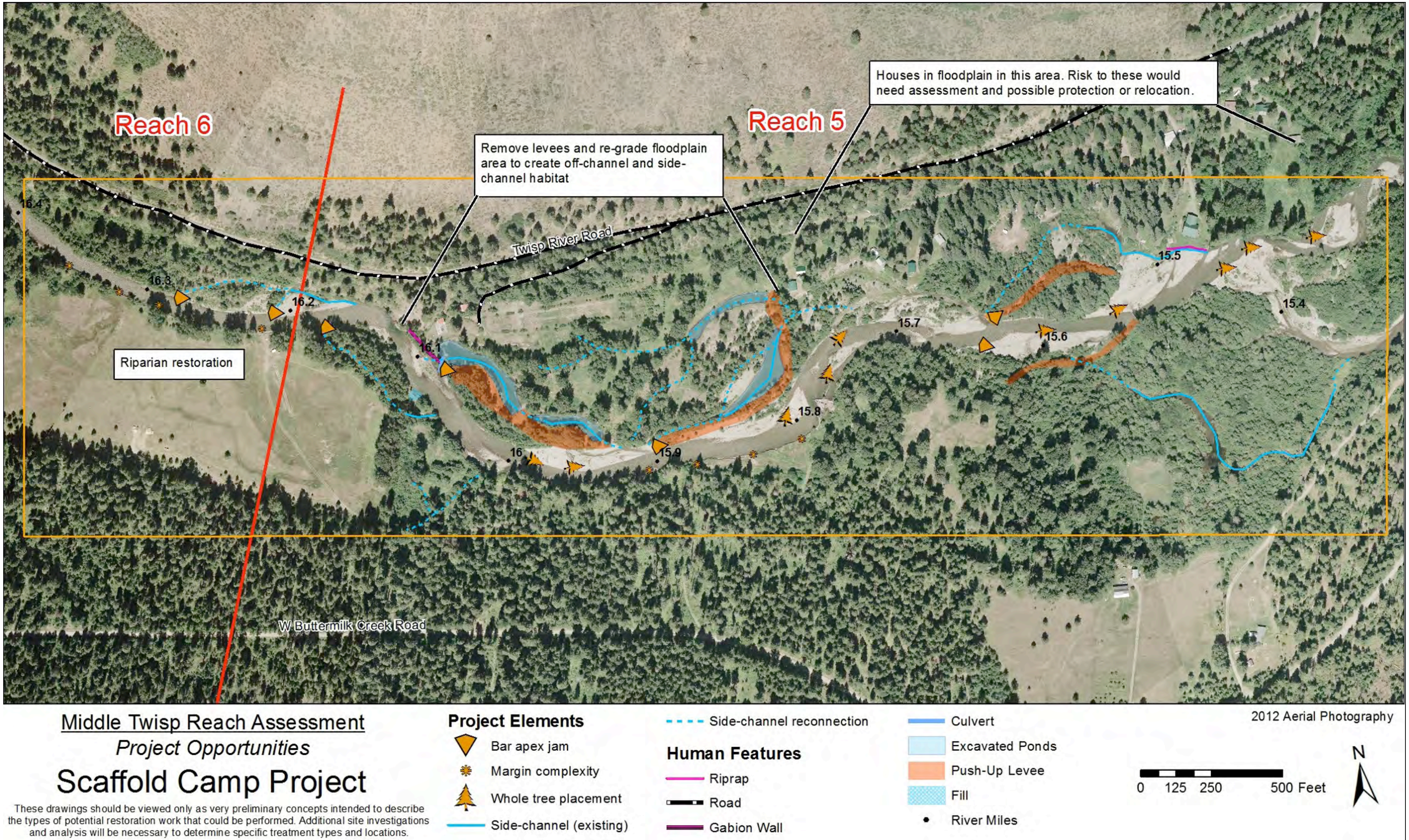
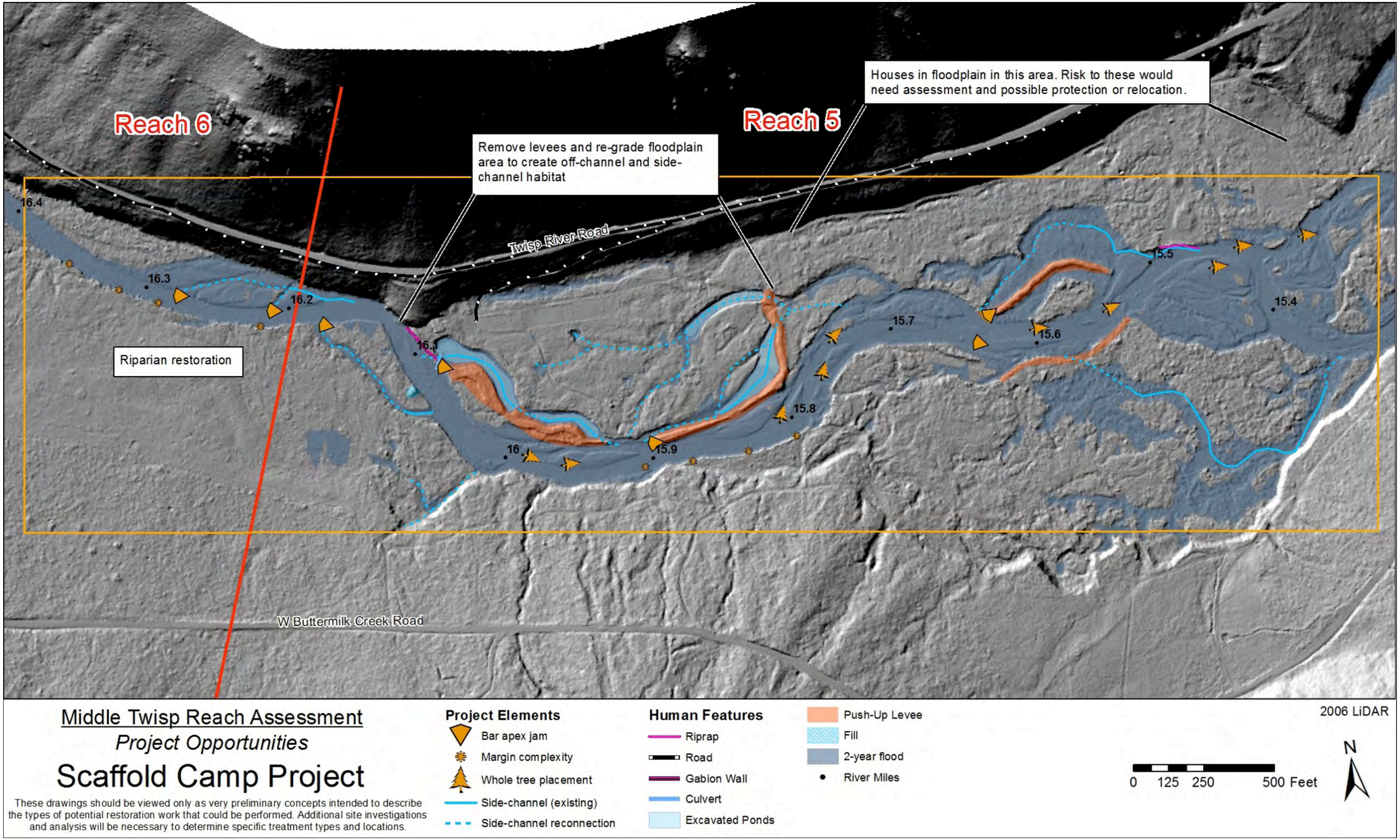
500 Feet
N


Reach 6
Reach 5
Houses in floodplain in this area. Risk to these would need assessment and possible protection or relocation.
Remove levees and re-grade floodplain area to create off-channel and side-channel habitat
Riparian restoration
Twisp River Road
W Buttermilk Creek Road
16.4
16.3
16.2
16.1
16
15.9
15.8
15.7
15.6
15.5
15.4
Middle Twisp Reach Assessment
Project Opportunities
Scaffold Camp Project
These drawings should be viewed only as very preliminary concepts intended to describe the types of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations.
Project Elements
Bar apex jam
Margin complexity
Whole tree placement
Side-channel (existing)
Side-channel reconnection
Human Features
Riprap
Road
Gabion Wall
Culvert
Excavated Ponds
Push-Up Levee
Fill
River Miles
2012 Aerial Photography
N
0 125 250 500 Feet



Houses in floodplain in this area. Risk to these would need assessment and possible protection or relocation.
Reach 6
Reach 5
Remove levees and re-grade floodplain area to create off-channel and side-channel habitat
Twisp River Road
Riparian restoration
W Buttermilk Creek Road
16.4
16.3
16.2
16.1
16
15.9
15.8
15.7
15.6
15.5
15.4
Middle Twisp Reach Assessment
Project Opportunities
Scaffold Camp Project
These drawings should be viewed only as very preliminary concepts intended to describe the types of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations.
Project Elements
Bar apex jam
Margin complexity
Whole tree placement
Side-channel (existing)
Side-channel reconnection
Human Features
Riprap
Road
Gabion Wall
Culvert
Excavated Ponds
Push-Up Levee
Fill
2-year flood
River Miles
2006 LiDAR
0 125 250 500 Feet
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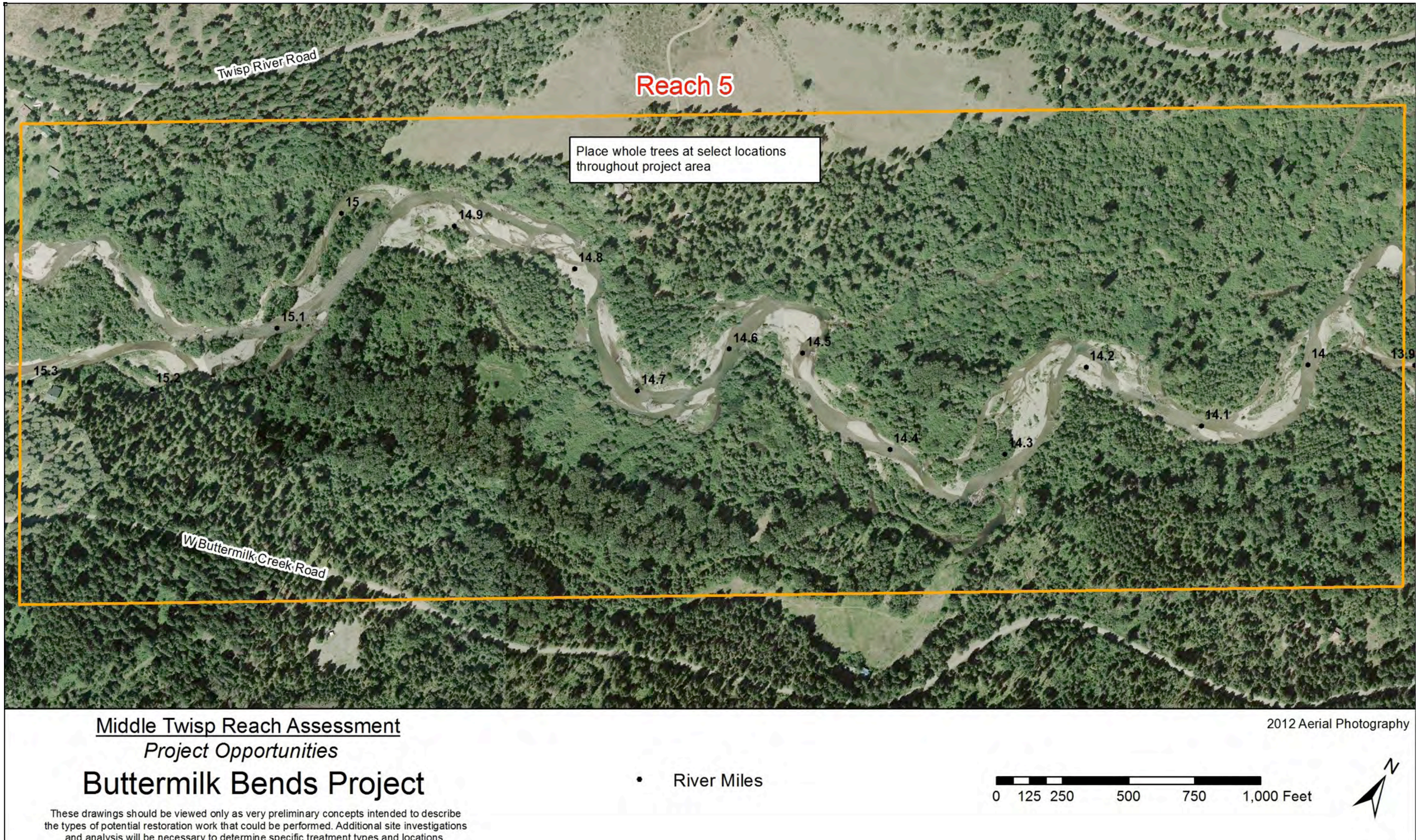
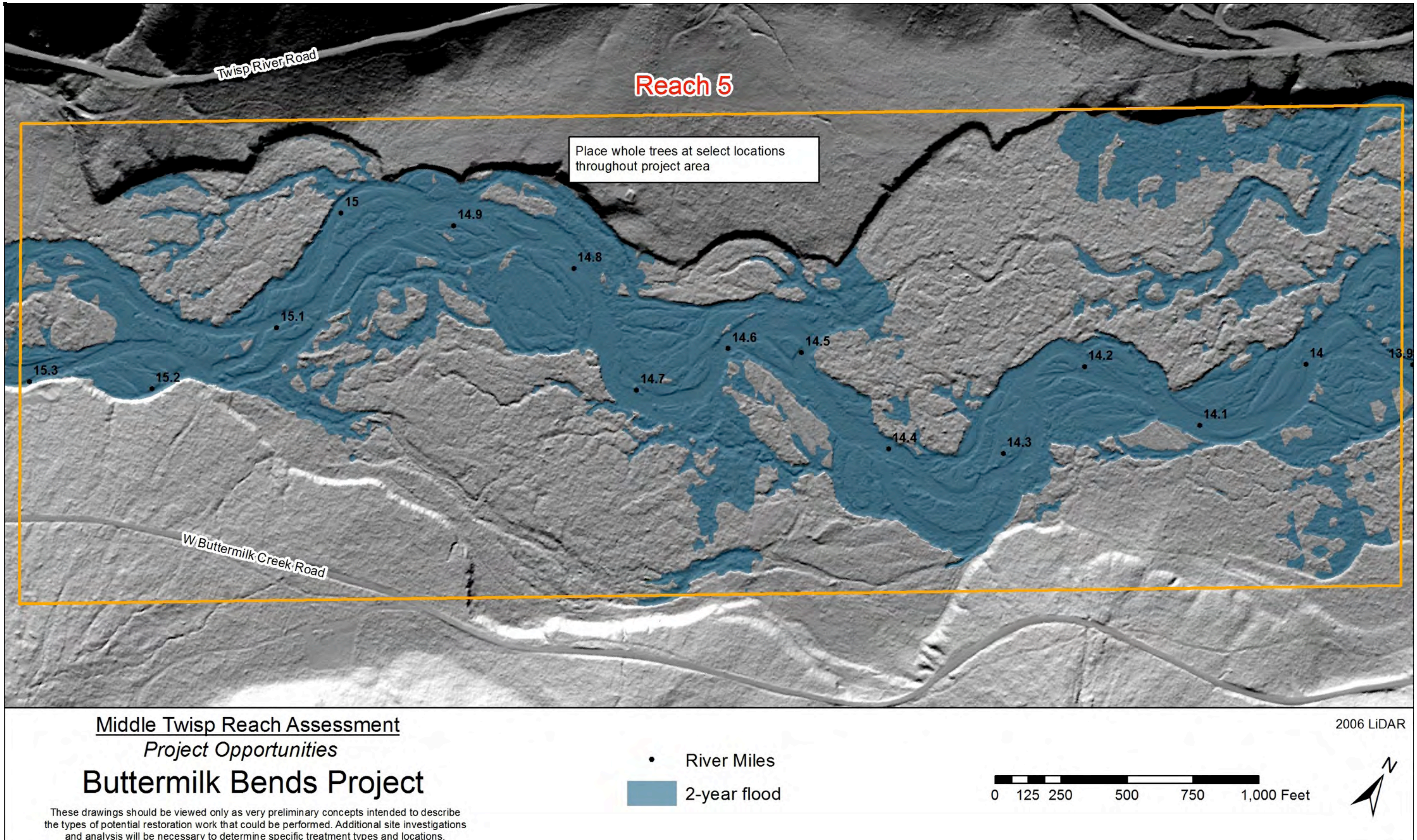


Middle Twisp Reach Assessment

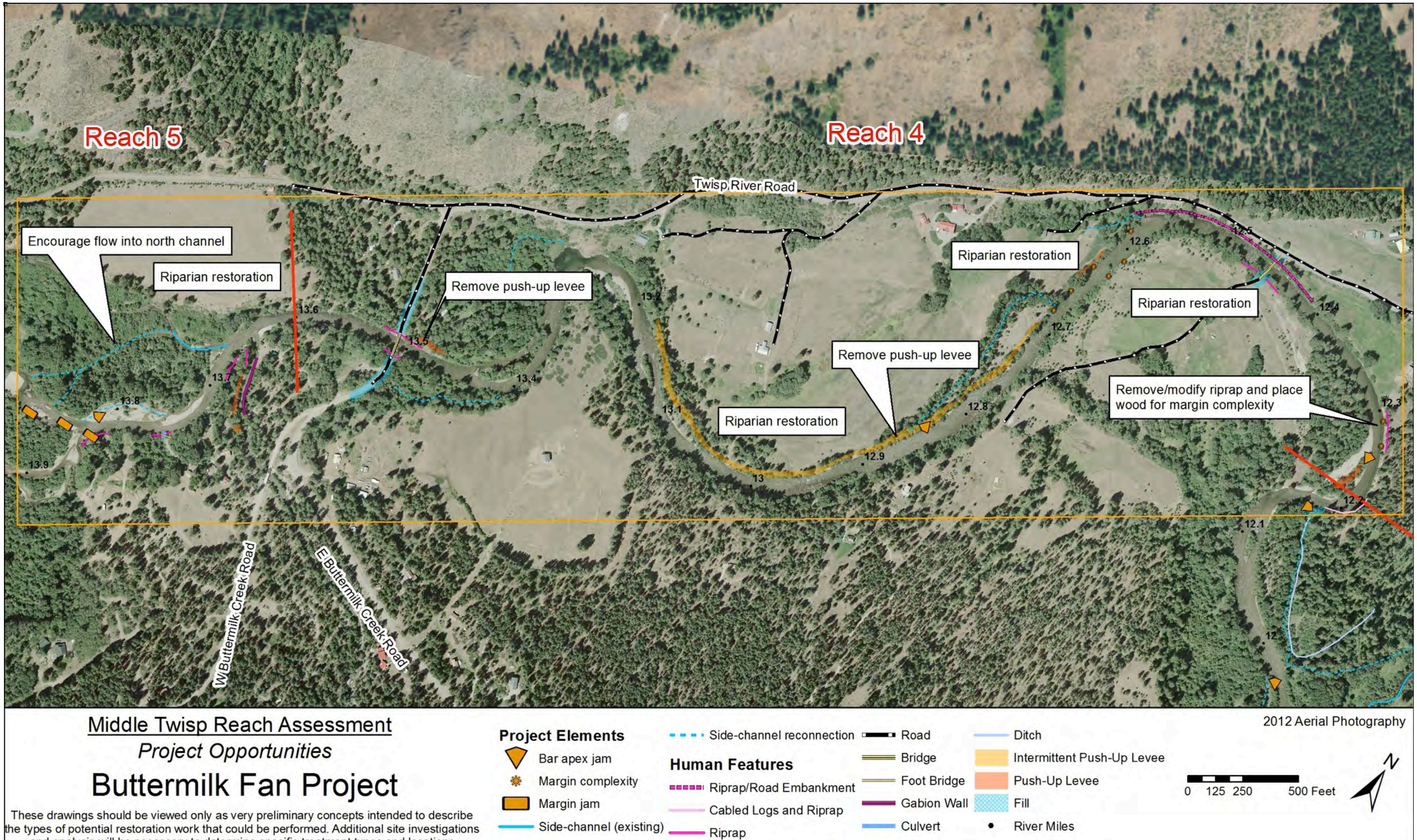
Project Opportunities

Buttermilk Bends Project

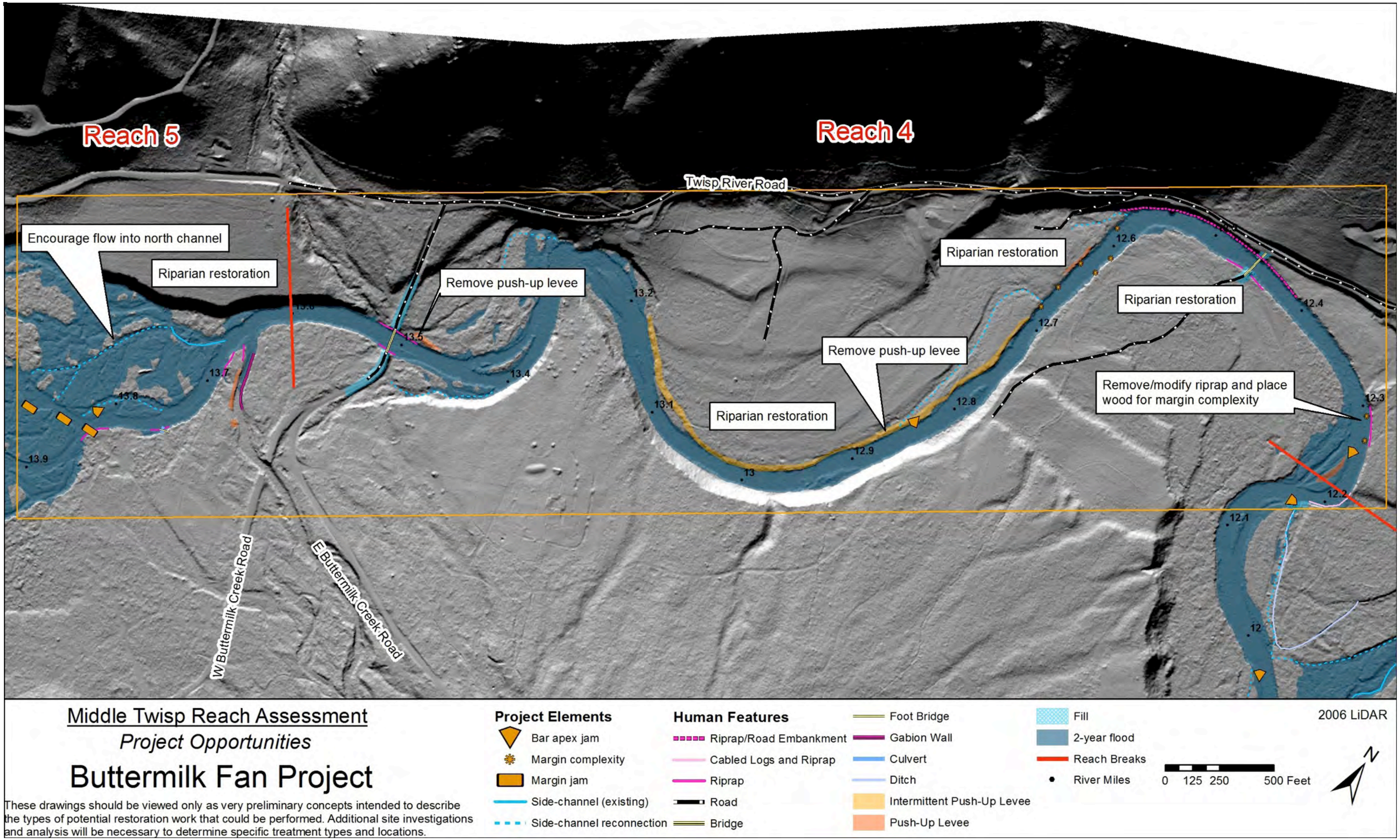
These drawings should be viewed only as very preliminary concepts intended to describe the types of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations.



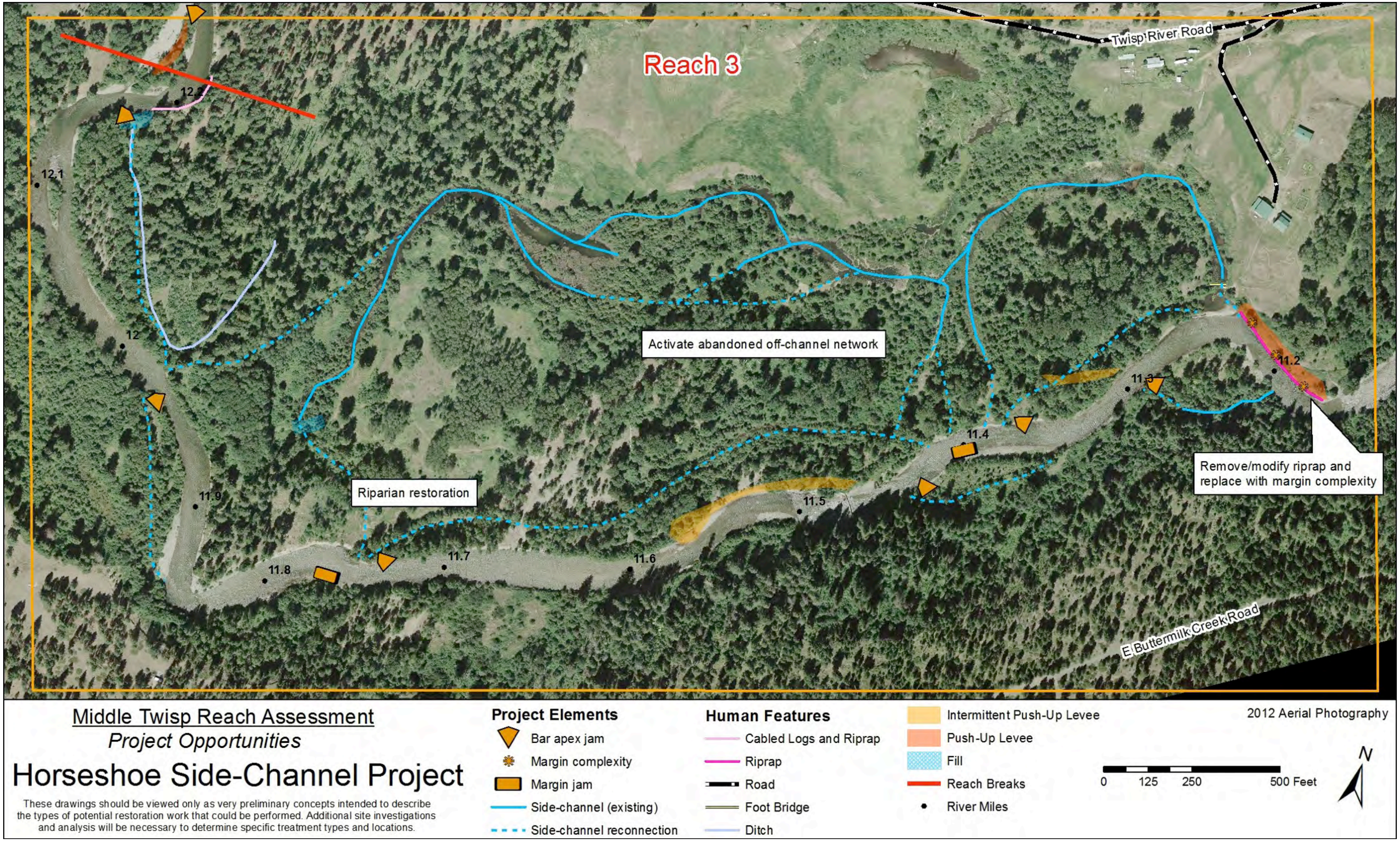
Twisp River Road
Reach 5
Place whole trees at select locations throughout project area
15
14.9
14.8
15.1
14.6
14.5
15.3
15.2
14.7
14.2
14
13.9
14.1
14.4
14.3
W Buttermilk Creek Road
Middle Twisp Reach Assessment
Project Opportunities
Buttermilk Bends Project
These drawings should be viewed only as very preliminary concepts intended to describe the types of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations.
River Miles
2-year flood
2006 LiDAR
0 125 250 500 750 1,000 Feet
N

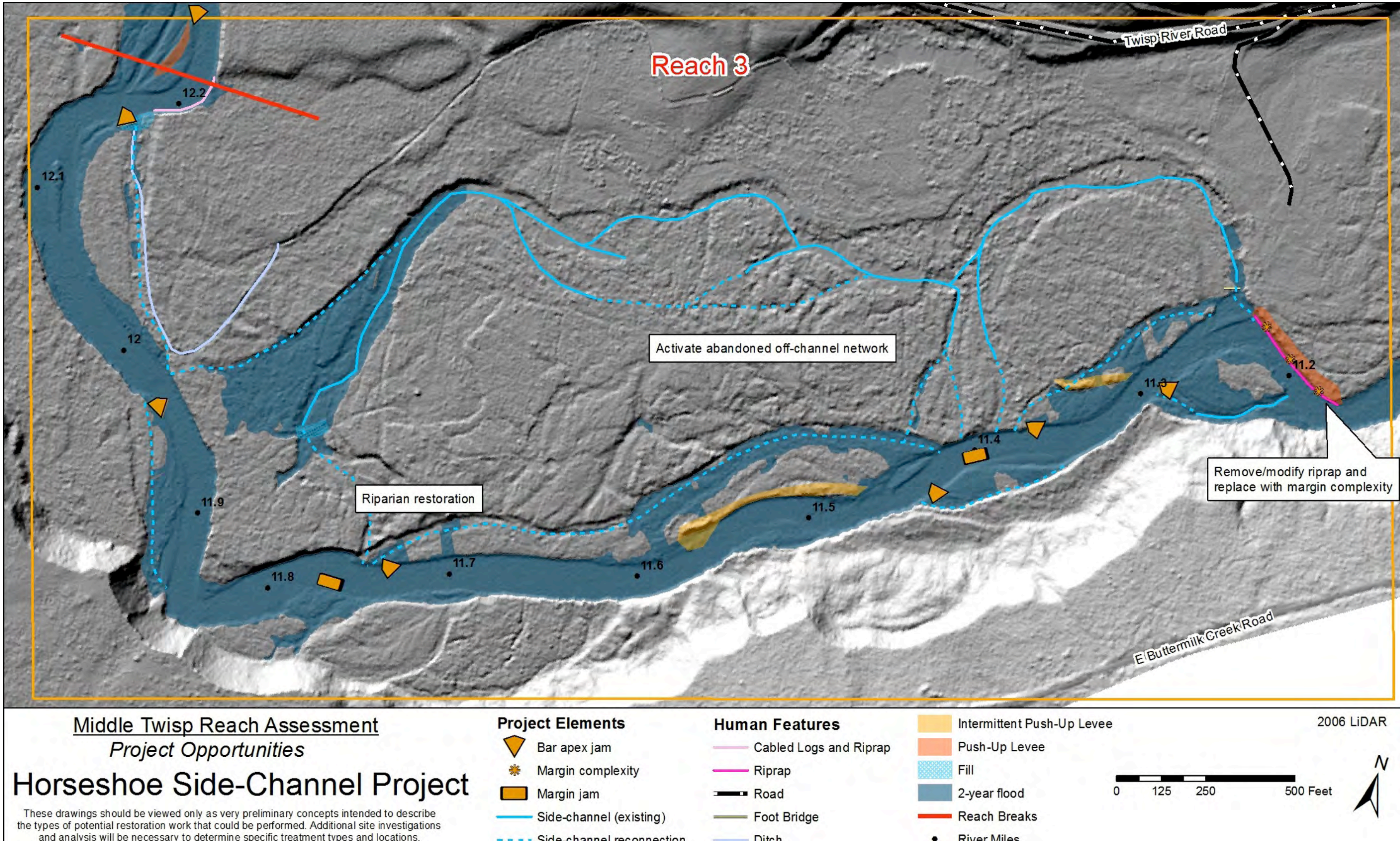


Reach 5
Reach 4
Twisp River Road
Encourage flow into north channel
Riparian restoration
Remove push-up levee
Riparian restoration
Riparian restoration
Remove push-up levee
Riparian restoration
Remove/modify riprap and place wood for margin complexity
W Buttermilk Creek Road
E Buttermilk Creek Road
13.9
13.8
13.7
13.6
13.5
13.4
13.2
13.1
13
12.9
12.8
12.7
12.6
12.5
12.4
12.3
12.2
12.1
12
Middle Twisp Reach Assessment
Project Opportunities
Buttermilk Fan Project
These drawings should be viewed only as very preliminary concepts intended to describe the types of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations.
Project Elements
Bar apex jam
Margin complexity
Margin jam
Side-channel (existing)
Side-channel reconnection
Human Features
Riprap/Road Embankment
Cabled Logs and Riprap
Riprap
Road
Bridge
Foot Bridge
Gabion Wall
Culvert
Ditch
Intermittent Push-Up Levee
Push-Up Levee
Fill
River Miles
2012 Aerial Photography
0 125 250 500 Feet
N

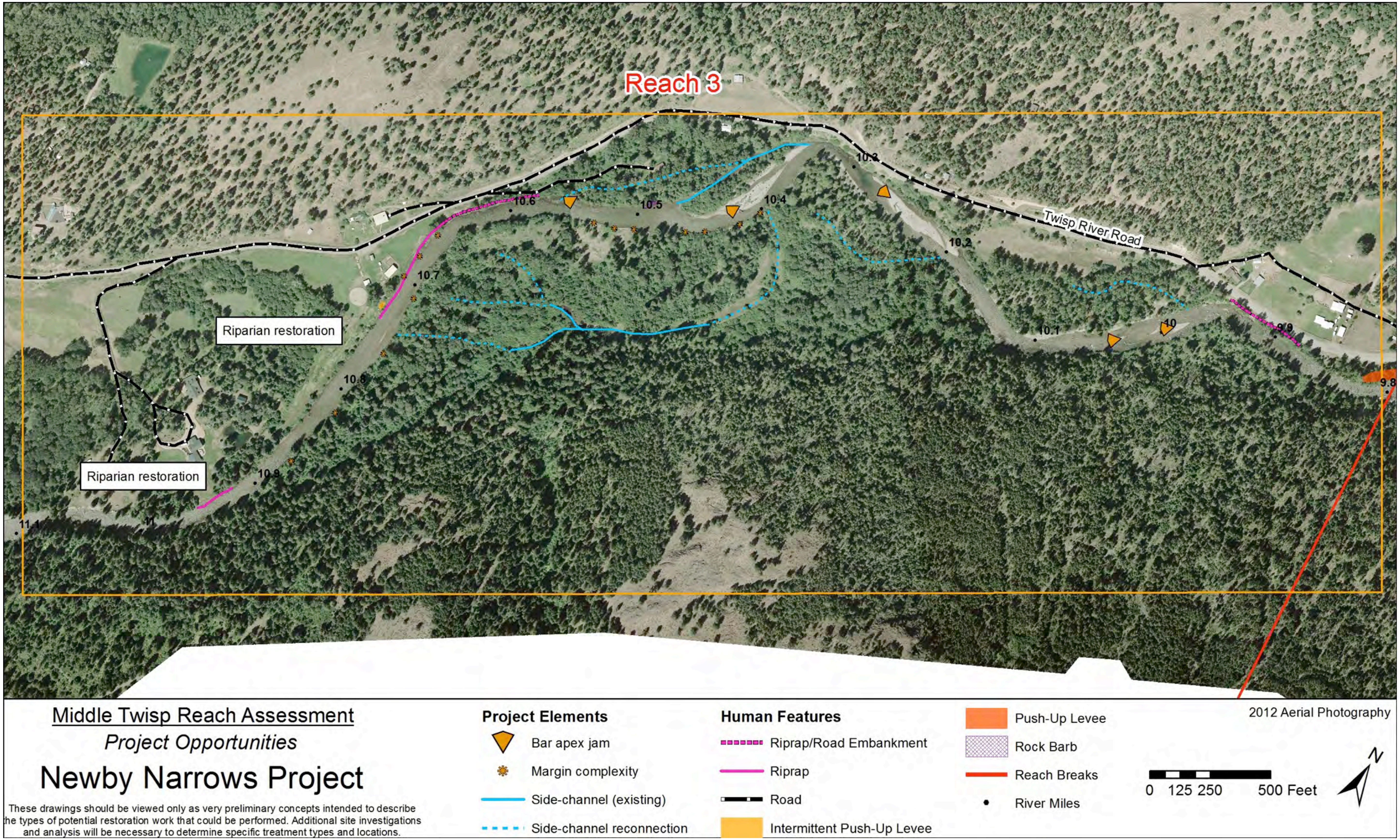


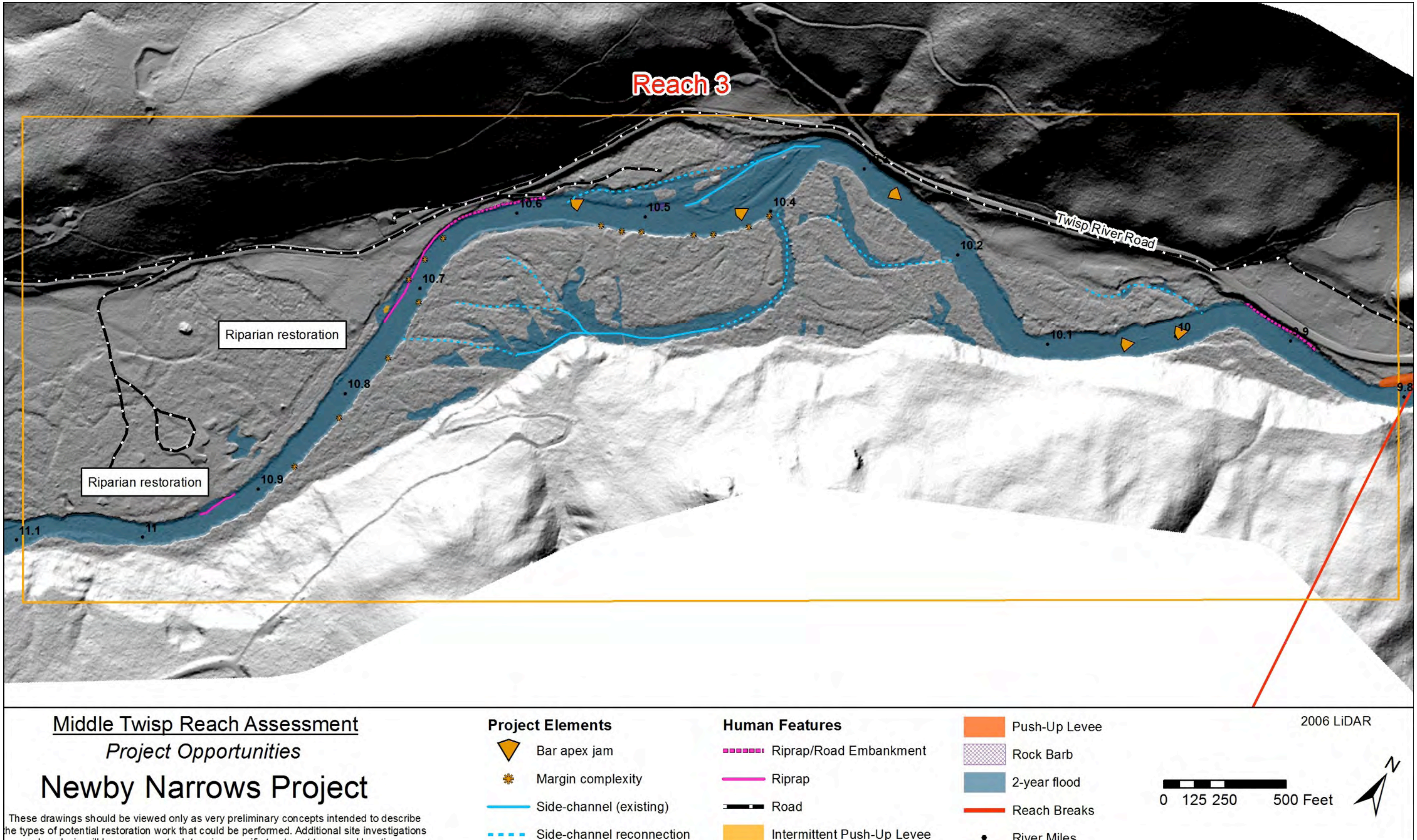
Reach 5
Reach 4
Twisp River Road
Encourage flow into north channel
Riparian restoration
Remove push-up levee
Riparian restoration
Riparian restoration
Remove push-up levee
Riparian restoration
Remove/modify riprap and place wood for margin complexity
W Buttermilk Creek Road
E Buttermilk Creek Road
13.9
13.8
13.7
13.5
13.4
13.2
13.1
13
12.9
12.8
12.7
12.6
12.4
12.3
12.2
12.1
12
Middle Twisp Reach Assessment
Project Opportunities
Buttermilk Fan Project
These drawings should be viewed only as very preliminary concepts intended to describe the types of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations.
Project Elements
Bar apex jam
Margin complexity
Margin jam
Side-channel (existing)
Side-channel reconnection
Human Features
Riprap/Road Embankment
Cabled Logs and Riprap
Riprap
Road
Bridge
Foot Bridge
Gabion Wall
Culvert
Ditch
Intermittent Push-Up Levee
Push-Up Levee
Fill
2-year flood
Reach Breaks
River Miles
2006 LiDAR
0 125 250 500 Feet
N

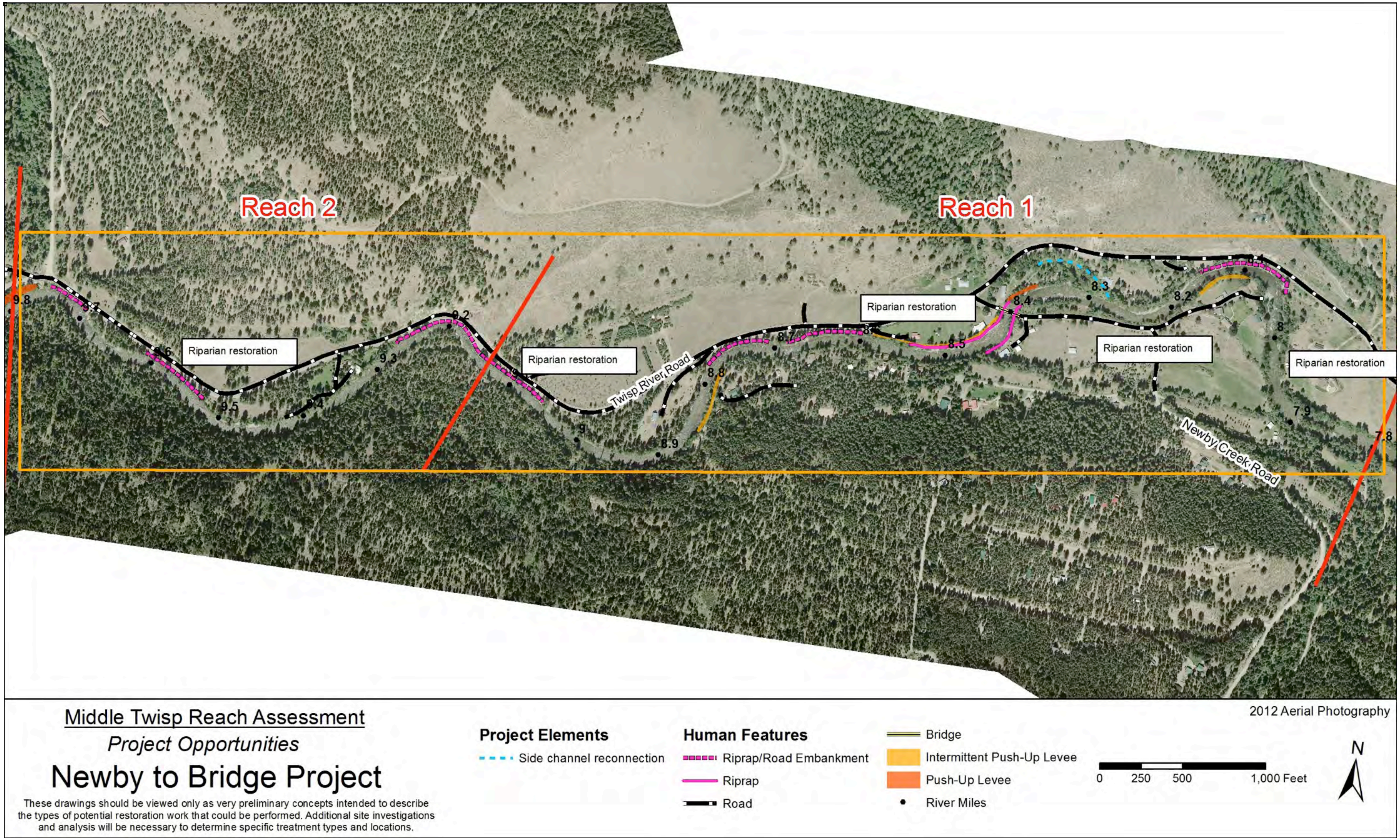

Reach 3
Twisp River Road
E Buttermilk Creek Road
12.2
12.1
12
11.9
11.8
11.7
11.6
11.5
11.4
11.3
11.2
Activate abandoned off-channel network
Riparian restoration
Remove/modify riprap and replace with margin complexity
Middle Twisp Reach Assessment
Project Opportunities
Horseshoe Side-Channel Project
These drawings should be viewed only as very preliminary concepts intended to describe the types of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations.
Project Elements
Bar apex jam
Margin complexity
Margin jam
Side-channel (existing)
Side-channel reconnection
Human Features
Cabled Logs and Riprap
Riprap
Road
Foot Bridge
Ditch
Intermittent Push-Up Levee
Push-Up Levee
Fill
Reach Breaks
River Miles
2012 Aerial Photography
0
125
250
500 Feet
N



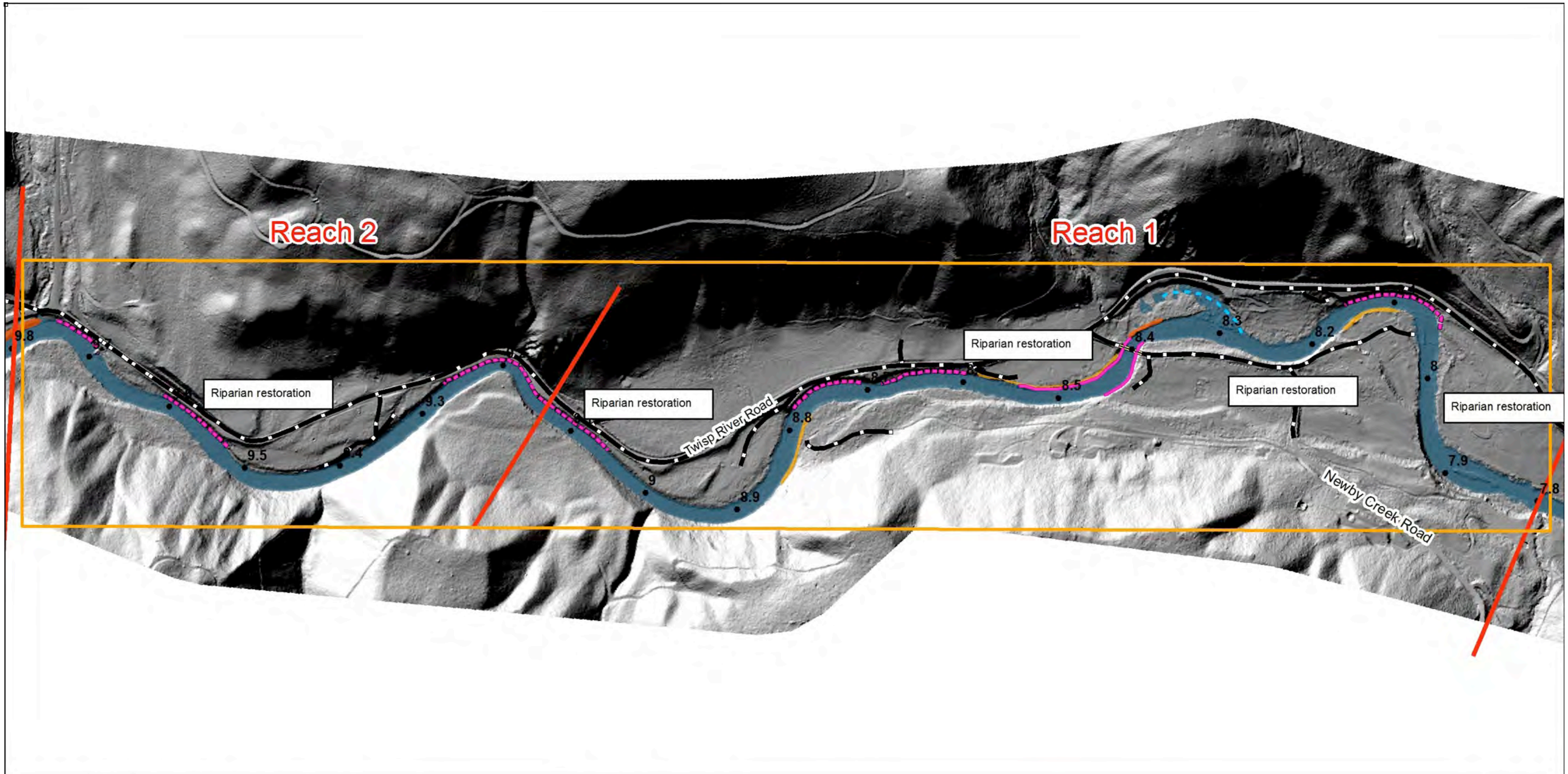
Reach 3
Twisp River Road
12.2
12.1
12
11.9
11.8
11.7
11.6
11.5
11.4
11.3
11.2
Activate abandoned off-channel network
Riparian restoration
Remove/modify riprap and replace with margin complexity
E Buttermilk Creek Road
Middle Twisp Reach Assessment
Project Opportunities
Horseshoe Side-Channel Project
These drawings should be viewed only as very preliminary concepts intended to describe the types of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations.
Project Elements
Bar apex jam
Margin complexity
Margin jam
Side-channel (existing)
Side-channel reconnection
Human Features
Cabled Logs and Riprap
Riprap
Road
Foot Bridge
Ditch
Intermittent Push-Up Levee
Push-Up Levee
Fill
2-year flood
Reach Breaks
River Miles
2006 LiDAR
0
125
250
500 Feet
N


Reach 3
Twisp River Road
Riparian restoration
Riparian restoration
10.8
10.5
10.4
10.3
10.2
10.1
10
9.9
9.8
10.6
10.7
10.9
11
11.1
Middle Twisp Reach Assessment
Project Opportunities
Newby Narrows Project
These drawings should be viewed only as very preliminary concepts intended to describe the types of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations.
Project Elements
Bar apex jam
Margin complexity
Side-channel (existing)
Side-channel reconnection
Human Features
Riprap/Road Embankment
Riprap
Road
Intermittent Push-Up Levee
Push-Up Levee
Rock Barb
Reach Breaks
River Miles
2012 Aerial Photography
0 125 250 500 Feet
N


Reach 3
Twisp River Road
Riparian restoration
Riparian restoration
11.1
11
10.9
10.8
10.7
10.6
10.5
10.4
10.2
10.1
10
9.9
9.8
Middle Twisp Reach Assessment
Project Opportunities
Newby Narrows Project
These drawings should be viewed only as very preliminary concepts intended to describe the types of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations.
Project Elements
Bar apex jam
Margin complexity
Side-channel (existing)
Side-channel reconnection
Human Features
Riprap/Road Embankment
Riprap
Road
Intermittent Push-Up Levee
Push-Up Levee
Rock Barb
2-year flood
Reach Breaks
River Miles
2006 LiDAR
0 125 250 500 Feet
N



Reach 2
Reach 1
Riparian restoration
Riparian restoration
Riparian restoration
Riparian restoration
Riparian restoration
Twisp River Road
Newby Creek Road
9.8
9.7
9.6
9.5
9.4
9.3
9.2
9
8.9
8.8
8.7
8.5
8.4
8.3
8.2
8
7.9
7.8
Middle Twisp Reach Assessment
Project Opportunities
Newby to Bridge Project
These drawings should be viewed only as very preliminary concepts intended to describe the types of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations.
Project Elements
Side channel reconnection
Human Features
Riprap/Road Embankment
Riprap
Road
Bridge
Intermittent Push-Up Levee
Push-Up Levee
River Miles
2012 Aerial Photography
0
250
500
1,000 Feet
N



Middle Twisp Reach Assessment

Project Opportunities

Newby to Bridge Project

These drawings should be viewed only as very preliminary concepts intended to describe the types of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations.

Project Elements

- Side channel reconnection

Human Features

- Riprap/Road Embankment
- Riprap
- Road
- Bridge
- Intermittent Push-Up Levee
- Push-Up Levee
- 2-year flood
- Reach Breaks
- River Miles

2006 LiDAR

0 250 500 1,000 Feet

N

Appendix D

Geology

Middle Twisp River (RM 7.8 – 18.12)

Contents

1 Geologic Setting

The Twisp River basin is located within the eastern portion of the Northern Cascades geologic province. Within this province, the Twisp River lies within the Methow Terrane. This terrane is a combination of sandstone and shale sediments left behind by the Methow Ocean, which covered today's Methow valley region 200 to 100 million years ago. A simplified geologic map is presented in Figure 1.

The Twisp River's U-shaped valley is derived primarily from consecutive glaciation cycles (see Section 4). Within this valley, development of the Twisp River, like almost any river system, has been governed by the underlying geology that it flows over and through. Over time, the Twisp River corridor has formed in a path more easily erodible than surrounding areas. Throughout the channel corridor, fault zones have fractured underlying bedrock and brought together geology types of differing composition, creating opportunities for incision and lateral migration (PWI 2003).

2 Bedrock Types

Within the contributing watershed of the study area, there are four primary types of bedrock: (1) Cretaceous igneous rocks, (2) Late Cretaceous continental sedimentary deposits, (3) Cretaceous-Jurassic volcanic sedimentary and volcanic conglomerate, and (4) Quaternary sedimentary rocks which line the channel corridor. Below RM 9, the bedrock is relatively erodible. Above RM 10, the crystalline structure of the bedrock is relatively erosion resistant. Further upstream, above RM 15, underlying lithology through the channel corridor includes mylonitized materials, rocks which are formed under shear pressures in fault zones, as well as glacially-transported clasts (fragments of larger rocks) and hillslope-sourced metamorphic and igneous rocks (PWI 2003, Bunning 1990). In this portion of the study reach, these lithology types are exposed through much of the study area where alluvium has been eroded away (PWI 2003).

3 Faulting and Geologic Structure

Regionally, there are several major fault systems that affect the study area. These fault systems create topographical and hydrographic divides, and affect the position of the major structural blocks and bedrock elements in the area.

The upper Twisp river corridor (above RM 15 and Scaffold Creek) primarily occupies the Twisp River-Foggy Dew fault zone, a fault-bound structural basin approximately 0.9 miles wide that trends from northwest to southeast (PWI 2003, Bunning 1990). Relative motion along these faults includes both strike-slip (primarily horizontal) and dip-slip (primarily vertical) movement (Haugerud and Tabot 2009). A graben-bounding fault crosses that channel at RM 9, which creates an erosion-resistant "step," or noticeable increase in grade, between RM 9 and RM 10. Downstream of Scaffold Creek, the Twisp flows across a northwest-trending syncline, a fold where the rock dips downward due to pressure from both sides (created between anticlines Thompson Ridge and the adjacent ridgeline) (PWI 2003).

Many faults run adjacent to the mainstem within the contributing drainages, intersecting the mainstem in a perpendicular fashion. This has led to right-angle confluences between many of the Twisp river tributaries and the mainstem (PWI 2003).

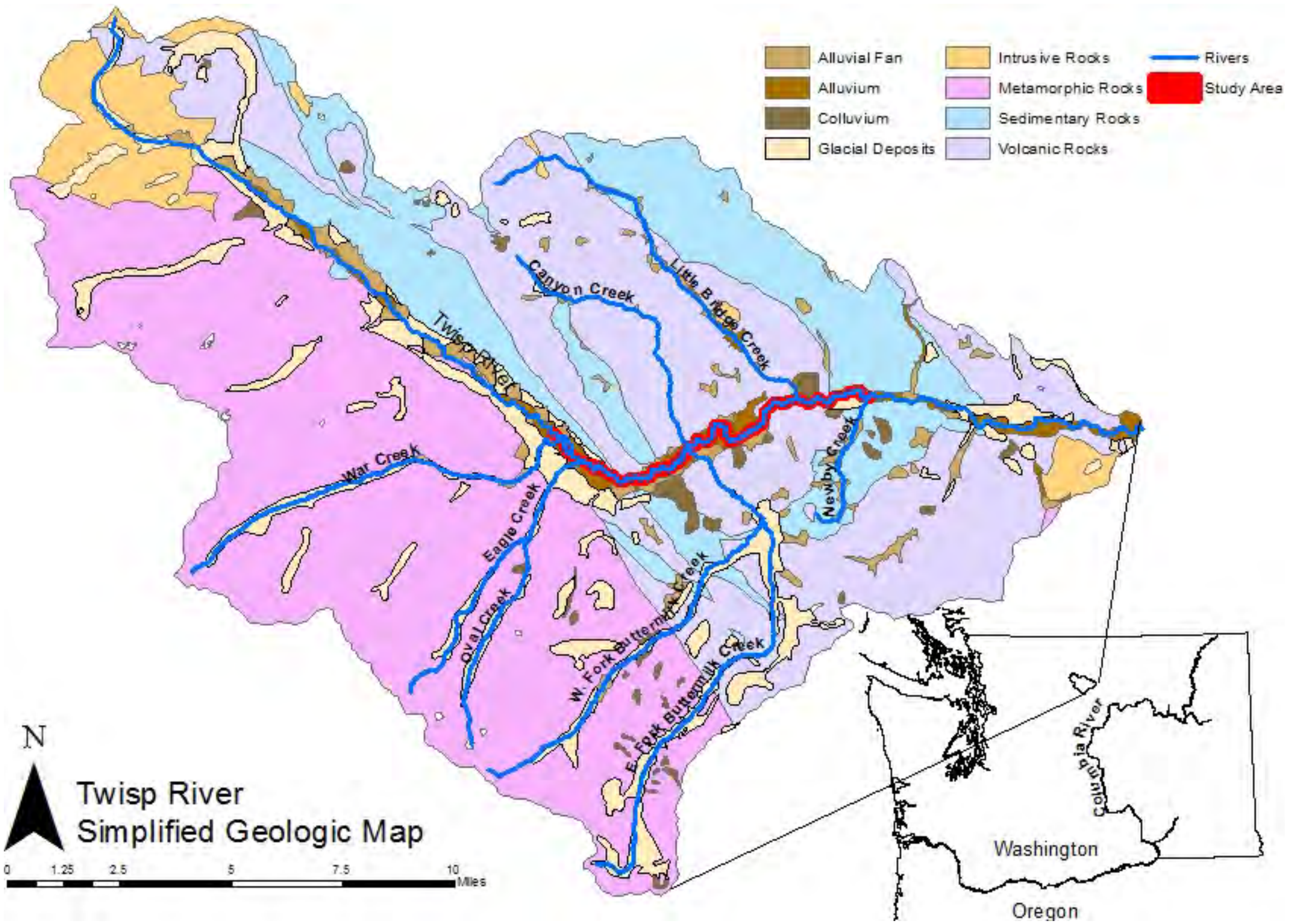


Figure 1. Generalized geologic map of the study area and its contributing watershed showing its location within Washington State and the Northern Cascades Geologic Province (Data acquired from US Bureau of Reclamation Tributary Assessment geodatabase).

4 Glacial History

Current channel and valley form is most directly influenced by glaciation that occurred as recently as 9,500 years ago (USBR 2008). From between 9,500 years ago to 30,000 years ago there were at least one, and potentially several, alpine glacial advances that carved out U-shaped valleys throughout the Methow River basin including the Twisp River basin. An advance of the continental ice sheet also covered the entire Methow basin, but had a greater effect on major topographic features than on morphology at the valley and channel scale. During periods of alpine glaciation, ice streams moved from higher elevations in the basin downslope, carving out rock masses and leaving behind glacial features including U-shaped valleys, till deposits (moraines), outwash deposits (terraces), and glacial erratics. Glaciation extended downstream from headwater valleys to approximately RM 9.3 on the mainstem Twisp River (Waitt 1972). This location approximately coincides with a major slope break in the long profile of the Twisp with slope being flatter upstream and steeper downstream.

Table 1. Methow valley ice sheet advances during the Fraser Glaciation cycle (adapted from Waitt 1972).

Fraser Glaciation Advances	Approximate Age of Deposit
Evans Creek stade	22,000 to 18,000
Cordilleran Ice Sheet	17,000 to 13,500

Although glacial advance carved out the valley of the Twisp River in the study area, fluvial and colluvial processes that occurred during and after glacial retreat have been the primary drivers of current river morphology in the study area. Upstream of RM 9.3, terraces were left behind by glacial outwash deposits and alluvial fans (Waitt 1972). These terraces and deposits have contributed to a flatter slope and exert significant influence on vertical stability, lateral migration, and bed material (Waitt 1972, USBR 2008).

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Appendix E

Historical Forms and Processes

Middle Twisp River (RM 7.8 – 18.12)

Contents

1 Historical Channel Form and Processes

Although there is little direct evidence of conditions prior to the mid-1900s, field observations, high resolution LiDAR, General Land Office maps (1902, 1913), underlying geology, and glaciation cycles can provide some theories on historical channel form. During the Pleistocene era, an era defined by a cooler climate and much larger precipitation volumes, the channel form was likely created by large, high volume flooding and sediment inputs. Large boulders and cobbles located on abandoned floodplain surfaces indicate historically the channel moved much larger volumes of water and sediment. This, combined with periodic bursts of glacial meltwater outwash, created a wide, deep channel, fit for transporting large flows and sediment loads. During this time period, the Twisp River's active corridor likely spanned much of the valley floor.

As the Pleistocene epoch came to a close, glaciers in the region retreated. This left behind thick deposits of glacial sediments (glacial terraces) from the upstream extent of the study area down to RM 10. Concurrently, the Twisp climate became much warmer and drier, and the channel no longer had the volumes of water necessary to fill its channel and span the valley floor. Over time, the now 'underfit' Twisp River down-cut into its channel bed, leaving behind abandoned floodplain surfaces and terrace deposits which serve as contemporary controls on lateral channel migration.

Limits on lateral migration processes were also imposed by bedrock outcrops, mass-wasting deposits, and alluvial fan inputs from contributing drainages throughout the study reach. Historically, alluvial fans delivered large amounts of material to the system. This material correlated with the larger discharges of the time, so these drainages were able to transport large cobbles and boulders. As these sediment inputs aggregated, they spanned across the valley floor. This process, as well as occasional mass-wasting events, would divert the boundaries of the channel, moving it towards the opposite slope. The channel would remain in its new course until larger flows would move this material through the system, allowing the channel to migrate into a new course.

Variations in confinement would have been a major driver of channel-scale geomorphic processes. These variations can be classified into three relative scales of confinement: confined, moderately confined, and unconfined. Throughout the confined reaches (e.g. Reach 2), lateral migration of the channel would have been highly limited by valley wall encroachment and narrow glacial terraces on either side. High confinement and high stream power would have limited habitat complexity principally to boulders. These boulders would have created hydraulic variability, scour pools, and temporary locations for the accumulation of large woody material. Within the moderately confined reaches (e.g. Reach 4), glacial terraces and alluvial fan deposits would have allowed for slightly more channel migration. Here, slightly lower stream power would have made habitat features less transient, with sediment deposition and sorting, wood accumulations, and occasional off and side-channel habitat. Lastly, the unconfined reaches (e.g. Reach 5) would have displayed the highest level of habitat complexity throughout the study area. The processes of channel avulsion, lateral migration, sediment deposition, channel braiding, floodplain scouring, and accumulation of large wood would have created complex habitat features.

2 Historical Hydrologic Regime

The headwaters of the Twisp River originate on the eastern slope of the Cascade Mountains. Historically, following the last period of glaciation, there were likely more active tributaries than contemporary conditions, and these tributaries would have input much larger discharges than today. Similar to contemporary conditions, the natural hydrologic regime within the study area was dominated by the seasonal dynamics of a snowmelt runoff system. The flow pattern would have exhibited increasing flow through the spring with an annual peak in June and a rapid decline to baseflow conditions by August. Due to the coarse alluvial and glaciofluvial sediments characteristic of the watershed, ground and surface water interactions likely had an impact on both discharge and stream temperature (Konrad 2002). Historical streamflows for the Twisp are unknown, as irrigation diversions occurred prior to installation of the first stream gage.

3 Historical Habitat Conditions

There is no information specifically describing the pre-disturbance habitat conditions of the Twisp River within the study area. Land-use development and disturbance had advanced quickly preceding the time of the first reports on conditions in the watershed. Despite a lack of pre-disturbance habitat observations, reasonable reconstruction of historical habitat can be accomplished based on observations of existing conditions, knowledge of first-order controls on channel processes (geology), and the typical results of early documented land-use activities (logging and grazing). Pre-disturbance conditions in the study area can be broken into three categories based on their confinement: confined, moderately confined, and unconfined.

The confined reaches (Reaches 1 and 2) would have had high lateral and vertical stability. These reaches are likely closer to their pre-disturbance condition where major habitat elements in the channel are large boulders, log jams, and plunge pool or dam pools. Off-channel habitat is naturally limited in these reaches, and a reduction in such habitat would not be expected via human disturbance. Log jams would have likely played a very transitory role in providing habitat, with only very large pieces being persistent, as high energy during floods would be capable of moving most large woody material (LWM) through these reaches.

Within moderately confined reaches (Reaches 3 and 4) there would have been an increase in channel complexity and associated habitat elements. Large floods would have created side channel habitat in select locations and large wood would have provided some gravel recruitment and sorting. In areas where glacial terraces and fan deposits created constriction points, habitat would have been less complex.

Within unconfined reaches (Reaches 5 and 6), a higher concentration of gravels, greater sinuosity, side-channels, and wider riparian areas would have combined to create complex habitat. Large wood would have provided cover and complexity, as well as serving as a geomorphic driver of channel form. Off-channel habitat would have been mainly composed of side-channels with some floodplain wetlands.

The earliest available habitat survey was performed in 1935. This habitat survey described a stream capable of supporting runs of several thousand salmon and steelhead with "an adequate number of large resting pools and sufficient shallow riffles to accommodate large runs of salmon and steelhead." Streambed substrate was documented as 65% medium and small rubble, a large portion of which was described as suitable for spawning.

4 Historical Large Wood Dynamics

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

4.1 SOURCES

In a pre-disturbance condition, there were two primary sources for large wood material on the Twisp River (1) additions from the active river corridor (floodplain, terrace slopes, and riparian areas), and (2) wood contributed from the upper basin that entered the system through periodic landslides. Through the study reach, riparian and upslope areas historically included pine and fir (GLO 1913).

The species and size of wood sourced from the contributing watershed would have varied depending upon time since the last disturbance (e.g. floods and fires). Although trees aged between 200 and 500 years of age were found in the watershed, if a disturbance was relatively recent, smaller hardwoods would have likely been predominant (USBR 2008). Conversely, if a disturbance had not occurred recently larger, coniferous trees likely were predominant. Compared to existing conditions, there would have been a greater source of large old-growth trees that would have been periodically recruited to the system. Early General Land Office (GLO) surveys note pines up to forty inches in diameter.

4.2 RECRUITMENT

Historically, large wood would have entered the Twisp from both chronic (i.e. single-tree) mortality and episodic disturbance-related events. Disturbance-related contributions would have included fire, floods, windstorms, avalanches, diseases, and landslides. The unconfined reaches would have recruited wood via lateral and transverse scrolling of the channel, whereas recruitment in the more confined reaches would have occurred primarily through single-tree mortality.

4.3 RETENTION

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

Another important factor affecting wood retention is the degree of channel complexity. A complex channel with numerous obstructions to flow (e.g. bank protrusions, islands, gravel deposits, boulders, wood pieces) will retain wood more readily than simplified uniform channels (Fetherston et al. 1995, Haga et al. 2002, Bocchiola et al. 2008). A historically more complex channel, prior to human alteration, would have retained more wood than contemporary conditions. These wood accumulations would have promoted both geomorphic and habitat functions including creation of pools, sediment retention (trapping) and sorting, increased channel complexity and cover for fish. Through the less confined reaches, these jams would have driven the creation of numerous point- and mid-channel bars and the creation of side channels. Within more confined reaches, large wood jams likely would have been created between large boulders. Wood would have accumulated behind these channel-spanning key pieces until a large enough flood would remobilize the wood and displace the jam.

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Appendix F

Human Disturbance History

Middle Twisp River (RM 7.8 – 18.12)

Contents

1 Early Disturbance

The first documented inhabitants of the region were members of three major bands of the Sinkaietk people (or Northern Okanagans): the Tokoratums, the Kartars, and the Knkonelps. The Sinkaietk spent winters in permanent camps and spent the summers out hunting deer and bears and fishing for salmon. Disturbance in the region was small-scale and related to using the floodplain and river systems as a basis for a subsistence economy. Conflicting reports regarding the origins of the word Twisp exist, but the leading theory is that it is derived from a combination of the native-American words "T-wapsp" which means "yellow jacket" and "Twistsp" which means "sound of the buzzing wasp."

With the exception of some early explorers, fur trappers, and miners, Euro-American settlement began in the Twisp in the late 1890s. Early settlement included construction of homesites, small-scale farming, and local logging. The Town of Twisp was established in 1897, first called "Glovers-Ville" on a plat drawn up by Henry C. Glover. In 1904, Twisp was one of the largest towns in Okanogan County and was filled with farmers, ranchers, and loggers. By this point, the town already included a number of amenities such as a post office, several general stores, a hotel, a state fish hatchery, and two restaurants (Figure 1).

Figure 1. Downtown Twisp in 1909 (West 2011).

2 Mining

The first major impact to the area was in the form of mining. The Methow Valley mining rush began in the Twisp River Valley in 1886, when a large gold ledge was discovered on War Creek (Smith 2013). Miners soon flocked to the area, using the town of Twisp as a supply point before heading up the Twisp River Valley to the Slate Creek Mining district (Smith 2013). By 1897, there were three mines registered in the Twisp mining district. The exact extent of disturbance and mining in the Twisp River Valley is unknown. GLO maps from 1902 and 1913 depict active mines. In the last eight months of 1939 alone, Twisp's Alder mine shipped "230 carloads of ore and four carloads of concrete" sourced from the Twisp area (Figure 2). The rugged conditions of the valley made mining difficult and dangerous, and in the end the region did not prove highly profitable (Smith 2013).

Upland mining and its associated practices have likely impacted the Twisp River in a number of ways, including potential changes to the hydrologic and sediment regime. These may have included removal of instream gravels, diversion of water, and deposition of mining waste in the channel or floodplain.

Figure 2. The Alder Mine outside of Twisp (Methow Valley Conservancy 2013).

3 Agriculture and Grazing

Small-scale agriculture, including clearing, farming, and agricultural diversion dates back to the mid-1800s. Available information for the majority of these uses is described at the wider Methow Basin scale. The first documented cattle grazing in the Methow region dates back to 1889, with sheep grazing becoming commonplace during the 1920s and 1930s (Figure 3). As demand for wool escalated during World War I, over 75,000 sheep grazed the headwaters of the Twisp (McLean 2011). Grazing rates slowed significantly in the 1940s and 50s. Most contemporary grazing is limited to the lower elevations, with about 2,800 cattle grazing the Methow valley annually.

Although a significant economic and cultural resource for the Methow valley, riparian grazing historically resulted in some localized soil compaction, bank erosion, and loss of riparian understory seedlings and shrubs. Perhaps the most significant historical impacts of agriculture on the Twisp River were water diversions. Many of these were unscreened and resulted in direct fish mortalities, while the combination of others withdrew instream flows during low flow periods critical to salmonid habitat.

Figure 3. Sheep grazing in the upper Methow (Methow Valley Conservancy 2012).

4 Timber Harvest

Timber harvest began in the region in the mid-1800s. Cabins, boat ramps, and early roads are visible on survey maps from GLO maps by 1902, indicating that by this point small-scale timber harvest was ongoing in the area. Land was usually cleared for farming and grazing (USBR 2008). In 1910, a traveler to the area noted seeing "billions of board feet of Timber" (West 2011). By 1940, the pace and scope of the region's timber harvest accelerated with the expansion of the railroad, improved technology, and the construction of sawmills in the area and continued until the 1970s. In the 1970s, a dramatic shift in USFS policy came in the form of the USFS Twisp/Winthrop/Conconully (TWC) Forest Environmental Impact Statement. This document brought timber harvest to a complete standstill (MVCC 2000). Eventually this plan was repealed allowing timber sales to return to some of the forest. Today, approximately 90% of the land in the Twisp River drainage is USFS land, about half of which is located within the Chelan-Sawtooth wilderness area and is administratively withdrawn from most active management activities including thinning and prescribed burns (USBR 2008). On non-wilderness lands, large-scale timber harvest and associated road building primarily occurs in the form of salvage operations following wildfires.

Upland timber harvest and its associated practices have likely impacted the Twisp River in a number of ways. In addition to removal of sources of large wood, these include potential changes to the hydrologic and sediment regime. Although mass-wasting events and alluvial fan contributions are a natural process in the Twisp, research indicates that forests with a history of timber harvest exhibit increased amounts of landslides and debris flows (Benda and Cundy 1990, Swanson and Lienkaemper 1978, Sidle et al. 1985). This is related to the destabilizing effect of tree removal and the hydrologic/erosion effects of the forest road network.

Timber harvest along the valley floor has also directly altered channel processes since the late 1800s. Harvest and removal of riparian trees was documented as early as 1902 (GLO) and continued through much of the 20th century. This removal of riparian vegetation led to the associated loss of the important channel functions this vegetation serves, including streambank stability, flood moderation, regulation of inundation processes, shade, moderation of stream temperature fluctuations, and providing future sources of large wood material to the channel. Although riparian clearing is no longer occurring in most of the study reach, the effects of this historical practice will continue to affect wood-loading for the foreseeable future.

5 Fire Suppression

The fire regime within the Twisp River Watershed is a major driver in forest ecology, which influences riparian stand conditions and ultimately, instream flow patterns and large wood conditions. Prior to Euro-American settlement, the Twisp River fire regime would have been primarily low intensity on a relatively frequent recurrence interval (e.g. every five years) (USFS 1995). Fire suppression began in 1911 and has continued through today. This has led to an altered fire regime and an increased risk of moderate to high intensity burns within the watershed (PWI 2004, USFS 1995).

Fire suppression within the basin has also led to shifts in vegetative composition from more open stands of fire-tolerant species (primarily ponderosa pine) to higher density stands of less fire-tolerant species (primarily Douglas fir). Since the 1920s, there has been a 73% reduction of ponderosa pine in the watershed, as well as a buildup of fuels along the forest floor (USFS 1995). The historically more open stands had larger trees than the higher density stands seen today, which has served to decrease the size of riparian trees that are now available to be recruited by the river.

6 Habitat Alterations

Habitat alterations within the Twisp River Watershed began in the late 1800s. Most of the historical information that is available applies to the lower Twisp River, below the study area, and may have only limited applicability to the Middle Twisp. Irrigation diversions were present on maps as early as 1902. These diversions were not screened until the 1930s or later, and combined with dams on the mainstem Methow and Columbia Rivers, led to a rapid decline in salmonid populations. By 1935, there were 16 documented irrigation diversions on the Twisp River. The majority of these were unscreened until the 1930s. One diversion, located at approximately RM 0.5, diverted the entirety of the Twisp River's flow during the late summer months. An early report noted that the numerous dams and diversions throughout the basin led to such unfavorable habitat conditions, that "only a few early run spring chinook and even less steelhead trout" remain (Bryant and Parkhurst 1950).

One of the most significant human impacts to stream channels has been direct wood removal. Wood has been removed from stream channels for various reasons. Following both the floods of 1948 and 1972, the Army Corps of Engineers utilized bulldozers to remove large wood and channelized Little Bridge Creek, a tributary of the Twisp (RM 9.78), as well as some segments of the mainstem Twisp River (KWA 2004, PWI 2003). These activities removed natural large wood accumulations and channel substrate, as well as straightened portions of the channel. This work was done for flood protection. Wood has also been removed in more recent years to address recreational safety issues and to protect against potential property damage.

7 Development Trends Since 1950

In addition to the historical trends in development that have taken place in the region, there was an increase in human disturbances throughout the study area since the 1950s resulting in significant impacts to the sediment transport and hydraulic regimes. The study area is currently 31.3% public property and 68.7% private property within the low geomorphic surface, with the National Forest accounting for a majority of the public property. Much of the private property has undergone vegetation clearing, floodplain grading, and residential development, which continues today and accounts for 18.8% of the surface area on the low geomorphic surface. The valley bottom within the study area has a road density of 3.4 mi/mi^2.

Flood mitigation practices of the mid- to late-1970s led to removal of native substrate and habitat elements such as log jams. Those practices also included the construction of levees to prevent flooding on private property, which reduces floodplain connectivity and lateral channel migration. Riprap was also used intermittently throughout the study area as a method of bank stabilization for residential properties as well as roadway embankments and bridge abutments. This armoring limits natural lateral channel migration and sediment sourcing from streambanks.

Table 1. Human alterations and development in the study area. The low geomorphic surface includes the contemporary floodplain and alluvial terraces.

Metric	Value in the Low Geomorphic Surface
Road Density	3.4 mi/mi^2
Public Land	31.3%
Private Land	68.7%
Portion of Channel with Levees and Bank Armoring	27.5%
Developed and Cleared Land	18.8%

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Appendix G

RTT Comments & IFI Response

Middle Twisp River (RM 7.8 – 18.12)

UCRTT
UPPER COLUMBIA
REGIONAL
TECHNICAL TEAM

December 10, 2014

To: Hans Smith
From: RTT
Re: Middle Twisp Reach Assessment

The RTT would like to thank the Yakama Nation for the opportunity to review the Middle Twisp Reach Assessment and appreciates the YN's patience in waiting for our response. The comments below were developed by Chuck Peven and Joe Lange on behalf of the RTT.

Introduction

The section of the Twisp River that this Reach Assessment (RA) addresses encompasses portions of two assessment units (AU); the Lower (RM 0-14) and Upper Twisp (RM 14-31). In the Upper Twisp, factors that the RTT believes (RTT 2014) are affecting habitat conditions are:

- Campground effects on riparian in several locations.
- Channel clearing and LWD removal reduced channel complexity.
- Road placement and bank hardening have isolated sections of the main channel from its floodplain and side channels in a few places.
- Skid roads in riparian areas increase dispersed recreation use impacts to the stream.

While in the Lower Twisp AU:

- Low instream flows and high water temperatures in the lower Twisp River affect several species at several life history stages (The lower Twisp River is listed on the Washington State 303(d) list for inadequate instream flow and for temperature exceedance).
- The Twisp River (from Buttermilk Creek to the mouth) has been cut off from its floodplain and side channels through dikes and riprap in places, resulting in a simplified channel; see (Inter-fluve 2010) for additional details.
- In the lower Twisp River (RM 0.0 – 16.5) LW levels and recruitment potential are well below geomorphic potential (Inter-fluve 2010).
- The MVID West Canal diversion on the Twisp River at RM 3.9 is a river cobble levee dam that must be pushed up each year, disturbing salmonid rearing and spawning habitat.
- Development of riparian and floodplain areas has impaired channel migration, riparian condition and floodplain function (Inter-fluve 2010).
- Residential development has impacted riparian in many locations.

In addition, the RTT believes (RTT 2014) that the ecological concerns (ECs; in priority order) in the Upper Twisp are:

1. Peripheral and Transitional Habitats (Side channel and Wetland Habitat Conditions)
2. Channel Structure and Form (Instream Structural Complexity)
3. Channel Structure and Form (Bed and Channel Form)
4. Riparian Condition (Riparian Condition)
5. Food (Altered Primary Productivity)
6. Sediment (Increased Sediment Quantity)
7. Species Interactions (Introduced Competitors and Predators)

And in the Lower Twisp:

1. Water Quantity (Decreased Water Quantity)
2. Channel Structure and Form (Bed and Channel Form)
3. Peripheral and Transitional Habitats (Side channel and Wetland Habitat Conditions)
4. Channel Structure and Form (Instream Structural Complexity) *(below Buttermilk Creek)*
5. Riparian Condition (Riparian Condition)
6. Food (Altered Primary Productivity)
7. Sediment (Increased Sediment Quantity)
8. Species Interactions (Introduced Competitors and Predators)

The RTT realizes that since the RA did not address the exact geographic area of the AUs, so some of the ECs may not apply to the area that was assessed. The RA broke the total study area into sub-reaches, and sub-reaches 1-4 (RMs 7.8-13.6) are in the Lower Twisp AU and sub-reaches 5 and 6 (RMs 13.6-18.12) are in the Upper Twisp AU.

Results

General Comments

The RTT believes that this RA could be improved with more attention to logic flow and editorial needs. In many cases, information is summarized and the text does not guide the reader in all cases to where the additional detail may be found.

We were curious why the USBR subbasin assessment (USBOR 2008) information was not used to a greater extent. There is information in some of the appendices that this assessment could have extended on instead of having to collect it all again.

As recommended in the Appendix D of the biological strategy, the reach assessment should describe the historic condition, how those historic conditions have been altered or changed, identify how/why the change occurred, and describe the target conditions for which habitat improvement actions should aim, understanding that complete replication of past conditions is likely not feasible. We did not see this information in the assessment.

Detailed Comments

Main Report

Section 2.4.2:

- Channel Manning's "n" should also be calculated on pebble count data (e.g. Limerinos or similar equations) and should be adjusted as depth/flow change.
- Use of LiDAR data should be validated with measurements of actual measured elevations in the field.
- The hydraulic analysis should also include low flows. Errors in the floodplain would have little to no effect for these small flood flows. A base flow should be determined at the time of the LiDAR flight. This base flow should be subtracted from the flood flows that are used in the hydraulic analysis if only LiDAR data is used. The BOR collected GPS or total station survey data which was used in the Methow Subbasin Geomorphic Assessment (USBOR 2008). These data should be used in combination with the LiDAR data.
- The results from the hydraulic analysis should be shown in detail in an appendix.
- There is no validation of the hydraulic model. The water surface elevation should be measured in the field, at several known discharges, and compared with the predicted water surface for the hydraulic model. Adjustments within the model should be made until the model results are comparable to field measurements.
- The USFS collected pebble counts for the Methow Subbasin Geomorphic Assessment (USBOR 2008) at each surveyed cross section (~2 per mile). This data should be combined with the data collected for the assessment. All data should be contained in an appendix.

Section 2.4.3:

- Figure 8: Should be reaches 1-3 (not 1-32).

Section 2.5.1:

- What data was utilized to determine stream morphology and how was it collected?
- How are the metrics (pool, glide, riffle, rapid, etc.) in Table 7 defined?
- Figure 61: RM 12.15, river-left: we could find no information on the ditch other than it located on Figure 61. Additional information should be included.

Section 3.5.2:

- Geology and Landforms: The term "healthy" may be misleading and should be removed.
- Figure 70: Hydraulic modeling of lower flows (<2-YR) would help identify low flow side channel features within this reach.

Section 3.5.3:

- Human Alterations: The statement that most of the reach length is largely unaffected by human alterations may be an incorrect. Removal of large trees through logging may be the primary cause of accelerated lateral migration and the extreme dynamic nature of the channel in this reach.
- Figure 80: Please add river miles to this figure.

Section 3.6.1:

- Last sentence, first paragraph, please remove the word “healthy.”

Appendix C

Page 2:

- Right and left bank margin jams should be considered in braided, high dynamic areas to reduce the rate of lateral migration. In addition to this measure, riparian re-vegetation should emphasize the establishment of large conifers and cottonwoods.
- Cooler water temperatures were identified at RM 14.48 in the TIR surveys (2001, 2009) which were stated as being from hyporheic flow and a side channel. Why are no projects identified that would improve these conditions?

Page 3:

- Is there potential for an apex jam or boulder cluster at the island at RM 13.15?
- Check referenced RM's. It appears that the high flow channel entrance is at ~RM 12.85, river-left, and extends down ~RM 12.68.
- Reach 4 is shown as extending from RM 12.22 to 13.60 (not 13.9). If kept with "Buttermilk Fan" project then Reach should be 4-5.
- RM 12.6 - 12.9: Boulder clusters?
- Is there potential for an apex jam or boulder cluster at the island at RM 12.1?

Page 4:

- Is there potential for the removal of the riprap on river-left at RM 10.95? It is difficult to tell from the ortho photo if the riprap is protecting infrastructure.
- Additional boulders could be added to the large boulder to form a boulder complex which could begin a natural log jam to form.
- Should this be RM 9.96 to 10.1 (not 10.96)?

Page 5:

- Reach 1: Why is there no proposed removal of riprap at RM 8.4 and reconnection of the oxbow from RM 8.3 to 8.4 (Reach 1).
- Reach 1 & 2: Why is large wood proposed in a high gradient, confined reach? It seems that channel margin complexity enhanced with large boulders may be more

appropriate in Reach 1 & 2. The assessment identifies hydraulic complexity being provided by boulders (page 52).

The next section is a broader view of some of the proposed actions.

Sub-reaches 1-4

In sub-reach 1, there appears to be little opportunity to do much except some riparian restoration (Section 4.5.1), which is the 6th priority EC (RTT 2014). One area may be available for side channel creation (4th priority EC), and other areas where large wood could be deployed to enhance in-stream habitat complexity. The RA states that the addition of wood structures may be small scale and isolated and may not provide enough benefit. The RTT disagrees based on monitoring information from the Entiat River that showed fish use of isolated, small wood structures was most likely beneficial (Polivka et al. in press).

In the table that follows Section 4.5.1 (we suggest numbering and titling these tables), under the attribute "Floodplain Connectivity," there is an action identified to reconnect habitat via "infrastructure modification." It is not clear what this action entails and the RTT is curious about this recommendation because the summary of this reach suggests that these opportunities are limited because of natural confinement of the reach. This same concern applies to the next attribute ("bank condition/channel migration," which would apply to the EC *bed and channel form*). In addition, an action is identified under this attribute for *placement of structural habitat elements*, but the RTT is not clear what this means and why it is suggested under this attribute. Under the attribute "off-channel habitat" an action type is identified for *habitat reconnection via infrastructure modification*. What existing infrastructure would be modified? Are there levees that can be removed? We suggest that if using the term infrastructure that it relate to man-made attributes, or the infrastructure items that will be addressed are identified.

In sub-reach 2, Section 4.5.2 states that there is "very limited opportunity for meaningful restoration." In the table that follows Section 4.5.2, under attributes "pools" and "large wood and log jams," the action type *placement of structural habitat elements* is suggested under the "Newby to Bridge" project, but Appendix C (what happened to B?) does not show where this action type could occur. If the direction is not to add these action types, then we suggest that they be removed from the table following section 4.5.2.

For sub-reach 3, there appears to be many restoration opportunities as discussed in section 4.5.3. Section 4.5.3 discusses two projects, "Newby Narrows" and "Jennings." However, in Appendix C, there is the Jennings project, but what we assume is the Newby Narrows project is entitled "Old Oxbow." We suggest making sure that these project names are reconciled. Regardless of the names, the project opportunities look like they will increase off-channel habitat to a significant degree, addressing the 4th priority EC. There are bar apex jams identified in various areas fir the "Old Oxbow" project in Appendix C that do not appear to be linked to reconnection of side channel habitat. Please explain why these structures are suggested in the places that are shown in Appendix C. We assume they are supposed to function as more than habitat complexity structures since there appears to be separate structures identified along the various locations. The same question relates to the Jennings project for some of the "margin jam" locations (most are clearly associated with side channels, but some do not appear to be).

The projects identified for sub-reach 4 appear straight forward and the potential constraints are identified well.

Conclusions for Sub-reaches 1-4

The top six ECs for the Lower Twisp AU that the RTT has identified appear to be addressed to various degrees within the reach assessment. While the number one priority EC (*water quantity*) and number 2 priority EC *(water quality (temperature))* are not directly addressed, the project types identified within the reach assessment will most likely address them through the amount of side channel reconnection that is suggested.

Sub-reaches 5 and 6

Based on the information presented, the bottom portion of sub-reach 5 appears to be well functioning habitat as discussed in section 4.5.5. The RTT agrees that protection should be the focus in this reach and does not believe the addition of large trees (Buttermilk Bends Project), as suggested within the reach assessment is necessary because it is not likely to provide a significant habitat increase for the likely amount of effort. In addition, the table that follows section 4.5.5 suggests that roads, riprap, lawns and houses are affecting the riparian zone and restoration is needed. We believe that the map on pages 11 and 12 of Appendix C are incorrect: they states "Reach 6" where most of what is viewed for the Scaffold Camp Project appears in sub-reach 5. This caused some confusion among reviewers, especially since the area of sub-reach 5 downstream from this area (downstream of RM 15.3) does not show any human attributes such as lawns and houses, which the Scaffold Project is aimed at addressing. We suggest rectifying this mistake.

In addition, the figure on page 12 shows placements of whole trees within the main channel of the river. We recognize that these drawings are preliminary, and the locations of suggested restoration actions need to be refined, but please explain what function they will perform, how they will be located, and how they will be held in place.

Also on page 12, one of the actions (large white box near top of page) suggested is to remove levees and re-grade the floodplain area to create side channel area. Before this is considered, it would be nice to understand how much floodplain area needs to be re-graded and whether the potential biological benefit would be worth the effort. Could the levees be removed and then the floodplain be allowed to re-grade itself in higher flows?

In the table that follows 4.5.5, the description for pools suggests that the current condition (13.2 pools/mile) far exceeds the target condition (~ 4 pools/mile). Why are there suggested action types? We realize that some of the actions that are meant to address other attributes will create pools, but it seems to be clear, no action types should be suggested (this is a comment that may relate to other tables as well).

For the “Eagle Project,” we have similar comments as above regarding the placement of whole trees. Also, we encourage the connection to the wetland as described. However, we do not understand the need for riparian restoration in the Eagle Project area; it appears to be intact.

The “War Project” appears straightforward and some of the same comments (whole tree placement, need for riparian restoration, suggested actions for pools when the existing condition exceeds the target) apply in this area also.

Conclusions for Sub-reaches 5 and 6

The reach assessment appears well focused on addressing the top three ECs identified by the RTT in this section of river, especially related to side channel development/reconnection. While we recognize that there may be discreet areas where riparian restoration is needed, the area appears in relatively good shape and we would recommend not extending a lot of effort for this restoration attribute.

Overall Conclusion

Overall, the reach assessment describes the current condition of the habitat well, including the threats that have existed in the past and continue to affect fish habitat condition. Some of the actions suggested may not be necessary or provide enough benefit to be worthwhile. Additional evaluation (beyond the assessment) will be needed once specific projects begin to be identified.

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Response to RTT Comments on the August 2014 DRAFT Middle Twisp Reach Assessment.

Comments received by Yakama Nation December 10, 2014.
Responses provided by Inter-Fluve January 2015

We appreciate the thorough review and thoughtful suggestions on the DRAFT Reach Assessment by Chuck Peven and Joe Lange on behalf of the RTT. The review comments have helped to strengthen and improve the final document. Responses to the comments are included below.

Introduction

Thank you for the summary of the RTT factors and Ecological Concerns. The findings of the Reach Assessment are very much in keeping with the factors and ECs that apply to the specific study area covered in the RA. The RA has further defined and characterized the specific degree and mechanisms of degradation with respect to these factors and ECs, and has also identified additional factors and concerns affecting channel processes and habitat.

General comments

1) Logic flow and editorial needs – Technical editing of the document was performed for the Final to address logic flow and editorial needs. Chapter 2 was re-configured to improve flow and readability. Detailed information on Geology, Historical Forms and Processes, and Human Disturbance History was moved into 3 separate appendices, replacing the previous "Appendix D" in the draft report.
2) Using USBR data – USBR data from the subbasin assessment was used extensively. We have added information to be clearer on when and how we used it. New data that were collected built upon and refined the USBR data for use at the reach-scale, but did not duplicate data collection efforts where sufficient data were already available.
3) Historic and target conditions – In the reviewed draft, historical information was placed in Appendix D (Historical Conditions and Human Disturbance History). In addition, the change from historical conditions is the focus of the reach chapters. Chapter 2 of the report has been re-arranged for the final draft and we now have a section in the main report on Historical Conditions, with most of this information still contained in an appendix in order to improve readability of the main document. There is also now a separate appendix for Human Disturbance History, which also helps identify how habitat and processes have changed from the historical condition. With respect to target conditions, these are a core part of the Restoration Strategy and we believe they are clearly stated there. The strategy also includes the recommended actions for bringing existing conditions up to target conditions.

Detailed Comments

Main Report

Section 2.4.2:

We appreciate these suggestions to improve the hydraulics analysis. Using a LiDAR-based model has been performed based on past recommendations by the RTT; and although we think it is useful for some purposes (e.g. to help understand general floodplain connectivity and effect of human structures), it is important to recognize that this is a coarse-scale planning-level tool to help inform the assessment. It is not intended for detailed analysis at the project-scale. Detailed 1D and 2D models, based on surveyed data, are currently being used for project design in specific areas. Model validation using surveyed WSEs, LiDAR validation using ground surveys, roughness based on pebble count data, etc are indeed used for the project-specific models, but are beyond the scope or purpose of the Reach Assessment model. As for the use of the model for analysis of low flows, we believe the LiDAR-based model would be inappropriate for this given the absence of bathymetry data. And although subtracting the flow at the time of the LiDAR flight may improve the results, it does not solve this problem. Thank you for the information regarding the USFS pebble counts. Although these are not included in the Reach Assessment analysis, we will apply these as appropriate for work at the project-scale.

Section 2.4.3:
Change made

Section 2.5.1:

- Bullet point 1 – Bed morphology is based on the habitat assessment (Appendix A). A reference to the habitat assessment was added here.
- Bullet point 2 – This information is included in the habitat assessment (Appendix A). A reference to the habitat assessment was added to the table caption.
- Bullet point 3 – Did not understand the comment. There is no mention of a ditch or Figure 61 in this section. Figure 61 does show a ditch, but not sure what "additional information" was being requested. We do not know what the origin of the ditch is.

Section 3.5.2:

- Bullet point 1 – Agreed. Removed the word "healthy" and replaced with a more detailed description of the conditions.
- Bullet point 2 – The LiDAR-based model is not adequate for evaluation of low flows due to the lack of channel bathymetry data.

Section 3.5.3:

- Bullet point 1 – Agreed, this paragraph was edited accordingly
- Bullet point 2 – Change made

Section 3.6.1:
Change made

Appendix C

The handful of editorial recommendations/corrections were made. With respect to the comments on the recommend treatments, it is important to note that the treatments identified in the RA are very preliminary (pre-concept) and are intended to convey the general recommended approach to restoration. More specific treatment alternatives will be developed based on detailed site surveys, detailed hydraulic modeling, input from landowners, and additional data collection. Site assessment and treatment alternatives are currently being developed for three top-priority sites in

Reaches 3, 5, and 6. The specific comments provided by the RTT will be considered and incorporated as appropriate as part of these project design efforts, where they apply.

Sub-reaches 1-4

This section contains some overall comments on the recommended restoration strategies for these reaches. As stated earlier in response to comments on Appendix C, we appreciate these suggestions and they will be considered and incorporated as appropriate as part of more detailed project design efforts.

Tables in Section 4.5.1 were numbered and titled.

The comments on the strategy tables resulted in some edits that improved the consistency between the Action Types and the specific elements contained in the Projects themselves. Some of the questions that were not specifically addressed may be clarified by referring to the definitions of the restoration "Action Types", which are included previously in Section 4.3.

As for not identifying specific places in Reaches 1 and 2 for "Placement of Structural Habitat Elements", we did not identify specific areas because we believe their locations will be opportunistic due to private lands, numerous riprap banks, houses and yards close to the channel, etc. We do, however, believe that where these wood placements can occur, they would be beneficial, so we think it is good to still include this potential action. Further coordination with landowners will be necessary to determine feasibility and specific locations.

We have reconciled the names for the Newby Narrows (formerly "Old Oxbow") project.

With respect to purposes of the jams, these are described in the Appendix C text. Apex jams are used to create split-flow conditions and to build mid-channel bars as well as to activate side-channels. Margin jams may serve numerous purposes. It is beyond the scope of this document to describe the purpose of every jam, especially since specific locations are very conceptual at this point. Further phases of design will identify and describe the specific location and purpose of each structure as well as for all other habitat enhancement actions.

Conclusions for Sub-reaches 1-4

No response required

Sub-reaches 5 and 6

This section contains some overall comments on the recommended restoration strategies for these reaches. As stated earlier in response to comments on Appendix C, we appreciate these suggestions and they will be considered and incorporated as appropriate as part of more detailed project design efforts.

Reach labels on the Scaffold Camp project maps were corrected

The function of the whole trees (map in Appendix C page 12) is explained in the text in the table ("…to serve as key members to collect fluvially-transported wood and build log jams").

Ballasting methods will be determined during project design based on detailed hydraulics analysis and with reference to stability criteria (yet to be developed). The same applies to the same comment for the Eagle Project and the War Project.

Agreed about the need to determine the biological benefit of floodplain work at Scaffold Camp. This is designed to be a long-term process-based approach to restoration. There will be numerous alternatives considered with respect to how to address the levees and floodplain restoration in order to maximize biological benefits.

With respect to actions to increase pools at Scaffold Camp, the high pools/mi is largely due to the downstream portion of the reach that is higher quality and has high pool frequency. Pools at the Scaffold Camp project area are of lessor quality and could benefit from enhancement efforts. The same applies to the same comment for the War Project.

Conclusions for Sub-reaches 5 and 6

No response required

Overall Conclusion

No response required