Twisp River Scaffold Camp
Concept Design Report

SUBMITTED TO
Yakama Nation Fisheries

JANUARY 2015

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Yakama Nation Fisheries
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Introduction

OVERVIEW

The Scaffold Camp project area is located in the middle segment of the Twisp River, approximately 16 miles upstream of the confluence with the Methow River. The attached concept design plans contain additional site information. The overall project goal is to improve habitat conditions for ESA-listed salmon and steelhead in accordance with the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (UCSRB 2007) and the associated Biological Strategy (RTT 2014). The goal of this phase of the project is to present concept design alternatives for restoration of the Scaffold Camp project area. This report describes existing information, describes the collection of data and subsequent analysis used to support designs and describes the various alternatives that were examined.

This report summarizes:

- Goals and objectives
- Design criteria
- Background on site conditions
- Site assessment
- Description of project components
- Conceptual designs

PROJECT AREA DESCRIPTION

The Scaffold Camp project area is located between River Mile (RM) 15.1 and 16.4 of the Twisp River. Land ownership along the project reach is mainly private, with two parcels on the right bank from RM 15.4 to RM 15.7 designated as “Common Areas”. Overview maps are included in Figure 1 and Figure 2.

The gradient through the project area is moderately steep (~0.7%) and portions of the reach are disconnected from the adjacent floodplain at all but the largest flood events. The Twisp River Road parallels the channel to the north of the site, at elevations 20 to 30 feet above the existing floodplain surface. Site access is possible from both sides of the valley but is much more straightforward from the north. A segment of the south side of the reach (RM 15.8 to 16.0) is bounded by steep cut banks along a high terrace, and another segment to the south (RM 15.4 to 15.7) is adjacent to a side channel/wetland complex. Channel modification is very prevalent in the reach, particularly from RM 15.55 to RM 16.1 where a series of pushup berms limits the river’s access to the floodplain surface to the north. A series of excavated ponds occupy portions of the former main channel alignment in this area. A few active side channels are present on the existing floodplain surface (for example, on river right between RM15.55 and RM 15.4). Limitations on in-stream fish habitat in this reach include channel planform simplification, floodplain disconnection, and a reduced quantity of in-stream wood. Habitat conditions are discussed in more detail below in the Fish Use and Habitat Conditions section.

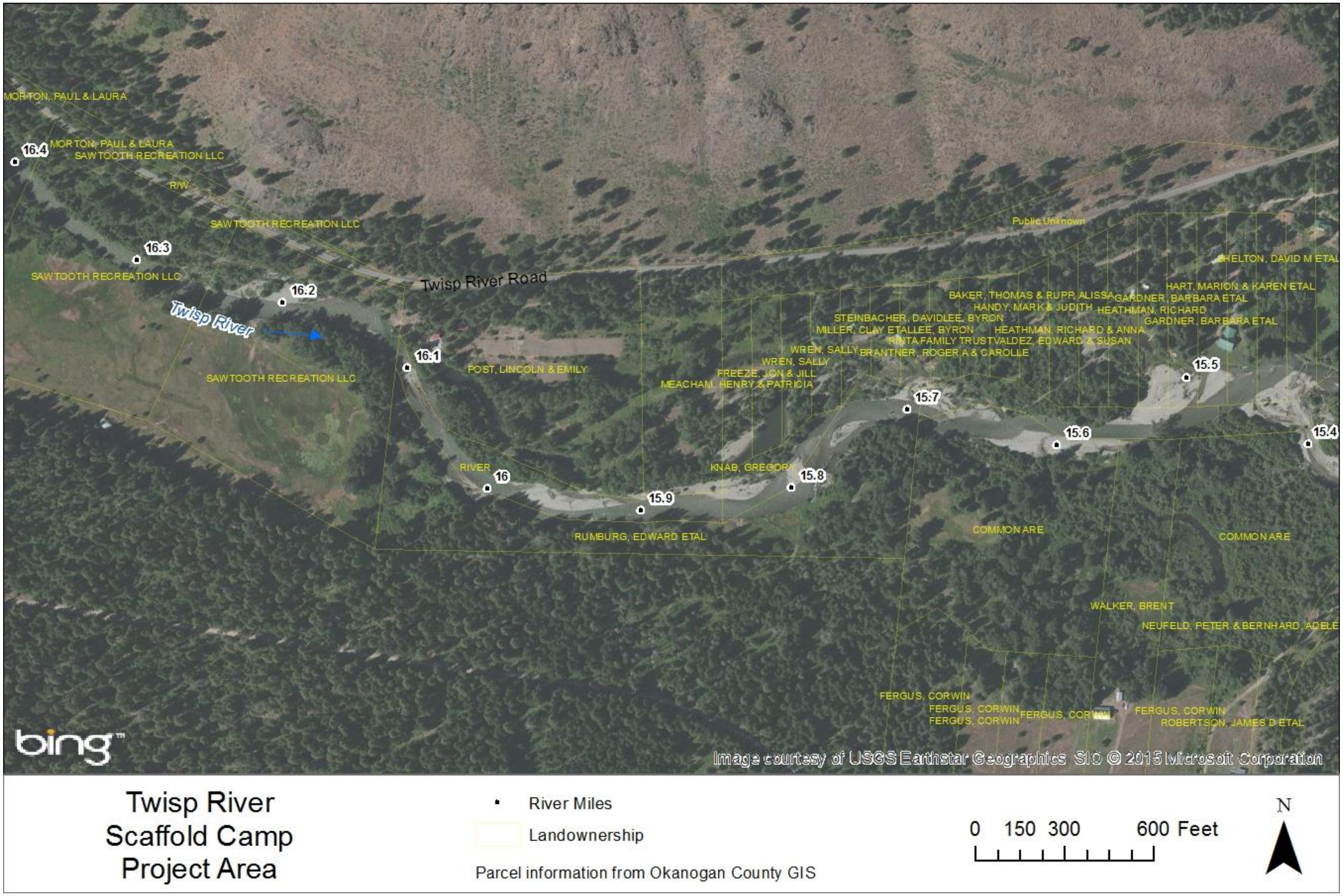

Figure 1 - Overview map of Scaffold Camp project area with aerial photo

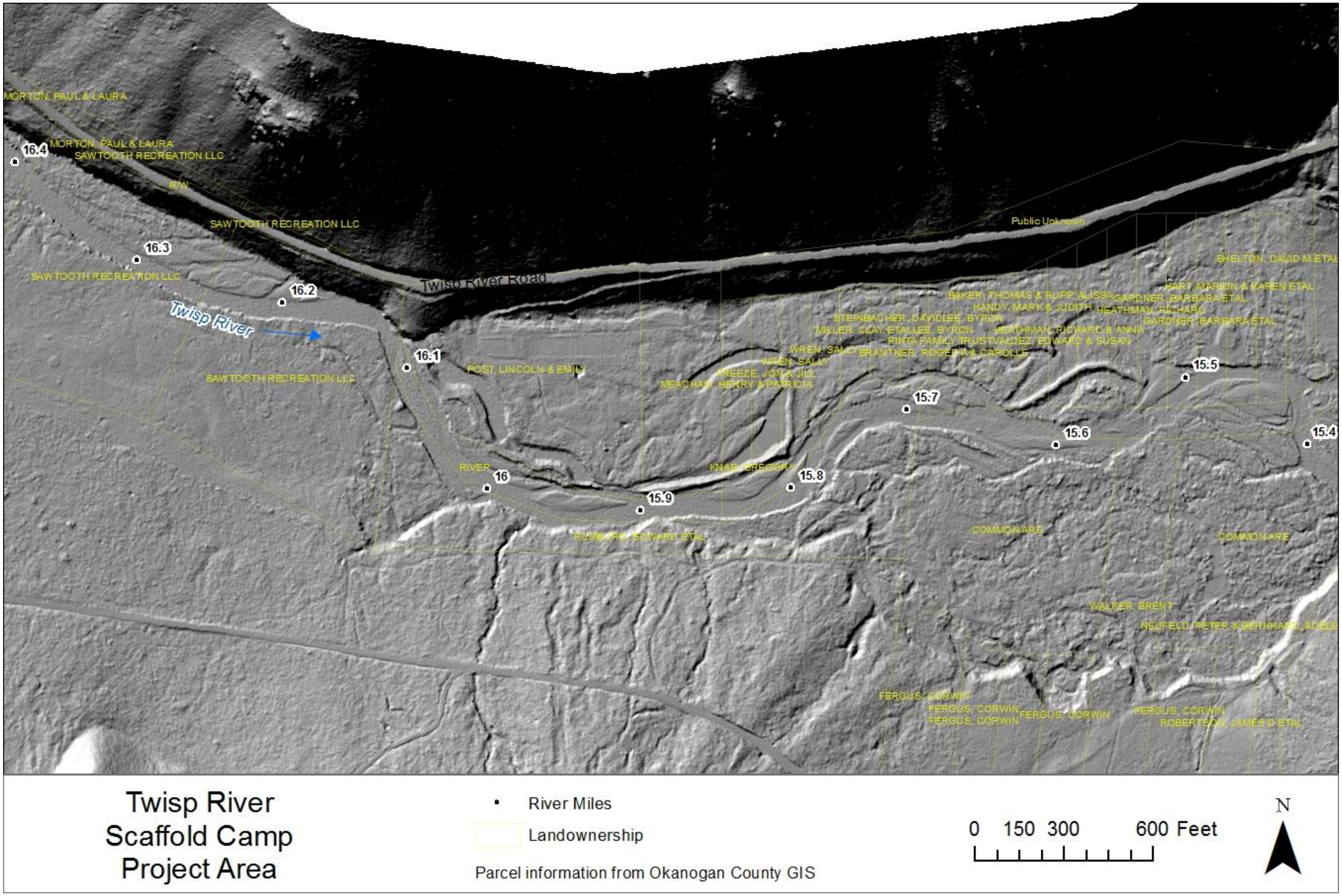

Figure 2- Overview map of Scaffold Camp project area with 2006 LiDAR hillshade

GOALS AND OBJECTIVES

Regional Objectives

Regional objectives that inform fish habitat work in the Upper Columbia are summarized in the document titled A Biological Strategy to Protect and Restore Salmonid Habitat in the Upper Columbia Region (2014), developed by the Upper Columbia Salmon Recovery Board Regional Technical Team (RTT). It serves as a guide for all restoration activities in the Upper Columbia River, and is an important appendix to the Upper Columbia Spring Chinook Salmon and Recovery Plan (UCSRB 2007). The Biological Strategy has identified several assessment units within each of the major Upper Columbia tributaries that differentiate broad scale physical and biological attributes. The Scaffold Camp project area is located in the Upper Twisp River Assessment Unit.

The unit is a major spawning area for migratory salmonids, including spring Chinook and steelhead. Resident spring Chinook use the area for rearing, foraging and over wintering. A local population of fluvial bull trout are known to use the project reach for migration to and from major spawning areas in the mainstem Twisp River above Reynolds Creek.

The Upper Twisp Assessment Unit (RM 14 - 31) has been characterized as a Tier 2 priority habitat for protection and Tier 1 priority habitat for restoration based on its existing biological and physical attributes and future habitat potential. The RTT has determined that the main factors affecting habitat conditions for salmonids in the Upper Twisp Assessment Unit are:

- The removal of large wood from the active channel has reduced channel complexity in the Upper Twisp River.
- Road alignments and bank hardening have isolated floodplain and side channel habitats from the main channel in a few locations.
- Recreation impacts to both the stream and riparian areas occur in locations of concentrated use (campgrounds) and locations of dispersed use (access via unmaintained skid roads)
- Brook trout are present in high densities in some tributaries

The above factors have cumulatively impacted stream ecological systems and salmonid habitat in the project reach. The RTT has prioritized a list of restoration actions to address these key ecological concerns impeding salmon recovery goals for the Upper Twisp Assessment Unit. Prioritized actions that are relevant to the Scaffold Camp project area are listed below.

1. **Peripheral and Transitional Habitats** (Side Channel and Wetland Habitat Conditions): Reconnect disconnected side channels or improve the hydraulic connection where low wood loading has changed the inundation frequency. Increase wood complexity within the side channels.
2. **Channel Structure and Form** (Instream Channel Complexity, Bed and Channel Form): Remove levees and install large wood and engineered log jams to provide short term habitat benefits and intermediate-term channel form and function benefits. Scale and locations should be consistent with the biological objectives and geomorphic potential for the reach and site.

3. **Riparian Condition**: Restore condition in degraded areas associated with residential development or where there are legacy effects from past riparian logging practices.

Concept alternatives for the Scaffold Camp project area were developed with the above factors in mind, as well as in consideration of the habitat restoration and preservation objectives described in the Recovery Plan (UCSRB 2007). These objectives are consistent with other regional goals as described in the Methow Subbasin Plan (KWA et al 2004) and the Methow Watershed Plan (MBPU 2005).

Middle Twisp River Reach Assessment and Restoration Strategy

The Middle Twisp Reach Assessment and Restoration Strategy, which covers the Twisp River from RMs 7.8 to 18.1, was completed in 2013-2014 (Inter-Fluve 2015). This assessment included geomorphic and habitat surveys and assessments within the Scaffold Camp project area. The goal of the assessment was to evaluate aquatic habitat and watershed/geomorphic process conditions in the Middle Twisp River and to identify habitat restoration strategies. The study involved examination of historical information, surficial geology, hydrology, hydraulics, sediment transport, topographic data (LiDAR), channel geometry, riparian vegetation, and habitat conditions. Supporting appendices included detailed analyses of habitat, reach-based ecosystem indicators (REI), historical data, and schematic sketches of potential restoration projects.

Restoration strategies were developed by comparing existing aquatic habitat conditions to target conditions obtained from reference areas and regional habitat thresholds. General restoration strategies included protection of quality habitat, restoration of riparian communities, reconnection of habitat via infrastructure modification, placement of structural habitat elements, and construction of off-channel habitat enhancement features. Specific to the Scaffold Camp project area, the following restoration techniques were recommended:

- Side channels on river left, activated by select excavation and protected by apex log jams.
- Partial or full removal of the pushup berms on river left, with riparian regarding and the possible creation of spit flow conditions maintained by bar apex jams.
- Wetland connection or enhanced connection on river right and river left – This includes increasing connectivity to existing wetland area on river right, as well as the development of off-channel habitat in the footprint of existing man-made ponds on river left.
- Development of a groundwater fed spring channel across the northern extent of the floodplain on river left.
- Removal of gabions and small berms that limit floodplain connectivity.
- Place log jams for interim stability until restored riparian vegetation can become established.
- Riparian restoration, including reforesting stream banks and cleared riparian areas.

PRELIMINARY DESIGN CRITERIA

A suite of preliminary design criteria have been developed that incorporate stakeholder objectives, the RTT Biological Strategy, the YN Reach Assessment, physical river constraints, construction impacts, aesthetics, and recreational user risk. Design criteria serve three primary purposes: 1) to clearly document and communicate specific project objectives and constraints, 2) to help inform and guide the design process so that objectives are met, and 3) provide a basis for future performance monitoring. The design criteria include preliminary performance criteria as well as prescriptive criteria. The design criteria will be refined as the design process moves forward and as more information becomes available to make criteria more specific and quantitative. The design criteria are divided into 6 categories: Habitat, Geomorphology/Hydrology, Engineering and Risk, River Safety, and Construction Impacts.

Habitat

- Increase the quantity and quality of main channel and off-channel spawning and rearing habitat for ESA-listed salmon and steelhead, including
    - Overhead cover
    - Hydraulic complexity
    - Pool scour
    - Velocity refuge
    - Increased food sources
    - Off-channel rearing
    - Sediment/bedload retention, storing, and sorting
- Design projects that restore or mimic the historical channel structure and complexity that salmonids have adapted to

Geomorphology/Hydrology

- Design projects that are consistent with current and projected hydrologic and geomorphic patterns and processes
- Allow for naturally dynamic and deformable processes to operate, within the constraints imposed by existing landownership, infrastructure, and safety considerations
- Design projects that increase the frequency, duration, and magnitude of floodplain inundation at frequent recurrence interval floods (1- to 10-year events)
- Increase the potential for future large wood recruitment and retention
- To the extent possible, remove fill/levees and bank armoring that disconnects side-channels and reduces floodplain connectivity.
- To the extent possible, design side-channels to maintain sediment transport continuity in order to maximize design life and reduce in-filling
- Preserve the quantity of existing functional wetland habitat or allow that habitat to modify to a new wetland type based on future expected hydrogeomorphic condition
- Address the risk of fish entrapment in the man-made ponds on river left

Engineering and Risk

- Do not increase flooding or erosion risk of public or private infrastructure
- Provide adequate ballasting of placed logs to withstand high flows that overtop the structures (i.e. compensate for buoyancy)
- Specific stability and other design criteria of placed structures to be determined in subsequent design phases

River Safety

- Take into account visibility of structures from upstream
- Take into account structure form to minimize entrapment potential
- Minimize channel encroachment to the extent possible to allow for avoidance by river users

Construction Impacts

- Minimize impacts to intact wetland habitat
- Minimize impacts to fish during the construction process by reducing the need for dewatering and worksite isolation during construction
- Locate and configure construction access routes to utilize existing access where possible and to minimize impacts to existing mature riparian vegetation
- Utilize onsite resources or plan channel alignments to take advantage of existing natural features where feasible (e.g. trees, beaver dam locations)

Site Conditions

SITE SURVEY AND DATA COLLECTION

Topographic surveys were conducted in from October 21st to 23rd, 2014. During these surveys, bathymetric data of the mainstem Twisp River and backwater areas, as well as detailed topographic data in particular sections of the floodplain was collected. Particular emphasis was paid to the complex of ponds on river left and areas of potential side channel reconnection throughout the project reach. The bathymetry and topography data was collected using rtkGPS and total station equipment. Data from the surveys was used for: 1) refinement of existing LiDAR data and provision of bathymetric data to support existing LiDAR ground surface data, 2) channel and floodplain cross-sections for hydraulic modeling of current and proposed restoration alternatives, and 3) creation of a grading plan and calculation of excavation quantities for the various alternatives. Additional follow-up survey is anticipated after a preferred alternative is moved forward in subsequent design phases.

Corrected survey data were compared to the LiDAR data (Watershed Sciences 2007), and elevations between the two data sets did not correlate well. The LiDAR data were consistently 2-3 ft higher than the survey data. We confirmed that these errors were associated with the LiDAR data after encountering similar offsets at four separate survey locations in the Middle Twisp Reach. To calibrate the LiDAR data, we tabulated survey points on harder surfaces in open areas where vegetation would likely not interfere with LiDAR data. This was performed for survey data we had collected at the Scaffold Camp site as well as at two other project sites located further downstream on the Twisp River. The average shift in LiDAR was 2.45 ft with a standard deviation of 0.63 ft. Accordingly, the LiDAR data were lowered by 2.45 ft to match the survey data.

In order to further refine and confirm the shift in the LiDAR data for this particular project site, we performed a follow-up survey on March 12, 2015 that included the collection of 131 observations within open areas at the site using GPS RTK equipment. This also included some areas of particular interest around existing infrastructure. Comparison of these data with the LiDAR data revealed a median shift of 2.51 ft. This comparison confirmed that our previous magnitude of shift (2.45 ft) was appropriate and so no additional changes were made to the topographic surface used previously for modeling.

A series of four pebble counts were performed in October 2014 to determine size gradation of surficial material on gravel bars and in riffles throughout the study reach. Pebble counts are performed by tallying the number of individual particles within various size categories from 100 randomly selected particles in a specific area. The three pebble counts at riffle crests are indicative of the size of material that is providing grade control in the reach. The gravel bar material was sampled in a depositional zone, and is a signature of sediment recently moved by the system, and is thus indicative of the size of bedload material typically transported.

Table 1 - Summary of grain size distribution measured in the project reach. Grain sizes are reported in inches.

River mile	Description	D_{16}	D_{50}	D_{84}
15.3	Riffle	0.9	2.6	4.7
15.45	Tail of bar	silt	0.4	1.4
16.1	Riffle	1.5	3.0	6.3
16.15	Riffle	1.3	3.1	6.3

Water surface elevation monitoring stations were installed throughout the project site in October 2014. Monitoring stations utilize HOBO U20 water level data loggers. These loggers are used to monitor water levels via a pressure transducer. Water level loggers were installed at five locations throughout the project reach; two in the main channel and three in the pond complex (Figure 3). An additional logger was deployed to collect atmospheric pressure readings, which are used during data processing to correct water level readings given barometric fluctuations. These stations are intended to provide accurate water surface data for the reach, which will be used for model calibration and design of channel features. The U20 loggers also record water temperature, which will be useful for assessing temperature conditions as it relates to aquatic habitat quality.

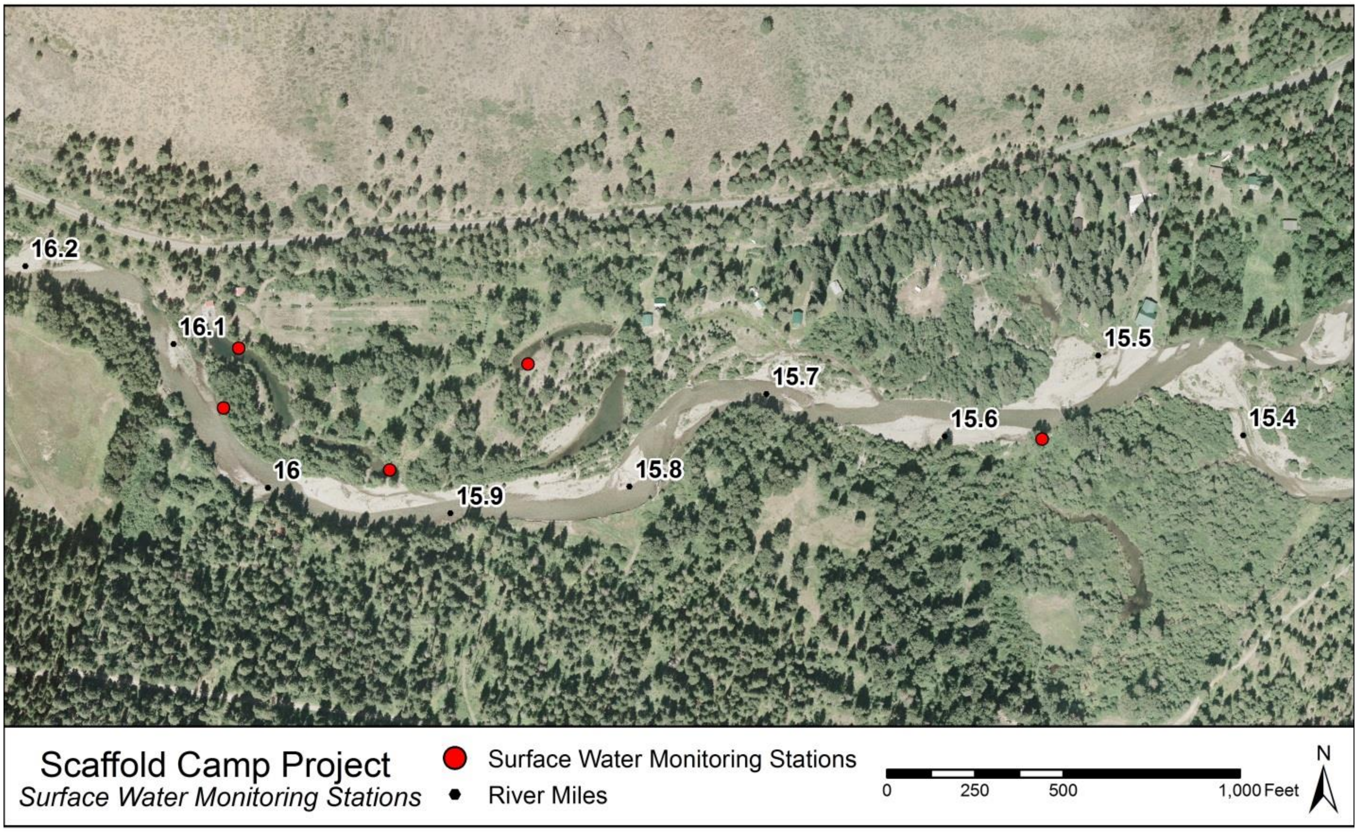

Figure 3 - Location of surface water monitoring stations installed in October 2014.

FISH USE AND HABITAT CONDITIONS

Current fish use in the project area includes ESA-listed (endangered) spring Chinook, ESA-listed (threatened) steelhead and bull trout, and non-listed rainbow trout, brook trout and west slope cutthroat trout.

Spring Chinook salmon and steelhead trout spawn and rear in the project area. Spring Chinook spawning in the Twisp River primarily occurs from RM 10 to RM 27. Spawning occurs throughout August and September. Juvenile rearing occurs year-round throughout the lower river, including the project area. 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 (USBR 2008, App F).

Spawning ground surveys are performed annually throughout the Methow basin. The project area falls within a 4.6 mile long reach that consistently contains the highest number of spring Chinook redds in the Twisp River as well as a significant number of steelhead redds. During the 2012 survey, 74 spring Chinook redds and 43 steelhead redds were identified within this reach. (Snow et al. 2014). Surveyed locations of steelhead and Chinook redds from 2003 to 2012 are shown in Figure 4 and Figure 5.

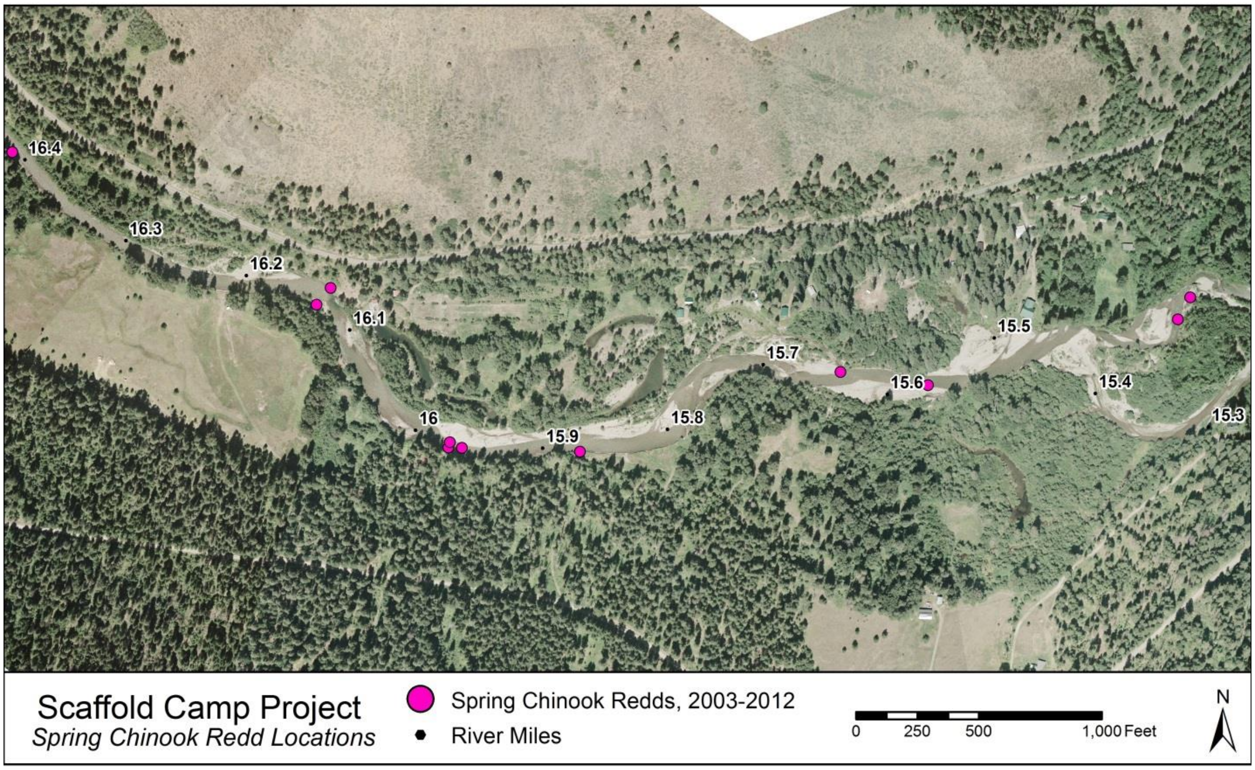

Figure 4 - Spring Chinook redds. Data acquired from UCSRB online GIS and Data Library, retrieved 12 January 2015.

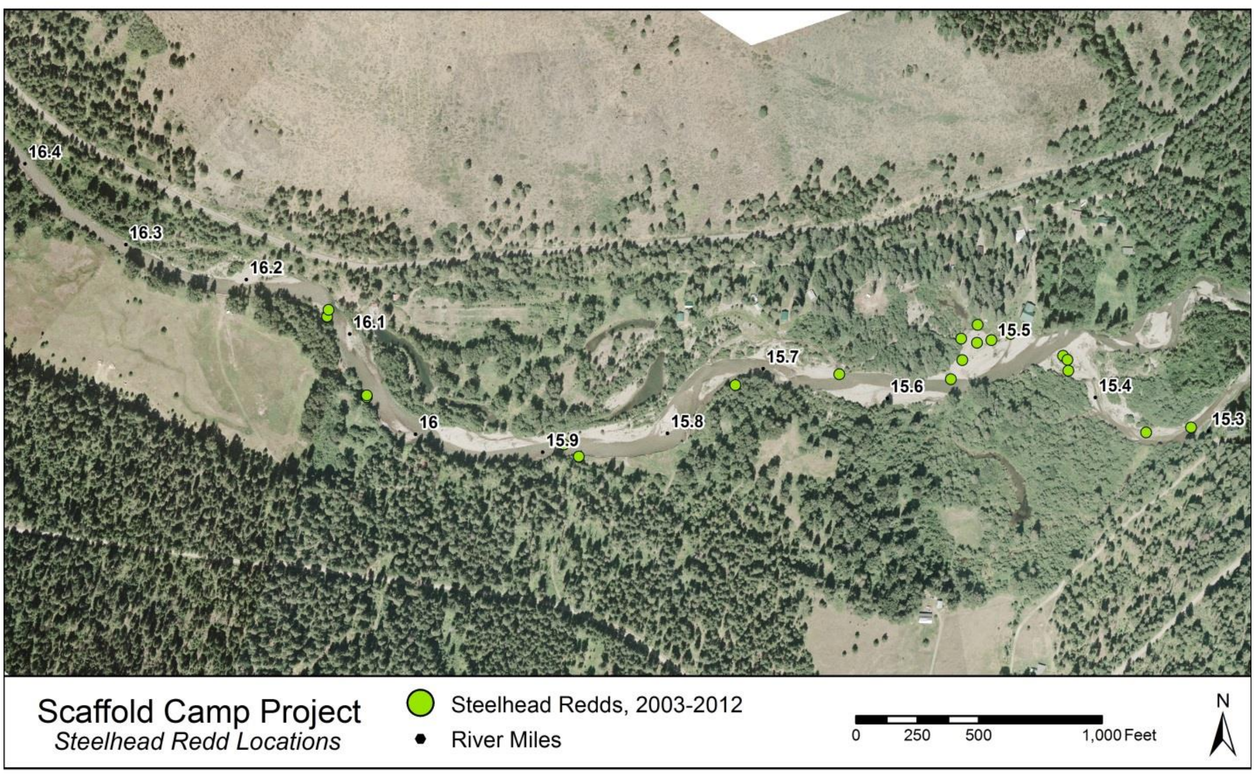

Figure 5. Steelhead trout redds. Data acquired from UCSRB online GIS and Data Library, retrieved 12 January 2015.

Considered "stream-type" salmonids, both steelhead and spring Chinook spend a minimum of one year residing in freshwater rivers. The length of residency for both adult and juvenile life histories causes these fish to rely more heavily on quality freshwater habitat than fish species that migrate rapidly downstream following redd emergence. The duration of time that juvenile steelhead reside in freshwater streams is highly variable. In the cold rivers of the Upper Columbia region, the average length of residency for steelhead is two years, but durations of up to seven years have been observed (Peven et al. 1994, Mullan et al. 1992).

The Washington Department of Fish and Wildlife seasonally operates a rotary screw trap on the lower Twisp River just upstream from the confluence with the Methow River. This trap is used to capture out-migrating salmonid smolts from the Twisp River basin. Permanent PIT tag arrays are located just downstream of the trap. Mark-recapture studies have been performed year round on the Twisp River using information from both of these sources. The information gained from these surveys can be used to estimate fish abundance.

Spring Chinook smolts captured from summer 2012 through spring 2013 reflect the success of 2011 brood year adults. The total number of emigrating wild spring Chinook produced by the 2011 brood year population was estimated to be 12,759 (± 1,744, 95% CI). Rates of survival to different life stages have been calculated using this information in conjunction with information obtained from spawning ground surveys and carcass surveys. Eggs deposited by the 2011 brood year spring Chinook had a 4.7% chance of surviving to become smolts. This rate can be expanded to estimate that an average of 203 smolts were produced per redd during that year. Average survival from smolt to adult for fish from brood years 2003-2008 was 0.61% (Snow et al. 2014).

Since there is so much variability in the age at which steelhead emigrate from their natal rivers, estimating the total success of a particular brood year requires four years of emigration data from the basin. The total number of smolts produced by the 2009 brood was estimated to be 6,913 (± 1,089, 95% CI) fish. Egg to emigrant survival rate was 0.31% for this brood which corresponds to a total of 19 emigrants produced per redd. Smolt to adult survival rates can vary substantially from year to year. Fish which migrated out of the basin in 2010 had a 1.1% chance of returning as adults. Fish leaving the basin in 2011 had a 0.33% of returning as adults (Snow et al. 2014).

The WA Department of Ecology listed the Twisp River as a "waters of concern" for temperature in 2012. This classification was based on measurements collected in 1999 near War Creek CG which exceeded the established temperature criterion developed for ESA-listed salmonids. More recently, 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 on the Twisp River. The data show a general warming trend over the 33 miles of the Twisp River as the water moves downstream from the headwaters to the confluence with the Methow River. Water flowing through the project area follows this trend, gradually increasing in temperature as it flows downstream.

A 2013 stream habitat survey (Inter-Fluve 2015) recorded information on habitat unit composition, habitat unit characteristics including pool depth, substrate size, large wood quantity, riparian conditions, and bankfull channel dimensions. The Scaffold Camp project falls primarily within Reach 5 of the habitat assessment. Two-tenths of a mile of the project area is within Reach 6. Habitat area composition was relatively equal amongst the four habitat types: Glide (30%), Riffle (29%), Pool (23%) and Side Channels (18%) for the reach as a whole. The side channels were located in the downstream portion of the reach, and in the project area there were no active side channels observed at the time of the survey. The localized habitat composition for the Scaffold Camp project area also has a larger proportion of glide habitat than riffles or pools. The project area within Reach 6 contains primarily riffle habitat, with short glide habitats interspersed between the riffles. The quality of pools in Reach 5 was relatively good with approximately 40% of the pools having residual depths greater than 3 feet. Bed substrate in Reach 5 consisted of equal parts cobbles (47%) and gravels (47%) with only 6% sand. The size, availability, and quantity of wood was lower than what would have been expected historically, which has affected instream channel dynamics and habitat suitability for salmonids. Riparian vegetation in the reach is young and varied, with 43% of the riparian corridor vegetation consisting of the shrub/seedling size class, followed by the sapling/pole (29%) and small tree (21%) size classes.

GEOMORPHIC SETTING AND HISTORICAL TRENDS

Geomorphic Setting

The Twisp River main channel drops over a mile of elevation in its 30 miles, draining an area of 244 square miles and entering the Methow River at RM 40.2. Roughly 90% of the land in the Twisp River subbasin is managed by the USFS, including nearly all of the land above the valley floor upstream of RM 10, while most of the Twisp River valley bottom from the mouth to the confluence with Eagle Creek (RM 17) is privately owned (USBR 2008).

A major slope break occurs at RM 10 along the longitudinal profile of the Twisp River, corresponding to the downstream limit of the last glacial advance. Glacial erosion upstream resulted in a wider valley with a more gentle valley slope. The channel incised through glacial deposits downstream, resulting in a more confined valley with steeper channel slopes. The Scaffold Camp project area is well upstream of this grade change and is located in a lower gradient portion of the reach. The main channel is confined within the project reach in some locations due to a combination of natural local downcutting and human induced channelization, berm construction, and bank armoring. The historical aerial photos, discussed below under Historical Trends, show that dynamic floodplain processes (such as meander scrolling) have decreased significantly since the 1950s, likely as a result of pushup berm construction, and a reduction in instream large wood from direct removal and riparian clearing. For a more detailed examination of Twisp River geomorphology, see Inter-Fluve (2010, 2015) and USBR (2008).

Historical Trends

A series of historical aerial photos is presented in Figure 6 to Figure 8 below. The earliest photos (1953) are not early enough to capture pre-disturbance conditions; significant agricultural and residential uses appear to be established by then. There is nevertheless a significant increase in land-use disturbance and channel change that occurs between 1953 and contemporary times. The channel segment between RM

16.5 and 16.2 changes very little over the nearly 60 year photo history. Between RM 16.2 and 16.05, an area to the south of the existing channel has transitioned from being an un-vegetated floodplain surface to one with mature riparian vegetation. The most dramatic change within the project area has occurred between RM 16.1 and RM 15.53 on river left. A series of pushup berms has been constructed along the channel margin, with ponds excavated behind them. It is assumed, but not verified, that the material excavated from the ponds was used to create the pushup berms. The aerial photos show that the pushup berm construction occurred between 1975 and 1998. USBR mapping of the channel centerline suggests that portions of the pushup berm (between RM 15.53 and 15.63 and RM 15.75 and 15.9) were not constructed until after 1985. The meander bend between RM 15.75 and 15.9, delineated by the un-vegetated floodplain area observed in the 1953 photograph, scrolls to the east over the course of the photo record. A similar trend is observed in the meander bend located between RM 15.65 and 15.5 in the 1953 image. The channel planform through the project reach is fairly static between the 1998 and 2011 images, likely in part due to the influence of the pushup berms. At the downstream end of the site, a split flow channel is observed to form to the south of the existing channel near RM 15.4 at some point between 1975 and 1998. By 2006, this channel is the main low flow channel, but by 2011 (and confirmed during the 2014 ground survey), the main low flow channel is again in the alignment to the north near RM 15.4.

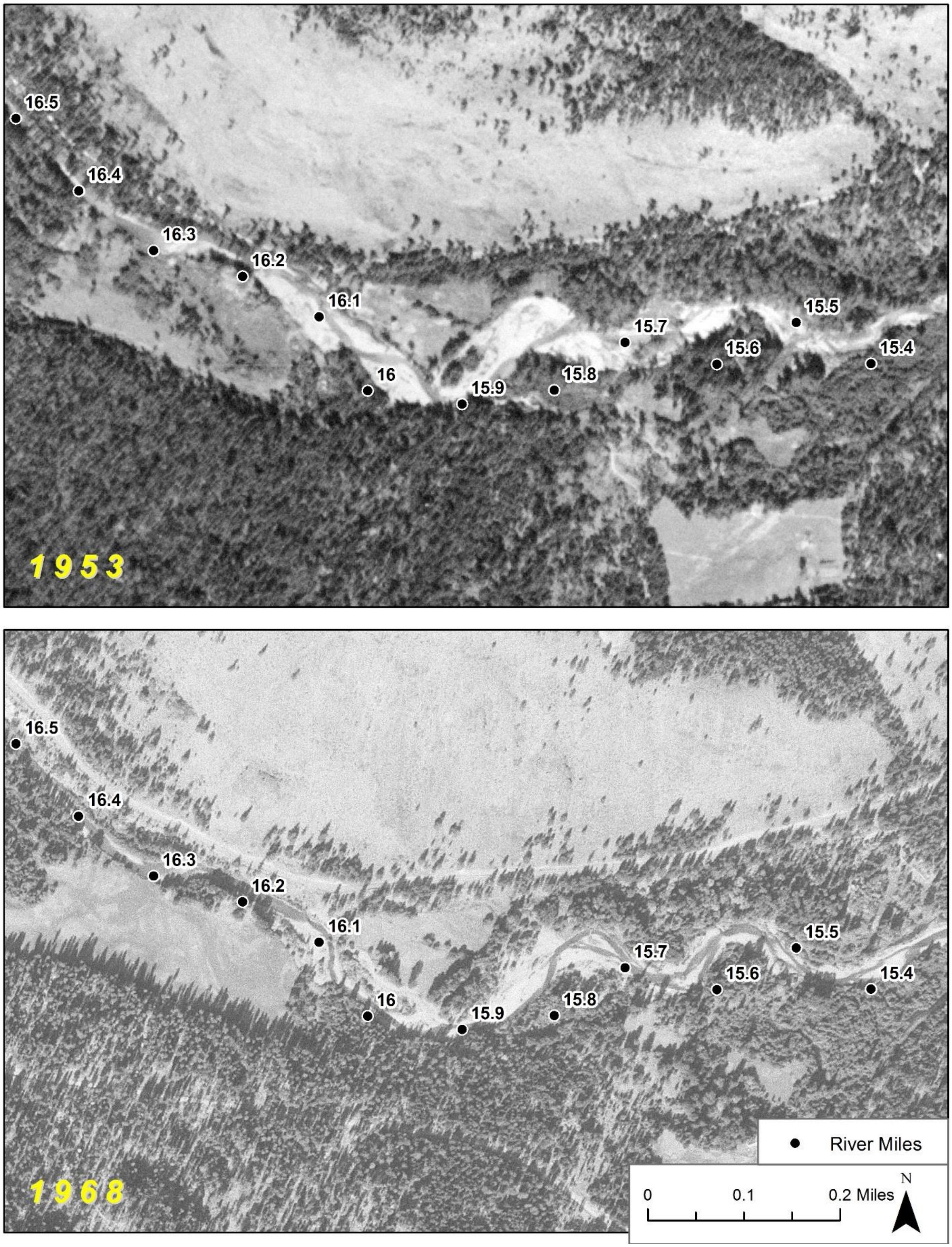

Figure 6 - 1953 and 1968 aerial photographs.

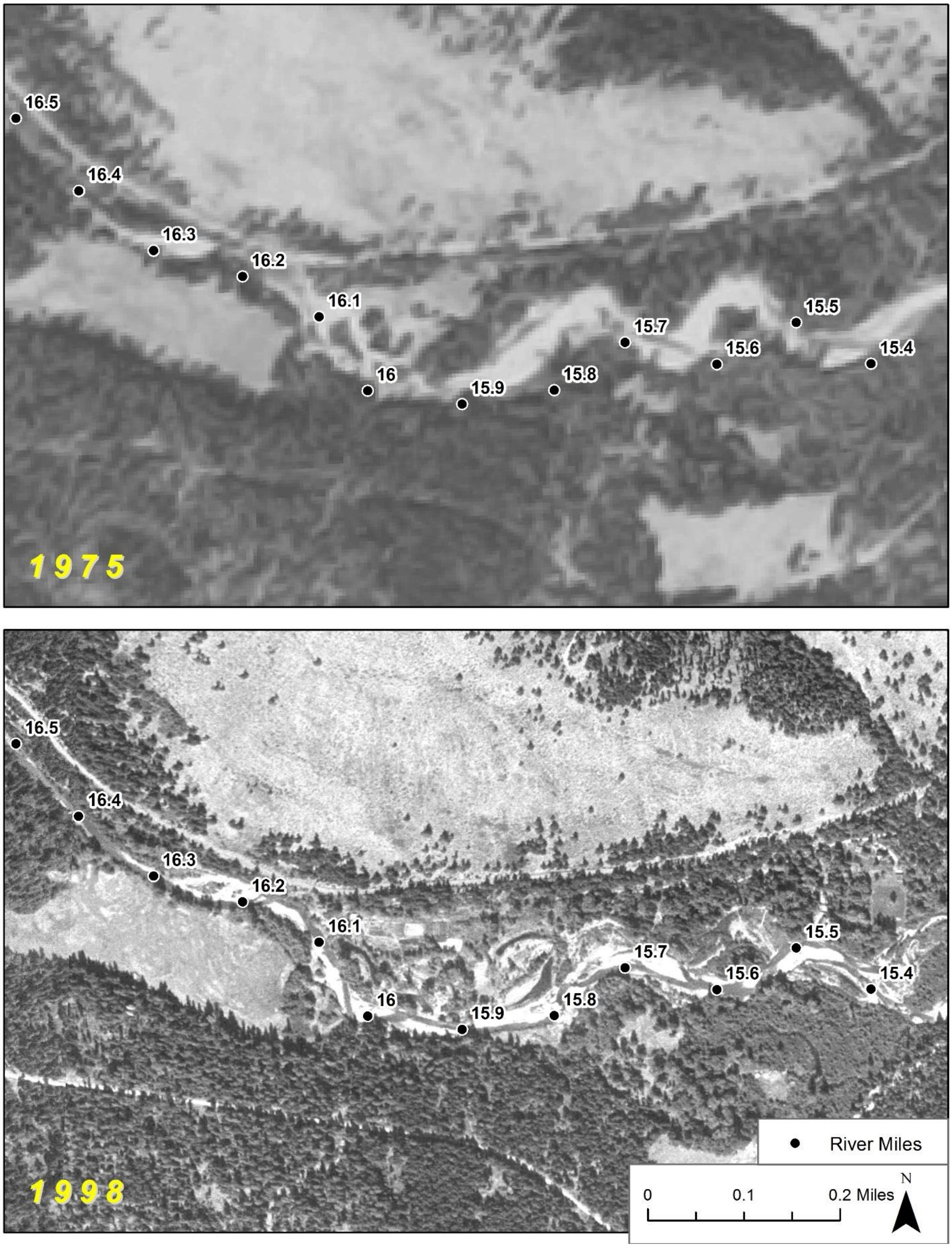

Figure 7 - 1975 and 1998 aerial photographs.

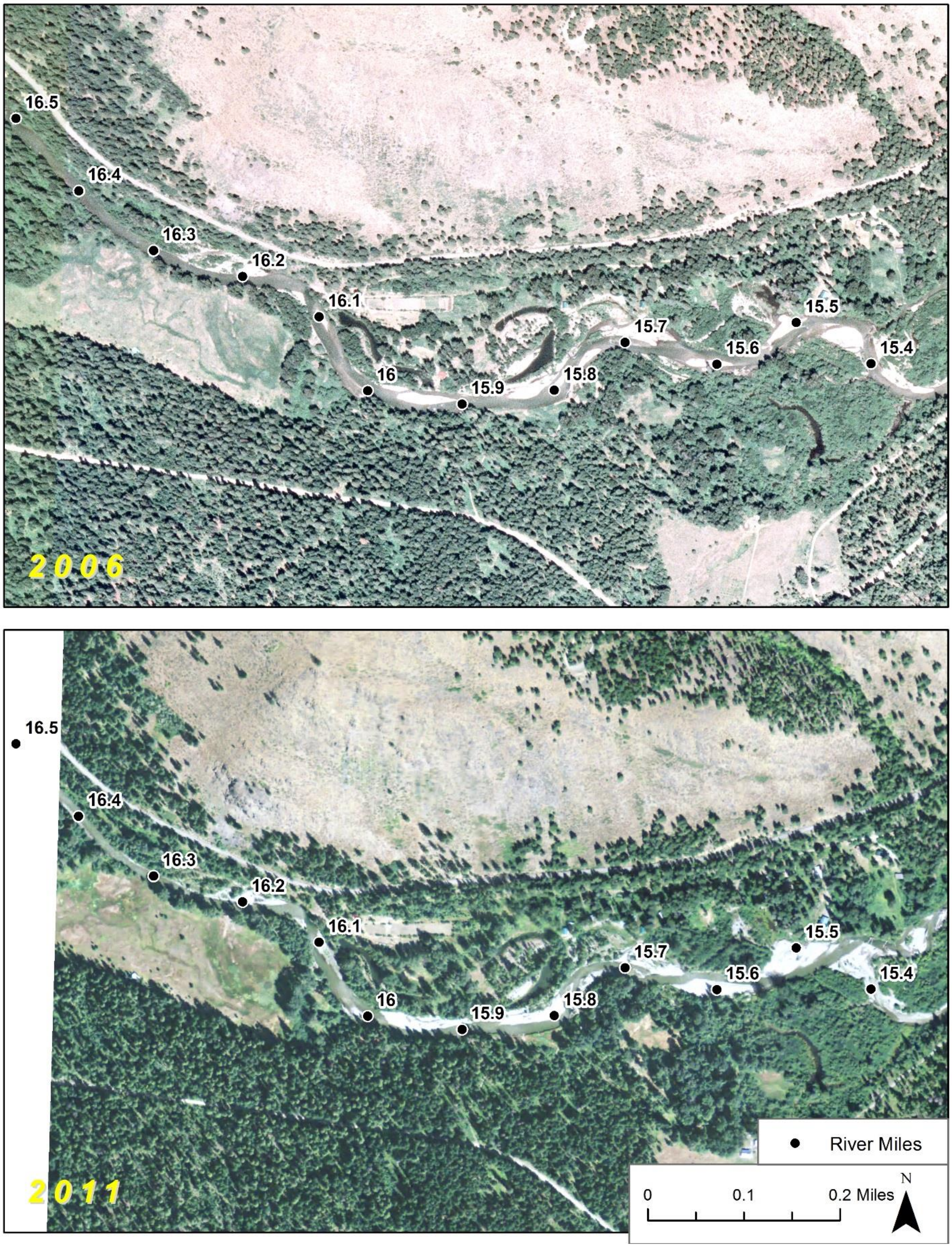

Figure 8 - Aerial photographs from 2006 and 2011.

HYDROLOGY

The Twisp River watershed is a sub-basin to the Methow River basin in western Okanogan County, Washington, in the eastern Cascades. The Methow River empties into the Columbia River near Pateros, Washington.

Significant tributary inputs in the project area include Lime Creek (RM 15.45) and Scaffold Camp Creek (RM 15.86). Hyporheic flow is assumed to occur throughout the area in low gradient alluvial sections with higher sinuosity and the presence of gravel bars.

Dominant hydrologic patterns are driven by precipitation in the form of snow and the subsequent spring snowmelt. Precipitation amounts vary with elevation and distance from source areas. In the higher elevation areas of the basin, where maximum elevations are near 8,780 feet, average annual precipitation is 65-70 inches, falling mainly as snow. Mean annual precipitation in the Twisp River watershed is about 43 inches (USGS 2013). Peak runoff usually occurs from April to August, with the highest discharges typically in June (Figure 9). Baseflow discharge conditions typically return in the Twisp River by September.

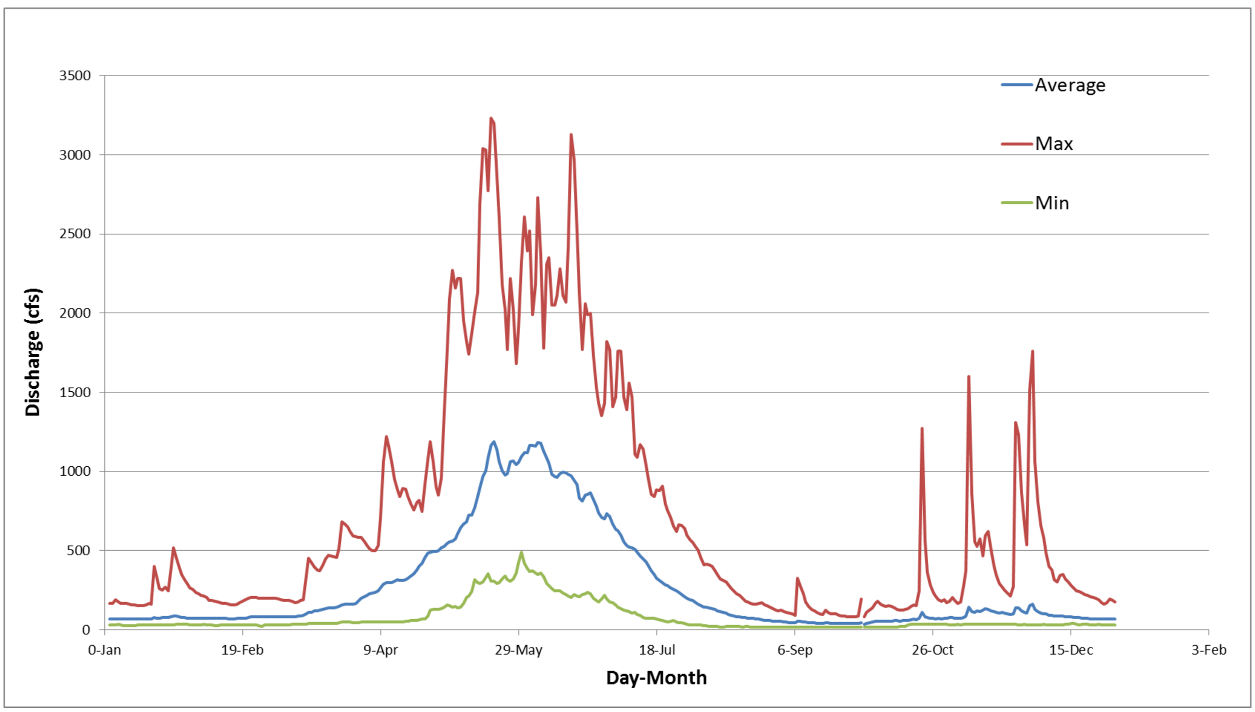

Figure 9 - Average, maximum, and minimum values of average daily flows for the period between 10/1/1989 to 9/30/2013 (as measured at USGS gage number 12448998).

Flood History

There is one U.S. Geological Survey stream gage on the Twisp River (#12448998) located downstream of the project area at RM 1.6. The drainage area to the gage is 245 square miles while the drainage area to the project site is 129 square miles. The gage has been in operation continuously since 2002; additional data were collected for the years 1975-1979 and 1990-1999. One flood peak from 1948 has been documented by the USGS (Figure 10).

The largest flood event on record in the Twisp River was 9,440 cfs in 1948. Although the gaging station was not in operation, the U.S. Geological Survey estimated the magnitude based on a contracted opening method with high water marks. The magnitude of the flood was nearly 2.5 times the magnitude of the next largest flood, which occurred in May 2006. Other notable flood events occurred in the Methow Valley in 1894 and 1972, although there is no gage data available for the Twisp River for any of these years. Of the 28 annual peak discharges in the gage record, only two took place outside the months of May or June.

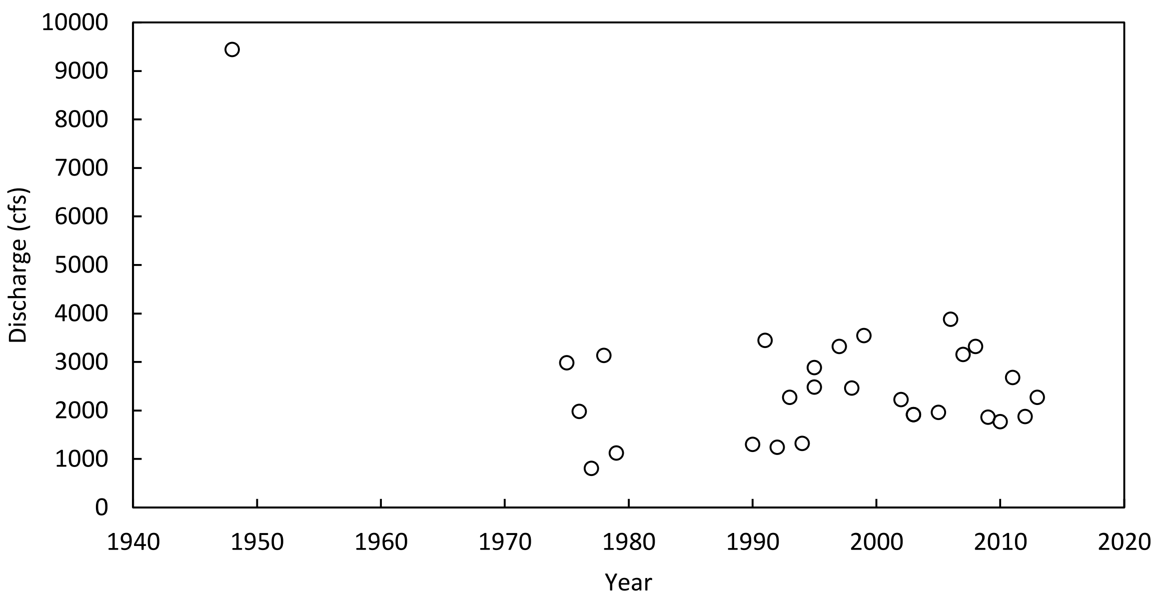

Figure 10. Annual peak floods at the Twisp River gage (USGS 12448998). The 1948 magnitude of 9,440 cfs was estimated using high water marks by the USGS.

Flood Quantiles

Flood magnitudes for specific recurrence intervals were estimated using the USGS gage on the Twisp River at Twisp, WA (#12448998). The data included annual instantaneous peak flood discharges for the years 1948, 1975-1979, 1990-1999, and 2002-2013. Quantiles were estimated by fitting these data to a log-Pearson Type III (LP3) probability distribution as recommended by the Interagency Advisory Committee on Water Data and described in Bulletin 17B (1981). Since the development of Bulletin 17B, however, there have been further improvements in flood quantile estimation. These improvements include the expected moments algorithm (EMA) for utilizing historic peak flood data (Cohn et al. 1997), a new procedure for estimating confidence intervals (Cohn et al., 2001), and the Multiple Grubbs-Beck (MGB) Test for low outliers (Cohn et al. 2013).

The LP3 procedure is based on the estimation of the first (average), second (standard deviation) and third (skew coefficient) moments of the annual peak flood data. Fitting the LP3 distribution to the data is particularly sensitive to the skew coefficient. To minimize anomalous data that could distort the long-term statistics of the Twisp River flood quantiles, we used a weighted skew coefficient. The weighted coefficient combines the station skew with the average skew coefficient from nearby gages in the region. The skew with a lower mean squared error has a stronger influence on the combined value. The Twisp River station skew was 0.566 and the regional average was -0.038. The combined value was 0.280.

The EMA was applied to the historic flood in 1948 and to handle the data gaps between 1980-1989 and 2000-2001. The MGB Test removed one low outlier from the analysis. The results at the gaging station are shown in Table 2.

To transfer the flood quantiles at the gage to the Scaffold Camp site, we used the adjustment method described by Sumioka et al. (1998). The method multiplies the ratio of drainage areas by an exponent that was fitted to regional flood data.

Table 2 - Flood quantiles at the Twisp River gage (USGS 12448998) and estimated at the Scaffold Camp Project site.

Recurrence interval (years)	Q_{gage} (cfs)	Q_{site} (cfs)
2	2,254	1152
5	3,357	1714
10	4,185	2111
25	5,345	2639
50	6,292	3050
100	7,314	3473

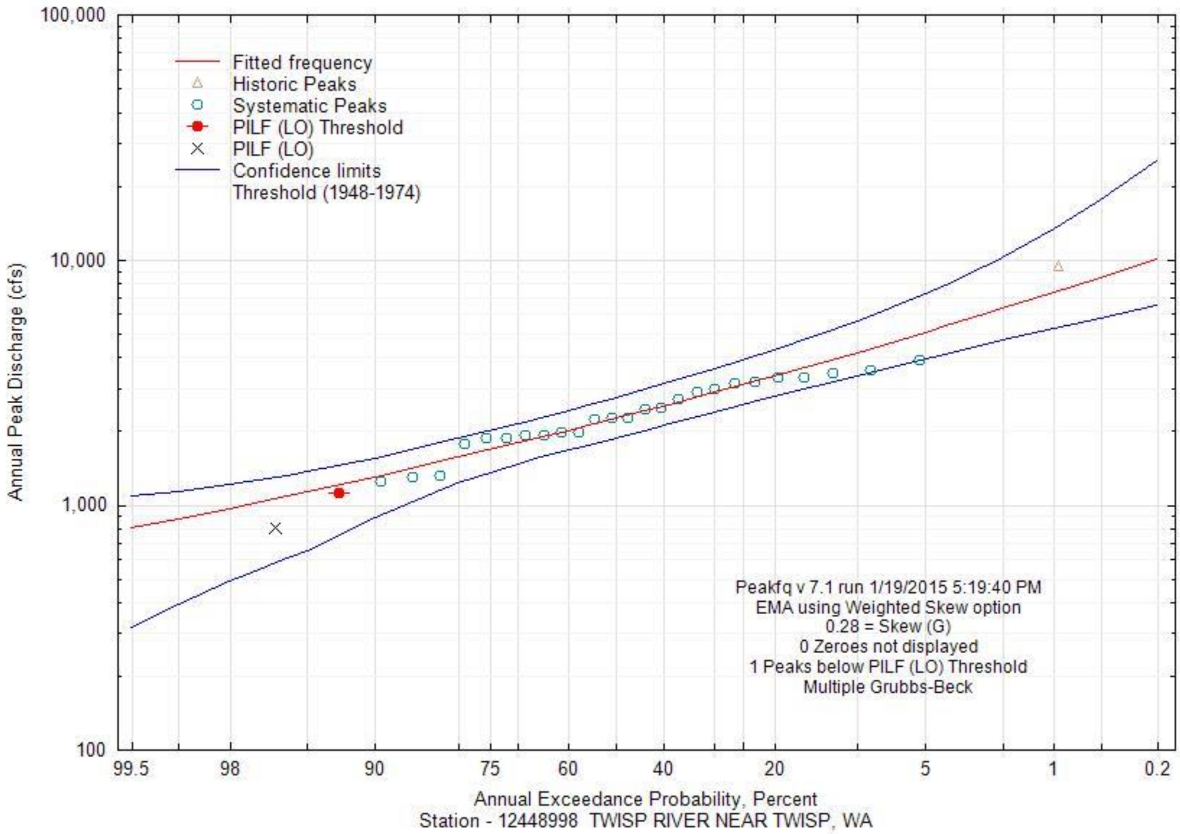

Figure 11. Flood quantiles for the Twisp River gage along with the corresponding confidence limits, low outlier, and historic peak data.

HYDRAULICS

Existing channel and floodplain hydraulics were simulated using the U.S. Army Corps of Engineers River Analysis System (HEC-RAS 4.1.0; USACE 2010). HEC-RAS is a computer program that models the hydraulics of water flow through natural rivers and other channels. The program is one-dimensional, meaning that there is no direct modeling of the hydraulic effect of lateral cross section shape changes, bends, and other two- and three-dimensional aspects of flow. The hydraulic model calculates channel and floodplain water surface elevations, velocities, depths, and shear stresses (along with other metrics) for various input flows.

The model geometry was developed using topographic data obtained through surveys completed by Inter-Fluve on October 21 to 23, 2014. Survey data were supplemented with available LiDAR data in select locations. The existing conditions model geometry includes 52 cross sections (Figure 12) spaced over the 0.96-mile project reach on the Twisp River. Reach slope was estimated at 0.7% using the survey data from riffle crest to riffle crest and verified as an accurate estimate for the larger reach by sampling several pairs of water surface points from LiDAR at a greater distance apart (0.5 to 1.0 miles). Cross sections extend through the floodplain and to surfaces on both banks which are inundated infrequently, but contain sections of manmade levees and various artificial ponds, some of which have bed elevations lower than the elevation in the adjacent main channel. These topographic features create complex cross-sections, which without model manipulation would result in inaccurate flow diversions through the ponds and thus the ponds were set as ineffective areas of conveyance.

Initial model calibration was accomplished through simulating estimated low flow rates and adjusting the roughness in order to best match the surveyed water surface elevations. The estimated flow rates for this specific reach were derived using the nearest stream gage data (12448998, near Twisp, WA) and the USGS StreamStats' two methods of 1) "Estimate Flows using Regression Equations" and 2) "Estimate Flows Based on Similar Gages" (USGS 2014). The flow using Method 2 was calculated with the following equation:

$$Q_u = \left(\frac{A_u}{A_g}\right)^b Q_g$$

where Qu is the flow at the ungaged site, Qg is the flow at the gaged site, A_u is the ungaged basin area, A_g is the gaged basin area, and b is an exponent that represents a derived drainage regression for the corresponding state and local area. In order to use this equation, A_u must be within 50-150% of A_g, which is met for the Scaffold Camp reach (52.7%). At the time of survey, the flow rate at USGS Twisp River gage was 75 cfs, which resulted in the estimated flow rate of 56 cfs and 40 cfs for the regression and similar gages methods, respectively.

Initial simulations of the estimated flow rates with comparisons between the modeled and surveyed water surface elevations revealed that Q = 56 cfs produced a realistic bed roughness value that aligns with professional judgment, analogous systems, and similarity to reference photographs in USGS (1967). Therefore, this flow rate was adopted as Q for initial model calibrations, which produced a value of n = 0.055 for the channel, and 0.1 for the floodplain. One possible reason for the discrepancy in estimated flows could be that the Similar Gages method was near the limits of its application (i.e. Ag compared to Au), which also corresponds to a large distance between the reach site and the gage (approximately 12.5 miles).

Following the initial calibration, hydraulic simulations were conducted using the 2, 5, 10, 25, 50, and 100-year recurrence interval floods. These flow values were calculated from the flood frequency analysis based on hydrologic analyses described above. Inundation maps for the 2 year and 100 year flood were created from the model results (Figure 13 and Figure 14. Detailed model results are presented in Attachment C. Finally, it should be noted that the initial calibration was performed using survey data collected at low flow, and additional model calibration will be performed with the collection of water surface elevation information using on-site data loggers, which will capture the high flow data from the winter and spring.

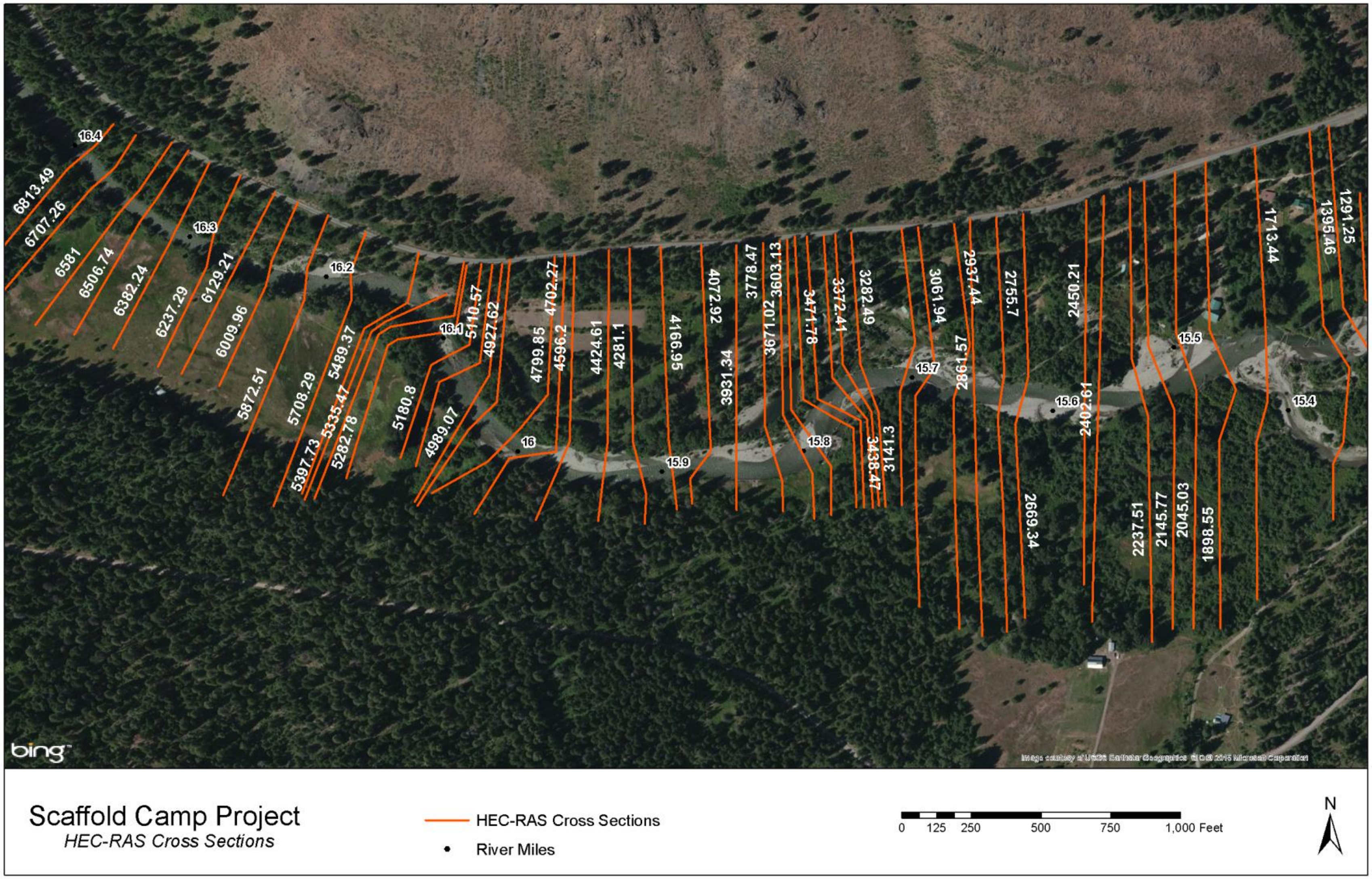

Figure 12. HEC-RAS Cross sections at Scaffold Camp project site.

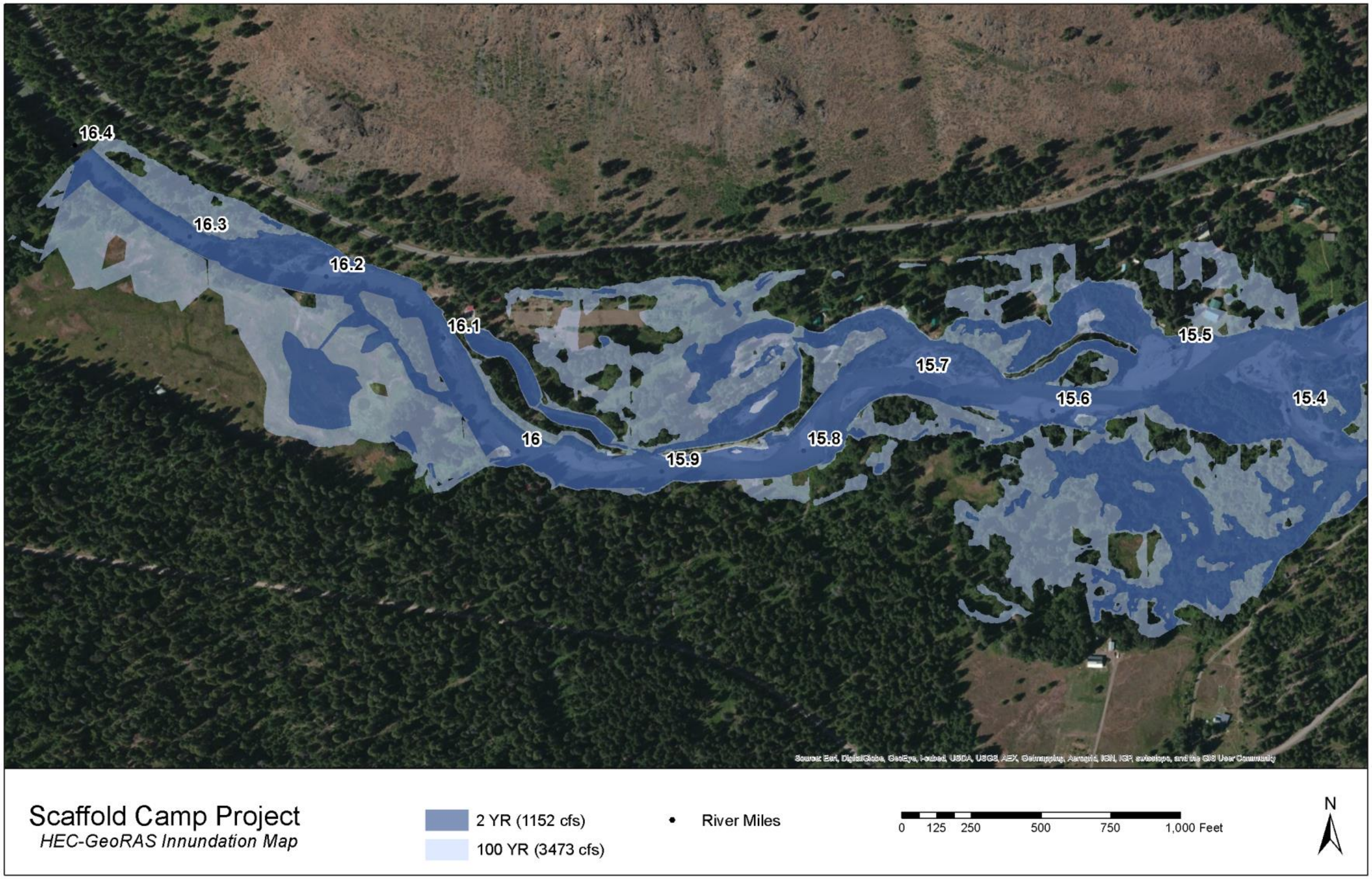

Figure 13. Inundation map showing model results for the Scaffold Camp project site, aerial photo background.

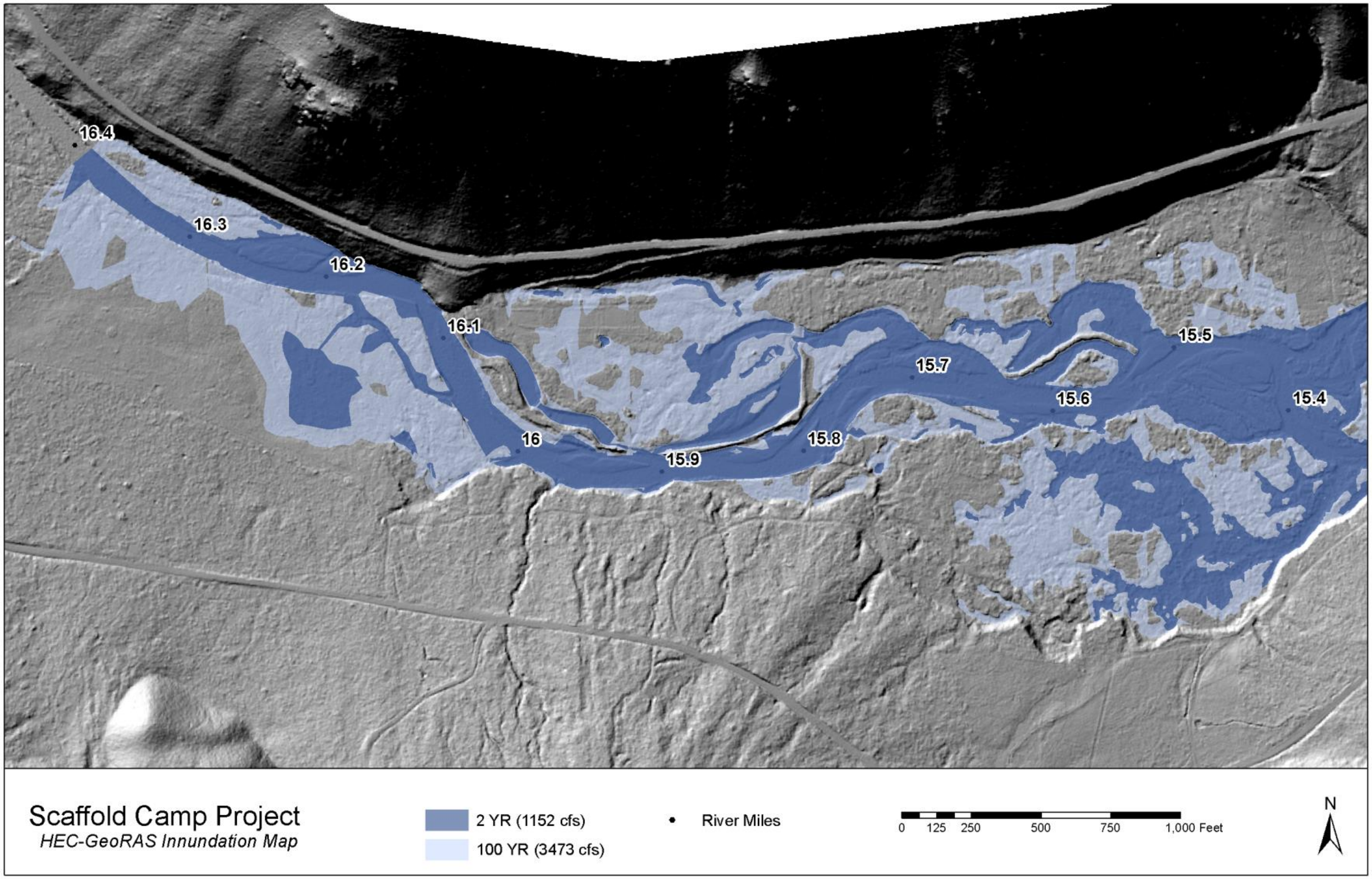

Figure 14. Inundation map showing model results for the Scaffold Camp project site, LiDAR hillshade background.

VEGETATION

The Scaffold Camp area project area has a mix of coniferous forests and some aspen stands in the uplands, coupled with an understory of grassland and deciduous shrubs. Mature cottonwoods are present along the river margins throughout the site. Canopy height information, depicted in Figure 15, shows mature vegetation established on the north floodplain area between the pushup berms near RM 15.9. The berms themselves have less mature vegetation, another piece of evidence that they have been created somewhat recently. The side channel / wetland complex zone has a canopy dominated by willows and dogwoods.

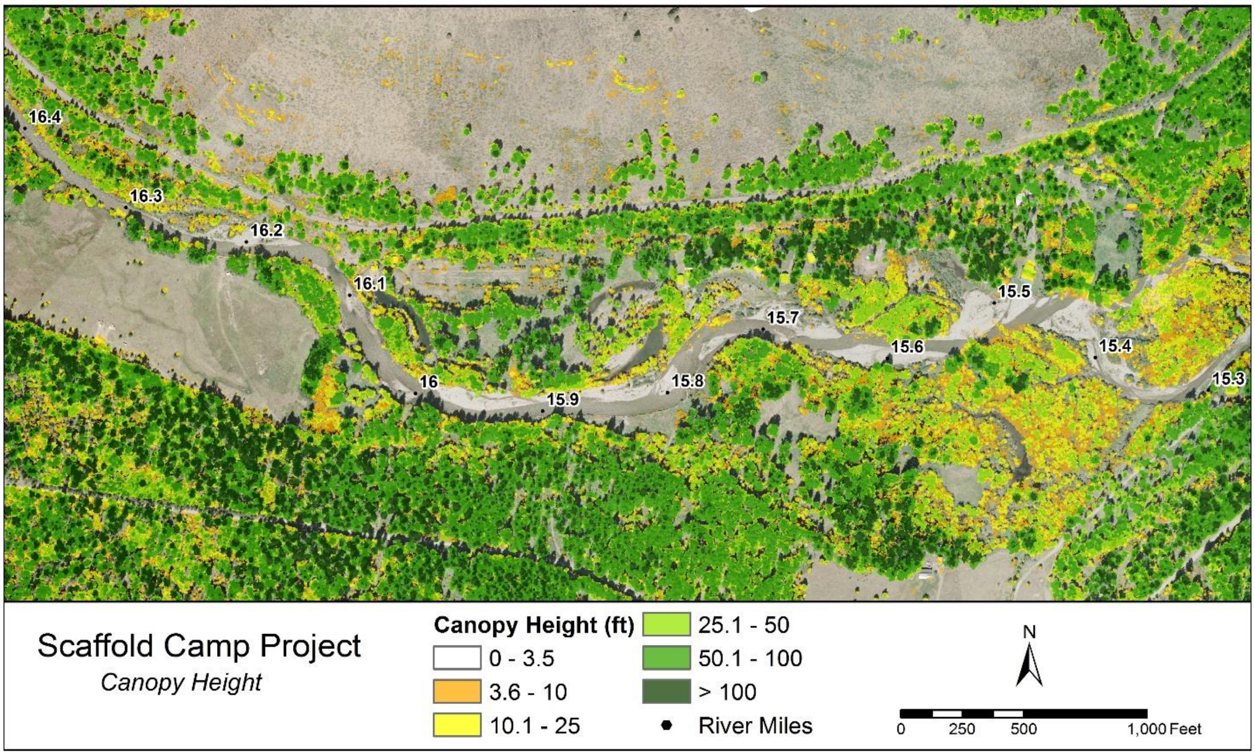

Figure 15. Canopy heights at the Scaffold Camp project site estimated from LiDAR data.

Description of Project Components

The project components described below have been organized into three subareas within the Scaffold Camp project locations: Upper Scaffold (~RM 16.4 to 16.1), Middle Scaffold (~RM 16.1 to 15.8) and Lower Scaffold (below RM 15.8). The alternatives within each subarea are not all mutually exclusive, and in some cases, multiple separate elements could be moved forward to design and analysis. Alternatives that were considered but not moved forward to the concept design level are discussed first below.

ALTERNATIVES CONSIDERED BUT NOT SELECTED

Instream wood between RM 15.7 and 15.45

Instream wood placed in this river segment has the potential to provide both immediate habitat benefits as well as structure that would be beneficial to geomorphic process over the long term. However, given the proximity of homes and other structures to the main channel in this portion of the reach, the placement of instream wood that forces flow to the north presents a significant likelihood of conflicts with existing infrastructure. It is possible that smaller structures or individual wood placements that would not be expected to have any effect on channel erosion, flood elevations, or channel position could be considered along this segment. It should be noted that, even in the absence of wood placement here, wood will likely continue to recruit naturally in this section of the river, and the current level of risk may increase in the future regardless of restoration actions.

Full excavation of long side channel with inlet at RM 15.57

Although this 1,300 foot long side channel alignment on river-right could potentially provide quality rearing habitat for juvenile salmonids, there are a couple of factors that make full excavation and reconnection with the main channel challenging: 1) About 90% of the existing channel contains a combination of emergent and open water wetland habitats, which would be disturbed by construction activities; and 2) Initial survey of the inlet area suggests that this side channel may be activated at lower flows with limited excavation to the inlet to provide access to the existing high quality wetland and off-channel habitat further down the alignment.

Remove/Replace Riprap at RM 15.5

Large rounded river rock has been placed as bank protection along a portion of the left bank near RM 15.5. This oversized material represents a clear impediment to geomorphic process in this reach. The riprap embankment is in close proximity (~40 ft) to an existing structure, which is currently at risk for impacts from both flooding and channel erosion. Given the level of current risk to existing infrastructure, undertaking restoration actions in this particular location would be very challenging.

UPPER SCAFFOLD LARGE WOOD PLACEMENT

Description and Potential Benefits

Two primary types of large wood treatments are described for the main channel in the Scaffold Camp project area: 1) wood placements along the bank margin, and 2) wood placements at the apex of either existing mid-channel bars or potential split flow locations. This alternative would place two bar apex log jams on the left bank of the channel between RM 16.3 and 16.2 as well as 2 or more small bank log jams on the right bank.

The large wood and log jam placements are intended to serve numerous purposes, including direct habitat enhancement as well indirect improvements to habitat through enhancing geomorphic function. Placement of log jams will work to replace an important component of the system that no longer exists due to the history of land management. Depending on their location and configuration, large wood and log jams will achieve one or more of the following objectives: increase hydraulic complexity and cover; reduce channel width:depth ratios, create and maintain scour pools, increase connections to side-channels or floodplain areas, restore natural rates of bank migration, trap and sort gravels to benefit spawning and food resources (i.e. benthic invertebrates), and create split-flow conditions around stable island and bar features.

The margin jams would be located adjacent to the thalweg along the bank of the mainstem Twisp River. These jams are meant to mimic natural log jams that form through tree fall as the stream erodes into forested banks. They can also be configured to catch fluvially-transported wood from upstream, similar to natural jams. These jams are strategically located in areas where riparian vegetation has been cleared such that bank strength and recruitment potential is impaired. Jams in these locations will reduce erosion until planted riparian vegetation can mature and provide long-term structure and a source for recruitment. Margin jams will also maintain scour pools and provide cover and complexity to juvenile salmonids during rearing and migration. Jam placement along the right bank in the Upper Scaffold area could vary in configuration and intensity based on site conditions and input from landowners and stakeholders.

Bar apex jams would be located in mid-channel areas at the upstream end of areas prone to deposition, creating (and maintaining) a horseshoe-shaped scour pool at the face of the jam and increasing deposition behind the jam structure. These jams, designed to rack additional wood, would help to stabilize aggraded material into stable bars/islands that may become vegetated over time. These jams, and the split-flow conditions that result, provide dynamic complexity and increase channel margin habitat. The jams, often in combination with margin jams, can also be used to activate side-channels and reconnect floodplains. The apex jams that are associated with the side-channel alternatives are intended to serve this purpose.

The bar apex jams described for this alternative would force a portion of flow along the river left valley wall containing mature vegetation and areas of exposed bedrock. Flow would also be directed strategically toward the right bank toward areas with either mature riparian vegetation or constructed bank margin jams, with the expectation that some bank adjustment would occur. The rate of adjustment along the right bank will be slowed by the presence of either 1) constructed bank margin jams in areas lacking mature vegetation and currently experiencing unnatural rates of erosion or 2) existing mature riparian vegetation providing hydraulic roughness and potential large wood recruitment. Longer term lateral migration of the right bank will encounter maturing riparian vegetation which will contribute wood to the reach, increasing complexity.

Design Considerations

Construction of log jams will require access through private lands and permissions or easements will be required. The in-water work and access, particularly for apex jam construction, will be permitting considerations. Stability criteria have not yet been developed, and these will affect anchoring requirements and techniques, which will also affect permitting.

A study describing recreation and large wood was completed in 2013 for the section of the Twisp River that extends from Buttermilk Creek (RM 13.5) to the mouth and does not include the project area. However, the conclusion drawn in the report that the Twisp is a "low use, locally used recreational resource" primarily due to private land and river access constraints. This is assumed to hold true for the Scaffold Camp project site as well. Even though recreational use is not high, the potential safety of river users must be considered when designing log jams that interface with the main channel. Both mid-channel and bank jams will be designed with bumper logs or other appropriate strategies to shed floating objects; and a reduction in the intensity and profile of any wood treatment described above may be warranted due to recreational safety concerns.

UPPER SCAFFOLD SIDE CHANNEL AND ALCOVE ENHANCEMENTS

Description and Potential Benefits

This alternative consists of enhancements of two existing features: 1) a river-right side channel extending from RM 16.2 to RM 16.05 that is currently activated at only high flows. This side-channel would be excavated to reconnect it to perennial surface flow; and 2) a river-right alcove at RM 16 along a steep terrace that would be connected to the mainstem at an elevation that maintains a low flow connection.

Side channel

An apex log jam would be placed at the side channel inlet in order to force water into the side channel and help maintain a scour pool at the inlet. The channel alignment would be excavated at a slope matching that of the adjacent main channel. Large wood would be added along the length of the side-channel to provide cover and habitat complexity.

Alcove

A large bank log jam would be constructed along the bank downstream of the inlet. This log jam would create scour conditions at the mouth of the inlet as well as provide cover. The inlet to the alcove would be deepened and widened in order to facilitate more connectivity with the main channel. The existing alcove would be selectively excavated so that perennial connectivity would be maintained. Additionally, select excavation could extend the alcove along the terrace wall to the south and along an existing swale parallel to the main channel. Large wood would be added along the length of the alcove to provide cover and habitat complexity.

Design Considerations

Access to both off-channel enhancement locations can be obtained from the south near RM 16.3. Both features can be constructed without temporary river crossings. Ideally, the bank log jam near the alcove inlet would be built mainly from the top of terrace, which would require access to this location. Design considerations related to stability analysis, ballast requirements and recreational safety are discussed in the Upper Scaffold Wood Placement alternative.

Beaver are active at this site, and their potential effect on the connectivity and hydraulic conditions within constructed side channels and alcoves will be considered in the design process.

MIDDLE SCAFFOLD BERM REMOVAL WITH REGRADED BANKS

Description and Potential Benefits

Currently, push up berms limit floodplain inundation rates and patterns on river-left between RM 15.75 and 16.1. Behind the berms are excavated ponds, likely the source of material for the berm construction. The berms are not continuous and do allow for some inundation of the floodplain surface to the north, and the ponds likely provide some winter refuge for salmonids. However, the berm/pond complex focusses flow and energy into the main channel, impairing floodplain inundation rates and patterns, and constraining the channel migration zone. The ponds are disconnected from the channel at low flow and thus pose a stranding hazard for fish that do find refuge during winter high flows.

This alternative includes a full re-grading of the berm/pond complex to approximate the pre-disturbance floodplain topography. This action would use material from the pushup berms to fill the existing ponds. The floodplain and riparian zone would be re-graded and replanted to a condition more analogous to the downstream right bank from RM 15.1 to 14.7. The gabion bank revetment at the upstream end on river-left would also be removed. The re-graded banks would allow for more natural meander migration in the floodplain north of the existing channel. Aerial photographs from 1953 and 1968 show an active floodplain area with exposed gravels and significant channel movement in the location of the berm/pond complex (Figure 6). Over time, this condition would be expected to re-establish.

For the purposes of the Concept Designs, we have assumed that a bank treatment along the river-left bank near RM 15.7 to 15.8 would be a necessary component to mitigate potential future erosion risk to properties. The need for and specific configuration of this bank treatment needs to be investigated further as part of subsequent design phases. If required, this treatment could be configured as wood placements along an enhanced backwater channel feature in order to also provide significant habitat value.

Design Considerations

Several homes and outbuildings are constructed in this area, one near RM 16.1 and several between RM 15.75 and 15.5. Preliminary modeling shows that some of these structures could be affected by flooding under current conditions. The pushup berms possibly provide some level of erosion risk mitigation by limiting the movement of the Twisp River to the north. Although this alternative is not expected to cause any rise in the water surface of floods, the removal of these berms and re-engagement of floodplain processes between RM 16.1 and 15.7 has the potential to allow channel movement to the north over the long-term. Changes in channel pattern and floodplain inundation under proposed conditions will need to be modeled and thoroughly evaluated in order to assess the potential impact of future floods on infrastructure adjacent to the river. This analysis would also be used to help inform the need for and configuration of potential bank treatments in this area.

Depending on the results of further analysis of erosion risk, a sub-alternative that could be considered is the removal of only the upstream berm/pond and gabions on river-left between RM 16.1 and 15.9. This sub-alternative would leave the existing pushup berm in place from RM 15.9 to RM 15.7, which would maintain the existing level of risk to downstream properties, and would not require any additional bank stabilization; with the tradeoff being a reduced degree of floodplain restoration.

MIDDLE SCAFFOLD BERM REMOVAL WITH SPLIT FLOW CHANNELS

Description and Potential Benefits

Similar to the previous alternative, this alternative would remove and reconfigure the berm/pond complex in the north floodplain, but it would then take a more aggressive approach to create floodplain habitats accessible to fish. The grading in this case would create split flow channels in two locations near RM 16.05 and RM 15.9. Some filling of the ponds may be necessary in the process of re-grading them into split flow channels. The two ponds furthest away from the existing river channel would be connected to the split flow channels as backwater alcoves. Bar apex jams would be constructed at the point of split flow in order to help maintain the flow divergence. Habitat cover wood would be added to the newly created side channels and backwater alcoves. There are various alternative configurations with this component that would be evaluated as part of subsequent design phases.

This alternative creates channel complexity more actively than the previous alternative with the creation of side-channel and off-channel features and the inclusion of mid-channel large wood that forces split flow and encourages island formation. The bar apex jams would have immediate habitat benefits of increased cover and scour pool formation. Existing analogs of these types of split flow channels can be found in the reach immediately downstream near RM 14.9 and 14.8. Historical aerial photos from 1953 and 1968 (Figure 6) show a wide un-vegetated floodplain in this area with split flow conditions observed in some locations. It is expected that the location of the main channel would vary over time across the expanded channel migration zone. Increased lateral channel dynamics would also increase planform complexity.

The potential need for bank stabilization measures for downstream properties, as described as part of the previous alternative, would also apply to this alternative.

The inlet to the upstream split flow channel would be excavated from a point near RM 16.05 (Sta 519+50), passing through an existing pond and re-entering the main channel at RM 15.95 (Sta 513+50). This channel would also be roughly aligned with the Upper Scaffold side channel described earlier, providing a potential future flow path if the upstream side channel captures more of the main channel flow over time. The downstream split flow channel would diverge from the main channel at RM 15.85 (~Sta 509+00) and re-enter the main channel near RM 15.75 (~Sta 503+00).

Backwater alcoves would be connected to both split flow alignments, taking advantage of and enhancing the existing pond alignments. Bank logjams placed at the downstream side of each inlet would encourage scour and help maintain access to the backwater areas for juvenile salmonids. Habitat cover wood would be placed in both backwater alcoves.

Design Considerations

Similar design considerations related to the removal of the berm/pond complex (previous alternative) and its potential effects on nearby existing infrastructure pertain to this alternative as well. Proposed split flow conditions would be modeled at a range of flows to assess their impact on channel hydraulics and flooding.

This alternative would result in a net removal of material from the 100 year floodplain. It would likely be necessary to identify a potential fill disposal area (either onsite above the 100 year floodplain, or off site) prior to construction.

Depending on the results of further analysis of erosion risk, a sub-alternative that could be considered under this alternative is the removal of only the upstream berm/pond and gabions on river-left between RM 16.1 and 15.9. A split flow channel would be excavated in the same alignment described above at the upstream berm removal location. A bar apex log jam would be placed on the downstream side of the inlet to help maintain the flow split. The backwater alcove described above would also be constructed for this sub-alternative. This sub-alternative would leave the existing pushup berm in place from RM 15.9 to RM 15.7, which would maintain the existing level of risk to downstream properties, and would not require any additional bank stabilization; with the tradeoff being a reduced degree of floodplain restoration.

MIDDLE SCAFFOLD GROUNDWATER GALLERY AND SIDE CHANNEL

Description and Potential Benefits

Increasing flow to a side channel using a groundwater gallery has shown promise in some segments of the mainstem Methow River valley where local groundwater conditions and slope can support it. The relationship between groundwater and surface water at the Scaffold Camp site is currently unknown, but recently-installed water level loggers in disconnected backwater ponds should begin to provide some insight. Based on existing side channel alignments and slope, the area between RM 16.1 and RM 15.75 has the potential for a groundwater gallery to supply flow to an excavated side channel. The feasibility of a groundwater-fed side channel will be contingent on groundwater pump testing results.

Groundwater side channels can provide beneficial cold water habitat in the summer months as well as more productive warm-water habitat in the winter months. The warm water habitat during winter is particularly important because an ice free habitat can be very valuable for salmonid rearing.

Design Considerations

A groundwater pump test will be needed to verify several key variables including: 1) the quantity of water that can be harvested reliably for a groundwater-fed side channel, and 2) water table elevation at the proposed location of the gallery. The water table elevation will be important to determine whether adequate slope exists to support a gravity fed channel.

MIDDLE SCAFFOLD WOOD PLACEMENT

Description and Potential Benefits

This alternative consists of two bar apex jams at RM 15.93 and RM 15.98 near the margin of the low flow active channel but more central to the un-vegetated active floodplain zone, as well as three bank margin jams on the river right. The potential benefits of these structures are discussed in the Upper Scaffold Wood Placement alternative.

Design Considerations

Design considerations related to access, stability analysis and ballast requirements and recreational safety are discussed in the Upper Scaffold Wood Placement alternative.

LOWER SCAFFOLD SIDE CHANNEL INLET EXCAVATION

Description and Potential Benefits

There is a long backwater channel with an outlet near RM 15.35. The outlet of this channel empties into a section of the channel that was recently active but has been supplanted at low flow by an alignment further to the north. However, this side channel still contains residual pools and some minimal amount of water even during low flow. The length of the backwater channel is approximately 1,300 ft. The channel likely receives some input from upstream (near RM 15.6) during high flow events, but the inlet is not active during lower flows. This alternative involves select excavation at the inlet of the channel to provide more connectivity at lower flows, which would benefit salmonids by providing access to a large amount of off-channel juvenile rearing habitat. A log jam near the inlet would provide conditions for scour and maintenance of connectivity as well as directing flows into the channel.

Design Considerations

The backwater channel is currently a mix of open water wetland (~30%) and emergent wetland covered with thick aquatic vegetation (~70%). Major excavation along this alignment would be challenging given potential wetland impacts. Sediment continuity should be examined in further detail to verify that nuisance deposition of fines near the inlet would not be problematic. The best access to this site needs to be further evaluated. Access from the south side may be possible but has not been evaluated. Access from the north would require crossing the main channel.

LOWER SCAFFOLD BERM REMOVAL AND SIDE CHANNEL EXCAVATION

Description and Potential Benefits

There are two small pushup berms on river-right near RM 15.75 and 15.7. These features, while not as significant as the berms on river-left, still serve to limit channel migration in this area. Their removal would be relatively simple, would eliminate an obvious human feature, and may increase the potential for channel migration into a mature riparian area.

There is a series of channel scars to the south of the main channel between RM 15.8 and RM 15.7, through which a side channel could be excavated and connected to the main channel at low flows to provide juvenile rearing habitat. A log jam at the inlet would route flows into the side channel. Habitat cover wood would be placed along the side channel alignment.

Design Considerations

Access from the south side may be possible but has not been evaluated. Access to this site from the north would require a wet channel crossing. The alignment of the side channel would be adjusted during construction to minimize impact to existing mature vegetation.

LOWER SCAFFOLD MAIN CHANNEL BERM REMOVAL

Description and Potential Benefits

There is a push-up berm along river-left between RM 15.53 and 15.64. Based on inundation mapping, this berm has little effect on floodplain inundation extent or patterns. However, there is likely some impact to channel migration rates. Removal of this berm would have relatively little short-term habitat benefit, but may have some long-term benefits to channel migration processes. Increasing channel migration rates toward the north, however, would also increase exposure of private residences to bank erosion. For this reason, removal of the berm may need to be combined with a bank treatment along the bank in front of the houses. This could be constructed similar to the bank treatment described above for the alternative "Middle Scaffold Berm Removal with Regraded Banks" and could consist of wood placements along approximately 800 feet of bank combined with enhancement to the existing backwater area.

Design Considerations

There are several homes located on the floodplain surface (and former active channel bank) to the north, extending from approximately RM 15.47 to 15.65. Preliminary modeling shows that some of these structures could be affected by flooding under current conditions. The pushup berm likely provides some level of erosion risk mitigation by somewhat limiting the movement of the Twisp River to the north, although the berm is not tied into any high banks and does not fully prevent erosion risk from developing under current conditions. Although this alternative is not expected to cause any rise in the water surface of floods, the removal of this berm could promote channel movement to the north. Potential future changes in channel pattern under proposed conditions will need to be modeled and thoroughly evaluated in order to assess the potential impact of future floods and erosion on infrastructure adjacent to the river. This analysis would also be used to help inform the need for and configuration of potential bank treatments in this area.

RIPARIAN PLANTING

Description and Potential Benefits

Riparian restoration and revegetation would occur in the areas that have been cleared or are otherwise devoid of mature woody vegetation due to past land management activities, or within areas disturbed as part of construction of other restoration components. Low bank areas would be planted with riparian shrubs, while high bank and floodplain areas would be planted with shrubs and trees. Over time, these plantings would provide bank stability, hydraulic roughness, shade of the channel, and large wood recruitment. The amount of required riparian planting varies substantially depending on the alternative chosen for the berm complex area.

Design Considerations

The target species communities and the planting methods and timing would be determined as part of subsequent design phases. Some of the areas identified for riparian restoration, particularly along the river-right bank between RM 16.1 and 16.4, may currently have agricultural or rural residential uses. Riparian enhancement work in these areas may require working with landowners to find re-vegetation solutions that achieve multiple landowner and resource enhancement objectives.

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