2022 UPPER COLUMBIA AND SANPOIL HABITAT RESTORATION PLAN

Prepared for:
Confederated Tribes of the Colville Reservation

Prepared by:
Phil Roni, Ph.D., Kai Ross, Ph.D., and Raymond K. Timm, Ph.D.,

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EXECUTIVE SUMMARY

Columbia River Redband Trout *Oncorhynchus mykiss gairdneri* are a culturally and ecologically important as well as sensitive species in the Upper Columbia, Sanpoil, and other Columbia River subbasins. The Confederated Tribes of the Colville Reservation (CCT) lead several projects aimed at improving Redband Trout habitat and productivity within the Upper Columbia (Barnaby Creek, Hall Creek, Stranger Creek, and Nez Perce Creek) and Sanpoil subbasins. While considerable physical, biological, and other data exist throughout the Upper Columbia and Sanpoil subbasins, no consistent watershed assessment and restoration plan has been developed using all the available information. The following restoration plan provides a detailed watershed assessment of habitat conditions and restoration opportunities to improve the productivity and diversity of Columbia River Redband Trout in the Upper Columbia and Sanpoil subbasins. The overall goal of this effort was to use the latest science and data to assess watershed conditions, identify causes of degradation, and develop a comprehensive process-based watershed restoration plan that addresses critical Redband Trout habitat concerns. To achieve this, we developed a systematic, hierarchical watershed assessment that incorporates existing watershed, landscape, riparian, and instream habitat conditions coupled with outputs and data from the Ecosystem Diagnosis and Treatment (EDT) model. River and stream reaches previously identified through EDT modeling were used to define watersheds contributing to each EDT reach (EDTshed). These EDTsheds provided the foundational units for summarizing all contributing upslope and instream habitat conditions to identify habitat conditions potentially limiting Redband Trout. EDT model results on potential improvements in Redband Trout productivity, diversity, and abundance were used to identify the highest priority reaches for restoration. Of the more than 700 EDT reaches in the study area, 25 priority reaches were identified. Fifteen of these reaches are in the Sanpoil subbasin. Moreover, EDT model results suggest that fully restoring these 25 reaches will improve Redband Trout productivity, diversity, and abundance by 38% within the study area.

Due to the massive quantities of data that exist for the Upper Columbia and Sanpoil subbasins, determining the spatial and temporal overlap of datasets was a critical step. While extensive physical, biological, and water quality data exist, much of the coverage is limited to selected reaches or portions of those reaches. The most comprehensive data sets included, but were not limited to, Lake Roosevelt Habitat Improvement Project habitat survey data, NorWeST Temperature model data, Beechie and Imaki (2014) channel data, National Land Cover data, and Department of Natural Resources roads data, as well as summary habitat ratings used in the EDT modeling effort. Data on upland forest cover, roads (density, crossings), riparian cover and condition, channel condition (confinement, type), and instream habitat (e.g., large woody debris, fine sediment, pool area) were then summarized by EDTshed. Results of the assessment indicate that the most common degraded habitat conditions were large woody debris (LWD) levels, riparian conditions, fine sediment, and channel and floodplain connectivity. Barriers are potentially an issue in some of the EDTsheds, but the barrier data we had were incomplete and need to be confirmed.

The assessment results were then coupled with predicted Beechie and Imaki (2014) channel conditions, aerial imagery, and information on the most successful restoration strategies to identify potential restoration actions for each of the 25 priority reaches. The most common restoration measures suggested including: additions of large wood to the channel, riparian restoration,

livestock exclusion, floodplain reconnections, remeandering straightened channels, wetland restoration, barrier removal, and protection.

We conducted site visits of all 25 priority reaches in June of 2017 to confirm that the recommended restoration measures were appropriate and feasible, and to identify any other constraints or other potential issues needed to further prioritize reaches for restoration. We then reprioritized the reaches using a multi-criteria decision analysis with input from CCT. This included reprioritizing reaches based on site access and logistics, land ownership, cultural significance, and whether the restoration measures prescribed for the reach were expected to restore processes and ameliorate the effects of climate change. We outlined an action plan to address key constraints, next steps to implement the restoration plan, and provide preliminary cost estimates for restoring all 25 priority reaches. Finally, based on comments received from the Independent Scientific Review Panel of the Northwest Power Conservation Council, in 2022 we updated the restoration plan to include biological targets (juvenile Redband Trout capacity) and a monitoring and adaptive management plan. The pre-project monitoring proposed was developed to be part of the design and implementation of restoration projects. Implementation of post-project monitoring, which is critical for adaptive management of the program, is dependent upon additional funding.

INTRODUCTION AND BACKGROUND

Columbia River Redband Trout *Oncorhynchus mykiss gairdneri* are a culturally and ecologically important fish native to the Columbia Basin and are classified as a sensitive species, a species of special concern, and a Washington Department of Fish and Wildlife (WDFW) Priority Species (WDFW 1997; Muhlfeld et al. 2001). The Fish and Wildlife Department of the Confederated Tribes of the Colville Reservation (hereafter CCT) leads several mitigation projects aimed at enhancing Redband Trout and other fish and wildlife resources on the CCT Reservation including the Lake Roosevelt Habitat Improvement Project (LRHIP). A major goal of the LRHIP is to improve Redband Trout populations by maintaining or restoring ecological processes and functions in the Upper Columbia (i.e., Barnaby, Hall, Stranger and Nez Perce creeks) and Sanpoil subbasin streams. A variety of land-use practices (e.g., residential, agricultural, road building, logging, and grazing) have degraded habitat conditions and isolated habitats for Redband Trout throughout many of the watersheds that are part of the CCT's usual and accustomed fishing areas. Moreover, the CCT has conducted numerous habitat investigations in the study area including inventorying more than 310 km (193 miles) of stream habitat and modeling studies in the Upper Columbia and Sanpoil subbasins using the Oregon Department of Fish and Wildlife Aquatic Inventory methods and Ecosystem Diagnosis and Treatment (EDT) (Moore et al. 2013; Lestelle 2004). These efforts and other data sources can assist with identification of degraded habitats. However, a comprehensive watershed assessment and restoration plan is needed to synthesize these efforts, identify restoration opportunities, prioritize potential restoration actions, and develop an action plan to restore and enhance Redband Trout in the Upper Columbia and Sanpoil subbasins.

The following restoration plan was designed to provide a detailed assessment of the intensity and spatial extent of habitat degradation in the study area and to identify specific restoration actions that are likely to improve the productivity as well as diversity of interior Redband Trout. Moreover, this effort is designed as a process-based restoration plan that uses information derived from comprehensive, spatially explicit watershed assessments to identify underlying causes of habitat degradation and recommend restoration actions that will both improve habitat and address root causes of habitat degradation. Consistent with the strategies of the Upper Columbia Regional Technical Team (RTT 2014) that focus on connections between habitat conditions and viable salmonid population (VSP) parameters, restoration actions presented in this document were developed in response to identified, specific habitat problems by reach.

This plan was first completed in January of 2017. Based on comments from the Independent Scientific Review Panel (ISRP) of the Northwest Power and Conservation Council, the plan was updated to include biological targets for priority reaches and a monitoring and adaptive management section (ISRP 2020).

Goals and Objectives

The goal of this effort was to use the latest science to assess watershed conditions, identify causes of degradation, and develop a comprehensive watershed restoration plan that addresses critical spawning, summer rearing, and overwintering habitat concerns. The restoration plan uses empirical observations of habitat conditions as well as modeled predictions to identify and prioritize specific restoration and protection actions. Our approach relies on determining spatial and temporal overlap of available datasets to identify consistent coverage across the study area.

The major objectives are to:

1) Develop a watershed assessment defining current conditions, distributions of stream habitats relative to regional benchmark values appropriate for local stream geomorphic types and sizes;

2) Identify intact habitats for protection, degraded habitats for restoration including potential mechanisms of degradation and restoration measures that directly address the interrupted processes affecting habitat conditions;

3) Create a cohesive restoration plan with clearly articulated restoration actions that address specific local degraded habitats and expected changes in habitat capacity resulting from restoration actions;

4) Develop an action strategy that addresses social, economic, ecological and logistical factors that potentially affect restoration success;

5) Develop quantitative biological targets for restoration based on the EDT model; and

6) Provide a monitoring and adaptive management framework to evaluate success of restoration actions and adapt restoration actions.

The last two objective were added in 2022 in response to comments from the ISRP in 2020. The following report summarizes our methods, findings, and recommendations for these tasks. Our effort focused on the entire Sanpoil Subbasin and select Upper Columbia Subbasin streams that drain directly to Lake Roosevelt, including Barnaby, Hall, Stranger, and Nez Perce creeks (Figure 1).

BACKGROUND AND LANDSCAPE CONTEXT

Columbia Redband Trout

Columbia River Redband Trout are a culturally important and sensitive species and concerns about their abundance pre-date 1990 when the LRHIP was initiated (Klett et al. 2015). There are multiple life strategies employed by Redband Trout in the study area—fluvial (resident), fluvial-adfluvial, and lacustrine-adfluvial (Brown et al. 2013). Fluvial fish use the entire range of habitats in their natal stream, which could include mainstem rivers and tributaries to rear until they mature and spawn. By contrast, fluvial-adfluvial fish are thought to rear and mature in mainstem river habitats and return to their natal tributary streams to spawn. Lacustrine-adfluvial fish tend to rear in lakes and reservoirs before migrating upstream to spawn (Quinn 2005). In addition, there are known distributions of introduced Coastal Rainbow Trout *O. m. irideus* below barriers in the system (Brown et al. 2013). Historically, before upstream migrations were blocked by the construction of the Grand Coulee Dam, steelhead—the anadromous form of *O. mykiss*—were also present (RTT 2014). The LRHIP investigation was motivated by desires to improve Tribal subsistence and recreational fishing opportunities for Redband Trout and other fishes on the CCT Reservation. Originally, the LRHIP consisted of baseline assessments of habitat and fish populations, habitat restoration, and effectiveness monitoring. Subsequent modeling efforts have included EDT models for the Sanpoil River and Upper Columbia tributaries along the eastern boundary for the CCT (Klett et al. 2015).

Watershed Physiography

The Upper Columbia and Sanpoil subbasins drain a mountainous landscape dominated by coniferous forests in north-central Washington State (Figure 1). The Sanpoil River drainage originates north of the CCT Reservation boundary. The upper Columbia tributaries evaluated in this study originate east of a divide that drains east to Lake Roosevelt. Precipitation ranges from approximately 28 cm (11 in) near the confluence with the Columbia to more than 76 cm (30 in) in higher elevations. Hydrology is snowmelt-dominated with the largest flows occurring during spring and early summer with occasional rain-on-snow events resulting in fall and winter high flow events (Brown et al. 2013). Elevation in the study area ranges from 230 m (765 ft) to 2,060 m (6,800 ft). Geology is comprised of igneous and metamorphic formations overlain by glacial deposits and volcanic ash that cover approximately 75% of the CCT Reservation. In the Sanpoil drainage, the Sanpoil lobe of the Cordilleran ice sheet extended the full length of the valley all the way to the Columbia. The eastern drainages of the reservation were covered by the Columbia River lobe during the last ice age. In addition, Pleistocene Lake Columbia inundated much of the study area up to approximately 750 m (1,500 ft) elevation. Glacial and volcanic soils dominate, contributing to the productive capacity as well as the sensitivity of the landscape (Hunner and Jones 1996).

The Sanpoil drainage covers more than 2,600 km^2 and consists of 95.5 km (59.3 miles) of rivers with channels greater than 8 m (25 ft) in bankfull width, 1,450 km (925 miles) of streams with channels less than 8 m (25 ft) in bankfull width[1]. Within the Sanpoil drainage, 468 reaches were defined according to EDT modeling efforts (ICF unpublished GIS data; Figure 2).

The Upper Columbia tributaries examined in this study include Barnaby, Hall, Stranger, and Nez Perce creeks and drain 93, 445, 195 and 71 km^2, respectively (804 km^2 total). These reaches are comprised of 54 km (34 miles) of rivers with channels greater than 8 m (25 ft) in bankfull width, and 808 km (502 miles) of streams with channels less than 8 m (25 ft) in bankfull width (Figure 2).

[1] Geomorphic stream breaks based on 8 m bankfull width were adapted from Hall et al. (2007) and Beechie and Imaki (2014). Channels smaller than 8 m don't tend to migrate laterally across their floodplains; processes differ between these two channel dimensions as well.

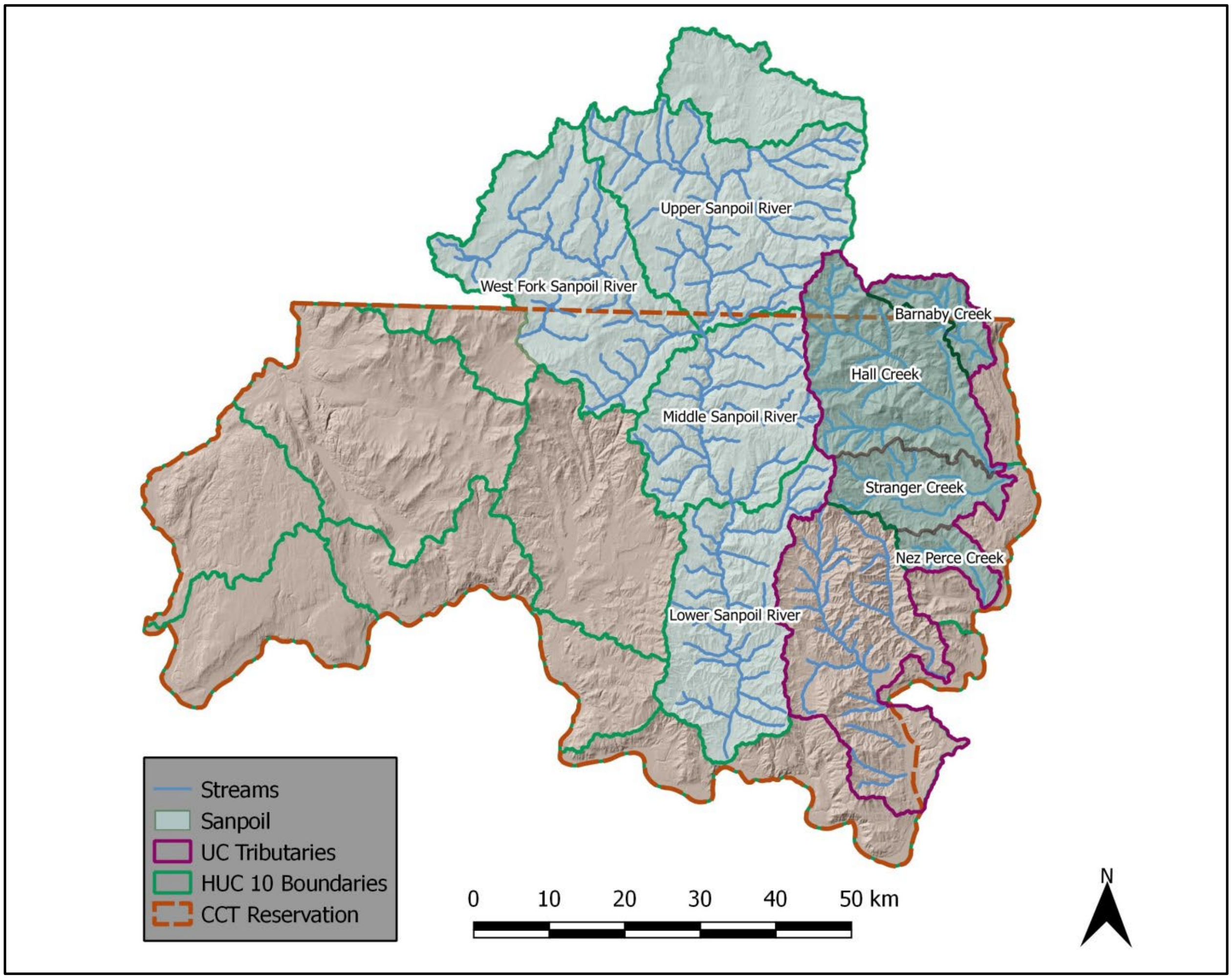

Figure 1. Map of study area showing Upper Columbia (UC) and Sanpoil subbasins. Dashed line indicates the Colville Confederated Tribes Reservation boundary. Green lines represent HUC 10 watershed boundaries.

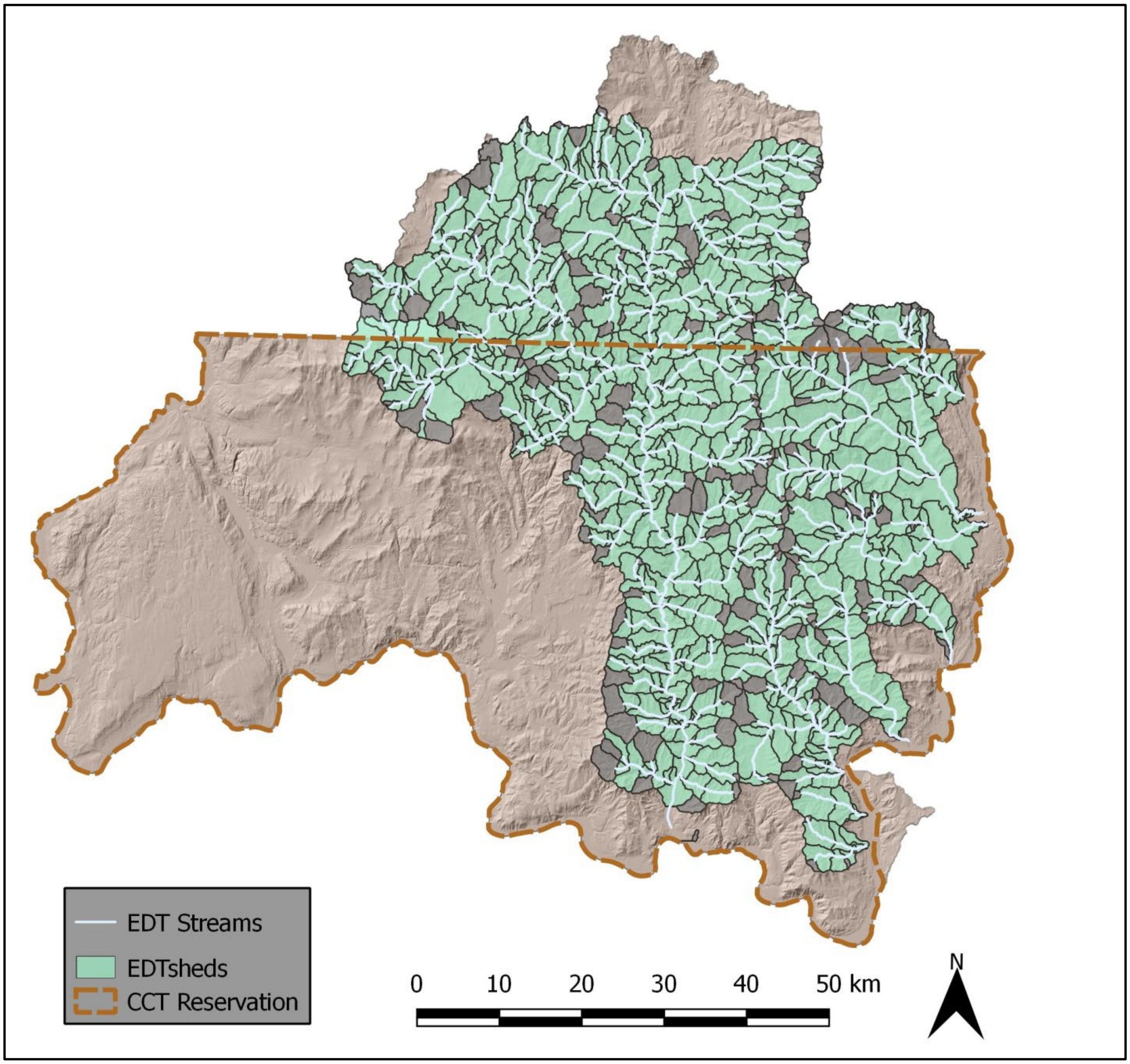

Figure 2. Map of all EDT reaches for the Upper Columbia and Sanpoil subbasins.

WATERSHED ASSESSMENT

Assessing watershed and habitat conditions in the Upper Columbia and Sanpoil subbasins involved four hierarchical steps.

1) Delineation of area draining into each EDT reach (EDTsheds, which are the geomorphic template for assessment and restoration planning).

2) Prioritization of EDT reaches to identify EDTsheds and reaches that are highest priority for protection and restoration.

3) Synthesizing and summarizing existing data to determine geographic and temporal overlap and which datasets can be used for assessment and characterization of habitat conditions.

4) Summary and assessment of conditions in EDTsheds using appropriate data from step 3 including sediment, riparian, instream, and other habitat conditions.

Methods

Identification of EDTsheds

The watershed area that drains into existing EDT stream reaches is defined as the EDTshed. These EDTsheds form the basis for summarizing and analyzing up-slope conditions to help determine the factors contributing to instream habitat conditions. Each EDTshed is defined using the X and Y coordinates of the upstream and downstream node of each EDT reach break. They are important because EDT modeling results are categorized and presented for each reach as defined by the reach breaks. In addition, the EDTshed summaries were derived from the watershed land covers and instream habitat conditions associated with each EDT reach.

A complete, hydrologically corrected 10 m digital elevation model (DEM) was developed to determine the watershed landscape areas that drain to each EDT reach. The DEM was compiled from 48 individual 7.5-minute datasets downloaded from USGS through datageo.com. These data were re-projected to UTM Zone 11 N, NAD 83, merged together into a single file, and clipped to the Upper Columbia and Sanpoil study area (Figure 1). This step was necessary because local upslope watershed areas commonly occurred on multiple 7.5-minute data tiles. The resulting EDTsheds were determined by finding the upslope elevation maxima (i.e., ridgelines) for every EDT reach. EDTshed boundaries were then used to compute flow accumulation in a grid cell to grid cell fashion. Because water always flows downhill in a hydrologically corrected DEM, the elevation for each grid cell must be evaluated relative to all of its adjacent grid cells to determine flow direction and accumulation in a downslope direction that ends at a “pour point”. Pour points for this study were determined by the downstream end of each EDT reach (Maidment and Djokic 2000). All EDTshed extents were defined using the “Hydrologic Analysis” tools in ArcGIS 10.1. Once these EDTshed boundaries were defined, they were converted to polygons that were then used to summarize landscape variables that could be important for fish.

Because EDTsheds serve as the fundamental spatial unit for the watershed analysis, they are a critical component of the study. Deriving EDTsheds is technically complex because differences in geographic registration can complicate analyses when data with disparate sources and resolutions are employed in the analyses. For example, the hydrologic correction process calculates flow accumulation for each grid cell relative to its upslope neighbors. In turn, this is used to “locate” the stream network in the bottom of valleys. In many cases, the existing EDT stream network was not perfectly coincident with the flow accumulation grid, resulting in errors during the EDTshed calculation process. This was likely the result of coarser spatial data used to derive the EDT streams, resulting in registration errors.

We relied on modeled geomorphic predictions for “streams” (<8 m bankfull width) and “rivers” (>8 m bankfull width) because they provided a reasonable approximation of the actual drainage network (Beechie and Imaki 2014). The “streams” dataset is based on Montgomery and Buffington (1997) channel classifications and the “rivers” data, which are predictions of major channel types (i.e., braided, confined, island braided, meandering, and straight; Figure 2) are both derived from well-known fluvial geomorphic relationships that control the physical template of instream habitat conditions (Leopold and Wolman 1957). To ensure complete geographic overlap among all datasets in the analyses, a multi-step process was followed to provide clarity and reproducibility. Details of this process are provided in Appendix A.

Prioritization of EDTsheds for restoration and protection

While there is some debate about the accuracy and precision of EDT model predictions of population abundance and productivity, EDT has been shown to be a robust tool for ranking of reaches for restoration and protection (Steel et al. 2010; McElhany et al. 2010). Priority reaches were determined for all EDT reaches within the study area based on summaries of existing modeling results that predicted increases in important Redband Trout population parameters. Summaries were converted to rankings and the highest rankings were identified as high priority for protection and restoration actions.

For this study, priority rankings (), were determined by ordering summed EDT model outputs for the potential percent changes in diversity (Div), productivity (Prod), and equilibrium abundance (NEQ) reported in the EDT analysis.

Following equation 1, we identified the top 25 EDTsheds and ranked them for prioritization. Aggregated, these 25 EDTsheds represent 38% of the total amount of potential percent improvement in Redband Trout diversity, productivity, and population size across the entire study area.

$$P_{rank} = \Delta Div\% + \Delta Prod\% + \Delta NEQ\% \qquad \text{Eq. 1}$$

Synthesis and summary of existing data

The Upper Columbia and Sanpoil have been studied extensively and offer a rich source of habitat data throughout much of the study area. For this study, published reports, and published and unpublished datasets included, but were not limited to CCT, ICF International, Stream and River geomorphic datasets (Beechie and Imaki 2014), NorWeST Stream Temperature Regional Database, U.S. Geological Survey, Washington Department of Natural Resources, and various other data sources including annual monitoring reports dating back to the early 1990s. Thus, one of the largest tasks was assimilating these data and information and determining which data sets were useful for assessing conditions and identifying restoration actions for Redband Trout (Table 1). Our approach was hierarchical following Roni and Beechie (2013; Figure 3). Datasets evaluated in this effort describe the range of conditions from the landscape level down to the reach and habitat levels. We focused on data that proved useful in assessing watershed conditions, habitat-forming processes, and restoration opportunities.

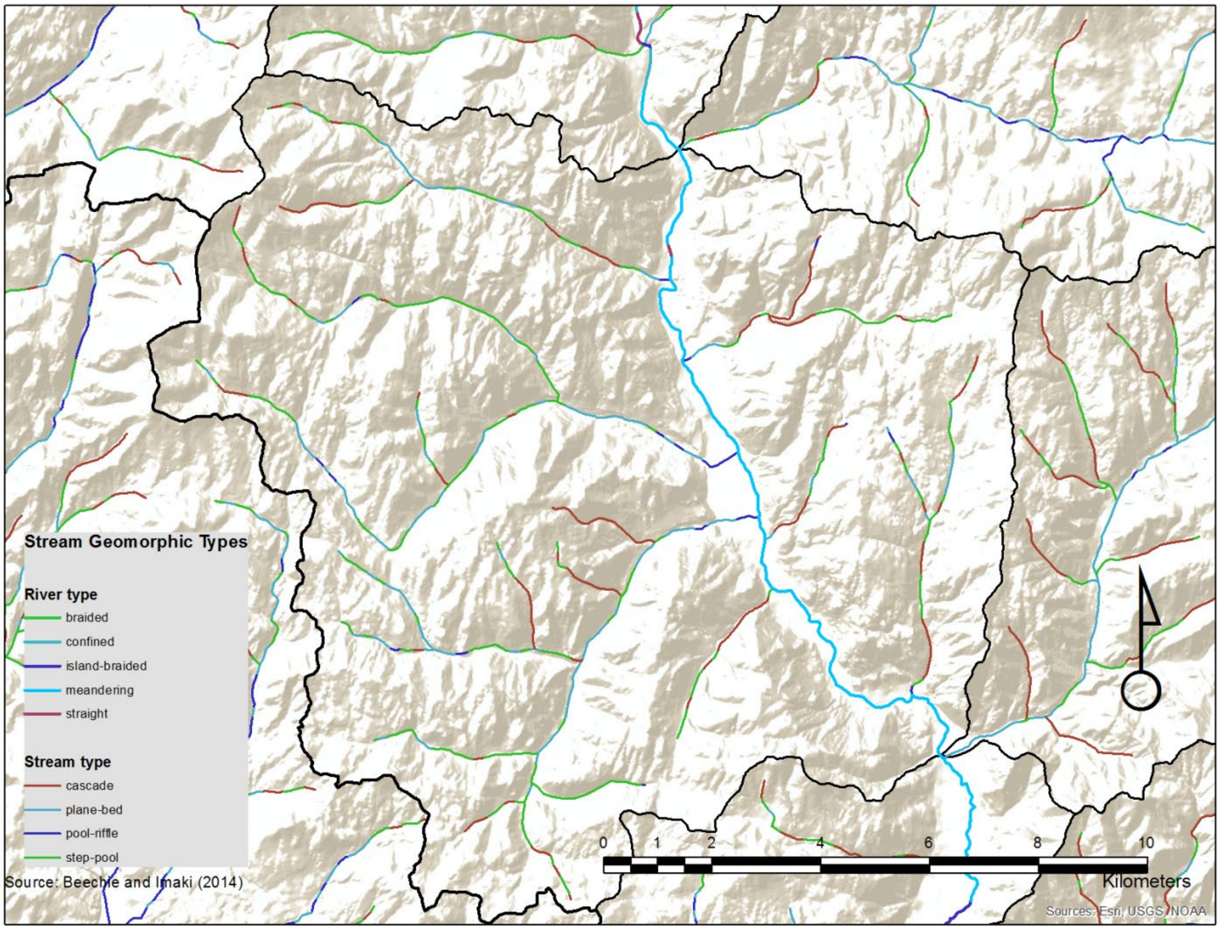

Figure 2. Example of modeled stream and river geomorphic data from Beechie and Imaki (2014) for a portion of the Sanpoil Basin. In this example, the dominant "River" channel type is meandering, and all "Stream" types are visible, distributed throughout the map. Predictions of "Stream" channel types are all 200 m in length. "River" channel types vary in length based on expected length for a channel type.

We reviewed data, reports, and publications provided by the CCT as well as performed web searches to locate other documents and data sources including modeling studies performed in the study area. Many of the previous watershed analyses incorporated syntheses at multiple scales, which made categorizing them into simple boxes like those presented in Figure 3 difficult. Nonetheless, the various data sources and analyses were either used directly in our assessment, or as part of collected information used to guide restoration suggestions. These data were then evaluated to determine their degree of spatial and temporal overlap. This was crucial to the overall assessment because it allowed us to filter out those sources that were not useful in system-wide examination of important watershed processes and habitat conditions (Table 2). It should be noted, however, that the existence of a data set in a given reach does not necessarily indicate that coverage was complete for that EDT reach. On the contrary, the length of the habitat survey varied according to the protocol used for collection. In addition, many more datasets were screened for this assessment that provided extremely valuable information and insights despite their inconsistent spatial and temporal characteristics. However, when evaluated in aggregate, the subset of data sources that provide consistent spatial and temporal coverage presents an impressive collection of knowledge that has been compiled for the study area and is the framework upon which the assessment and restoration planning were based (Table 2).

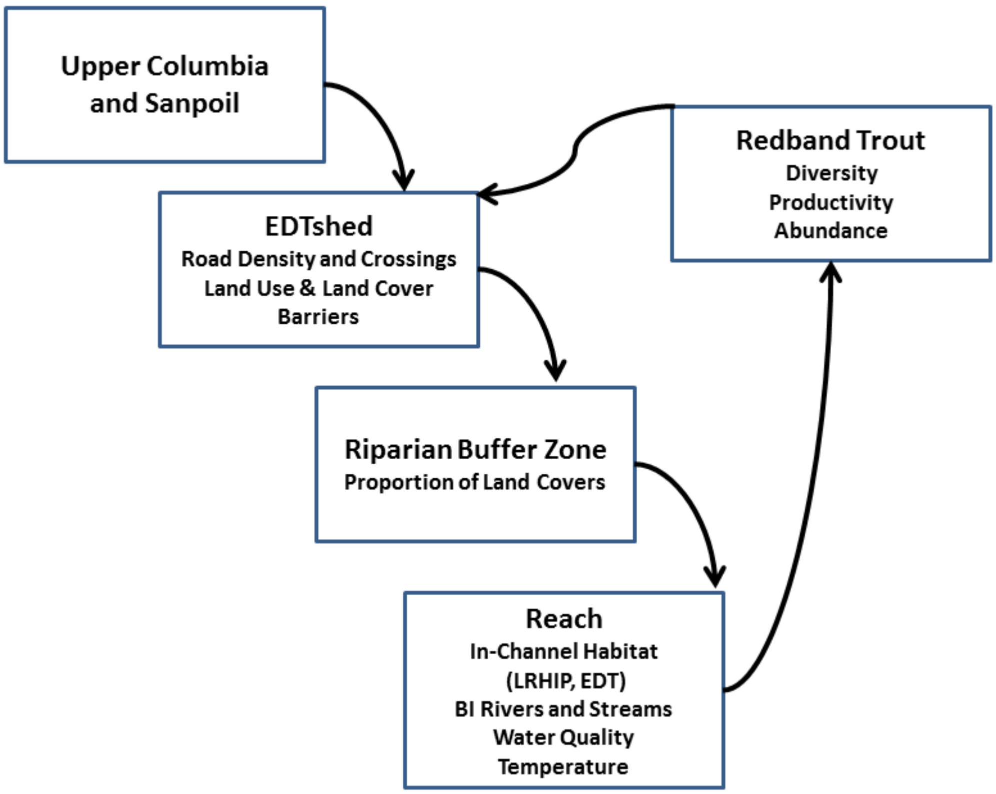

Figure 3. Hierarchical watershed assessment approach that describes ecosystem conditions from the landscape scale down to instream habitat conditions at the reach scale. Each box represents datasets evaluated (see Table 1 for a more complete description of each dataset). Arrows represent functional linkages across scales.

Watershed scale – Basin-wide watershed studies have been done for both the Upper Columbia (ICF 2011), and the Sanpoil (ICF 2013). Both of these studies facilitated EDT modeling to determine reach-scale habitat conditions that might be limiting Redband Trout. The Colville National Forest (USFS 2012) produced a Watershed Action Plan for the portions of the Sanpoil drainage within the national forest lands, including summaries of watershed and stream geomorphic conditions and fish habitat. Perhaps the most comprehensive watershed analysis was performed by Hunner and Jones (1996) as part of an Integrated Resources Management Plan. This report detailed historic and contemporary watershed, soil, and vegetation conditions and their relations to lakes, riparian areas, and fisheries resources on the CCT Reservation. In addition, Brown et al. (2013) performed a three-year study evaluating the viability and life history diversity of Redband Trout and associated critical spawning, overwintering, and migration habitats in the

Sanpoil River drainage. The report unfortunately lacks geographic specificity. So, while there appears to be potential geographic overlap with priority reaches, it's not clearly verifiable. All of these studies provide relevant data related to watershed and sediment processes that drive riparian and channel conditions. In addition, other GIS data that were summarized included roads from the Washington Department of Natural Resources (WDNR 2014), land cover from the National Land Cover Dataset (NLCD; Homer et al. 2015), and system-wide modeled stream temperature from the NorWeST stream temperature model (Chandler et al. 2016).

EDTshed – As mentioned above, the EDT modeling efforts produced reach breaks that were used to determine the upslope contributing watershed areas draining to each reach. Specific computation details are included in Appendix A. The polygons defining EDTsheds were used to summarize landscape conditions for each reach and were the basic unit of analysis for all subsequent scales of interest. Land covers were summarized within these buffers to evaluate the condition of riparian zones and support restoration suggestions. The NLCD provided the most complete and consistent coverage for these summaries. Land covers were aggregated to classes that included "forest", "scrub shrub", "wetland", and "other" within these polygons. "Forest" classes were comprised of coniferous, deciduous, and mixed coniferous and deciduous forest classes. "Wetland" classes were comprised of open water, woody wetland, and emergent wetland. "Scrub shrub" land cover classes were not aggregated from other available classes. The remaining land covers were aggregated into the "other" class and reflected anthropogenic alterations including agricultural land covers, and roads.

Riparian buffer extents - Summaries of riparian conditions were generated by creating 30 m (100 ft) and 100 m (328 ft) buffer polygons around the stream layer. The expectation was that percent land covers would differ between the EDTshed and riparian buffer extents; therefore, changing the value of the summary information to focus more specifically on riparian conditions and impacts. Estimates of percent forest cover were used as a surrogate for forest stand age and size to determine the effect of shading and the likelihood of natural large wood recruitment to the channel. Summaries of "scrub shrub" and "non-woody vegetation" classes were included in evaluations of riparian conditions that might indicate grazing impacts in proximity to stream channels. Wetland classes were used to help identify locations within the riparian zone that might be candidates for channel-floodplain reconnection, habitat enhancement through beaver relocation, and potential hyporheic recharge and discharge opportunities that could provide thermal refugia for fish during cold or warm periods (Torgersen et al. 2012; Pollock 2014).

Riparian summaries were evaluated by EDT reach, and when coupled with the Beechie and Imaki (2014) geomorphic stream classifications, are useful for identifying beneficial restoration actions. For example, riparian areas with a high proportion of non-woody vegetation in a meandering stream section would be good candidates for large wood installations and riparian plantings that would encourage beaver colonization (i.e., willows).

Habitat data –The CCT provided numerous instream habitat datasets including some recently collected by CCT and its agents following the Columbia Habitat Monitoring Program (CHaMP) and Lake Roosevelt Habitat Improvement Project (LRHIP) methods (Moore et al. 2013; Bouwes et al. 2011). These studies provided detailed habitat survey data on short stream reaches (<600 m) throughout the study area, but also provided incomplete coverage in the Upper Columbia and Sanpoil River subbasins. Additional surveys performed by Duck Creek Environmental provided detailed information on pools and other important habitats. These various habitat data are extensive throughout the study area, but do not provide complete spatial coverage (Table 2). In addition, even for those habitat surveys containing data within our priority reaches, in most cases, the survey data failed to cover the full extent of the reach.

Due to their combined geographic extent and predictions of physical instream habitat conditions, we relied on the modeled geomorphic stream and river datasets (Beechie and Imaki 2014). These data represent potential channel geomorphology for 200 m reaches under natural undisturbed conditions. Thus, data from Beechie and Imaki (2014) were especially useful for identifying potential channel conditions and restoration measures. The Beechie and Imaki (2014) data on channel types, bankfull widths and depths, shear stress, and floodplain width were particularly useful for identifying areas in need of floodplain restoration or addition of large woody debris.

In addition, there were several high intensity temperature and water quality datasets associated with specific fish-related studies. The most comprehensive of these studies evaluated fish use and migration throughout the Sanpoil River (Brown et al. 2013). However, most of the temperature studies we reviewed provided inconsistent temporal records that precluded basin-wide analyses. As a result, we relied on the NorWeST temperature model data (Chandler et al. 2016), which utilized the original local temperature data collected in the study area to produce continuous stream temperature output. Several other datasets were associated with previous total maximum daily load (TMDL) efforts in the study area and indicate that there are some ongoing water quality problems (WDOE 2016).

The EDT modeling results, in addition to determining the reach breaks noted above, provided detailed analyses of instream habitat conditions and generated EDT performance factors (limiting habitats and conditions) at the reach scale. The habitat data in the EDT model are largely from recent CCT, as well as other habitat surveys. The EDT models assimilated and incorporated various other data sources for both the Upper Columbia and Sanpoil (ICF 2011, 2013). Summary habitat data, habitat intrinsic potential, affinity ratings, and other information used in the EDT model attempt to link channel and habitat data with other watershed and landscape data. These data were made available by ICF in electronic GIS and tabular formats.

Instead of an attempt to assimilate all the disparate original data (some of which are based on maps or professional opinion), we relied on and summarized habitat scores from EDT model outputs and empirical field measurements from LRHIP and CHaMP surveys (e.g., area, percent pool, LWD) and further assessed habitat condition based on the stream geomorphic data of these summaries. Moreover, by evaluating habitat conditions at multiple spatial extents (i.e., EDTshed, riparian buffer, and instream), differences in the collection of factors that drive habitat conditions can focus efforts at the appropriate scale. This spatially nested analysis provides for both the landscape assessment of conditions as well as the detailed view of riparian conditions affecting stream habitats. The combination of these datasets provides useful information for identifying underlying causes of degradation at reach and subbasin scales, and consequently, for identifying appropriate restoration measures.

Table 1. Existing spatial data layers used in the watershed assessment. Datasets in this table represent sources available with complete coverage across the entire Upper Columbia and Sanpoil study area.

Data Type	Source	Description
National Elevation Dataset (NED), Digital Elevation Models (DEMs)	USGS 2012	USGS 10m Digital Elevation Models. Multiple DEMS were mosaicked to cover the study area.
Beechie & Imaki Stream Data (BI Streams)	Beechie and Imaki 2014	Modeled data on expected stream channel typing
Beechie & Imaki River Data (BI Rivers)	Beechie and Imaki 2014	Modeled data on expected river channel typing
EDT Prioritization Data	ICF 2014-16	EDT modeling results including the potential % change in diversity, productivity, and equilibrium abundance for each reach
EDT Limiting Factor Data	ICF 2014-16	EDT modeling results that rank the limiting survival factors for each life stage in each reach.
EDT Habitat Data	ICF 2014-16	EDT habitat scores ranked 0-4
EDT Reach Breaks	ICF 2014-16	EDT reach delineations
National Land Cover Dataset (NLCD)	Homer et al. 2015	2011 land cover at 30 m resolution
% Land Cover	Derived from NLCD	The percent of each EDTshed designated into each land cover class
% Land Cover - Stream and River Buffers	Derived from NLCD	Buffered land covers (30 m and 100 m) buffers around the streams and rivers
NorWeST Temperature-EDTshed	Chandler et al. 2016	Interpolated temperature data from August 2013, averaged over the reach
NorWeST Predicted Temperature	Chandler et al. 2016	Interpolated predicted temperature for August 2080, averaged over the reach.
WA DNR Roads EDTshed Area	WDNR 2014	Washington State roads, and their associated attributes summed for area of EDTshed
Road Density	WDNR 2014	Total road length / Area of EDTshed
Road Crossings on BI Streams	WDNR 2014	The number of times a road crosses the streams and rivers in each EDTshed
Total Road Length	WDNR 2014	The total length of road found within the EDTshed

Table 2. Habitat data sources and spatial coverage for the Upper Columbia and Sanpoil study area for 25 priority EDT reaches. Data sources are presented according to reach, drainage, and data source. Cells shaded green containing an X indicate complete coverage for the respective reach. BI = Beechie and Imaki, LRHIP = Lake Roosevelt Habitat Improvement Project, CHaMP = Columbia River Habitat Monitoring Program, CCT = Colville Confederated Tribal Fisheries monitoring, Duck = habitat surveys performed by Duck Creek Environmental Consultants.

Reach	Rank	Drainage	BI Stream	BI River	LRHIP	CHAMP	CCT Monitoring	Duck Instream	Duck Pools
Sanpoil 4B	1	Sanpoil	X	X	X	X	-	X	X
Silver 1	2	Sanpoil	X	X	-	-	-	-	-
Sanpoil 2I	3	Sanpoil	X	X	X	X	-	X	X
Sanpoil 3C	4	Sanpoil	X	X	X	X	-	X	X
Sanpoil 4A	5	Sanpoil	X	X	X	-	X	X	X
Stranger 7	6	Upper Columbia	X	-	X	-	-	-	-
Hall 4	7	Upper Columbia	X	X	X	X	X	-	-
Cornstalk 5C	8	Upper Columbia	X	-	-	-	-	-	-
Sanpoil 5C	9	Sanpoil	X	X	X	X	-	X	X
Sanpoil 2J	10	Sanpoil	X	X	X	X	X	X	X
Hall 3	11	Upper Columbia	X	X	X	X	-	-	-
Sanpoil 2F	12	Sanpoil	X	X	X	X	X	X	X
Sanpoil 5E	13	Sanpoil	X	X	X	X	-	X	X
Hall 2B	14	Upper Columbia	-	X	X	X	X	-	-
Lynx Trib 2A	15	Upper Columbia	X	-	-	-	-	-	-
Sanpoil 4G	16	Sanpoil	X	X	X	X	X	X	X
Sanpoil 7D	17	Sanpoil	X	X	-	-	-	-	-
Sanpoil 1F	18	Sanpoil	X	X	X	X	-	-	-
WF Hall 2	19	Upper Columbia	X	-	-	X	-	-	-
Cedar 1	20	Upper Columbia	X	-	X	X	-	-	-
Barnaby 1	21	Upper Columbia	X	-	X	-	X	-	-
Lost 6	22	Sanpoil	X	X	-	-	-	-	-
Sanpoil 4C	23	Sanpoil	X	X	X	-	-	X	X
NF Hall 1B	24	Upper Columbia	X	-	-	X	X	-	-
Sanpoil 3D	25	Sanpoil	X	X	X	X	X	X	X

Results

Our assessment process evaluated key watershed factors within EDTsheds that drive riparian and instream habitat conditions. By aggregating various data sources across EDTsheds, we were able to summarize riparian, upslope, and instream conditions for each prioritized reach. Results are presented for priority EDTsheds, buffered (30 m and 100 m) stream extents for all streams within priority EDTsheds, and instream habitat conditions in priority reaches. These hierarchical assessments effectively link landscape processes with stream reach and habitat conditions when coupled at the correct scales (Frissell 1986).

Priority EDTsheds for restoration

We identified 25 high-priority EDT reaches from the more than 700 in the study area. This included 10 priority reaches in the Upper Columbia and 15 priority reaches in the Sanpoil. As outlined previously, priority reaches for restoration and protection were determined by their potential influence on Redband Trout productivity, diversity, and abundance (Figure 4). Areas for these 25 EDTsheds ranged from less than 0.5 km^2 to more than 21 km^2 and varied in elevation from approximately 393 m (1,290 ft) at the surface of Lake Roosevelt, to more than 675 m (2,212 ft) at the top of the watershed. Land covers were dominated by forest, but included wetland, scrub shrub, and other classes (Table 3). If fully restored, these 25 EDTsheds would be responsible for 38% of the total potential improvement in Redband Trout diversity, productivity, and abundance across the entire study area, according to EDT model estimates.

Landscape conditions

For all priority EDTsheds, summaries of land cover were calculated for all the watershed surfaces draining to the downstream end of each EDT reach. Forest coverage averaged nearly 60% and ranged from 4.4% in the North Fork of Hall Creek 1B to 100% in Lynx Trib 2A. Similarly, wetland land covers averaged 4.5% and ranged from 0% to 13%. Shrub land covers averaged 25% ranging from 1.5% to 47%. Developed, modified, or barren land covers (Other) ranged from 0% to 21% and averaged 8.6% (Table 3). In addition, roads within each EDTshed were summarized by density, which ranged from nearly 0 km/km^2 in West Hall 2, to more than 3 km/km^2 in Hall 4. The number of stream crossings ranged from 0 to a high of 12 in Hall 4 (Table 3). This is important because of the well-documented linkages between roads and fine sediment impacts to streams.

Riparian conditions

As mentioned earlier, 30 m (100 ft) and 100 m (328 ft) buffers were applied to the stream and river layers. Riparian conditions were summarized for these buffer extents for each priority reach using the same land cover categories used for forest cover (Table 4). Quantifying riparian land covers provides important information because these are the conditions in proximity to the stream that contribute to instream habitat conditions. In addition, when evaluated at this scale, the proportions of dominant land covers can change. For example, Sanpoil 4B is a mainstem priority reach with a large wetland at the confluence of a small stream. Consequently, when summarized across the 30 m riparian zone, wetlands comprise 53% of the buffer area compared to 44% of the 100 m buffer and only 6% for the entire EDTshed.

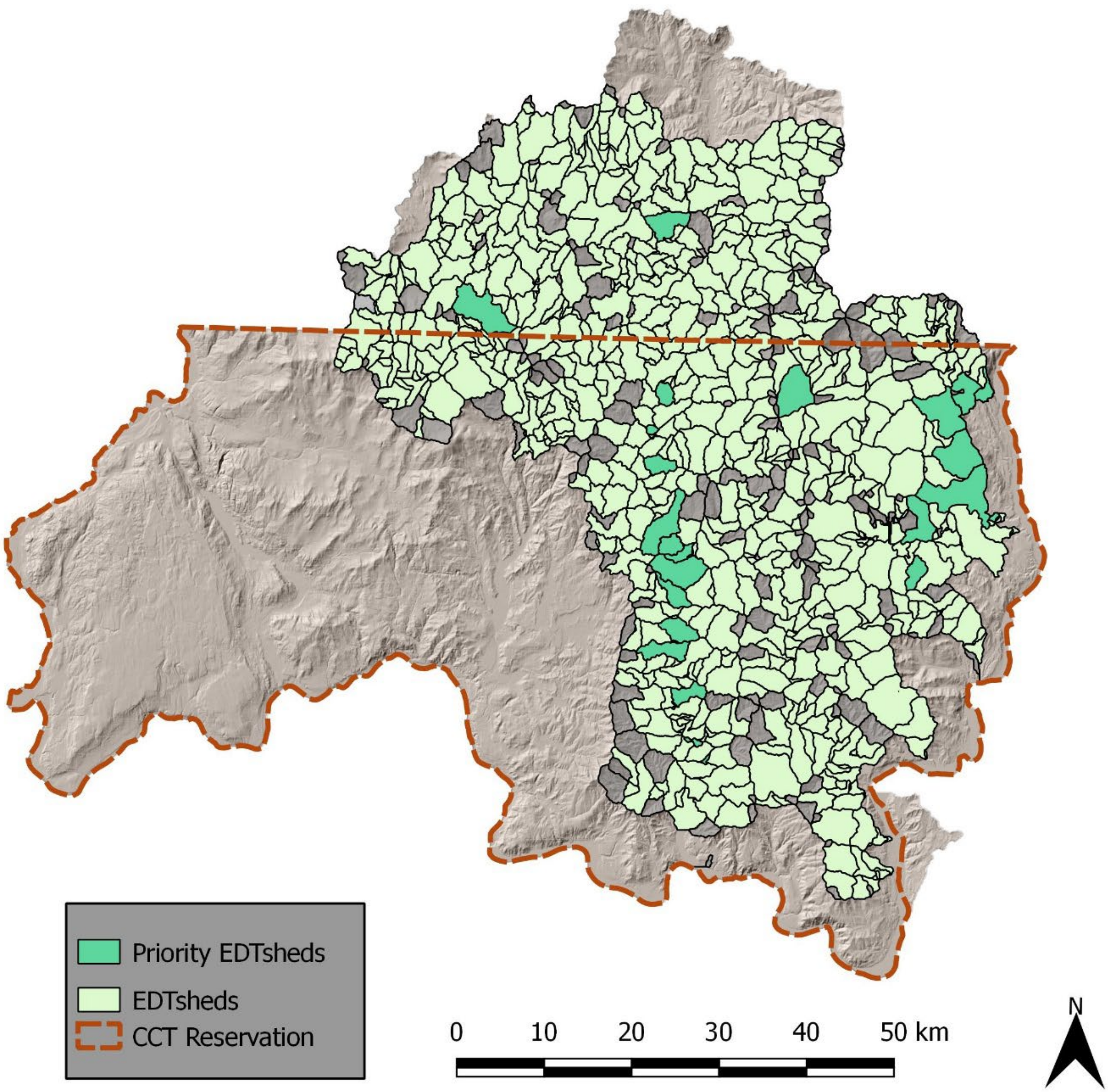

Figure 4. Twenty-five high priority (dark green) of the more than 700 total EDTsheds in the Upper Columbia and Sanpoil study area.

For all priority reach 30 m riparian zones, forest coverage averaged nearly 60%, and ranged from 8% in Barnaby Creek 1 to 100% in Lynx Trib 2A. Similarly, wetland land covers averaged 20% and ranged from 0% to 72%. Shrub land covers averaged 10%, ranging from 0% to 68%. All developed or otherwise modified land covers are included as “Other”, which averaged 13% and ranged from 0% to 62%. In addition, road density and the number of road crossings within each priority reach riparian zone were summarized because of their proximity to streams and their well-documented delivery of fine sediment to stream and river habitats. Average road densities for all priority reaches were 2.0 km/km^2 of riparian zone, with a range of 0 km/km^2 to 8.1 km/km^2. When the 100 m buffer was evaluated, proportions of land covers changed in nearly all cases except for in Lynx Trib 2A, which was 100% forest under both buffer extents. Percent forest ranged from 9% (NF Hall 1B) to 100% with a mean of 55%. Wetland ranged from 0% (Lynx Trib 2A and Lost 6) to 55% (Hall 4) with a mean of 23%. Shrub values ranged from 0% (Lynx Trib 2A) to 24% in

Sanpoil 1F with a mean of 10%. Other land cover classes ranged from 0% (Lynx Trib 2A, WF Hall 2, and Cedar 1) to 52% (Sanpoil 7D) with a mean of 12%. Road densities ranged from 0 km/km^2 (WF Hall 2 and Lost 6) to 10.9 km/km^2 (Barnaby 1), with a mean of 3.0 km/km^2. Somewhat surprisingly, riparian zones with the highest road density (at both buffer widths) are not necessarily those with the most crossings, which averaged only 2, with a range of 0 to 12 (Table 4).

Table 3. Summaries of upslope conditions within EDTsheds including: upslope contributing area (km^2), percent forest (coniferous, deciduous, and mixed), wetland (water, woody wetlands, and emergent herbaceous wetlands), shrub (shrub/scrub), and other (anthropogenic classes) land classification, as well as road density (km/km^2), and number of road-stream crossings. SP indicates Sanpoil River drainage. UC indicates Upper Columbia tributaries.

Drainage	Reach	EDT Rank	Area (km^2)	Length (m)	Forest (%)	Wetland (%)	Shrub (%)	Other (%)	Road Density (km/km^2)	No. Road Crossings
SP	Sanpoil 4B	1	5.21	3211	60	6	27	8	0.65	2
SP	Silver 1	2	0.48	865	44	2	47	7	2.20	1
SP	Sanpoil 2I	3	9.15	2805	79	4	13	4	0.68	0
SP	Sanpoil 3C	4	6.64	4172	56	11	21	12	1.48	1
SP	Sanpoil 4A	5	3.25	2079	52	6	31	10	0.91	0
UC	Stranger 7	6	5.92	2305	63	3	21	13	2.78	2
UC	Hall 4	7	18.43	5871	57	13	22	9	3.18	12
UC	Cornstalk 5C	8	11.84	2468	80	7	11	3	2.69	2
SP	Sanpoil 5C	9	1.14	1154	31	3	45	21	2.00	1
SP	Sanpoil 2J	10	8.27	3785	60	1	30	9	1.16	2
UC	Hall 3	11	26.81	7400	51	9	20	20	2.38	10
SP	Sanpoil 2F	12	6.19	2423	44	3	43	9	1.17	1
SP	Sanpoil 5E	13	4.32	3391	58	2	29	10	1.72	1
UC	Hall 2B	14	0.67	1651	64	5	26	5	0.47	0
UC	Lynx Trib 2A	15	0.12	388	98	0	2	0	1.91	0
SP	Sanpoil 4G	16	5.92	2904	48	2	40	9	0.99	2
SP	Sanpoil 7D	17	10.62	4562	49	2	28	21	2.00	3
SP	Sanpoil 1F	18	0.99	1137	61	6	25	9	2.16	0
UC	WF Hall 2	19	16.95	6594	89	0	10	0	0.07	0
UC	Cedar 1	20	9.52	3354	73	10	12	5	2.26	3
UC	Barnaby 1	21	3.64	1414	68	0	26	6	1.23	0
SP	Lost 6	22	21.12	4475	78	0	19	3	0.94	0
SP	Sanpoil 4C	23	15.34	3265	68	6	23	3	0.89	3
UC	NF Hall 1B	24	18.09	5310	68	4	20	8	2.59	2
SP	Sanpoil 3D	25	16.18	5347	57	8	24	12	1.07	6

Table 4. Summaries of forest (coniferous, deciduous, and mixed), wetland (water, woody wetlands, and emergent herbaceous wetlands), shrub (shrub/scrub), and other (anthropogenic classes) land classes, plus road densities and number of road crossings that fall within 30 m (100 ft) and 100 m (328 ft) stream buffers for all priority reaches.

Drainage	Reach	Area (ha)	Length (m)	Forest (%) 30 m	Forest (%) 100 m	Wetland (%) 30 m	Wetland (%) 100 m	Shrub (%) 30 m	Shrub (%) 100 m	Other (%) 30 m	Other (%) 100 m	Road Density (km/km^2) 30 m	Road Density (km/km^2) 100 m	No. Road Crossings
SP	Sanpoil 4B	19.27	3211	33	34	53	44	0	2	14	21	0.8	2.4	2
SP	Silver 1	5.19	865	24	75	8	4	68	16	0	5	1.3	4.6	1
SP	Sanpoil 2I	16.83	2805	91	65	0	23	8	5	2	8	1.2	1.6	0
SP	Sanpoil 3C	25.03	4172	83	48	11	41	6	3	0	7	1.9	3.6	1
SP	Sanpoil 4A	12.47	2079	92	31	8	53	1	6	0	9	0	2.3	0
UC	Stranger 7	13.83	2305	22	51	72	30	6	8	0	11	2.9	3.8	2
UC	Hall 4	35.23	5871	92	30	8	55	0	7	0	8	5.5	2.7	12
UC	Cornstalk 5C	14.81	2468	19	33	62	54	13	4	6	9	1.1	2.2	2
SP	Sanpoil 5C	6.92	1154	17	40	17	15	5	9	62	36	4.1	6.0	1
SP	Sanpoil 2J	22.71	3785	90	67	0	6	10	19	0	9	1.5	1.6	2
UC	Hall 3	44.4	7400	22	37	0	37	56	14	22	11	4.3	2.8	10
SP	Sanpoil 2F	14.54	2423	44	61	19	15	12	15	25	8	6.0	1.3	1
SP	Sanpoil 5E	20.35	3391	23	51	17	16	0	5	60	29	41	6.2	1
UC	Hall 2B	9.91	1651	99	75	0	8	1	16	0	1	0	2.0	0
UC	Lynx Trib 2A	2.33	388	100	100	0	0	0	0	0	0	9.0	3.8	0
SP	Sanpoil 4G	17.42	2904	48	65	32	24	7	6	12	5	8.0	3.1	2
SP	Sanpoil 7D	27.37	4562	98	27	0	11	0	11	2	52	1.5	1.8	3
SP	Sanpoil 1F	6.82	1137	40	52	51	24	9	24	0	0	2.5	3.5	0
UC	WF Hall 2	39.56	6594	91	93	3	2	6	5	0	0	0	0	0
UC	Cedar 1	20.12	3354	9	68	70	20	9	11	12	1	1.8	2.1	3
UC	Barnaby 1	8.48	1414	8	89	30	1	14	8	48	3	8.1	10.9	0
SP	Lost 6	26.85	4475	42	74	6	0	0	23	52	3	0	0	0
SP	Sanpoil 4C	19.59	3265	70	66	22	26	6	5	1	3	1.5	1.5	3
UC	NF Hall 1B	31.86	5310	98	9	0	25	2	17	0	49	1.4	3.6	2
SP	Sanpoil 3D	32.08	5347	88	35	5	35	3	16	4	14	2.8	1.9	6

Habitat conditions

The most data rich portion of the watershed assessment was reach-scale habitat data. In the following paragraphs, we summarize the finding of EDT habitat scores, temperature modeling, Beechie and Imaki (2014) channel types, and LHRIP habitat data to highlight degraded geomorphic processes (channel confinement and type and fine sediment) and habitat conditions (pool area, large woody debris).

Average EDT habitat attribute scores that describe physical and thermal stream conditions which are known to affect Redband Trout were examined and summarized for each priority reach (Table 5). We evaluated habitat scores in each priority reach for large woody debris (LWD), scour pools, backwater pools, minimum winter temperatures, fine sediment, and artificial confinement. These scores range from 4 (least favorable conditions) to 0 (most favorable). Shaded values in the table indicate which habitat attribute scores reflect the most influence in this relative comparison. In other words, the darker shades of red indicate higher (least favorable) average EDT scores. Conversely, light pink shading indicates EDT output of relatively functional habitats. Average habitat attribute scores approaching 4 represent conditions that may be limiting for Redband Trout. Consistent with findings reported by Brown et al. (2013), over-winter temperatures are relatively important in comparison with other EDT scores for LWD, fine sediment, and degree of artificial confinement.

In addition, we evaluated the modeled daily average August temperatures under 2013 conditions and those expected to occur in 2080 (Chandler et al. 2016). These data are summaries of modeled temperatures aggregated for each priority reach. We know that there is substantial thermal heterogeneity within reaches that exists on the order of square meters that can be much warmer or cooler than conditions averaged over a stream reach (Torgerson et al. 2012). However, the spatial distribution of these temperature model outputs presents a striking picture of the areas where temperature is potentially problematic and where those problems may be exacerbated under future climate changes predictions (Figure 5). Stranger 7 and Cornstalk 5C—both of which exhibit among the highest current and expected future (2080) temperatures—also show the biggest increase in temperature under future climate scenarios. On average, across all priority reaches, we expect water temperatures to increase 2.5 degrees C by 2080 (Chandler et al. 2016). With respect to potentially limiting winter temperatures, EDT minimum winter temperature scores suggest that Sanpoil 1F is the most resilient and Lynx Trib 2A is most affected (Table 5).

The Beechie and Imaki (2014) data provided important summaries on potential channel types and conditions. Differences in habitat-forming processes generally become apparent when streams exceed 8 m bankfull width and start to migrate laterally (Hall et al. 2007). Because of these fluvial geomorphic shifts, we present data summaries for habitat conditions in streams <8 m bankfull width (BFW) in Table 6, and > 8 m BFW in Table 7. In both cases, summaries for priority reaches are presented in ranked order. However, for streams < 8 m BFW, the rankings begin at 6 because the five highest priority reaches exceed 8 m BFW. For streams < 8 m BFW, ranks ranged from 6 to 24, BFW ranged from 2 m to 6 m, bankfull depths (BFD) were all less than 0.5 m, ranging from 0.2 m to 0.4 m. All reach lengths were 200 m except for the plane-bed reach in Cornstalk 5C (162 m) and a cascade reach in WF Hall 2 (185 m). Average gradients (%) ranged from approximately 0% to 17%. Modeled shear stresses and floodplain widths (FPW) were variable (Table 6).

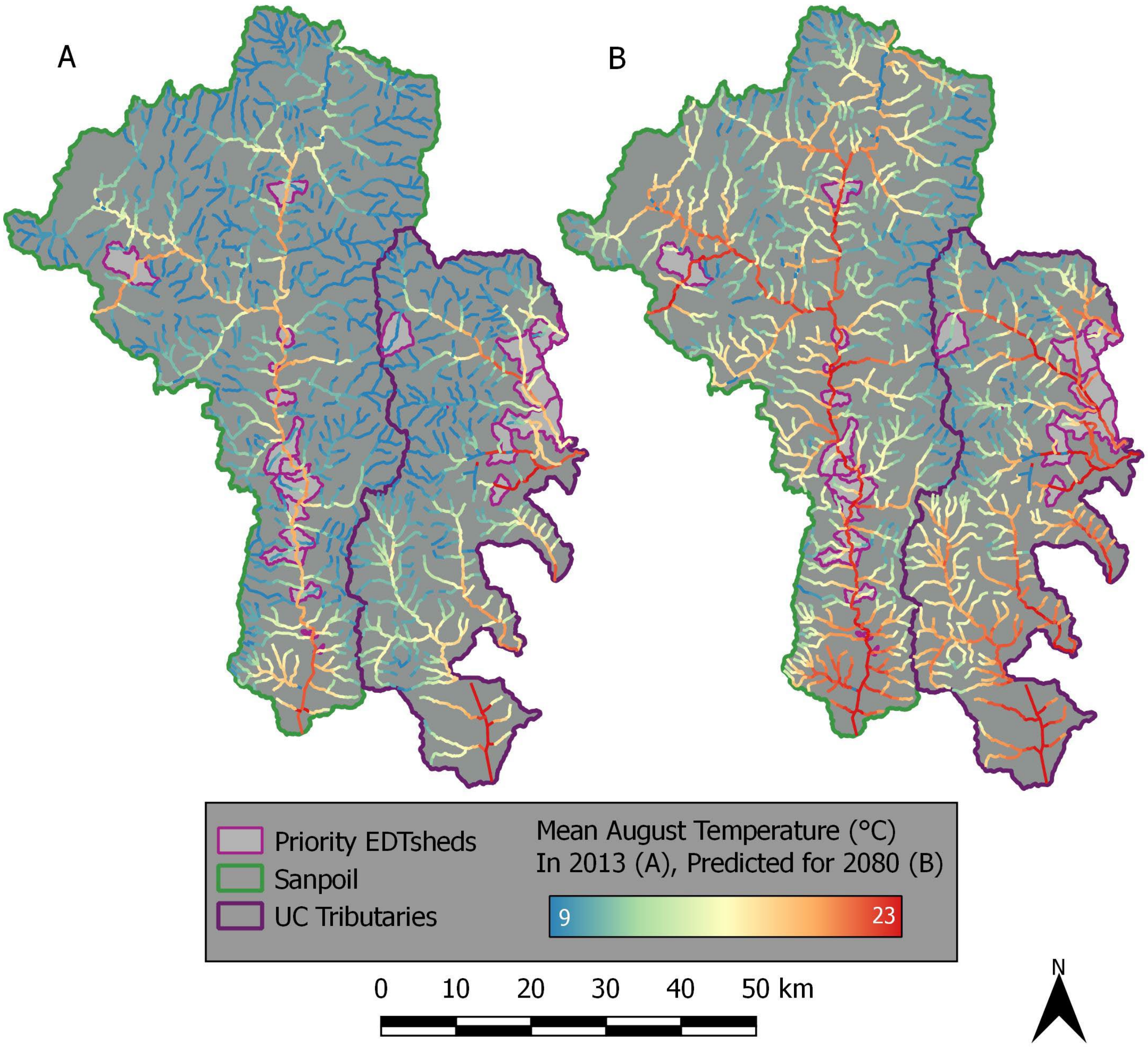

Figure 5. NorWeST modeled daily average August stream temperatures for Upper Columbia and Sanpoil subbasins under current (A) and 2080 future climate scenarios (B). Temperatures range from 9 to 23 degrees Celsius.

Table 5. Summaries of EDT reach instream habitat conditions including: upslope contributing area (km^2), reach length (m), EDT scores for woody debris, scour pools, backwater pools, minimum winter temperature, fine sediment and both natural and artificial confinement. All scores range from 4 (least favorable conditions) to 0 (most favorable). Modeled average daily maximum August stream temperature is presented for 2013 and future conditions expected to occur in 2080.

Drainage	Reach	EDT Rank	Length (m)	Woody Debris Score	Scour Pools Score	Backwater Pools Score	Min Winter Temp Score	Fine Sediment Score	Confine Artificial	2013 Mean August T (C)	2080 Mean August T (C)
SP	Sanpoil 4B	1	3211	2.8	0.6	0.0	3.8	1.2	1.7	14.7	17.4
SP	Silver 1	2	865	3.0	0.2	0.0	3.8	0.9	0.5	13.7	16.3
SP	Sanpoil 2I	3	2805	3.2	0.5	0.0	3.8	0.8	0.0	12.4	14.7
SP	Sanpoil 3C	4	4172	3.1	0.7	0.0	3.7	1.5	1.5	13.4	15.9
SP	Sanpoil 4A	5	2079	2.8	0.7	0.0	3.7	1.7	1.0	14.7	17.3
UC	Stranger 7	6	2305	2.3	0.0	0.0	3.9	4.0	0.0	18.5	21.7
UC	Hall 4	7	5871	2.6	0.6	0.0	3.9	2.4	0.2	14.2	16.8
UC	Cornstalk 5C	8	2468	2.5	0.0	1.0	2.7	2.5	0.0	16.9	19.9
SP	Sanpoil 5C	9	1154	2.8	0.4	0.0	3.8	0.8	2.3	13.9	16.5
SP	Sanpoil 2J	10	3785	3.1	0.5	0.0	3.7	2.1	0.6	12.4	14.8
UC	Hall 3	11	7400	2.5	0.3	0.0	3.1	1.2	0.2	12.9	15.4
SP	Sanpoil 2F	12	2423	3.3	0.4	0.0	3.8	2.1	0.0	12.6	14.9
SP	Sanpoil 5E	13	3391	3.1	0.5	0.0	3.9	1.0	2.1	14.7	17.4
UC	Hall 2B	14	1651	2.5	0.1	0.0	3.8	0.5	0.0	13.3	15.8
UC	Lynx Trib 2A	15	388	2.3	0.0	0.0	4.0	0.5	0.0	10.6	12.8
SP	Sanpoil 4G	16	2904	3.1	0.4	0.0	3.8	0.5	2.0	14.8	17.5
SP	Sanpoil 7D	17	4562	3.8	0.4	0.0	3.7	0.8	2.5	12.8	15.2
SP	Sanpoil 1F	18	1137	2. 5	0.0	0.0	1.0	1.2	0.0	15.4	18.2
UC	WF Hall 2	19	6594	0.9	0.1	0.0	4.0	0.8	0.0	9.3	11.3
UC	Cedar 1	20	3354	3.3	0.4	0.0	2.3	1.5	0.3	11.9	14.3
UC	Barnaby 1	21	1414	1.5	0.1	0.0	2.5	1.0	0.0	13.0	15.5
SP	Lost 6	22	4475	2.8	0.5	0.0	3.8	1.8	0.0	13.2	15.6
SP	Sanpoil 4C	23	3265	2.8	0.5	0.1	3.8	0.9	2.2	12.1	14.4
UC	NF Hall 1B	24	5310	2.1	0.0	0.1	2.8	1.1	3.0	13.5	15.9
SP	Sanpoil 3D	25	5347	2.8	0.6	0.0	3.6	1.20	1.7	12.9	15.4

Table 6. Modeled stream data - channel types, bankfull width (BFW), bankfull depth (BFD), shear stress, length, gradient and floodplain width (FPW) from Beechie and Imaki (2014). Note that only priority reaches less than 8 m BFW are presented in this table. Priority rankings are consistent with the restoration priorities defined in previous sections. Beechie and Imaki (2014) defined multiple reaches within each EDT priority reach. We report averages for each channel type and habitat variable where multiples of each channel type were predicted.

Reach	Channel Type	EDT Rank	BFW (m)	BFD (m)	Shear Stress	Total Length (m)	Gradient (%)	Floodplain Width (m)
Stranger 7	plane-bed	6	2.3	0.2	165	200	4.5	130
Stranger 7	pool-riffle	6	4.0	0.3	43	2600	1.0	119
Cornstalk 5C	plane-bed	8	1.8	0.2	126	810	4.0	1,139
Cornstalk 5C	pool-riffle	8	6.1	0.4	22	2400	0.6	362
Cornstalk 5C	step-pool	8	5.8	0.4	82	200	6.5	240
Lynx Trib 2A	plane-bed	15	2.2	0.2	24	400	2.0	49
Lynx Trib 2A	step-pool	15	1.9	0.2	68	400	10.3	14
WF Hall 2	Cascade	19	1.9	0.2	303	1478	12.5	18
WF Hall 2	plane-bed	19	2.5	0.3	77	2200	3.8	62
WF Hall 2	pool-riffle	19	2.9	0.3	55	200	2.5	70
WF Hall 2	step-pool	19	2.7	0.3	223	2800	8.3	24
Cedar 1	Cascade	20	1.8	0.2	235	200	17.0	11
Cedar 1	plane-bed	20	2.2	0.2	204	1800	9.6	10
Cedar 1	pool-riffle	20	1.8	0.2	137	200	4.5	21
Cedar 1	step-pool	20	1.6	0.2	190	1400	12.0	141
Barnaby 1	plane-bed	21	6.2	0.4	320	1400	5.0	26
Barnaby 1	pool-riffle	21	6.3	0.4	0	200	3.0	26
Barnaby 1	step-pool	21	2.4	0.3	417	200	12.5	26
NF Hall 1B	plane-bed	24	4.0	0.3	67	200	5.0	76
NF Hall 1B	pool-riffle	24	4.4	0.4	11	5000	0.3	356

Nineteen of the 25 priority reaches were in rivers > 8 m BFW (Table 7). Data reported for rivers included major channel types, BFW (m), floodplain width (m), reach length (m), and channel gradient (%). For all categories of channel type occurring within priority reaches, values were summarized by average. Frequently, priority reaches were comprised of multiple instances of each channel type. Bankfull widths of all channel types except “confined” ranged from 10 m to 22 m and generally flowed through floodplains 5 to 10 times their width. Confined channels had considerably smaller floodplain widths. Summed channel types within priority reaches had collective lengths from 200 m to more than 5 km. Highest average gradients (%) existed in the Hall Creek reaches (Lost 6, Hall 2B, Hall 3, Sanpoil 4G, Hall 4, respectively exhibited maximum average gradients 3.1%, 2.9%, 3.8%, 2.5%, 1.5%). Each of these relatively steep sections occurred in either “straight” or “confined” channel types. All other reaches were 1% or less.

Table 7. Modeled river (> 8 m BFW) major channel forms including, bankfull width (BFW), floodplain width (FPW), reach length slope (Grad), (Beechie and Imaki 2014). Note that not all EDT priority reaches contain rivers of this size. Reaches populated with "NA" reflect priority reaches that are less than 8 m BFW. Respective units are in parentheses. Beechie and Imaki (2014) may have defined multiple reaches within each EDT priority reach. We report averages for each channel type and habitat variable where multiples of each channel type were predicted.

Reach	Major Type	EDT Rank	BFW (m)	FPW (m)	Length (m)	Grad (%)
Sanpoil 4B	meandering	1	20	273	5000	0.1
Silver 1	meandering	2	22	332	5600	0.2
Sanpoil 2I	confined	3	21	78	200	0.3
Sanpoil 2I	island-braided	3	21	246	2600	0.3
Sanpoil 2I	meandering	3	21	106	700	0.3
Sanpoil 3C	confined	4	21	76	300	0.4
Sanpoil 3C	island-braided	4	21	336	920	0.5
Sanpoil 3C	meandering	4	21	847	1000	0.2
Sanpoil 4A	meandering	5	20	401	4100	0.2
Stranger 7	NA	6	NA	NA	NA	NA
Hall 4	meandering	7	11	437	1480	0.5
Hall 4	straight	7	10	236	200	1.5
Cornstalk 5C	NA	8	NA	NA	NA	NA
Sanpoil 5C	confined	9	19	52	400	0.5
Sanpoil 5C	meandering	9	19	113	1400	0.3
Sanpoil 5C	Straight	9	19	136	600	1.0
Sanpoil 2J	confined	10	21	71	200	0.5
Sanpoil 2J	island-braided	10	21	210	2067	0.4
Hall 3	confined	11	12	29	250	2.9
Hall 3	meandering	11	12	159	1400	0.6
Hall 3	Straight	11	12	83	200	1.9
Sanpoil 2F	confined	12	21	63	280	1.0
Sanpoil 2F	island-braided	12	21	119	300	0.6
Sanpoil 2F	meandering	12	21	160	1400	0.2
Sanpoil 5E	confined	13	19	51	1000	0.3
Sanpoil 5E	meandering	13	19	109	600	0.3
Hall 2B	confined	14	12	12	200	3.8
Hall 2B	meandering	14	12	92	400	0.5
Hall 2B	Straight	14	12	201	200	1.5
Lynx Trib 2A	NA	15	NA	NA	NA	NA
Sanpoil 4G	meandering	16	20	202	3200	0.2
Sanpoil 4G	straight	16	20	116	200	2.5
Sanpoil 7D	meandering	17	12	337	2467	0.3
Sanpoil 1F	meandering	18	22	332	5600	0.2
WF Hall 2	NA	19	NA	NA	NA	NA

Reach	Major Type	EDT Rank	BFW (m)	FPW (m)	Length (m)	Grad (%)
Cedar 1	NA	20	NA	NA	NA	NA
Barnaby 1	NA	21	NA	NA	NA	NA
Lost 6	braided	22	9	162	200	1.0
Lost 6	confined	22	9	13	217	2.9
Lost 6	meandering	22	9	55	500	1.0
Lost 6	straight	22	9	54	333	3.1
Sanpoil 4C	meandering	23	20	369	4300	0.2
NF Hall 1B	NA	24	NA	NA	NA	NA
Sanpoil 3D	island-braided	25	21	503	800	0.9
Sanpoil 3D	meandering	25	21	688	2100	0.2

Priority reaches were originally selected according to EDT model predictions of how each reach was affecting Redband Trout abundance, diversity, and productivity. Across the study area, many of these reaches were mainstem Sanpoil River reaches. Several sources of stream survey data evaluated are useful for identifying stream reaches impacted in ways that can affect the survival and reproductive success of Redband Trout in the study area. As mentioned above, the coverage is not consistent among all datasets (see Table 2). The EDT modeling efforts produced multiple limiting factors suspected of negatively affecting specific life stages of Redband Trout (Table 8). However, these summaries are not particularly useful for identifying degraded habitat conditions because in most priority reaches, highest value EDT performance factors identify key habitats (KH) and life stages in need of protection, rather than degraded habitat.

Our evaluation directly used other data that more clearly identified specific habitat conditions and problems useful for prescribing restoration actions (see Table 3, Table 4, Table 5, Table 6, and Table 7). In addition, LRHIP datasets cataloged detailed habitat conditions that had a relatively high spatial agreement with the priority reaches (see Table 2). The datasets that counted and measured LWD in channels were of particular interest (Table 9). Summaries break data by size class (diameter > 30 cm) because larger pieces have a higher likelihood of remaining in a location, thus, being hydraulically engaged as a result. When expressed for each priority reach as average pieces per 100 m of channel length, numbers for LWD ≤ 30 cm in diameter ranged from 1 to 11 pieces. For LWD > 30 cm in diameter, average numbers per 100 m ranged from 1 in Sanpoil 5C to 22 pieces in Sanpoil 4A. In general, priority reaches exceeding 8 m BFW should have an average of 17 pieces of large wood for every 100 m of channel length (Fox and Bolton 2007). Percent pool ranged from 3% to nearly 80% in Cedar 1 and Sanpoil 4A, respectively. Average fine sediment was high nearly everywhere except for Sanpoil 5C and Hall 2B (12% and 16%, respectively; Table 9). While it varies by geology, generally, fine sediment levels in excess of 20% significantly reduce egg-to-fry survival (Chapman 1988; Jensen et al.2009).

Table 8. EDT performance factors (Perf. Factor) for specific Redband Trout life stage by reach. Reaches are prioritized according to equation 1. The top five performance factors are ordered by their relative influence on EDT modeling results for each reach.

Reach	EDT Rank	Perf Factor 1	Perf Factor 2	Perf Factor 3
Sanpoil 4B	1	KH _ Holding PS	KH _ 0-age resident rearing	KH _ 1-age inactive
Silver 1	2	KH _ Spawning	KH _ Egg incubation	KH _ Holding PS
Sanpoil 2I	3	KH _ Spawning	KH _ Egg incubation	KH _ Holding PS
Sanpoil 3C	4	KH _ Spawning	KH _ Holding PS	KH _ Egg incubation
Sanpoil 4A	5	KH _ Spawning	KH _ Holding PS	KH _ Egg incubation
Stranger 7	6	Predation _ 2+-age inactive	Predation _ 1-age inactive	Food Density Scalar _ Holding PS
Hall 4	7	KH _ Spawning	KH _ Egg incubation	KH _ Holding PS
Cornstalk 5C	8	Predation _ 1-age inactive	Food Density Scalar _ Holding PS	Chemicals _ Holding PS
Sanpoil 5C	9	KH _ Spawning	KH _ Egg incubation	KH _ Holding PS
Sanpoil 2J	10	KH _ Spawning	KH _ Egg incubation	KH _ Holding PS
Hall 3	11	KH _ Spawning	KH _ Egg incubation	KH _ Holding PS
Sanpoil 2F	12	KH _ Spawning	KH _ Egg incubation	KH _ Holding PS
Sanpoil 5E	13	KH _ Spawning	KH _ Egg incubation	KH _ Holding PS
Hall 2B	14	KH _ Spawning	KH _ Egg incubation	Predation _ 0-age inactive
Lynx Trib 2A	15	KH _ 2+-age resident rearing	Chemicals _ 2+-age resident rearing	Obstructions _ 2+-age resident rearing
Sanpoil 4G	16	KH _ Spawning	KH _ Egg incubation	KH _ Holding PS
Sanpoil 7D	17	KH _ Holding PS	Food Density Scalar _ Holding PS	Flow _ Holding PS
Sanpoil 1F	18	KH _ 0-age resident rearing	KH _ 1-age inactive	KH _ 0-age inactive
WF Hall 2	19	KH _ Spawning	KH _ Egg incubation	KH _ Holding PS
Cedar 1	20	KH _ Spawning	KH _ Egg incubation	Predation _ 0-age inactive
Barnaby 1	21	KH _ Spawning	KH _ Egg incubation	Predation _ 0-age inactive
Lost 6	22	KH _ Spawning	KH _ Egg incubation	KH _ Holding PS
Sanpoil 4C	23	KH _ Spawning	KH _ Holding PS	KH _ Egg incubation
NF Hall 1B	24	Predation _ 1-age inactive	Food Density Scalar _ Holding PS	Chemicals _ Holding PS
Sanpoil 3D	25	KH _ Spawning	KH _ Holding PS	KH _ Egg incubation

Table 9. Large wood and fine sediment characteristics summarized for LRHIP datasets where they coincided with priority reaches. The number of sites was variable within priority reaches. Total pieces LWD, total ≤ 30 cm diameter, and total < 30 cm diameter are presented in the left side of the table. Averages per 100 m of channel length are presented in the right side of table. Percent pool and average percent fine sediment are also presented.

		Total Pieces LWD				Pieces per 100 m				
Reach	EDT Rank	No. sites	Total	No. ≤ 30 cm	No. < 30 cm	Average	No. ≤30 cm	No. > 30 cm	Pool (%)	Avg. Fine Sed. (%)
Sanpoil 4B	1	41	262	149	113	12	7	5	0.77	40
Silver 1	2	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sanpoil 2I	3	36	99	62	37	6	4	2	0.52	25
Sanpoil 3C	4	41	184	111	73	6	4	2	0.75	36
Sanpoil 4A	5	71	709	246	463	33	11	22	0.79	32
Stranger 7	6	NA	NA	NA	NA	NA	NA	NA	NA	86
Hall 4	7	9	43	23	20	13	7	6	0.60	44
Cornstalk 5C	8	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sanpoil 5C	9	29	79	69	10	7	6	1	0.43	12
Sanpoil 2J	10	56	263	137	126	7	3	3	0.60	34
Hall 3	11	4	14	6	8	26	11	15	0.40	30
Sanpoil 2F	12	26	71	31	40	4	2	2	0.51	21
Sanpoil 5E	13	56	336	219	117	12	8	4	0.55	26
Hall 2B	14	3	16	8	8	10	5	5	0.08	16
Lynx Trib 2A	15	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sanpoil 4G	16	31	144	79	65	6	3	3	0.46	22
Sanpoil 7D	17	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sanpoil 1F	18	25	94	44	50	8	4	4	0.48	20
WF Hall 2	19	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cedar 1	20	5	28	6	22	7	1	5	0.03	24
Barnaby 1	21	3	20	10	10	20	10	10	0.14	20
Lost 6	22	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sanpoil 4C	23	46	263	170	93	10	7	4	0.61	37
NF Hall 1B	24	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sanpoil 3D	25	80	361	224	137	10	6	4	0.73	22

RECOMMENDED RESTORATION MEASURES BY REACH

Identifying potential restoration actions is perhaps the most challenging task in developing a watershed restoration plan (Beechie et al. 2013). This is especially true when identifying actions for a particular species. Even in situations where extensive amounts of data on riparian condition, water quality, sediment, woody debris, habitat, and other watershed processes are available, linking the physical processes and habitats to outputs of life cycle models and actions that will benefit a single species is particularly difficult. Moreover, in basins like the Upper Columbia and Sanpoil, where hundreds of kilometers of habitat and literally hundreds of multi-kilometer reaches exist, narrowing those reaches down to the most important is extremely challenging. To facilitate this, we used a systematic approach, examining seven pieces of information to assist with our recommendations for restoration actions including:

1) Summary of upslope forest conditions, road density, stream crossings, and water temperature in each EDTshed (Table 3);

2) Summary of EDT scores for each of the 25 priority reaches including woody debris, fine sediment, and artificial confinement (Table 5);

3) Summary of habitat data from LRHIP surveys including fine sediment, LWD, pool area, and other instream habitat features (Table 9);

4) Expected channel type and confinement under ideal (no human impact) conditions as predicted by Beechie and Imaki (2014) (Table 6; Table 7);

5) Riparian buffer conditions including percent “Forest”, “Wetland”, “Shrub”, and “Other” derived from NLCD (Homer et al. 2015) (Table 4);

6) Examination of aerial imagery (largely Google Earth) to see basic land cover, land use, riparian forest, and instream channel conditions; and,

7) Recommended restoration types to address disrupted processes and degraded habitat (Table 10).

Systematic evaluation of each priority reach—hierarchically stepping through each of these seven pieces of information—yielded restoration recommendations. In addition to the initial recommendations, we provide the rationale for our recommendations and identified additional information or data needs and items that require examination during site visits to confirm feasibility of recommended restoration measures (Table 11).

Table 10. Restoration techniques and the major habitats and processes they restore. Processes: Con = connectivity, Sed = sediment, Hyd = hydrology, Rip = riparian and organic matter. Habitats: Flp = floodplain, Rif = riffle, Pl = pool, Spw = spawning, Cov = cover. Flp is considered both a process and habitat type. From Roni et al. (2013b).

	Process					Habitat			
Technique	**Con**	**Sed**	**Hyd**	**Rip**	**Flp**	**Rif**	**Pl**	**Spw**	**Cov**
Dam removal		X	X	X	X			X	
Culvert replacement	X	X		X					
Fish passage structures	X								
Levee removal or setback	X	X		X	X				
Reconnection of floodplain habitats	X	X	X		X				
Road removal	X	X	X						
Road resurfacing		X							
Stabilization, upgrading stream crossings		X	X						
Reduce impervious surface			X						
Instream flows			X						
Agricultural practices		X							
Restore sediment sources		X				X		X	
Riparian replanting		X		X					
Thinning or removal of understory				X					
Removal or control of invasives				X					
Fencing (livestock exclusion)		X		X					
Rest-rotation or grazing strategy		X		X					
Log or boulder structures						X	X	X	X
Natural LWD placement					X		X	X	X
Engineered logjams					X		X		X
Brush or other cover									X
Gravel addition					X	X	X	X	X
Remeandering of straightened channel	X				X	X	X	X	X
Creation of floodplain habitats					X			X	
Beaver reintroduction	X				X		X		
Bank stabilization		X		X					X

Table 11. Recommended restoration measures, rational for recommendations, and field verification needs for each of the 25 highest-priority EDT reaches in Upper Columbia and Sanpoil. These are initial recommendations based on the assessment data prior to field visits.

Reach	Restoration Measures	Rational for Recommended Restoration Treatments	Field Verification or Additional Data Needs
Sanpoil 4b	LWD, riparian rest.	Decent forest cover. Heavy livestock grazing in the riparian, and recent burn history in the EDTshed outside of the riparian zone.	Need more info on sediment sources.
Silver1	Protection, LWD	Low EDT LWD score. Potential sediment delivery from the major road.	No habitat data for this reach. Need field verification re: cattle and sediment delivery. Confirm that culvert is passable.
Sanpoil 2l	Riparian rest., livestock exclusion, LWD	LWD counts (LRHIP) and scores are low, looks heavily grazed.	Need field confirmation of side channel connectivity. Need to confirm that fine sediment is NOT an issue (LRHIP 25% fine sediment but EDT score is low).
Sanpoil 3c	Riparian rest., livestock exclusion, LWD	Riparian vegetation is severely degraded along ag. fields and residences. Unstable eroding banks next to ag. field. Reach should all be island braided or meandering. LWD score indicates lack of LWD.	Need field confirmation that there is no bank armoring. Confirm fine sediment levels (LRHIP indicates 36%). Consider sediment budget to determine if sediment load is elevated above natural.
Sanpoil 4A	Riparian rest., livestock exclusion, LWD	Severely impacted by grazing. Watershed looks to have recent fire history, relatively low LWD levels, low forest cover, riparian and upland forest cover.	Confirm that fine sediment is NOT an issue. LRHIP reports 32% but EDT indicates 1.7 fine sediment score, which suggests it's a minor issue.
Stranger 7	Riparian rest., livestock exclusion	Large wetland system. This reach is more of a protection reach. LWD score is moderate.	Confirm that culvert is passable. Confirm if fine sediment is an issue.
Hall4	LWD, riparian rest. (selected reaches), livestock exclusion (?)	6 km long reach with some reaches in good shape with lots of LWD, but others appear degraded. Impacts on ag. lands are greatest. Apparent heavy beaver activity in large wetland/stream to west.	Confirm that fine sediment and water withdrawals are not an issue. Twelve road crossings and relatively high road density. Confirm if roads are source of sediment.

Reach	Restoration Measures	Rational for Recommended Restoration Treatments	Field Verification or Additional Data Needs
Cornstalk 5C	Protection (wetland), riparian rest., remeander (lake outlet)	Very low LWD and high fine sediment - but could be natural due to predominant wetland character of reach.	Confirm if there is a barrier at stream crossing and lake outlet, and if stream channel can be restored to natural location and configuration without damaging wetland.
Sanpoil 5C	LWD, riparian rest., livestock exclusion	LRHIP data suggest relatively low fine %, EDT has 2.5. Impinged by highway along right bank for most of reach.	Confirm riparian restoration options.
Sanpoil 2J	LWD, riparian rest.	EDT fine sediment is moderate, LRHIP says 34% fine sediment. Channel is nearly devoid of LWD.	Confirm if channel incision and straight configuration is natural or due to historic alteration, and if livestock grazing is an issue. Confirm if confinement and incision is natural.
Hall 3	Barrier removal (downstream), riparian rest. (buffer on ag. lands), LWD	Stream channel looks to be in relatively good shape. Some riparian impacts up near the top of reach and anywhere else where ag lands impinge upon channel. Channel types appear to be consistent with expected.	LRHIP high fine sediment needs to be confirmed. Stream channel looks to be in relatively good shape. Some riparian impacts near the top of reach and bank stabilization LWD. Look at roads to see if there are fine sediment issues at the upper end.
Sanpoil 2F	LWD, riparian rest., livestock exclusion.	Poor LWD, low habitat complexity, largely plane-bed channel, but should be meandering or island braided. There are a few places where roads may be impinging.	Confirm if channels are artificially straightened. Confirm if livestock access is an issue.
Sanpoil 5E	LWD, riparian rest.	Highly confined by highway on right bank for much of the reach, and naturally confined on left bank.	Short of moving the highway, it would be difficult to address the confinement issues. Confirm grazing impacts and riparian restoration opportunities.
Hall 2B	Barrier removal (bottom of reach), LWD (?)	Barrier at downstream end, LWD moderate.	Confirm if LWD is needed.
LynxTrib2A	Protection, address downstream barrier?	Appears to be high quality habitat.	Confirm downstream barriers are addressed. Lynx culvert 3 looks like a barrier.

Reach	Restoration Measures	Rational for Recommended Restoration Treatments	Field Verification or Additional Data Needs
Sanpoil 4G	LWD, possibly riparian restoration	Low LWD score. Channel type and confinement consistent with expected.	Confirm riparian conditions and restoration opportunities.
Sanpoil 7D	Floodplain reconnection, LWD, riparian rest., livestock exclusion.	Channel should be island-braided but is highly channelized, low LWD score, riparian forest, and upland forest nearly non-existent.	The shortest path to restoration in this reach might be to purchase it. The entire reach is modified.
Sanpoil 1F	LWD, riparian rest.	Massive landslide on right bank in center of reach, but EDT fine sediment score is 1.25 and LRHIP is 20%, LWD score low to moderate.	Confirm riparian conditions and restoration opportunities.
WF Hall 2	Protection (downstream barriers?)	Appears to be high quality habitat. Up to 4 known culverts downstream that may present migration barriers.	Confirm downstream barriers in other reaches are addressed.
Cedar 1	Protection, possible LWD, riparian rest. Opportunities	EDT shows mid to poor LWD score, no other habitat data.	Field verify if barriers downstream create problems. Also, check wetland/riparian restoration options.
Barnaby 1	Protection	Appears to be in reasonable condition.	Need confirmation that the culvert at the mouth is not an issue. Also, the road goes right next to the creek for entire reach length - confirm that fine sediment is not a problem.
Lost 6	Protection	Appears to be high quality habitat at fairly high elevation, though EDT suggests LWD may be an issue. However, satellite imagery appears to show a considerable wood in the channel. Forest cover is high in the riparian and stream is generally unaffected by anthropogenic problems.	Confirm downstream culverts do not present passage barriers. Also confirm livestock aren't overgrazing the understory in the riparian.

Reach	Restoration Measures	Rational for Recommended Restoration Treatments	Field Verification or Additional Data Needs
Sanpoil 4C	LWD, riparian rest., floodplain reconnection, upland forest restoration	Appears to have had recent burn history on eastern slope adjacent to river. Low LWD score. LRHIP fine sediment is high - perhaps from fires. Channel type is meandering and could benefit from LWD in upper 1/2 of reach in particular. Highway on west side of valley, 2 track on east side that may be responsible for some fine sediment.	Confirm dirt road on left bank is not a major source of fine sediment.
NF Hall 1B	Riparian rest., livestock exclusion, re-meander channel, LWD	Stream reach is highly modified, channelized and straightened through wetland. Riparian zone is nonexistent, several places of apparent beaver history are visible on satellite imagery.	Confirm road on east side of valley is not a major source of sediment.
Sanpoil 3D	LWD, riparian rest., livestock exclusion, floodplain reconnection, floodplain (wetland) restoration	River is island-braided and responds well to large wood where it is in the channel. The upper portion of the reach is devoid of LWD and exhibits heavy damage due to livestock in the riparian zone. This reach has lots of meander scars in the floodplain, indicating active lateral movement history. Riparian restoration is necessary, particularly in upper portions of the reach.	

Recommended restoration measures varied by reach, but the most common were LWD placement (18), riparian restoration or livestock exclusion (12), a few reaches needing floodplain reconnection or re-meandering (5), and seven (7) reaches recommended for protection as they were largely high-quality habitat. A handful of reaches had downstream barriers that appeared to be the major restoration treatment needed. However, the culvert and barrier data layer we were provided had limited detail on whether barriers are complete or partial blockages to fish passage. Thus, confirmation of the passability of these barriers is needed. While fine sediment levels based on EDT or LRHIP data were high, road densities were low and field confirmation of whether fine sediment is still an issue is also needed. Moreover, the EDT and LRHIP data show some inconsistencies in sediment and LWD levels at times, thus requiring confirmation during site visits.

A sediment budget identifying background and current sediment sources and supply would be helpful in understanding if fine sediment levels are truly elevated and whether their sources are natural or anthropogenic. Moreover, a historical reconstruction of floodplain, riparian forest, and upland forest conditions would also be extremely helpful, particularly for the Sanpoil basin where much of the riparian and floodplain restoration opportunities exist.

Field Review of Initial Restoration Recommendations

Site visits were conducted in all 25 priority reaches in June of 2017 to:

1) Confirm if initial restoration measures and recommendations based on assessment data and listed in Table 11 were appropriate,

2) Identify where in the reach restoration measures are appropriate,

3) Confirm feasibility, and

4) Identify possible constraints (access, ownership, cultural resources).

Based on the site visits, we developed brief summaries for each reach, with revised restoration recommendations (Appendix B). Each write-up includes site photos, location and site description, restoration objectives (both initial, based on assessment, and revised, based on site visit), special considerations, life stage benefits, prioritization considerations, and data needs. These were developed to serve as the basis for prioritization of restoration actions and to provide information for preliminary restoration design.

Based on the site visits, initial restoration recommendations from assessment data (see Table 11) were updated. This included changing recommendations because of presence or absence of barriers or identification or confirmation of sediment or other issues. In some cases, due to channel size or need for floodplain restoration, engineered log jams (ELJs) were recommended rather than typical LWD placement. In addition, because of high flow events during spring 2017, substantial changes in some channels occurred—particularly in many of the mainstem Sanpoil reaches (e.g., 4B, 4G, 5C, 5E). In some cases, large amounts of sediment and wood were delivered to the channel and created high quality habitat, reducing the need for restoration. A summary of revised recommendations is provided in the following section on prioritization.

ACTION STRATEGY AND RECOMMENDED NEXT STEPS

Prioritization of Restoration Actions

Following identification of potential restoration actions in each reach, the next steps were to prioritize the reaches and develop a comprehensive action strategy for designing and implementing the restoration actions. The overall objective was to identify the highest value projects based on scientific, technical, and socioeconomic factors. Numerous methods exist for prioritizing restoration and conservation measures (Roni et al. 2002; Roni et al. 2013a), ranging from professional opinion to complex computer models. Being able to incorporate both technical and other information for prioritization of restoration projects is critical. While technical issues can limit the extent and costs of restoration, social and economic constraints frequently limit the pace of restoration actions and their extent. Design and construction can be a lengthy process for large phased-restoration actions, and stakeholders should be engaged throughout the process to assure expectations are explicit and transparent (Beechie et al. 2013; Souder et al. 2013). Typically, there is a diversity of values that often exist with stakeholders in a subbasin. Therefore, the best and most transparent approach for incorporating biological (e.g., fish numbers, diversity), physical (e.g., project size, habitat type, process restored), socio-economic (e.g., cost, cost-benefit), and other factors is a scoring system; often called multi-criteria decision analysis or MCDA (Beechie et al. 2008; Roni et al. 2013a).

While MCDA is relatively straightforward, it is important to follow a series of steps to ensure that the process is rigorous, transparent, and repeatable (

Figure **6**). This is important as, typically, projects need to be reprioritized periodically as they are completed, new information becomes available, or project costs and other factors change. In addition, prioritization typically occurs at two or more scales. First, reaches or subbasins need to be prioritized for restoration. Next, once the highest priority reaches and specific restoration projects are identified in those reaches, restoration actions need to be prioritized across those high priority reaches. For Upper Columbia and Sanpoil, the highest priority reaches were identified in the watershed assessment using output from the EDT model. Thus, here we describe the second level of prioritization, which was performed once specific restoration measures for each reach were identified and confirmed or refined during field visits.

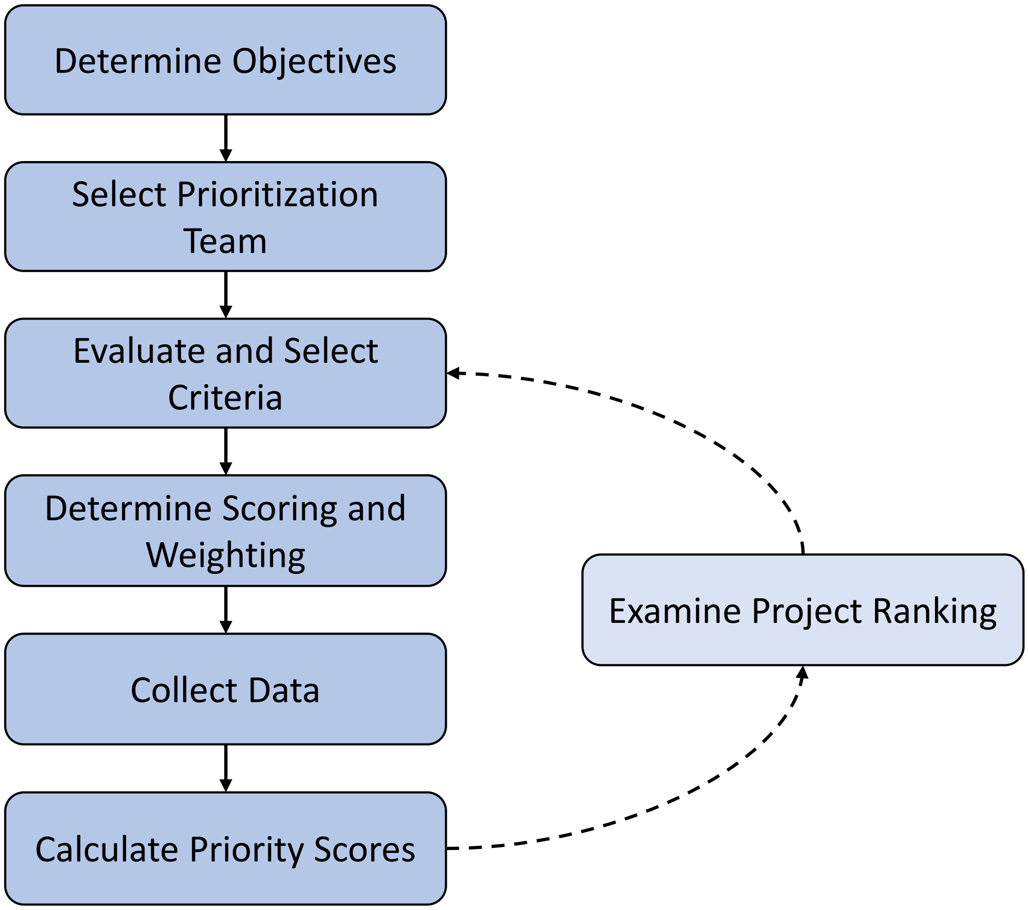

Figure 6. Steps to follow for developing an effective and repeatable prioritization process (modified from Roni et al. 2013a).

A key driving factor of prioritization was outlining the restoration objectives and translating those into objectives for prioritization. The objectives of the Upper Columbia and Sanpoil Restoration plan are to develop a process-based plan for habitat restoration to increase Redband Trout abundance, resilience, and diversity. Thus, two key prioritization criteria considered were increasing Redband Trout numbers and focusing on process-based restoration actions that restore processes and prepare the system for long-term recovery.

It is also important to determine who will help identify criteria and score and rank restoration actions. The prioritization team for the Upper Columbia and Sanpoil consisted of Jason McLellan, Dennis Moore, Bret Nine, Amelia Stanger (CCT), and Phil Roni and Ray Timm (CFS). It will be important to have other stakeholders provide input on the criteria for prioritizing projects, as buy-in from a variety of stakeholders is important for successful restoration projects and plans (Souder et al. 2013). This will be done through the restoration plan review process.

Based on the restoration objectives, results of the watershed assessment, and our experience prioritizing restoration actions in other areas, we initially considered the following criteria: EDT (ranking based in potential increase in abundance, resilience and diversity), whether an action restores processes or improves habitat, potential increase in juvenile *O. mykiss* due to restoration measures (based on data from steelhead), effectiveness of restoration type, preliminary project cost (TBD), cost-benefit (cost per unit area or per fish), site access, logistic constraints, land ownership, landowner willingness, cultural significance of project area, whether the project will ameliorate predicted climate change impacts (Beechie et al. 2013), and socio-economic impact (e.g., jobs created or lost, fishing opportunity).

After much discussion, the prioritization team identified five criteria that were most important based on the restoration plan goals and CCT values and for which information was readily available. These included: 1) whether the action restores process, 2) site access and logistics, 3) land ownership within 100 m (328 ft) of priority reach, 4) cultural significance and socio-economics, and 5) whether the action ameliorates climate change. Project cost was excluded because we did not want to eliminate a high priority action just because it was expensive. EDT rankings—which were based on EDT model estimates of increased abundance, resilience, and diversity for restoring each reach—were already used to select reaches. Thus, this criterion was excluded as it would have been redundant. Land ownership and landowner willingness were combined into one criterion as they are often closely linked. The cultural significance of the area, which included not only whether properties in a reach were of historical or cultural significance but also use or access for hunting, fishing, and other activities was combined with socio-economic impact.

Another critical step was to determine how to score the criteria and whether criteria would be given equal weights. There are many approaches for scoring criteria, ranging from simple scoring of 1 to 5 or 1 to 3 to more complex scoring (1 to 10 or 1 to 25). However, more complex scoring systems are more difficult to use, more subjective, and less repeatable. Thus, the team selected a simple scoring system from 1 to 5 because we believe it would be most transparent and repeatable. To assist with scoring, we developed basic guidelines on how to score each criterion and what constituted a 1, 2, 3, 4 or 5 (Table 12).

One of our primary operating assumptions was that all criteria should be given equal weight since there were only five criteria, the reaches had already been screened as highest priority under EDT modeling, and weighting would make scoring and ranking less transparent. The actual scoring of the project can be done collectively by a group, or by each member of the team; these scores must then be combined or averaged to report the final result (Roni et al. 2013a). We used a group consensus approach, with CCT staff drafting initial scores for cultural significance and socioeconomics, and CFS staff drafting scores for the other criteria. The prioritization team then met to discuss and revise scores based on group consensus for each of the 25 priority reaches.

Scores for prioritization ranged for 14 to 22, with the five highest priority projects being Sanpoil 4B, Lost 6, Sanpoil 7D, Cedar 1, and Cornstalk 5C (Table 13). It should be noted that many factors can influence the feasibility of a project, and these cannot be totally captured in a prioritization process. It also may take several years of planning, negotiating with landowners, and other factors to obtain funding and complete a project. Therefore, rather than focusing all efforts on the highest ranked project, the ranking should be used to highlight high priority, medium priority, and lower priority reaches where efforts should initially focus. Thus, we recommend initially focusing efforts on the top 9 or 10 projects and working on other lower priority reaches as the top third are completed or are delayed.

Table 12. Criteria for scoring and prioritizing priority reaches and guidelines used to score each criterion. The historic property designation indicates that the property is potentially eligible for the National Register of Historic Places (NRHP). Cultural resources are other archaeological/cultural sites that are not eligible for NRHP. Habitat protection was assumed to have no effect on climate change.

	Score (1 to 5)				
Criterion	**1**	**2**	**3**	**4**	**5**
Restores processes based on Roni et al. 2013b	Restores neither processes nor habitat	Restores physical habitat	Restores one or two processes (connectivity, riparian, hydrology, sediment, floodplain)	Restores more than two processes	Restores process and habitat or protects fully functioning habitat
Site access & logistics	Helicopter only (no roads or staging)	No roads within 0.5 km of site, but staging area if equipment/ supplies/ LWD brought in by helicopter	Roads within 0.5 km of site. No staging area	Roads within 0.5 km of site. Good staging area	Roads and staging area adjacent to site
Land ownership ≤ 100 m from reach	Private, reservation fee, or tribal allotment with unwilling landowner or more than 6 landowners	Public ownership or tribal trust uncooperative/restricted or 5 to 6 landowners	Public ownership cooperative partner (Federal, State, County, City) or 3 or 4 different landowners	Private, reservation fee, tribal allotment, with willing owner/allottee or 1 or 2 different landowners	Tribal trust lands (entire site)
Cultural significance & socio-economics	Adverse effect to historic properties/ cultural properties with no mitigation	Adverse effect to historic properties/ cultural resources with mitigation	No adverse effect to historic properties, but adverse to cultural resources or vice versa, with mitigation	No adverse effect to historic properties or cultural resources	No effect and benefits to cultural resources (i.e., re-establishes first foods)
Ameliorates climate change (Based on Beechie et al. 2012)	No effect on low flow, peak flow, temperature, or Redband Trout resilience	Ameliorates climate effect on either peak flow, low flow, temperature, or Redband Trout resilience	Ameliorates climate effect on two of the following: peak flow, low flow, temperature, or Redband Trout resilience	Ameliorates climate effect on three of the following: peak flow, low flow, temperature, or Redband Trout resilience	Ameliorates climate effect on all of the following: peak flow, low flow, temperature, or Redband Trout resilience

Table 13. Priority reaches, revised restoration measures based on site visits, individual scores for each criterion (1 to 5 points), and total score. Reaches are ranked from highest score to lowest total score. ELJ = engineered log jam.

Reach	Restoration Measures (revised based on site visits)	Restore Process	Site Access/ Logistics	Land Ownership ≤ 100 m	Cultural Resource Score	Climate Change	Total Score
Sanpoil 4B	Protection, riparian rest. livestock exclusion, LWD, possible ELJs	5	5	4	4	4	22
Lost 6	Protection, livestock exclusion, LWD	5	5	4	4	3	21
Sanpoil 7D	Floodplain reconnection, LWD, riparian rest., livestock exclusion.	5	4	1	5	5	20
Cedar 1	Dam removal, protection	5	5	2	4	4	20
Cornstalk 5C	Protect wetland and riparian buffers, remeander lake outlet	4	5	3	5	3	20
Sanpoil 4A	Riparian rest., LWD, possible ELJs	3	5	3	4	4	19
Sanpoil 5C	Protection	5	4	4	5	1	19
Sanpoil 3D	LWD, riparian rest., livestock exclusion, floodplain reconnection, floodplain (wetland) restoration	5	5	1	3	5	19
Sanpoil 5E	Protection	5	3	4	5	1	18
Hall4	LWD, riparian rest. (selected reaches), livestock exclusion, wetland reconnection	4	4	1	4	5	18
Sanpoil 4G	Protection, possible LWD	5	4	5	2	2	18
NF Hall 1B	Wetland restoration, riparian rest., remeander channel, LWD, culvert removal	5	4	1	3	5	18
Sanpoil 2F	Riparian rest., LWD, possible ELJs	3	5	1	4	4	17

Reach	Restoration Measures (revised based on site visits)	Restore Process	Site Access/ Logistics	Land Ownership ≤ 100 m	Cultural Resource Score	Climate Change	Total Score
Sanpoil 2J	Riparian rest., LWD, possible ELJs	3	5	1	4	4	17
Stranger 7	Riparian rest., livestock exclusion	3	5	3	4	2	17
Sanpoil 2I	Riparian rest., livestock exclusion, LWD, possible ELJs	3	5	1	4	3	16
Sanpoil 3C	LWD, possible ELJs, riparian rest., livestock exclusion	3	3	1	5	4	16
Hall 2B	Protection, possible LWD	5	3	2	4	2	16
LynxTrib2A	Protection	5	1	5	4	1	16
WF Hall 2	Protection	5	1	5	4	1	16
Barnaby 1	Road restoration, protection	5	5	3	2	1	16
Sanpoil 4C	Protection, possible ELJs	4	4	1	4	2	15
Silver1	Protection, fine sediment control, LWD	5	3	1	4	2	15
Sanpoil 1F	Riparian rest., LWD, possible ELJs	3	5	1	2	4	15
Hall 3	Riparian rest., livestock exclusion	3	4	1	4	2	14

Process for Addressing Key Constraints

In conducting the assessment, identifying potential restoration opportunities, and preparing the prioritization approach, a handful of additional constraints and data needs became apparent. While there was a wealth of habitat, physical and biological data for the study area, there were several data or assessment pieces that were missing and would be helpful for confirming habitat impacts and restoration designs.

First, for high priority reaches that are not on tribal trust lands, the willingness of landowners to participate in any restoration program needs to be confirmed.

Second, a sediment budget for the Upper Columbia and Sanpoil subbasins is needed to confirm the source of fine sediment in many reaches and whether the sediment levels are elevated due to anthropogenic impacts. While we acquired data on the road network and stream crossings, information on landslides, surface erosion, and road surface erosion would be extremely helpful for confirming restoration measures needed.

Third, historical reconstruction of channel patterns and riparian conditions based on General Land Office Notes (typically from mid to late 1800s) and historical aerial photographs (typically 1930s to present) would be extremely useful in determining what historical channel conditions and channel types were observed in the Sanpoil and other floodplain reaches. This would be helpful for designing restoration projects for these reaches.

Fourth, the data layers we had for fish passage barriers were somewhat incomplete and did not always identify whether barriers were completely impassable or if barriers in downstream reaches limited productivity of a particular reach.

Fifth, there are clearly extensive livestock impacts in many areas and if more detailed information were available on grazing allotments or grazing management it would be very helpful, particularly for riparian restoration and fencing projects.

Finally, while the EDT model is useful for prioritizing reaches, a simple limiting factors type analysis done at the subbasin scale that identified the limiting life stage and habitat (summer, overwinter, spawning) would be useful for focusing restoration actions on highest priority habitats and life stages (e.g., Beechie et al. 1994; Roni and Timm 2016). It is possible to do this analysis based on habitat area summaries drawn from EDT and coupled with data for steelhead as a surrogate for Redband Trout. It may also be possible to extract and aggregate life-stage specific capacities from EDT to do the analysis.

Next Steps and Estimated Cost

The next steps include confirming land ownership and landowner willingness, preparing more detailed restoration designs for priority reaches and, most importantly, obtaining funding either for individual projects or for an entire restoration program.

To assist with planning, we prepared approximate cost estimates to restore each priority reach. For each reach, we estimated the approximate extent of each restoration treatment by either area or length, based on satellite imagery and information from our sites visits (Appendix B). We then applied typical costs for each restoration based on Shared Strategy (2003), Roni et al. (2010), and Fullerton et al. (2010). We cost-adjusted these to December 2021 dollars based on the consumer price index (CPI) (http://data.bls.gov/cgi-bin/cpicalc.pl). Costs are approximate and may also be different based on the price of labor, in kind contributions, etc.

Based on this information, a rough estimate of the cost of restoration measures for all 25 reaches is approximately $14 million (

Table 14). This does not include permitting costs, or any land purchases or easements needed for either protection or restoration, or the cost of road restoration or improvements. Land acquisition or easements could easily cost $5 million to $10 million or more, depending upon land values and alternative uses. Therefore, the total program would likely cost $20 million or more. Again, it needs to be emphasized that these are just ballpark estimates for planning purposes. This does not include any additional costs related to road restoration or improvement which can be highly variable based on length and type of forest road that needs to be treated.

Table 14. Approximate cost in December 2021 U.S. dollars to restore each priority reach. These are approximate design and construction costs for initial planning purposes and do not include costs for land acquisitions, easement, and permitting. Moreover, we did not estimate the cost of road repair or restoration. Costs: LWD $86,759/km, ELJs = $123,941/ELJ, Riparian = $6/m^2, Livestock fencing = $33/m, Remeander = $301/m, and Barriers = $295,896/barrier. Road removal, upgrade, or decommissioning costs were not estimated. ELJ = engineered log jam.

		Length or Area Treated						
Reach	**Reach Length (m)**	**LWD (km)**	**ELJ (#)**	**Riparian (m^2)**	**Livestock Fencing (m)**	**Remeander (m)**	**Barriers (#)**	**Total Cost 2021 $**
Sanpoil 4B	3,100	0.5		87,000	7,000			774,906
Silver1	850	0.5						43,380
Sanpoil 2I	3,500	2			7,000			528,737
Sanpoil 3c	2,200	2.2	1	54,000	8,800			916,060
Sanpoil 4A	1,700	1.5	2	102,000				964,522
Stranger 7	2,100			43,500	3,000			349,244
Hall4	5,000	3		42,000	1,400			548,034
Cornstalk 5C	2,500					750		225,975
Sanpoil 5C	1,000							-
Sanpoil 2J	3,700	3	1	142,500				1,203,595
Hall 3	7,100			60,000	3,000			444,119
Sanpoil 2F	2,400	1.5	2	84,000				861,022
Sanpoil 5E	3,400							-

Reach	Reach Length (m)	LWD (km)	ELJ (#)	Riparian (m^2)	Livestock Fencing (m)	Remeander (m)	Barriers (#)	Total Cost 2021 $
				Length or Area Treated				
Hall 2B	1,600	0.5						43,380
LynxTrib2A	400							-
Sanpoil 4G	2,800	0.5						43,380
Sanpoil 7D	2,500	2.5		150,000	5,000	2,000		1,847,196
Sanpoil 1F	1,100	1	2	18,000				438,142
WF Hall 2	6,600							-
Cedar 1	3,350						1	295,896
Barnaby 1	1,400							-
Lost 6	7,400	5			14,800			922,782
Sanpoil 4C	5,350		2					247,883
NF Hall 1B	5,100	4		225,000		1,500		2,092,738
Sanpoil 3D	2,800	2.8	2	135,000	5,600			1,452,080
								14,243,067

QUANTITATIVE BIOLOGICAL OBJECTIVES FOR PROJECT DESIGN AND EVALUATION

Setting biological objectives or benchmarks is an important part of both project planning and evaluating success of restoration and protection efforts for salmon, trout, and other fishes (Cowx et al. 2013; Roni and Beechie 2013). Setting these targets can be challenging, particularly if reach specific empirical data are not available on current conditions. It can be further complicated by limited information on restoration effectiveness. While considerable habitat data are available for the Sanpoil and Upper Columbia, it is either limited to short sections (500 m or less), a subset of all EDT reaches (CHaMP sites), or does not cover the entire project area (Table 2). More importantly, there is limited information on juvenile and adult Redband Trout abundance for priority reaches. In cases of limited data, a life cycle model like EDT can be useful for both examining potential restoration scenarios and prioritizing reaches. It has been widely used to assist with restoration planning and prioritization and EDT model outputs on diversity, productivity, and abundance were used to help identify the 25 highest priority reaches for restoration and protection. The EDT model also predicts juvenile and adult capacity and abundance for each reach and diagnostic unit. These can be used to set biological targets but should be done with caution (Mobrand et al. 1997; McElhany et al. 2010) because it is unknown how accurate EDT outputs on capacity and abundance are. EDT outputs need to be used in combination with other information to set targets for restoration and monitoring.

While EDT produces both estimates of juvenile and adult abundance and the ISRP suggested setting targets for adults and juveniles based on EDT, we set targets using juvenile abundance for four major reasons. First, many of the Redband Trout in Sanpoil and Upper Columbia are adfluvial and multiple factors outside the reach influence their survival and production. Second, while some effort is made to enumerate spawning adults or redds in some priority reaches by CCT, this is not regularly done on an annual basis or on all reaches, and surveys are difficult to conduct during spring flows. Third, juveniles more directly represent the changes in riverine habitat conditions, and they can also be enumerated in the summer, fall, or winter. Finally, juvenile Redband Trout numbers, density, and capacity can more readily be estimated with different capacity models, both historical (e.g., Reeves et al. 1989; Beechie et al. 1994) and more recent models (Bond et al. 2019; Isaak et al. 2021; See et al. 2021).

Thus, to set biological targets for the 25 highest priority reaches for restoration in the Sanpoil and Upper Columbia, we used a three-step process that used a combination of EDT model outputs, literature-based targets, and restoration action type. First, the EDT model provided estimates of juvenile (parr) and adult abundance at baseline (current) and template conditions (fully restored). The baseline was 2014 when the EDT model was run, and we assumed that this represented current or pre-restoration conditions. Template conditions assumed that all impairments were fully restored. While EDT separated the Sanpoil and Upper Columbia into more than 700 reaches, the model was run on "diagnostic units" that represented a combination of multiple reaches in each watershed. For example, diagnostic unit Sanpoil 2 was composed of 10 EDT reaches (Sanpoil 2A through 2J). To estimate EDT reach specific baseline and restored estimates of Redband Trout abundance, we divided the total estimates of abundance for a diagnostic unit by the total reach length, which provided an increase in abundance per channel length (

Table 15). We then multiplied that by the total length of individual reaches that made up Sanpoil 2. For example, for the Sanpoil 2 diagnostic unit, template conditions predicted juvenile abundance of 7,093 for the entire diagnostic reach (14,902 m), resulting in 0.476 juveniles per linear meter (Table 16). The estimate of juveniles per meter and the length of each individual EDT reach were multiplied together to provide reach-specific estimates of juvenile abundance for each of the 25 highest priority EDT reaches.

Second, to calculate the increase in juvenile abundance when each reach is fully restored, we took the difference between the current and template juvenile abundance. However, increases due to restoration are typically not additive, but multiplicative. In other words, we do not expect that when we restore habitat, we will get 0.5 more fish per meter, but rather that the numbers will increase by a certain percentage based on the pre-restoration conditions and productivity of the stream or reach (Roni et al. 2005). In a statistical sense, we expect the response to habitat restoration to be multiplicative rather than additive. Therefore, we also looked at the ratio of the template to current conditions to understand the multiplier or percent increase.

We know from studies on restoration effectiveness that it is rare for studies to produce more than a two (100%) or three-fold increase in juvenile salmon or trout (Roni et al. 2010; Roni et al. 2015), and, in fact, most studies show more modest increases (25 to 50%). In reviewing the literature on effectiveness of different restoration techniques for *O. mykiss* in the Columbia Basin, we found several studies that help inform the levels of increase we might see from different restoration techniques (e.g., Viola et al. 1991; Keeley et al. 1996; Connor et al. 2015; Polivka et al. 2015, 2020; Bouwes et al. 2016; Clark et al. 2019, 2020). In particular, recent evaluations as part of BPAs Action Effectiveness Monitoring Program and other programs provide information on barriers and large wood placement (Clark et al. 2019, 2020). Other studies have examined floodplain and wetland restoration (Bouwes et al. 2016). While there are many other studies on restoration effectiveness (Roni et al. 2010, 2014, 2015, 2019; Hillman et al. 2016), most of these studies focused either on coastal areas or on Coho *O. kisutch* and Chinook Salmon *O. tshawytscha*. Using information on the results of studies specific to *O. mykiss*, which suggest increases of more than 2.5-fold (150%) are rare , we reviewed the potential changes or percent increases in juvenile abundance predicted for each priority EDT reach and the proposed restoration measures.

Eleven of the 25 reaches had potential increases in juvenile abundance that exceeded what was generally reported in the literature. Data for large wood placement, the most well evaluated of the restoration techniques, suggests an average increase of 2.3-fold for juvenile *O. mykiss*. Therefore, for any project that projected a more than 2.3-fold increase in juvenile abundance, we adjusted the target down to a 2.3-fold increase (130% increase). Some of the reaches scheduled for protection had increases predicted by EDT. However, these reaches were identified for protection because of their high-quality habitat. We assume protection would maintain the current level of abundance and targets in these reaches were adjusted to no increase (multiple of 1 or 0% increase). Finally, there was one diagnostic unit (Sanpoil Mainstem 1) where no changes in abundance or capacity were provided by the EDT model. Lacking output from the EDT model for priority reach Sanpoil 1F, we applied numbers from the nearest priority reach (2F).

The numbers in Table 16 represent initial biological targets and will be adjusted when the projects go to the design phase. This is important because, while we have initial concepts of what needs to occur in each reach, it is at the design phase that the total area that will be treated and specific restoration actions will be determined. Based on this, the targets can be recalculated to provide realistic estimates. For example, the assessment identified riparian restoration and large wood placement as potential restoration measures for Sanpoil 2F, but the number of logs or ELJs is not specified nor is the length of the reach that needs to be restored. If only half of the reach will actually be restored, then the juvenile abundance target can be recalculated just for the area to be restored. In Table 16, we present both the juvenile abundance estimates and the multiplier (percent increase) that is expected based on the EDT model. As noted previously, abundance estimates from EDT need to be used with caution as biological targets. Ideally, pre- and post-restoration fish surveys or habitat surveys will be used to estimate the percent increase following restoration and whether the project met its biological objectives as predicted by EDT modeling.

Table 15. EDT diagnostic units and estimated current (2014) and template (restored) juvenile Redband Trout capacity and density.

Diagnostic Unit	Length (m)	Capacity (number)		Density (fish/m)	
		Current	Template	Current	Template
Barnaby	5,858	4,556	5,835	0.78	1.00
Hall Creek Upper	44,724	34,322	42,281	0.77	0.95
LK Roosevelt Minor Tribs.	18,507		2,523	0.00	0.14
Lost Creek	76,846	11,293	47,315	0.15	0.62
Lynx	38,978	20,879	31,887	0.54	0.82
NF Hall Creek	26,071	17,240	26,519	0.66	1.02
Stranger	30,642	21,169	32,688	0.69	1.07
Sanpoil Mainstem 1	3,685			0.00	0.00
Sanpoil Mainstem 2	14,903	562	7,093	0.04	0.48
Sanpoil Mainstem 3	10,284	460	5,556	0.04	0.54
Sanpoil Mainstem 4	17,461	7,366	15,542	0.42	0.89
Sanpoil Mainstem 5	13,132	5,019	11,834	0.38	0.90
Sanpoil Mainstem 7	12,553	3,865	7,835	0.31	0.62

Table 16. Initial biological objectives for juvenile Redband Trout each priority reach. The multiplier represents the ratio (percentage) of template to current. Thus, a value of 1.3 means that template (restored) juvenile abundance is expected to increase 1.3 times that of current (30% increase). Because the precision of juvenile abundance estimates is uncertain, we recommend using the multiplier as the biological objective or target. Percent increase (ratio) in bold are numbers that were capped based on literature (1 for protection, 2.3 for restoration measures).

Reach	Rank	Length (m)	Juvenile Abundance		Percent Increase (Multiplier)	Restoration Measures
			Template	Current		
Barnaby 1	21	1414	1,408	1,100	1.3	Road restoration, protection
Cedar 1	20	3354	3,341	2,609	1.3	Dam removal, protection
Cornstalk 5C	8	2468	2,633	1,705	1.5	Protect wetland and riparian buffers, remeander lake outlet

Reach	Rank	Length (m)	Juvenile Abundance Template	Juvenile Abundance Current	Percent Increase (Multiplier)	Restoration Measures
Hall 2B	14	1651	1,679	1,092	1.5	Protection, possible LWD
Hall 3	11	7400	7,527	4,893	1.5	Riparian rest., livestock exclusion
Hall 4	7	5871	5,972	3,882	1.5	LWD, riparian rest. (selected reaches), livestock exclusion, wetland reconnection
Lost 6	22	4475	2,755	658	**2.3**	Protection, livestock exclusion, LWD
Lynx Trib. 2A	15	388	317	208	**1.0**	Protection
NF Hall 1B	24	5310	5,401	3,511	1.5	Wetland restoration, riparian rest., remeander channel, LWD, culvert removal
Sanpoil 1F	18	1137	541	43	**2.3**	Riparian rest., LWD, possible ELJs
Sanpoil 2F	12	2423	1,153	91	**2.3**	Riparian rest., LWD, possible ELJs
Sanpoil 2I	3	2805	1,335	106	**2.3**	Riparian rest., livestock exclusion, LWD, possible ELJs
Sanpoil 2J	10	3785	1,802	143	**2.3**	Riparian rest., LWD, possible ELJs
Sanpoil 3C	4	4172	2,254	187	**2.3**	LWD, possible ELJs, riparian rest., livestock exclusion
Sanpoil 3D	25	5347	2,889	239	**2.3**	LWD, riparian rest., livestock exclusion, floodplain reconnection, floodplain (wetland) restoration
Sanpoil 4A	5	2079	1,850	877	2.1	Riparian rest., LWD, possible ELJs
Sanpoil 4B	1	3211	2,858	1,355	2.1	Protection, riparian rest. livestock exclusion, LWD, possible ELJs
Sanpoil 4C	23	3265	2,906	1,377	2.1	Protection, possible ELJs
Sanpoil 4G	16	2904	2,585	1,225	2.1	Protection, possible LWD
Sanpoil 5C	9	1154	1,040	441	**1.0**	Protection
Sanpoil 5E	13	3391	3,056	1,296	**1.0**	Protection
Sanpoil 7D	17	4562	2,847	1,405	2.0	Floodplain reconnection, LWD, riparian rest., livestock exclusion.
Silver 1	2	865	118	-	**2.3**	Protection, fine sediment control, LWD
Stranger 7	6	2305	2,459	1,592	1.5	Riparian rest., livestock exclusion

Reach	Rank	Length (m)	Juvenile Abundance Template	Current	Percent Increase (Multiplier)	Restoration Measures
WF Hall 2	19	6594	6,234	5,060	**1.0**	Protection

MONITORING AND ADAPTIVE MANAGEMENT PLAN

An important component of a robust restoration plan is monitoring to determine effectiveness of restoration actions and to inform an adaptive management plan. In the following section, we describe both an effectiveness monitoring plan and an approach for adaptive management, which are directly linked to the goals of the plan. The overall goal of the Upper Columbia and Sanpoil Habitat Restoration Plan is to use the latest science and data to assess watershed conditions, identify causes of degradation, and develop a comprehensive process-based watershed restoration plan that addresses critical Redband Trout habitat concerns. The goal of the following monitoring plan is to evaluate the physical and biological effectiveness of projects implemented in priority EDT reaches under the restoration plan and provide an adaptive management approach. The monitoring plan follows the step-by-step approach for developing effectiveness monitoring plans (Figure 7). This includes monitoring questions, design, methods, spatial and temporal replication, and reporting.

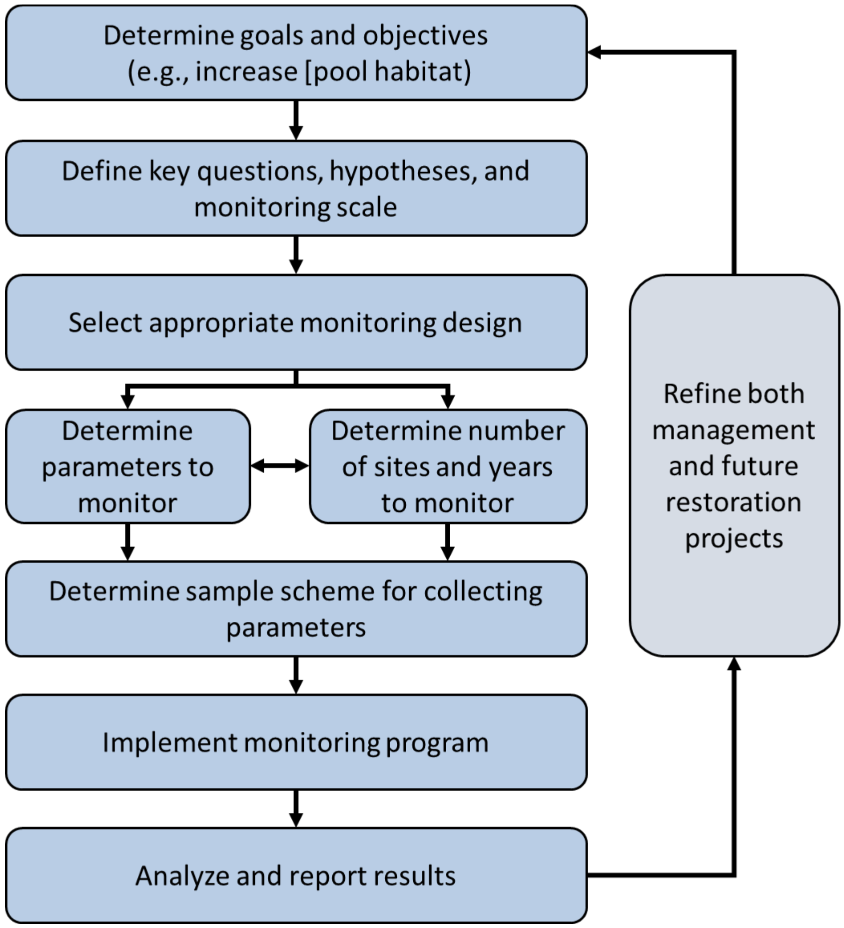

Figure 7. Steps for designing a successful monitoring program to evaluate restoration success (modified from Roni et al. 2005, 2013c).

The type of restoration determines the monitoring methods. The major types of restoration in the priority reaches include LWD (individual or multiple pieces, ELJs), floodplain (remeander or reconnection), riparian (planting and livestock exclusion), as well as one barrier removal project (Cedar 1). Many projects include a combination of these project types (e.g., floodplain, riparian, livestock exclusion) and the types of actions implemented in a particular priority reach will dictate the questions and protocols needed to evaluate success of restoration within that reach. For example, a LWD placement project focused on increasing in-channel complexity and pool habitat in an area with an intact and functioning riparian zone will include monitoring of physical habitat, but not necessarily detailed monitoring of riparian conditions. In contrast, a reach where floodplain, LWD placement, and riparian restoration are implemented will include monitoring of all these components. Because there is only one barrier removal project, and correctly implemented culvert and dam removals in the Columbia basin have been shown to be highly effective at reconnecting habitat and increasing juvenile salmon and trout numbers above former barriers (Clark et al. 2019), we did not develop a detailed effectiveness monitoring plan for the barrier project. Rather, we recommend implementation monitoring to confirm that the culvert replacement, barrier removal, or fish passage structure is passable by fish at a variety of flows. Thus, this plan focuses on monitoring and evaluation of LWD, floodplain, and riparian projects.

If other types of restoration are identified during the design and implementation phase, then the monitoring plan will be modified to address these.

To develop the monitoring plan, we built off recent efforts by the Salmon Recovery Funding Board (SRFB) and Bonneville Power Administration (BPA) Action Effectiveness Monitoring (AEM) to update and test monitoring protocols that use the latest technology including LiDAR and remote sensing for evaluating riparian and floodplain restoration projects (Roni et al. 2020a, 2021). These efforts include pilot studies that are underway to evaluate floodplain and riparian projects throughout Washington State for the SRFB that are similar to those proposed for the Sanpoil and Upper Columbia. Ultimately, these approaches use a combination of remote sensing and field data to evaluate not only effectiveness but also overall project design.

Monitoring Questions

The monitoring questions drive the overall design and methods for a monitoring plan. We outlined the following questions based on initial goals and project types defined in the restoration plan. These questions should be refined as the projects go to conceptual and preliminary design as it is likely that the restoration techniques and objectives for a particular priority reach or project will change based on detailed site survey data collected during the design phase.

The following are the major questions to be answered by the monitoring program. We indicate if the questions are appropriate for floodplain, LWD, and riparian projects.

1. Did the project increase floodplain and channel connectivity and complexity (e.g., River Complexity Index [RCI], Morphological Quality Index [MQI]) at different flows (base, 2 year, and 10 year reoccurrence intervals)? (floodplain and LWD projects)

2. Did the project increase the amount and quality of Redband Trout habitat including LWD, pool area, side channel, and other habitat metrics? (floodplain and LWD projects)

3. Did the project improve habitat suitability and capacity for Redband Trout in the project reach or segment? (floodplain and LWD projects)

4. Did the project meet its EDT based biological targets for juvenile Redband Trout capacity?

5. Did the project meet its specific physical and biological design objectives for each design component and treatment and at target flows? Which design elements were successful and unsuccessful and why or why not? (floodplain and LWD projects).

6. What is the riparian vegetation areal extent by vegetation class (e.g., grasses, forbs, shrubs, trees, etc.), species composition, and density and how much do they change over time? (floodplain and riparian projects)

7. Has riparian/floodplain restoration led to restored riparian function including shade and bank stabilization following riparian restoration? (floodplain and riparian projects)

8. Is the fencing intact and continuing to exclude livestock from the riparian zone and stream channel? (riparian projects with livestock exclusion)

Monitoring Design and Replication

There are a handful of different experimental designs used to evaluate restoration projects, each with strengths and weaknesses. Common designs used to evaluate restoration projects include before-after (BA), before-after control-impact (BACI), multiple-BA (mBA) or multiple-BACI (mBACI), extensive post-treatment (EPT), and intensive post-treatment (IPT; Hicks et al. 1991; Downes et al. 2002; Roni et al. 2005, 2013). The BACI design was considered the optimal design but has proven costly and difficult to implement at more than a handful of restoration sites due to coordination, identifying and maintaining suitable controls, and other factors (Bennett et al. 2016; Roni et al. 2018). The level of physical changes expected at projects that cover more than 1 or 2 kilometers should be large enough to detect with a simple before and after design, particularly with the level of detail and spatial coverage that can be obtained using a combination of remote sensing and field data. Moreover, the in difficulty locating suitable controls given the length of most priority EDT reaches and limited monitoring funds further preclude a BACI monitoring design. Therefore, we will use a simple before-after design with monitoring immediately before restoration and three years after restoration or after adequate channel forming flows. Based on work being conducted on three large (>2 km long) floodplain pilot sites for the SRFB, adequate channel forming flows include a bankfull or higher flow for a minimum of 24 hours, or a five year or higher flow event for more than 1 hour. With this design, projects can be evaluated individually as well as collectively. Given that it is likely that it will take several years for the restoration projects in all 25 priority reaches to be implemented, this design is not dependent upon extensive spatial replication. However, a periodic roll up and analysis of all projects collectively to see if there are some common themes in what is working and what is not will greatly help with the adaptive management plan described below.

Monitoring Parameter and Metrics

The monitoring parameters need to be directly linked to the monitoring questions. Thus, we determined specific monitoring parameters, metrics, or indices that need to be calculated to answer each question (

Table **17**). For example, for question one, to determine floodplain and side channel complexity, we need to measure floodplain area and side channels. We also need to calculate metrics or indices on complexity and morphology like the RCI and MQI, and others that measure changes in complexity and connectivity. Similarly, monitoring of riparian areas consists of metrics that summarize and evaluate changes in vegetation cover, species composition, bank stability, organic matter inputs, and shade. These metrics were selected based, in part, on an extensive review of other monitoring programs and a recent review of floodplain monitoring methods, livestock exclusion, and pilot studies to test new methods (Roni et al. 2019a, 2019b, 2021; Krall et al. 2021)

Table 17. Monitoring questions and key parameter and metrics needed to answer each question. Related project-level design questions are in parentheses. RCI = river complexity index, MQI = morphological quality index, DEM = digital elevation model, HSI = habitat suitability index, GUT = geomorphic unit tool.

Monitoring Question	Parameter or Metric

1. Did the project increase floodplain and channel connectivity and complexity (e.g., RCI, MQI) at different flows (base, 2 year, and 10 year reoccurrence intervals)?	Floodplain area, floodplain inundation index, RCI, MQI, sinuosity, habitat diversity, width:depth ratio, side channel ratio, aggradation and degradation (comparison of DEMs)
2. Did the project increase the amount and quality of Redband Trout habitat including large wood, pool area, side channel metrics, and other habitat metrics?	Pool area, percent pool, habitat diversity (H), LW, functional LW, side channel area, length, and ratio
3. Did the project improve habitat suitability for Redband Trout in the project reach or segment?	HSI weighted usable area at base and bankfull flow for juvenile Redband Trout, juvenile Redband Trout capacity
4. Did the project meet its EDT based biological targets for juvenile Redband Trout capacity?	Juvenile Redband Trout capacity (maximum abundance) based habitat-based modeling
5. Did the project meet its specific physical and biological design objectives for each design component and treatment and at target flows? Which design elements were successful and unsuccessful and why or why not?	Aggradation and degradation (comparison of DEMs), change in fine-scale geomorphic units (GUT), HSI weighted usable area, based on goals of project, selected metrics from above
6. What is the riparian vegetation areal extent by vegetation class (e.g., grasses, forbs, shrubs, trees, etc.), species composition, and density and how much do they change over time? (floodplain and riparian projects)	Areal vegetation extent by class, riparian composition, richness, diversity, and density
7. Has riparian/floodplain restoration led to restored riparian function including shade and bank stabilization following riparian restoration? (floodplain and riparian)	Bank stability, shade
8. Is the fencing intact and continuing to exclude livestock from the riparian zone and stream channel? (riparian projects with livestock exclusion)	Percent of intact fencing and streambank without signs of livestock

Determining the appropriate monitoring protocol requires defining how each metric is calculated, the data that will need to be collected to calculate those metrics, and the method(s) needed to collect those data (Table 18). Many of these metrics are calculated using solely data obtained from remote sensing and many require some data collected from field surveys. The most common data need is bankfull width measurements for floodplain projects. However, assuming hydraulic modeling will be done as part of the design phase of floodplain and LWD projects, bankfull width can be estimated based on bankfull flow elevation generated during hydraulic modeling. As noted previously, which monitoring questions and protocols are applicable will depend upon the priority EDT reach and the restoration measures recommended (

Table 19).

Table 18. Floodplain and riparian metrics needed to answer monitoring questions and methods for calculating each metric. References provided where appropriate. F = field surveys, R = remote sensing, R* = requires hydraulic modeling using remote sensed data for topobathymetric data.

Metric	Calculation
Floodplain area	Floodprone area, which is determined using 2 times the average maximum bankfull depth. (R*)
Floodplain inundation index	Floodprone area divided by the mainstem wetted centerline length (R)
Side channel number, length, area, and ratio	Sum of the side channel wetted centerline lengths and areas (R) Sum of the side channel bankfull centerline lengths areas Sum of all the side channel bankfull centerline lengths divided by the mainstem bankfull centerline length (Beechie et al. 2017) (R)
Residual pool depth	Maximum pool depth minus the pool tail crest in pool habitats, averaged across a reach for pools that the thalweg runs through (Lisle 1987) (R or F)
Sinuosity	Divide the thalweg line length by the straight-line distance between the start and end points (i.e., top of site and bottom of site) of the thalweg (Rosgen 1994, 1996; Jones et al. 2015) (R)
River complexity index (RCI)	RCI = (S*(1 + J) / (reach length))*100, where S = sinuosity, J = # of side channel bankfull junctions, reach length = mainstem wetted centerline length (Brown 2002) (R)
Bankfull width to depth ratio	For each bankfull transect, divide the bankfull width by the maximum bankfull depth and average this ratio across transects within a reach (Rosgen 1996) (R)
Morphological quality index (MQI)	Extensive calculation using field data: confinement, sinuosity, anastomosing index, braiding index, mean bed slope, mean channel width, dominant bed sediment, and others (Rinaldi et al. 2013, 2017) (R)

Metric	Calculation
Pool area and percentage	Sum of pool habitat area, total pool area divided by total wetted area (R or F)
Habitat diversity	Shannon diversity index (H) of the channel units in the mainstem and side channels with habitat units delineated (Shannon 1948) (R & F)
Large wood	Count of jams and individual pieces from aerial imagery or LiDAR ((Richardson and Moskal 2016; Beechie et al. 2017; Roni et al. 2020b) (R)
Sediment deposition and storage	Create a DEM of Difference (DoD) for the years of interest and calculate the areas of deposition and storage (R)
Habitat suitability index (HSI)	Sum of weighted usable area (WUA) and normalized WUA by species and life stage based on hydraulic and HSI modeling (R*)
Riparian composition and density, richness, density, diversity	Ratio of number of lidar returns in understory height band to number in ground band. Similar for overstory (R, F) (Akay et al. 2012) Richness – count of unique species across all transects (F) Density – count of individual species across all transects, divided by the aggregated area of all transects (F) Diversity – Shannon's diversity index using species abundance data (Shannon 1948)
Bank stability	Measure of length of eroding bank (F)
Shading	Total insolation hours. Calculate using the GRASS r.Sun modules (R, F) (Greenberg et al. 2012)
Percent of intact fencing	Length of intact livestock exclusion fencing along both sides of stream that is functional divided and without signs of livestock within exclosure by total length of fencing (Crawford 2011)

Table 19. Monitoring protocol recommended for each priority EDT reach based on initial restoration recommended. While the Cedar 1 reach is listed for protection, there is a fish barrier that is a priority for replacement.

Protocol(s)	Reaches Applied to Based on Restoration Measures Proposed
Floodplain/LWD	Sanpoil 4G, Sanpoil 4C, Silver1, Cornstalk 5C, Hall 2B

Riparian	Hall 3, Stranger 7
Floodplain/LWD, Riparian	Sanpoil 2J, Sanpoil 2F, Sanpoil 1F, Lost 6, NF Hall 1B
Floodplain/LWD, Riparian, Livestock	Sanpoil 4B, Sanpoil 2I, Sanpoil 3C, Sanpoil 4A, Sanpoil 7D, Sanpoil 3D, Hall4
NA (Protection no restoration proposed)	LynxTrib2A, WF Hall 2, Cedar 1, Sanpoil 5E, Sanpoil 5C, Barnaby 1

Floodplain/LWD Protocols

Site layout

Site layout consists of delineating the top and bottom mainstem channel boundaries, which define the longitudinal extent of the site. For floodplain restoration sites, the upstream and downstream boundaries of the site should be delineated based on the proposed restoration plans. An additional length upstream and downstream of approximately 10 times the average bankfull width of the reach will be added to mark the top and bottom of the survey. The additional length above and below the project is needed to quantify any changes in habitat due to the restoration that might occur immediately upstream or downstream of the project footprint. Care should be taken to ensure the survey boundaries do not bisect a channel unit (e.g., do not split a pool unit with the boundary). All site visits following the initial survey will reoccupy the site boundaries (i.e., boundary locations to not change even if a channel unit is bisected during subsequent visits). The lateral survey extent for floodplain and LWD projects should include all of the floodplain. However, if the project is a LWD project designed to focus on improving instream structure and pool area it may not be necessary to survey the entire floodplain. The procedure for delineating the survey extent for riparian projects will include marking the upstream and downstream ends of the riparian treatment because additional length upstream and downstream of the project is not needed.

Topography and bathymetry

Floodplain and LWD projects rely on collecting topography and bathymetric data for the preliminary and final designs, hydraulic modeling to support the design and permitting, as well as for calculating many floodplain and habitat metrics for both before and after project implementation. This is typically done through acquisition of green LiDAR (topobathymetric LiDAR) or near-infrared LiDAR combined with a bathymetric survey with a real time kinematic (RTK) GPS, Total Station, sonar, or other methods for measuring depth and bathymetry. In general, for reaches less than 4 km in length, currently it may be less costly to collect near-infrared LiDAR with a drone and conduct a supplemental bathymetric survey than it is to collect green LiDAR with a fixed winged aircraft (Roni et al. 2020a). However, costs continue to change for LiDAR acquisition and the most cost-effective approach may change. In some cases, if existing near infrared LiDAR is available and little change has occurred since the data were collected, a supplemental field survey to collect in-channel topo-bathymetric data may suffice. This could then be stitched into previously collected LiDAR. Regardless, this data collection should be done as part of the design process to develop a digital elevation model (DEM) for hydraulic modeling and determining other design elements.

For post-treatment monitoring (year 3 or when high flow targets are achieved), similar data will need to be collected. Ideally, multiple sites could be done on the same LiDAR flight to be more cost-effective. This should be possible once a schedule for implementation of the highest priority projects is developed.

Channel and habitat survey

The approach for the channel and habitat survey will differ in intensity based on whether green LiDAR or red LiDAR is obtained. We first describe the approach assuming green LiDAR is acquired, we then describe additional bathymetric data needed if red LiDAR is collected. While green LiDAR allows for creation of a DEM and collection of detailed topographic and bathymetric data at a level not possible historically, it has not completely eliminated the need for field data. Supplemental field data is helpful in calculating many floodplain metrics, ground truthing elevations calculated from the LiDAR DEM, and is needed for hydraulic modeling and Habitat Suitability Index (HSI) calculations. To obtain the supplemental data, a field survey using an RTK GPS and a tablet with survey forms will be used to collect habitat unit boundaries, bankfull points, and side channel data.

While some geomorphic units can be calculated in the bankfull channel using the geomorphic unit tool (GUT; Bangen et al. 2017), these do not coincide with meso-habitat types that are indicators of fish-habitat quality (Roni et al. 2020b)[2]. Thus, characterization of habitat units at base flow (summer low-flow) will be conducted in the mainstem and flowing side channels as part of field surveys to accurately quantify fish habitats. Habitat units will be numbered and classified as pool, riffle, rapid, cascade, glide, or backwater (Hawkins et al. 1993), and recorded on a tablet with unit number and unit type. All habitat units within a reach will be delineated at the wetted edge in addition to across the bottom and top of the habitat units. These data will be used with the DEM to delineate the wetted edge and wetted area of each habitat unit at the surveyed flow. If a bar is present, additional habitat unit points (wetted edge) should be collected so the bar can be delineated in post-processing. In-channel habitat unit points should be collected for habitat units with complex boundaries (i.e., boundaries not perpendicular to channel orientation) for better delineating in post-processing. The top and bottom of all wetted or dry side channels will be delineated. For wetted side channels, where channel units greater than 10 m^2 can be delineated, then habitat units will be surveyed using the same procedures as described above for the main channel. Any other water features that are not connected to the mainstem will be delineated and classified as off channel habitats. Bankfull and wetted edge points will be collected using the RTK at 50 m intervals depending on site length beginning at the bottom of survey extent and continuing upstream along both stream margins to the top of the survey extent. Bankfull and wetted edge points will be collected using the RTK at 50 m intervals depending on site length beginning at the bottom of survey extent and continuing upstream along both stream margins to the top of the survey extent.

[2] Efforts are underway to modify GUT so that its outputs more closely resemble a fish-habitat survey. If these are successful, it may eliminate the need for a field survey of habitat units.

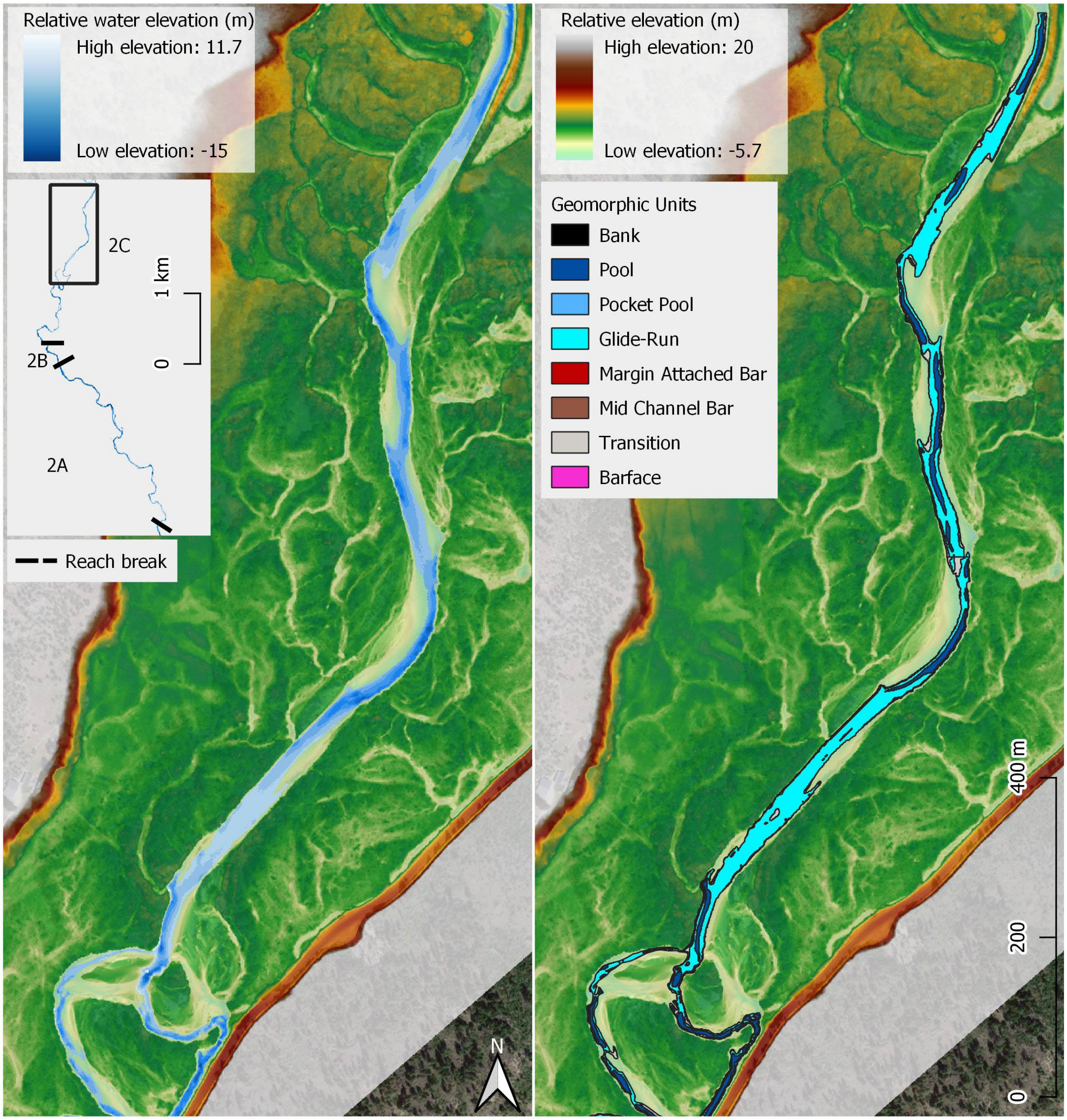

Figure 8. Example of topography and bathymetry from green LiDAR flown before restoration on the Entiat River (from Roni et al. 2020b) (Left Panel) and channel units based on the Geomorphic Unit Tool (GUT) analysis are displayed (Right Panel).

Data on substrate will be collected to assist with hydraulic and HSI modeling. The dominant (≥50%) and sub-dominant (<50%) substrate classes will be visually estimated within each habitat unit. Substrate will be assigned to categories of fines (<0.06 mm), sand (0.06–2 mm), gravel (2–64 mm), cobble (64–256 mm), small boulder (256–1,024 mm), large boulder (1,024–4,096 mm), bedrock (>4096 mm), or hardpan/clay.

Similarly, bank armoring, erosion, and riparian condition along the main channel are needed for calculating the Morphological Quality Index (MQI) and will be collected as part of the habitat and channel survey. The length (m) of eroding bank and length (m) of armored bank within each habitat unit will be visually estimated. In addition, any significant substrate embeddedness and bed armoring will be noted for each habitat unit as 'yes' or 'no', as well as the presence of a bed stability structure. Finally, any evidence of riparian vegetation removal within a habitat unit and along the banks will be noted as 'yes' or 'no'. Detailed riparian surveys to monitor riparian response are described below.

If red LiDAR is collected rather than green LiDAR, in addition to the above data, a bathymetric survey needs to be conducted while collecting habitat data so that a point cloud of the bathymetry can be created and meshed with the topography collected with red LiDAR. This may include using an RTK or other methods to conduct a longitudinal survey of the mainstem channel thalweg coupled with channel cross sections, and supplemental data points as necessary to capture inflections in bathymetry.

Large wood

Large wood jams and individual pieces within the bankfull channel and side channels will be identified using aerial imagery[3]. Imagery sources may range from the most current National Agriculture Imagery Program (NAIP) imagery, Google Satellite imagery, or imagery collected during site visits with a drone or during LiDAR flights. The imagery used needs to be collected at base flow to be consistent with topographic, bathymetric, and fish-habitat data collection. Jams and pieces will be enumerated within the site boundaries. Minimum discernable size will depend on the resolution of the imagery. Previous studies have reported a minimum diameter of 0.25 m and length of 2 m when using NAIP imagery (Roni et al. 2020b). In general, this method does not allow for exact counts of wood contribution for larger jams, therefore; large wood will be classified as small jams (3-4 pieces), large jams (>5 pieces) or individual pieces (1 or 2 pieces). Jams and pieces will be attributed as wet or dry based on having any visible contact with the water surface. All jams that encompass an area of > 50 m^2 will be delineated in GIS to calculate the total area of LW jams (e.g., Beechie et al. 2017). It is important that LW enumeration is done with aerial imagery from approximately base-flow. To ensure this, aerial imagery should also be collected during LiDAR flights. The acquired LiDAR can be used to enumerate in-channel wood obscured in aerial imagery by overhanging vegetation as well as on the floodplain (Richardson and Moskal 2016).

HSI modeling

A 2D hydraulic model will be developed using HEC-RAS (or similar 2D hydraulic modeling software) using the topobathymetry and selected data from the channel and habitat survey (Brunner 2016). Regardless of the methods used to collect and compile the topography and bathymetry, the final topobathymetric surface will include the entire floodplain and channel within the survey extent. The final topobathymetric surface will be the base surface for the hydraulic model and used to create a computational mesh covering as much of the valley bottom as possible. The river geometry including the channel centerline, banks, junctions, flow paths, and downstream and upstream boundaries will be created based on the topography.

[3] Few reaches in smaller streams (e.g., NF Hall Creek), where large wood in the active channel may be obscured by overhanging vegetation, supplemental field surveys may be needed.

The model will then be parameterized using data collected during the channel and habitat survey. Roughness values for the channel, banks, and floodplain will be informed by the dominant substrate of each habitat unit and estimated based on a range of typical values (Arcement and Schneider 1989; Yochum et al. 2014). The topographic mesh cell size will be set to 0.5–1 m, depending on quality of the topobathymetry. Steady flow model runs will be prepared for discharges that match biologically and geomorphically significant levels and seasonal timing. The model run for base flows will be based on the discharge measured during the field surveys. Discharges for the 2- (bankfull), 5-, and 10-year flow recurrence intervals will be estimated using local gauge data or based on regional regressions. Discharges for biologically significant model runs will be determined by site, depending on the periodicity of Redband Trout and, at a minimum, will cover mean discharge during rearing and spawning life stages (Figure 9).

The hydraulic model will contain values for water depth and velocity for each run and provide the basis for calculating the HSI. Habitat suitability curves (HSC) available in the literature express the preferences for water depth and velocity by species and life stage on a unitless scale of 0 (not suitable) to 1 (most suitable; Figure 9). Unless site-specific HSCs have been developed, the HSCs reported in Beecher et al. (2016), Maret et al. (2006), or others will be used. A suitability index for water depth and velocity will be calculated separately for every raster cell in the hydraulic model results. Then, depth and velocity suitability will be combined using the geometric mean, resulting in a final HSI value for every raster cell. As an option, substrate preferences may be added to this workflow if an appropriate HSC exists for the species and life stage in question. This process will be repeated for each steady flow model run.

Habitat suitability index results will be summarized graphically as histograms and maps to visualize the distribution of HSI values among each site and modeled discharge. To summarize HSI at the reach scale, weighted usable area (WUA) will be calculated as the sum of the product of HSI and cell area. WUA represents the amount of habitat that is available to a species during a given discharge (Kondolf et al. 2000; Hong et al. 2018). Normalized WUA (nWUA) is helpful to facilitate interpretation and compare discharges, reaches, and subsequent surveys. Normalized WUA is calculated as WUA divided by the total area evaluated.

Estimating juvenile Redband Trout capacity

While correlated with capacity, HSI values do not directly measure fish capacity. In addition, determining whether a project is meeting the capacity objectives as defined by EDT cannot be done by measuring fish numbers in the field for a number of reasons. These include the fact that it is unlikely that sites will be at capacity, it would take long term and costly before and after fish monitoring, low adult returns, and other factors that might influence spawner numbers. Moreover, capacity estimates based on EDT or other models are based on habitat conditions. Thus, the most tractable way to measure change in capacity is to use changes in habitat, which can be relatively

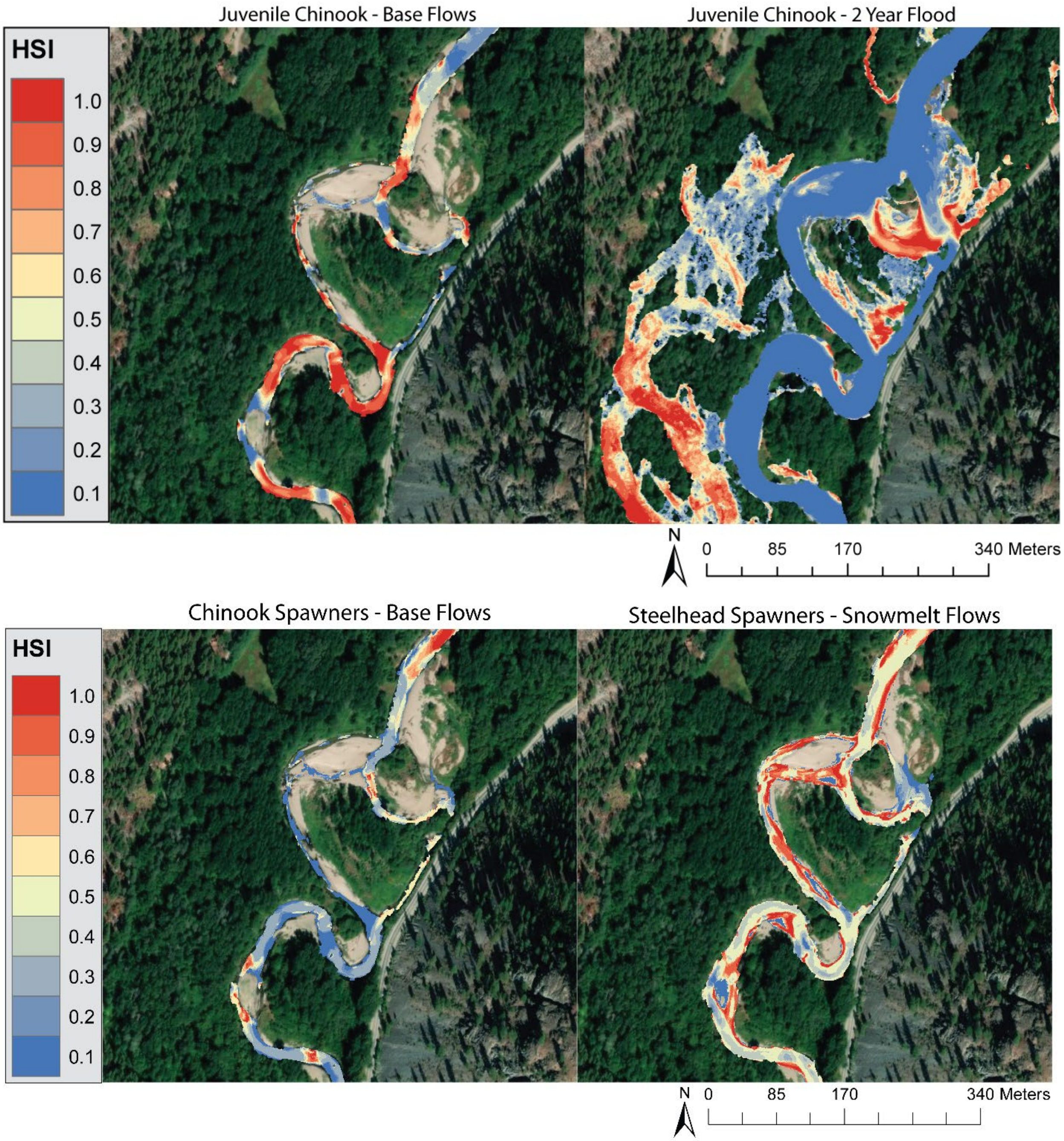

Figure 9. Example of HSI outputs and maps for different flows, species, and life stages for the Entiat River before restoration (Roni et al. 2020b).

easily measured using the previously described approaches, and then coupled with other types of fish-habitat models to estimate capacity. One approach would be to rerun the EDT model with post-restoration data periodically. However, this is not entirely feasible because it is costly to run and update the EDT model one site at a time. An approach is needed that can readily be updated for a particular site. Depending upon the funding and fish data available, there are a few recently developed approaches that could be applied (Cooper et al. 2020; Bond et al. 2021; See et al. 2021; Isaak et al. 2021). Less complex habitat-based capacity models that use simple changes in habitat to estimate capacity based on known densities of *O. mykiss* in different habitat types could also be used (e.g., Beechie et al. 1994; Cramer and Ackerman 2009; Roni and Timm 2016; Cooper et al. 2020). If further funding becomes available, we will determine which of these approaches might be most appropriate.

Riparian Monitoring Methods

The types of data required to monitor riparian projects are heavily influenced by the questions being investigated. Monitoring riparian response to floodplain or riparian restoration requires a combination of remotely sensed data (LiDAR data products) and field data. Field data is needed to both validate and verify remotely sensed estimates and to measure parameters necessary to calculate metrics that cannot be estimated from remotely sensed platforms (e.g., understory species composition). The point cloud associated with LiDAR data can be classified and analyzed to create several data products to calculate monitoring metrics such as canopy models, understory layers, and shade models, but does not eliminate the need for high quality field data to answer the key monitoring questions for this monitoring program. The canopy height model can be used to monitor tree growth and could be used to model future LW recruitment. In addition to topographic data (DEM) that will be obtained from the LiDAR, a digital surface model (DSM), as well as the point cloud itself (Figure 10) will be analyzed to help generate many of the riparian monitoring metrics. In general, most LiDAR vendors provide a classified point cloud along with a DEM and DSM, but these products should be considered required from the contractor or vendor for this study. Below we describe riparian field methods including initial site layout, which are based on and consistent with the recent U.S. Forest Service riparian monitoring guidance (Merritt et al. 2017), and those recently developed to monitor riparian projects as part of BPA's AEM Program (Roni et al. 2020c).

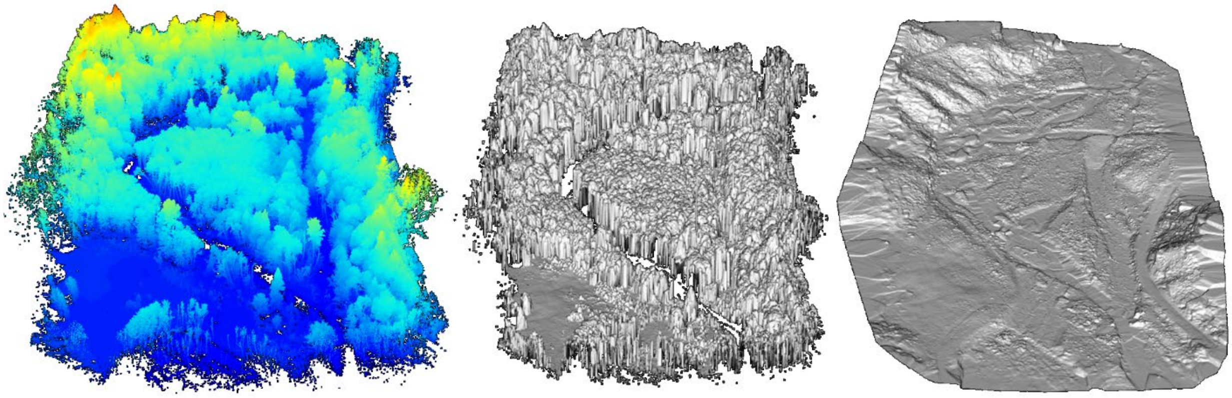

Figure 10. Example of point cloud (left) and digital surface model (DSM; middle) and digital elevation model (DEM) right from drone-based LiDAR flown on Morse Creek Washington in fall of 2019.

Riparian site layout and survey methods

The purpose of this survey is to (1) identify species, (2) provide validation data for remotely sensed metrics, and (3) record conditions relating to planting projects, such as evidence of browsing, or if planting protections are still functional (tree tubes, fencing). While we described delineation of the upstream and downstream location of site boundaries, additional detail on site layout for riparian monitoring is described in the following. Field sampling of riparian conditions at floodplain restoration sites or at floodplain and riparian only restoration sites will be done using a transect approach (Merritt et al. 2017). The sampling layout along a site consists of equally spaced 2-m wide transects every 100 m that extend from the active channel zone to the edge of the planting or riparian treatment or 30 m, whichever is greater, and are 90 degrees perpendicular to the stream channel at the location of each transect (

Figure **11**). Thirty meters was chosen as the extent of the transect because it is validation for the LiDAR and necessary for plant species and diversity data, and because many riparian plantings and other riparian treatments do not extend beyond this point. It also represents the extent of the riparian management zone for forest practices. For distances beyond 30 m, we are relying on the remote sensing. A meter tape will be strung down the middle of each transect allowing delineation of a 1 m-wide sampling area on each side of the meter tape. Sampling transects every 100 m will result in a minimum of 10 transects for a 1 km site. Additional transects can be added if the equally spaced transects do not cover the riparian treatment areas. The exact GPS coordinates of the transects will be recorded and benchmarks placed in the field to assist with relocated and sampling the exact same transects each year.

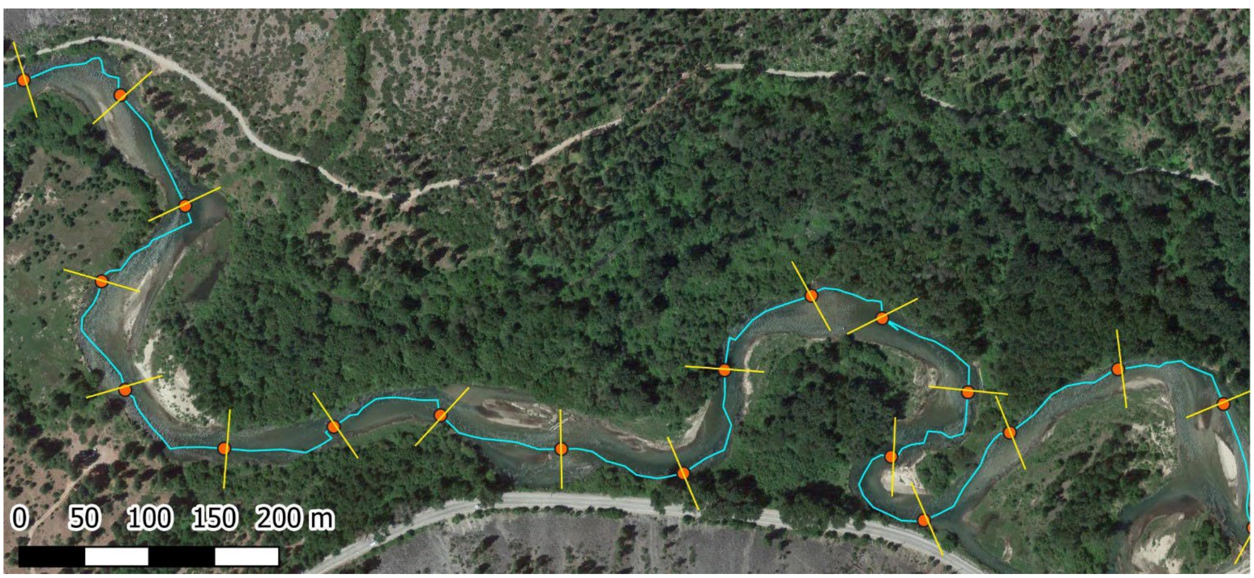

Figure 11. Example of site layout for riparian field surveys of a 2-kilometer long site (floodplain or riparian restoration) project. Transects will be spaced 100 m apart perpendicular to the flow and start at the edge of active channel and extend 30 m into the riparian treatment zone (plantings). Additional transects can be added if riparian treatments as part of floodplain restoration are not continuous and not intersected by 100 m transects and the same number of transects are surveyed before and after restoration at each site.

At each transect, all woody species (shrubs and trees) will be identified to species except for willows, which will be denoted as *Salix* spp. The location along the transect and the height of each woody plant specimen encountered will be recorded. Due to the complexities in identifying forbs and grasses, they will be assigned to a single category (forbs and grasses), and the continuous length they occupy along the meter tape will be recorded. Additional data on individual woody plant species will be collected as follows: bud browse (y/n), beaver damage (y/n), living or dead, and evidence of planting (e.g., planting tube, fence, tree marker).

Vegetation cover will be assessed in three different height categories using a line transect (meter tape located in the middle of the transect) following the line-intercept method (Elzinga et al. 2001). Cover estimates will be calculated along the transect by noting where along the tape the canopy of an individual plant begins and ends. Plant height categories include herbaceous (<1 m), shrub (1–5 m), and tree (>5 m). The length of the center line represented by bare earth will also be measured. Bare earth, logs, rocks, etc. must occupy more than 30 cm to be counted in the bare earth category.

While riparian shade will be calculated in part from remote sensing, some field data is useful to validate these estimates. Therefore, canopy cover (i.e., shading) will be measured using a convex spherical densiometer. The densiometer will be taped so that there is a "V" at the bottom with 17 grid intersections visible (Mulvey et al. 1992). Densiometer readings will be collected at the wetted edge of a stream and at the active channel boundary. At each point, four densiometer readings will be recorded: facing downstream, facing upstream, facing toward the center of the channel, and facing away from the main channel. The densiometer will be held 1 m above the water surface. The number of grid intersections covered by a tree, leaf, branch, or other vegetative shade providing feature will be recorded (0–17).

Multiple site characteristics will also be recorded during surveys for further analysis to elucidate why some plantings within and among projects are more successful than others. These characteristics include: (1) whether a planting plan was drafted and followed, (2) if ongoing maintenance has been taking place at the site (e.g., watering, soil augmentation), (3) the distance of the riparian restoration plot (site) from the active channel edge, and (4) the elevation from the stream bed surface to the floodplain or riparian planting site height (taken at the project midpoint). Additionally, for floodplain projects, the bankfull depth and incision (from floodplain monitoring) will be measured.

Areal vegetation extent by class

Areal extent of vegetation classes will be based on the methods developed by Akay et al. (2012). LiDAR returns between a minimum and maximum height (shrub height) will be enumerated and compared to the number of ground returns. More understory coverage will intercept more pulses, increasing the returns in the height band, and decreasing the number of ground returns, so this serves a relatively direct proxy for understory cover. A similar method will be used for measuring the overstory areal extent. Predicting the extent of the herbaceous layer is more difficult and will depend on site characteristics. Comparisons of LiDAR derived estimates to field based surveys will allow the LIDAR estimates to be calibrated and validated. Calculating this metric requires the point cloud and DEM data from LiDAR coupled with binned understory data and other field data to calibrate the LiDAR data.

Riparian composition and density

Riparian composition and density can only be reliably calculated using the field survey data. Species richness will be calculated as the sum of identified unique species, while density will be estimated by species counts divided by area of transects. Diversity will be calculated using Shannon's diversity index (Shannon 1948) and averaged across all transects. Additionally, there is potential to extrapolate values to unsampled areas using LiDAR data and machine learning techniques (Singh et al. 2015).

Bank stability

Coarse measures of bank stability and erosion can be done with remote sensing but can be unreliable under heavy riparian cover or too coarse for reach-scale monitoring (Longoni et al. 2016; Billah 2018). Therefore, to assess bank stability, field crews will measure and record the length of unstable banks at each transect.

Riparian shade

Riparian shade will be measured using the DEM and DSM to obtain vegetation height based on methods of Greenberg et al. (2012), which requires understory canopy height estimates from riparian transects. LiDAR data will be used to create surface models, and then 100 m stream buffers will be analyzed to estimate solar insulation using the r.Sun model (Hofierka and Suri 2002) incorporated into the GRASS geospatial software environment (GRASS Development Team 2017), which incorporates time of day, time of year, and atmospheric turbidity, and can model both clear sky and overcast conditions (Greenberg et al. 2012). Comparisons to bare earth model-based results can describe the impact and effect of riparian vegetation along the waterbody. The GRASS insolation workflow describes methods to estimate surface albedo and Linke atmospheric turbidity coefficients (Linke 1922), which are both required to run simulations.

Livestock fencing

For EDT reaches where fencing was used to exclude livestock, fencing needs to be checked and maintained on a regular basis to determine if it is continuing to exclude livestock from the riparian zone and stream channel. This should be done as part of the post-project riparian field monitoring and includes a surveyor walking the length of the fencing and noting any damage to the exclosure itself (fence) and signs of livestock presence (i.e., livestock, tracks, hair, feces) within the exclosure. The length of fence that is damaged or not intact and the length of the streambank with signs of livestock will be measured (Crawford 2011). Recent signs of livestock presence needs to be carefully assessed to distinguish among deer, elk, or other wildlife signs and domestic livestock.

Analyses and Reporting

Analysis of the monitoring data to detect change will occur at two levels: project level and across projects. First, because the focus of the monitoring design is at the project level and it is likely that only a few projects or priority EDT reaches can be restored each year, analyses will include evaluating the difference in metric values before and after restoration at an individual project. The change in each metric will be quantified and relativized (i.e., percent change) to help determine the effectiveness of projects. Some metrics will likely see immediate changes due to restoration treatments (e.g., large wood, side channel area), while some may take several years before a change can be seen or detected (e.g., increased shading from riparian planting). Others will depend on a large disturbance event taking place before changes can be detected (e.g., changes in sinuosity post flood).

Evaluating whether a project meets its design objectives is not as straightforward as traditional monitoring analysis, and requires detailed information on the project design, goals, and objectives as well as detailed "as-built" survey data. Previous programmatic effectiveness monitoring programs were designed to provide general recommendations on project design (e.g., most successful projects had more pool forming wood; Roni and Quinn 2001; Roni et al. 2018; Clark et al. 2019). Fortunately, for the proposed study, the pre-project topographic and bathymetric data and hydraulic and HSI models, combined with information from the aggradation and degradation and outputs from the GUT can be used to understand why certain actions (e.g., logjams, side channels, levee removal, meanders) did or did not result in the desired changes in scour, deposition, and habitat formation. This information can be used to provide detailed information on restoration design not previously examined in SRFB PE monitoring, and one of the main reasons that "as-built" surveys are needed once restoration has been completed.

Changes will be reported and analyzed both in tabular form as well as diagrams and figures that demonstrate changes over time as more data points are collected (

Table **20**; Figure 12). Metrics with continuous spatial representation (e.g., topography, bathymetry, solar insolation, cover class) derived from remote sensing will be displayed analogously to a DEM of Difference (DoD), where a new surface layer is created that represents the difference in metrics at that site. Compared to aggregated metrics (e.g., total insolation, aggradation, degradation), this provides a more granular summary of changes, highlights spatial patterns, and can help to understand the extent of effects.

Table 20. Example of tabular presentation of six floodplain restoration sites monitored before and after restoration. These sites were approximately 0.5 km in length and are being monitored as part of BPA's AEM Program but provide a simple example of tabular summaries for a subset of floodplain monitoring metrics. RCI = river complexity index, LW = large wood. Yr -1 = before restoration, Yr +1 or Yr +3 year of post-restoration monitoring.

Site name	Year	Pool:Riffle Ratio	Slow Water (%)	Residual Pool Depth (m)	Habitat Diversity (H)	RCI	LW
Hartsock	Yr -1	1.33	40	0.26	1.31	0.44	15.2
	Yr +1	0.86	40	0.32	1.24	1.62	73.8
Touchet	Yr -1	0.25	46	0.18	0.96	0.64	0.5
	Yr +3	0.60	39	0.29	1.08	0.65	15.4
Southern Cross	Yr -1	0.40	48	0.29	1.03	0.40	0.7
	Yr +3	1.00	72	0.62	1.10	0.40	110.9
Tucannon	Yr -1	1.00	31	0.58	1.37	3.22	75.3
	Yr +3	1.6	42	0.42	1.51	2.61	143.5
Pine	Yr -1	2.33	77	0.50	1.03	1.34	26.2
	Yr +3	2.33	82	0.53	1.23	1.41	203.7
Caribou	Yr -1	1.60	78	0.53	0.88	0.63	0.8
	Yr +1	2.67	90	0.65	1.16	1.25	31.1

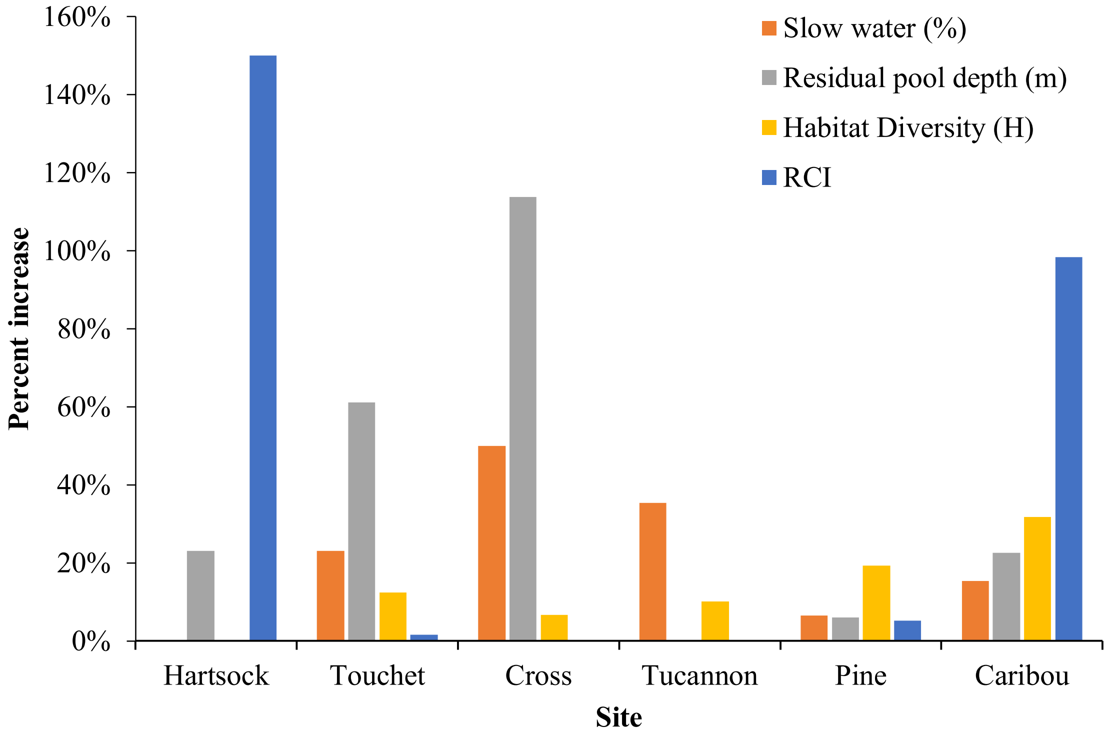

Figure 12. Example of simple graphical presentation of change of a sub-set of monitoring metrics for six floodplain restoration projects before and after restoration.

Second, because similar protocols will be used at each project, a combined analysis examining multiple projects can be conducted after several projects have been implemented and before and after data collected. A mixed-effects model could be used to collectively analyze floodplain and LW projects (Downes et al. 2002; Schwarz 2015). Other approaches (Bayesian, repeated-measures, boosted regression trees) are also potential methods for analyzing the data, but the mixed-effects model is considered the most robust method for analyzing data collected using BACI and BA designs (Downes et al. 2002; Schwarz 2015). Sample size can influence the ability to detect changes, but evaluation of smaller floodplain projects (<1 km in length) have shown differences due to restoration with a sample size of only six sites, assuming responses are relatively large (>50% change).

In terms of reporting, an annual report outlining the methods, sites sampled, and results will be prepared. When data on more than five projects (restored priority EDT reaches) have been completed, a combined analysis will be conducted and reported.

Potential Challenges and Contingencies

There are three major challenges for the effectiveness monitoring we have outlined. First, is the lack of funding to complete the monitoring program. Currently, monitoring is not funded as part of the Lake Roosevelt Habitat Improvement Project. Thus, whether the conceptual monitoring plan outlined above or some variation of it is implemented, is dependent upon adequate funding. Much of the pre-project data can be collected as part of the design phase, but post-project data collection will require dedicated funding.

Second, the pace at which the restoration occurs will determine how quickly results will be available as well as the annual costs of the monitoring plan. Table 21 below outlines a hypothetical monitoring schedule that could be modified once a better idea of an implementation scheduled is developed. It is possible that post-treatment monitoring could be staggered so that multiple restoration projects (EDT reaches) could be evaluated simultaneously. Moreover, grouping nearby reaches together for design, implementation, and monitoring should be considered as a cost-savings strategy.

In addition, the monitoring outlined relies on some of the latest remote sensing technologies, which work well on medium to large streams or on small streams where there is not dense forest or overhanging vegetation. This includes the vast majority of priority EDT reaches. However, for a few priority reaches, such as Silver 1, where the stream is very small and vegetation dense, a simple long profile habitat survey without the topography and bathymetry based on field or remote sensing may be adequate (Clark et al. 2019). This can be determined during the restoration design process. There are also two reaches in which there might potentially be sediment delivery from roads (Barnaby 1 and Silver 1). If this is the case, some additional field monitoring might be needed (e.g., pebble counts, fine sediment sampling). Modifications to the methods can be determined during the project design phase.

Finally, the approach we outline is designed to detect relatively large changes in physical habitat (>25%) and if small sections of stream (a few hundred meters) are treated within a lengthy reach, detecting changes will be difficult. However, even very robust monitoring programs using a BACI, multiple BACI, or other design typically can't detect significant changes of less than 25% in in physical and biological metrics (Smokorowski and Randall 2017; Roni et al. 2018). Moreover, it is expected that the majority of each reach will be restored and most reaches are multiple kilometers in length (Table 14). Thus, the proposed restoration treatments within a reach are lengthy and the physical response is expected to be easily detected. Our approach does not exclude the possibility of a BACI study in specific reaches, particularly in the Sanpoil where many priority reaches are several kilometers in length and a portion of a reach could be set aside as a control. Suitable control reaches need to be of similar channel type, gradient confinement, land use, riparian condition, and flow to the treatment (impact) reach. For example, for priority EDT reach 4G, reaches EDT 5A and 4F both appear to have similar characteristics to priority EDT reach 4G, and one of could be possible control reaches. As with design of any BACI study, site visits are needed to confirm selection of any control reaches.

Table 21. Examples of monitoring scheduled for a subset of priority EDT reaches for demonstration purposes. The schedule for restoration is approximate and will be modified as a more detailed implementation schedule and funding allow. Schedule A assumes project implementation (Imp) is staggered one per year and post-treatment monitoring (Post) occurs in year 3 after implementation (Imp). Pre-restoration monitoring (Pre) occurs one year before implementation in all scenarios, though it could be earlier if needed or implementation is delayed. Schedule B assumes multiple projects implemented each year, and Schedule C assumes all post treatment would occur in one year for a group of projects. Schedule C would mean projects received post-treatment monitoring at different times after restoration, but all in same year.

Schedule A

Priority Reach	2022	2023	2024	2025	2026	2027	2028	2029	2030	2021	2032
Sanpoil 4B	Pre	Imp.			Post						
Lost 6		Pre	Imp.			Post					
Sanpoil 7D			Pre	Imp.			Post				
Cornstalk 5C				Pre	Imp.			Post			
Sanpoil4A					Pre	Imp.			Post		
Sanpoil 5C						Pre	Imp.			Post	
Sanpoil 3D							Pre	Imp.			Post

Schedule B

Priority Reach	2022	2023	2024	2025	2026	2027	2028	2029	2030	2021	2032
Sanpoil 4B	Pre	Imp.			Post						
Lost 6	Pre	Imp.			Post						
Sanpoil 7D		Pre	Imp.			Post					
Cornstalk 5C		Pre	Imp.			Post					
Sanpoil4A			Pre	Imp.			Post				
Sanpoil 5C			Pre	Imp.			Post				
Sanpoil 3D			Pre	Imp.			Post				

Schedule C

Priority Reach	2022	2023	2024	2025	2026	2027	2028	2029	2030	2021	2032
Sanpoil 4B	Pre	Imp.					Post				
Lost 6	Pre	Imp.					Post				
Sanpoil 7D		Pre	Imp.				Post				
Cornstalk 5C		Pre	Imp.				Post				
Sanpoil4A			Pre	Imp.			Post				
Sanpoil 5C			Pre	Imp.			Post				
Sanpoil 3D			Pre	Imp.			Post				

Approximate Costs

The costs of the monitoring depend upon multiple factors including the length and area of the EDT reach to be restored, the number of priority reaches restored each year, the post-treatment monitoring schedule, type of restoration techniques implemented, and the cost of collecting data. Below we provide estimates for data collection for different protocols (floodplain, riparian) per kilometer assuming topographic data are collected with a drone-based LiDAR and bathymetric data with a field survey.

Table 22. Approximate cost for monitoring data collection. We assumed data collection for drone-based LiDAR would take 1.5 days (planning and field), bathymetric/habitat survey 3-4 days per kilometer and riparian field survey 2-3 days per kilometer. Amount of time needed could be less or more depending upon complexity of site and amount of vegetation.

Data Collection	Methods	Cost	Notes
Topography	Drone-based LiDAR	$6,000	Fixed cost for up to 3 kilometers, includes processing LiDAR
Bathymetry/Habitat	Field survey	$10,500	Per kilometer of stream
Riparian	Field survey	$4,500	Per kilometer of stream
Total	----	$21,000	

This does not include analysis and reporting, which would become more efficient or cost effective if multiple sites are done per year, but it should be assumed to cost $10,000 to $25,000 per year, depending upon the number of sites. If green LiDAR were collected with a fixed wing aircraft (currently it cannot be collected with a drone), the bathymetric field survey would be greatly reduced, but currently green LiDAR starts at approximately $30,000 for even the shortest reach. Thus, green LiDAR would likely only be feasible if several reaches were flown at once or a reach of more than four kilometers needs to be flown. As LiDAR and other remote sensing data become more commonplace, the cost is expected to decrease in the next 5 years.

Adaptive Management

A key challenge for any restoration or conservation program is an adaptive management process that involves planning, doing, evaluating, learning, and ultimately adjusting restoration design and implementation. The Independent Scientific Review Panel of the Northwest Power Conservation Council has noted the need for an adaptive management program in their categorical reviews of most resident and anadromous fish projects (ISRP 2017, 2020; White et al 2021). In regard to the LRHIP, the ISRP (2020) specifically asked the following questions related to adaptive management:

"Does the project have an explicit adaptive management plan? Is there an annual schedule for evaluating project actions and making decisions about actions for the coming year and adjustments to the project plans? Are the decisions documented and archived for future reference?"

The adaptive management process can be very complicated in large basins or areas with multiple entities conducting monitoring. In the case of the Upper Columbia and Sanpoil, while there has been some monitoring historically (see Table 2), the ongoing monitoring is relatively limited to occasional smolt trapping and adult surveys in the Sanpoil. This makes the adaptive management process more straightforward, but the lack of current habitat monitoring emphasizes the need for implementing an effectiveness monitoring program. To ensure that the Upper Columbia and Sanpoil Restoration Plan is adaptively managed to ensure that the latest science and lessons learned from within the program and elsewhere are used to improve restoration success, we developed an adaptive management process (Figure 13). The first step in this process, the "plan phase", has been outlined in the previous sections of this document. This included defining the goals and objectives, identifying and prioritizing actions, and describing the monitoring program to support implementation and adaptive management.

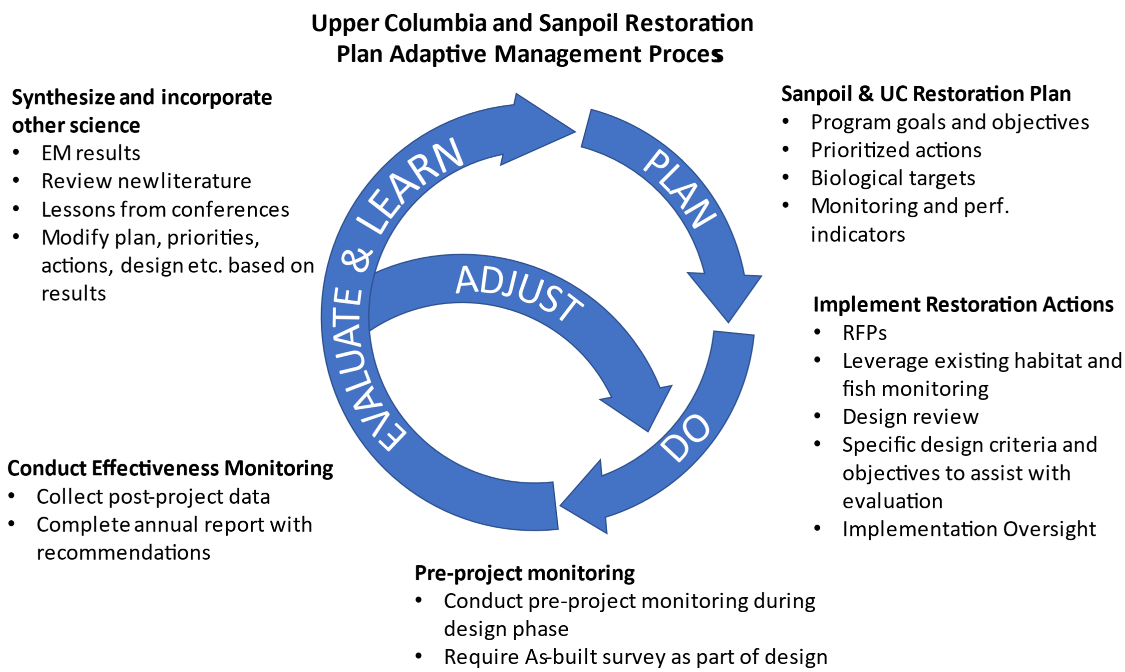

Figure 13. Diagram of adaptive management process for the Upper Columbia and Sanpoil Restoration Plan including key steps at each of the major steps. Wheel diagram based on Bouwes et al. (2016).

The "do" phase of this adaptive management plan is largely to design and implement the restoration in the priority reaches and collect pre-project monitoring data. Other restoration programs like the Upper Columbia Salmon Recovery Board or Grande Ronde Model Watershed have detailed design review processes at key stages (conceptual, preliminary, and final). A similar multi-stage review process for the Sanpoil and Upper Columbia will be developed to ensure the latest science and adequate input from stakeholders is incorporated into the design. The number of stakeholders for the Upper Columbia and Sanpoil is likely much smaller than other larger restoration plans or programs, so may require fewer steps than ones being used for larger restoration programs.

The evaluate and learn phase will include the collection and analysis of data from the effectiveness monitoring described earlier in this section and a synthesis of the latest science. Ideally, this will be accomplished by an annual synthesis report or memo prepared by the CCT Project Manager summarizing key findings from multiple sources, including but not limited to:

- Results of the Upper Columbia and Sanpoil Effectiveness Monitoring
- Review of new scientific literature on restoration
- Results from the regional science conferences (Lake Roosevelt, Upper Columbia, River Restoration Northwest)

Strong leadership of the adaptive management process is critical to ensure the latest monitoring results and science are used to revisit restoration priorities, objectives, and on the ground design (Allen and Gunderson 2011). Therefore, assuming adequate funding is obtained from BPA for the monitoring and adaptive management, the Project Manager or another staff will be assigned to lead the adaptive management. The Adaptive Management Lead will: 1) develop an annual or periodic review schedule for adaptive management, 2) ensure annual reporting of monitoring results, 3) prepare a memo documenting salient results from both monitoring and science that warrant modification (adaptive management) of the restoration plan (priorities, objectives, design), 4) determine whether revisions to the plan are needed, and 5) coordinate appropriate review and input of these products from stakeholders. To that end, if funding from BPA or elsewhere becomes available, the prioritization strategy developed and described previously in this document is such that it can be modified, and priority reaches can easily be reranked as new information and data become available.

Successful adaptive management processes are the exception rather than the rule and few examples at a basin-scale truly exist or have been undertaken (Allen and Gunderson 2011). Key reasons for failure of adaptive management include lack of stakeholder engagement, procrastination in the application of science, and risk averse leadership (Allen and Gunderson 2011). Moreover, the larger the area and the more complex the ownership and stakeholders involved, the more difficult adaptive management becomes. Fortunately, the LRHIP and the Upper Columbia and Sanpoil Restoration Plan has some unique features that increase the likelihood of successfully implementing an effective adaptive management process. First, most of the restoration actions are within the boundaries of the CCT Reservation and there are a limited number of stakeholders on the few priority reaches outside of the Reservation (e.g., USFS, DNR). Second, relative to some larger adaptive management processes for restoration projects like the Everglades, Colorado River, and even Upper Columbia Salmon Recovery Board, the geographic area is limited to the Sanpoil and a few upper Columbia River tributaries. Moreover, CCT is not averse to trying new and innovative restoration techniques or incorporating the latest science, and the small number of decision makers will allow changes in the priorities and design of projects to be applied relatively quickly.

The potential challenges, which were outlined in the monitoring section above, are lack of funding for monitoring and adaptive management and the length of time over which the restoration may occur. The latter means that even with adequate funding, the results of effectiveness monitoring may be slow in arriving. However, the restoration measures planned for implementation are common throughout the Pacific Northwest, and part of the adaptive management process is bringing in results from research, monitoring, and evaluation occurring elsewhere in the Columbia

Basin. For example, valley bottom restoration, sometimes called stage 0 restoration, has become quite common since the first draft of the Upper Columbia and Sanpoil Habitat Restoration Plan was developed in 2017 (e.g., Powers et al. 2018; Wohl et al. 2021). It is likely that several priority reaches for restoration are candidates for this type of restoration and this will be considered during the design process.

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Appendix A. Aligning pour points with modeled stream networks to calculate upslope contributing watersheds

One of the most crucial steps in defining the geography of EDTsheds is aligning and placing the EDT reach node points onto the hydrologic modeled stream grid at the correct location. It is also one of the most difficult to accomplish without substantial effort to manually fix errors that result from imposing dissimilar data structures into a single spatial analysis approach. Given the large number of EDTsheds (more than 700) in the Upper Columbia and Sanpoil study area, we developed an automated approach to address these spatial errors and reliably determine the upslope contributing watershed areas draining to each pour point. By definition, digital elevation models (DEM) are raster datasets (collections of elevation values organized in a gridded matrix). Computations performed on raster datasets proceed in a systematic, cell-by-cell fashion. The pour point of a DEM represents the location where drainage from all upslope grid cells collects. As a result, it is imperative that the correct cell within the raster is selected to determine what upslope area is included in the EDTshed for that reach. If the pour point is placed a single cell off of the stream network, it will result in an erroneously small EDTshed that does not follow the stream channel (A). Pour points located near confluences are also highly sensitive. If the pour point is located at or below the confluence, the upslope areas of both stream channels will be considered the same EDTshed (B). Placing the point just upstream of the confluence will limit the EDTshed to only one of the channel's upslope areas (C1 or C2) (Figure A-1).

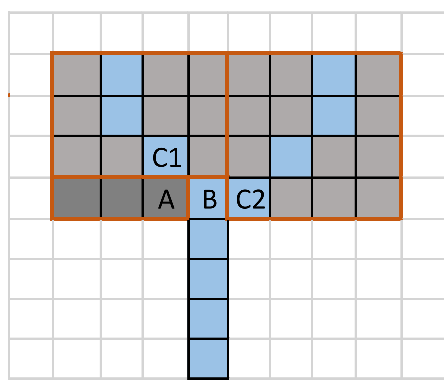


Figure A-1. Graphical representation of the steps necessary to avoid errors when using pour point (B) to determine EDTsheds for reaches C1 and C2. Pour point B needs to be moved upstream 1 grid cell in order to avoid miscalculation of both EDTsheds.

Because downstream nodes uniquely determine the areas draining EDTsheds, additional considerations are required if an individual node is used to define multiple reaches. By definition, the EDTshed for this node would include both reaches. To ensure that both reaches are represented separately, we must "split" the node into multiple pour points, each located just upstream of the confluence. The full process for aligning pour points onto a raster stream network are as follows:

1. Move nodes to the nearest hydrologically modeled stream cell.

2. Create a raster of stream neighbor cells (the number of cells out of the eight neighbor cells that are part of the stream network).

3. Normalize raster from step 1 (values range from 0-1).

4. Add raster from step 2 to raster from step 3, to create a combined flow-rank metric. This combined metric uses flow values to rank cells with identical number of neighbors. Using this metric, an additional neighbor always outranks flow value, but higher flow values are given a greater score for cells with equal number of neighbors.

5. Separate reach points that serve as down nodes for multiple reaches. These need additional pour points added.

6. Using the "snap" tool, move each pour point to the cell with highest combined metric score within a prescribed distance (for example 50 meters).

7. Create additional pour points for reach points that serve as down nodes for multiple reaches. For each pour point, compare the rank-flow metric to all neighboring cells. If a neighboring cell has a lower value, reassign it as a pour point. For each pour point, locate any neighbor cells that have a lower flow value, and mark these as the new pour points. This creates two pour points, each upstream from the confluence (Figure A-2, panel A green cells). If only one point is selected, choose the neighbor cell with smallest rank flow metric value greater than the current pour point by at least a certain threshold (1000 used) as an additional pour point. This catches situations where the confluence is placed on the tributary side of the stream instead of the main channel (Figure A-2, panel B).

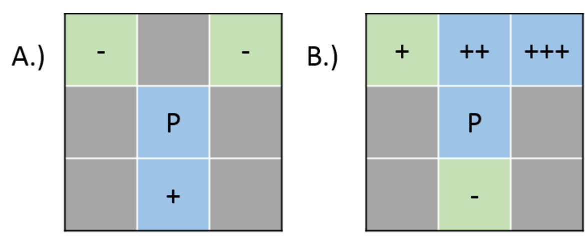


Figure A-2. New pour points (green cells) determined from the original pour point (P). Panel A shows the case where there are two neighboring cells with lower flow values (indicated by "-", and increasing flow accumulation indicated by plus symbols). Panel B shows the case where only one neighboring cell is of a lower flow value.

8. Merge the newly created pour points with those that serve as unique downnodes.

9. Delineate catchment areas using the adjusted pour points to create EDTsheds.

10. Lastly, manual inspection and correction is needed to adjust EDTsheds that were not correctly located. These errors arise from a variety of possible issues including stream network and reach line mismatches, insufficient snapping distances, or multiple confluences occurring within the snapping distance.

Appendix B. Site Visit Summaries

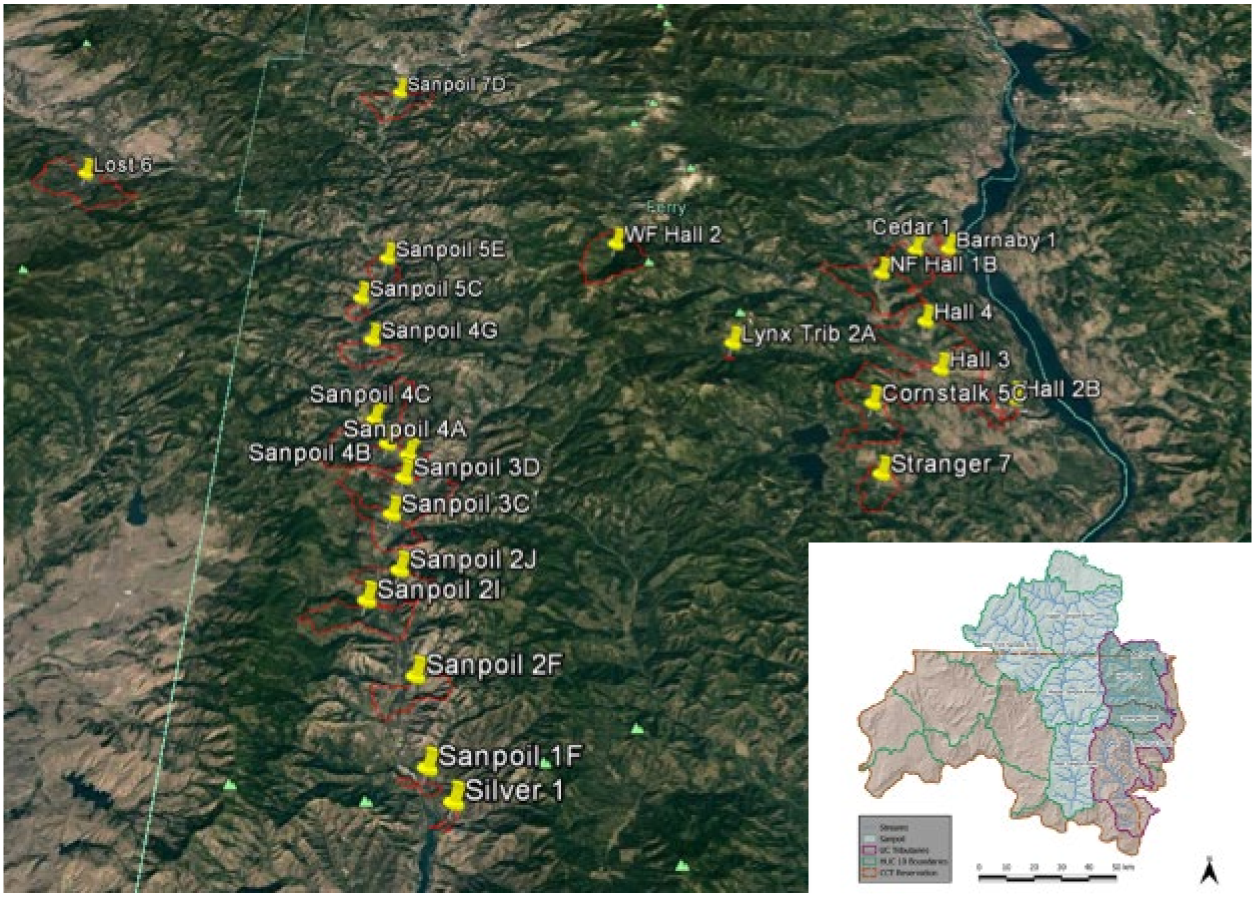


Figure B-1. Overview map showing the location of each of the 25 priority reaches evaluated for restoration actions. Inset map presents context of the Sanpoil River drainage as well as the Upper Columbia River tributaries relative to the Confederated Colville Tribal reservation lands.

Project Name: Upper Columbia and Sanpoil Restoration **Project Rank 1**

Reach Name: Sanpoil 4B

Figure B-2. Overview image of Sanpoil 4B reach taken from Google Earth. Red lines represent the boundaries of the reach and lands draining to the reach.

Figure B-3. Representative panoramic photo of Sanpoil 4B reach showing multi-thread channel, LWD and gravel stored in the channel resulting from large floods (discharge estimates exceed 12,500 cfs) during April 2017 rain-on-snow event. Discharge during this photo was approximately 125 cfs.

Location and Site Description: Sanpoil 4B drains an upslope area approximately 5.2 km^2 and is approximately 40.3 km from the confluence with the Columbia River. The Sanpoil is a meandering river here, approximately 3,100 m long. The bankfull width is approximately 20 m, and the floodplain width is 270 m. Average channel gradient is 0.1%. This reach was heavily altered by the April 2017 flood that caused dramatic changes in channel geomorphology, sediment, and LWD loads. The reach is recovering from the 2014 Devil's Elbow fire and exhibits decent mixed conifer and deciduous forest cover, even though much of the surrounding landscape was burned. In addition, the reach is currently processing a heavy sediment load resulting from the April 2017 flood. Thus, throughout the reach the channel is multi-thread with some log jams and associated pool habitats. There are two bridges associated with State Highway 21. The upper bridge is approximately 0.7 river kilometers from the top of the reach and the lower bridge is approximately the same distance from the bottom of the reach. In addition, there are gravel roads along the edge of the valley on both sides that afford excellent access to the river for staging, except where the mountains impinge on the valley floor and the road. In those locations, the road elevation is quite high compared to the river. Even though there are some large pieces of wood in the channel, with small jams racked up on them, overall, the channel could use more. It is likely that standing dead timber from the recent fires will be recruited to the channel in the near future. Many of the existing single pieces of LWD in the channel are too far apart to create any large pools or provide much cover for holding or rearing fish. In addition, the recent burn and the grazing practices have left the riparian zone in a relatively degraded condition.

Given the highly dynamic channel and potential for new LWD recruitment, we recommend that the focus in this reach be on protection—which should include riparian planting and livestock fencing. Additions of LWD and engineered log jams (ELJs) may also be important to encourage the river to engage floodplain habitats and to direct flows under the highway bridges as the sediment slug continues to move through this reach. These newly formed complex habitats should directly influence the hydraulic complexity that likely increases hyporheic exchange—which can provide local thermal refugia during both summer and winter months.

Revised Restoration Objectives:

Protection, riparian restoration, livestock exclusion, LWD, possible ELJs.

Preliminary Restoration Assessment:

LWD, riparian restoration.

Special Considerations:

The floodplain on the west side of the river exhibits livestock grazing in the riparian zone. Some fencing, as well as possible alternative water resource development, could decrease the livestock impacts to the riparian zone. On the east side of the valley, the recent burn history in the EDTshed is largely outside of the riparian zone. It is likely that standing dead timber will be recruited to the channel as lateral channel migration results from the river processing the large sediment load in the reach. In addition, there are two bridges in the reach on State Highway 21 that should be considered in plans for LWD and/or ELJ installations.

Species and Life Stage Benefit:

Pre-spawn adult fish, 0-age resident rearing, and 1-age over wintering.

Prioritization Criteria Considered:

- Protects fully functioning habitat, restores riparian and instream habitat.
- Access is generally good, although variable depending on specific location.
- Land ownership is unknown.
- Relatively high Culturally Significant Resources score and provides benefits by potentially restoring first foods.

- There may be Climate Change Amelioration benefits by restoring the riparian zone, instream habitat diversity, and floodplain wetlands.

Data Gaps/ Needs:

Specific landowner information such as ownership as well as willingness to participate in livestock fencing and riparian plantings needs to be gathered.

Project Name: Upper Columbia and Sanpoil Restoration **Project Rank 2**

Reach Name: Lost 6

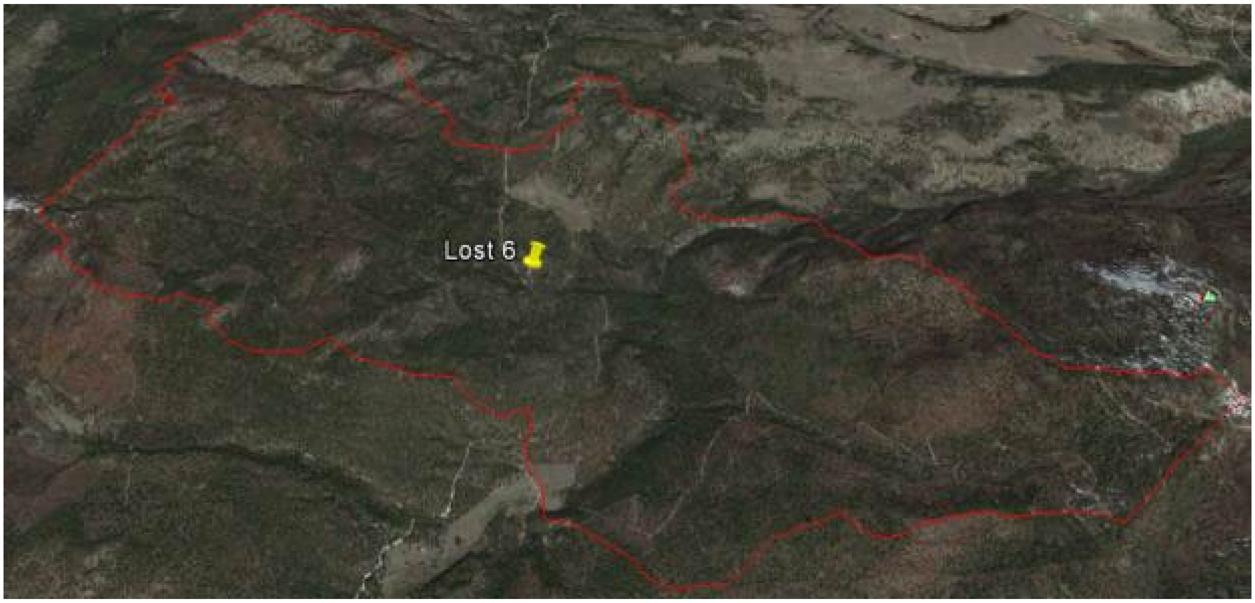


Figure B-4. Overview of Lost 6 reach. This reach is in the headwaters of the West Fork Sanpoil. Red lines indicate the boundary of upslope lands draining to the reach.

Figure B-5. Classic examples of grazing impacts at the top of Lost 6 reach. Left panel shows a failing fence and path where cattle access the stream. Right panel shows an over steepened, failing bank.

Figure B-6. Channel spanning log jam (left panel) and reach with high natural LWD loads in Lost 6 reach. This reach should be used to determine restoration targets for the rest of the reach, and other similar sized streams in the study.

Location and Site Description: Lost 6 drains approximately 21 km^2 and is approximately 90 km upstream of the confluence with the Columbia River. The priority reach is approximately 7,400 m long (Figure B-4). It is characterized by braided, confined, meandering, and straight channel morphologies. Bankfull width is approximately 9 m, while floodplain width varies between approximately 15 m and 160 m. Average channel gradient varies with channel type and ranges between approximately 1% and 3%. Livestock grazing is a known issue in this reach (Figure B-5). This reach is outside the CCT Reservation and is a mix of private lands and U.S. Forest Service lands. The reach is long and exhibits a range of habitat quality. It is generally in very good condition but lacks LWD for most of its length. There are some exceptionally high-quality areas in this stream that provide useful restoration targets for LWD loads and habitat diversity (Figure B-6). The lower 1.7 km of the reach is in a canyon and exhibit a single-thread channel form typical of confined high-gradient streams. The upper 6 km of the reach meanders across a broader forested valley floor. The top of the reach has several large channel-spanning jams (Figure B-6) that occur in the upper 1.5 km. This upper reach is very high quality habitat and could be used to generate restoration targets for other areas of the Lost 6 reach and possibly for all other similar-sized streams in the study.

Revised Restoration:

Protection, livestock exclusion, LWD.

Preliminary Restoration Assessment:

Protection.

Special Considerations:

There is a willing landowner at the very top of the reach with excellent access and staging potential. Forest Service roads exist elsewhere along the creek but are frequently behind locked gates. There is also excellent staging and access at the very bottom of the reach at an abandoned ranch. Land ownership and landowner willingness are unknown at the homestead. This reach is generally very high to high quality habitat at a fairly high elevation. LWD loads are variable in the reach, and some areas would benefit from having more. Forest cover is high in the riparian zone and the stream is generally unaffected by anthropogenic problems, except for some obvious grazing impacts in places.

Species and Life Stage Benefit:

Spawning fish, egg incubation, and holding for pre-spawn fish.

Prioritization Criteria Addressed

- Restores riparian process and instream habitat and protects fully functioning habitat.
- There is great access to this reach on U.S. Forest Service lands due to a logging road network that runs throughout the EDTshed. In addition, Jeff Creasy owns land on both sides of the stream at the very top of the reach and said he would potentially be willing to participate in restoration activities.
- Land ownership has been verified.
- Relatively high Culturally Significant Resources score.
- There are likely moderate additional Climate Change Amelioration benefits to this project through reduced temperature and improved habitat complexity.

Data Gaps/ Needs:

Livestock grazing plan details need to be confirmed with the U.S. Forest Service for this area to ensure that the plan to prevent over grazing the understory in the riparian zone is being followed.

Project Name: Upper Columbia and Sanpoil Restoration **Project Rank 3**

Reach Name: Sanpoil 7D

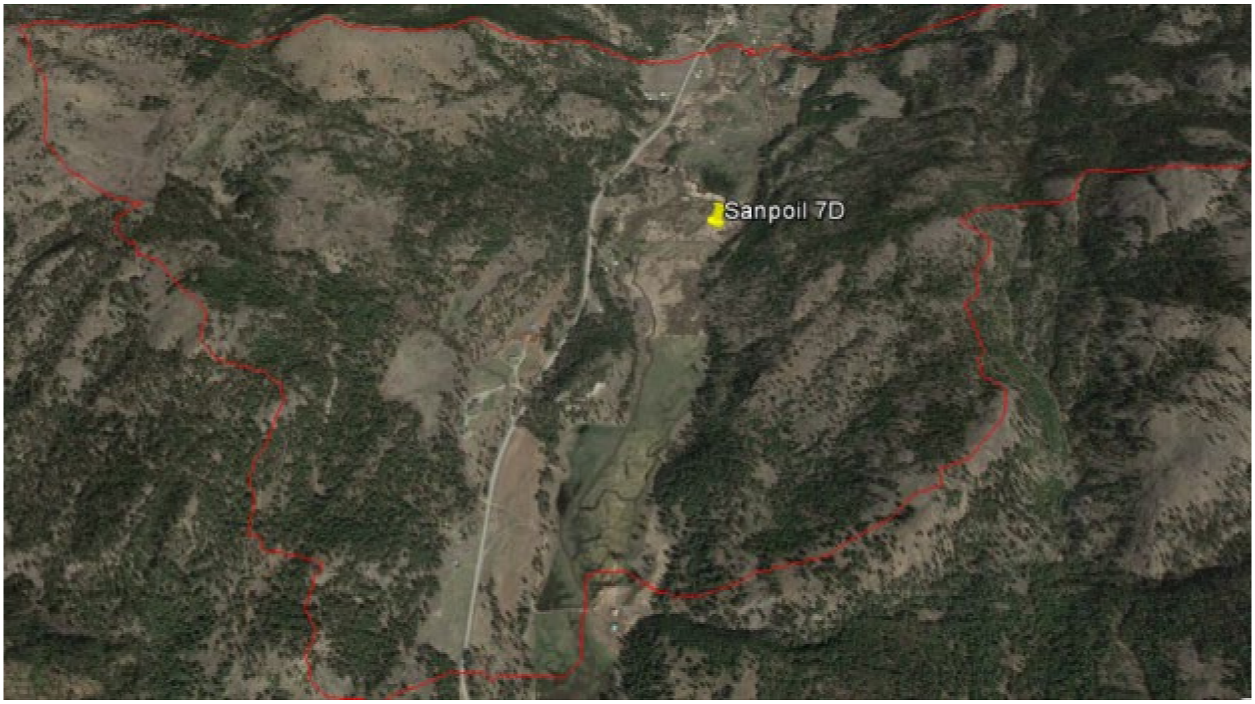


Figure B-7. Overview of Sanpoil 7D reach. This reach is almost entirely in agricultural production. There is virtually no shrub or tree riparian cover. Red lines indicate the boundary of upslope lands draining to the reach. Note the existence of historic channels on the east side of main channel that would provide excellent restoration opportunities.

Figure B-8. Sanpoil 7D reach representative section, looking downstream to the bottom of the reach (left panel). Note the complete lack of woody riparian vegetation, over steepened and collapsing banks, and straightened homogeneous channel form (right panel).

Location and Site Description: Sanpoil 7D drains approximately 11 km^2 and is approximately 80 km from the confluence with The Columbia River. The priority reach is the mainstem Sanpoil

River and is approximately 2,500 m long (Figure B-7). It is characterized by a straight, single-thread channel morphology. Bankfull width is approximately 12 m, and the floodplain width is approximately 340 m. Average channel gradient is approximately 0.3%. This reach is defined by altered channel morphology, loss of wetlands and riparian communities, and over-steepened and collapsing banks that are typically associated with overgrazing by livestock (Figure B-8). On the day of our field visit, turbidity precluded visibility in the water beyond approximately 20 cm. Restoration in this reach is dependent on landowner willingness. White-tailed deer and Canada geese were observed on the site and, along with other species, would likely increase in number if habitat were improved.

Revised Restoration:

Floodplain reconnection, LWD, riparian restoration, livestock exclusion.

Preliminary Restoration Assessment:

Floodplain reconnection, LWD, riparian restoration, livestock exclusion.

Special Considerations:

The shortest path to restoration in this reach might be to purchase it. The entire reach is modified.

Species and Life Stage Benefit:

Holding pre-spawn adult fish, prey item nutrition quality, and flow issues affecting pre-spawn adults.

Prioritization Criteria Addressed

- Restores riparian and floodplain process and habitat complexity.
- The lack of human infrastructure in this reach makes it a high priority for protection and restoration. LWD installations pose no immediate risk to buildings or bridges in the reach.
- All land ownership has not been verified and there is no assessment of landowner willingness.
- Very high Culturally Significant Resources score.
- There would likely be substantial Climate Change Amelioration benefits through riparian and floodplain restoration, including reduced temperature, peak flows, and low flows, as well as increased habitat complexity.

Data Gaps/ Needs:

Landowner willingness has not been determined.

Project Name: Upper Columbia and Sanpoil Restoration **Project Rank 4**

Reach Name: Cedar 1

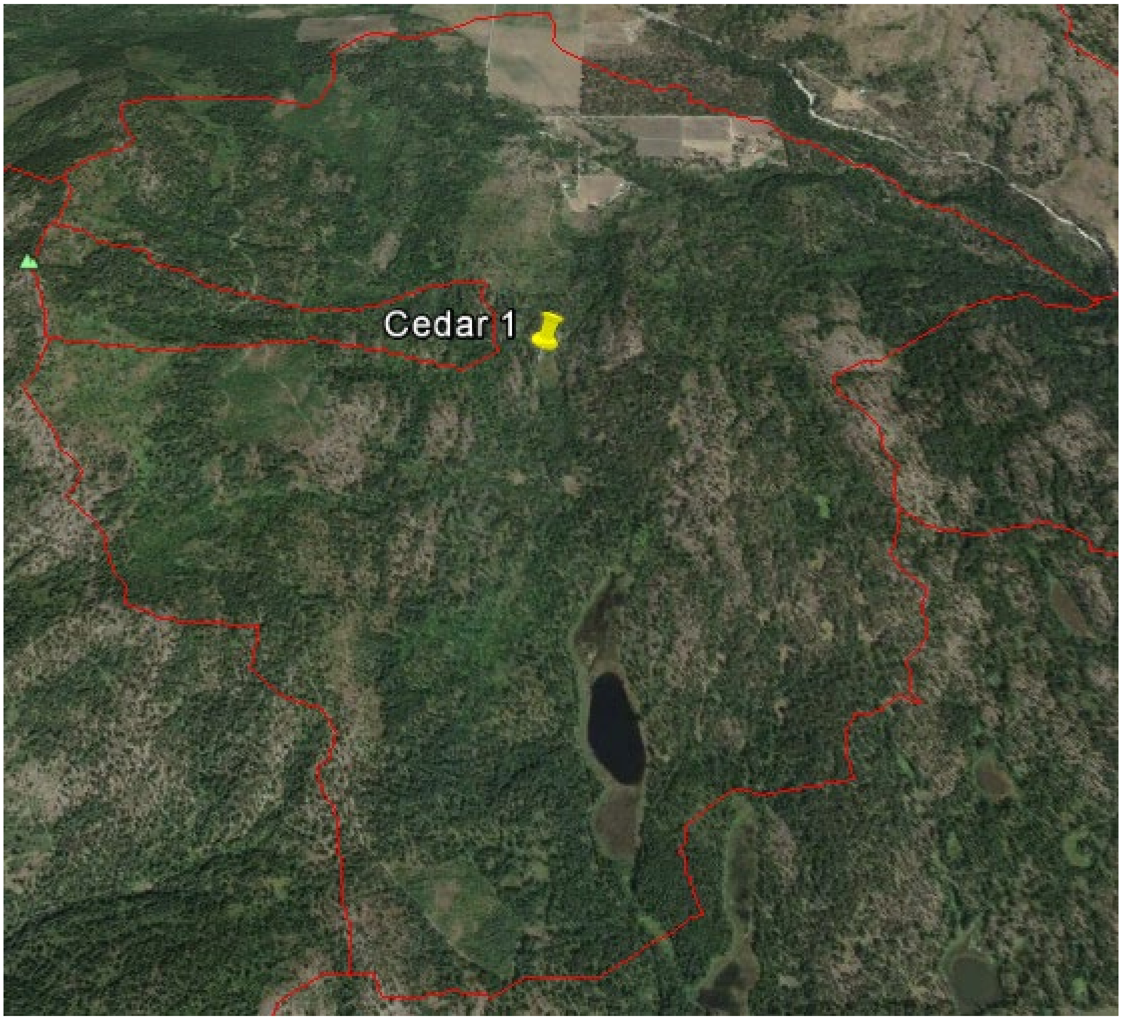


Figure B-9. Overview of Cedar 1 reach. This reach drains a mostly forested watershed with some mixed agricultural uses. The red lines indicate the upslope boundary of lands draining to the reach.

Figure B-10. Online pond impounded by a dam that is located along the left margin of the photo. The pond is approximately 35 m on a side. Very high quality fish and riparian habitat are located upstream.

Figure B-11. Concrete overflow chute on the Cedar Creek dam. Overflow water drains from the pond surface and falls approximately 4 meters with a 1 m impassable drop to the stream bed at the bottom of the chute.

Location and Site Description: Cedar 1 drains approximately 10 km^2 and is approximately 1.4 km from the confluence with Lake Roosevelt. The priority reach is approximately 3,350 m long (Figure B-9). It is characterized by cascade, plane-bed, pool-riffle, and step-pool channel morphology. Bankfull width is approximately 2 m, and the floodplain width ranges between approximately 10 m and 140 m. Average channel gradient varies with channel type and ranges between approximately 4.5% and 17%. Cedar Creek is a relatively small tributary to Barnaby Creek. The headwaters of the stream are impounded in a farm pond associated with the residences near Spring Creek Road and that drains through a closed canopy riparian zone downstream of the pond. Further downstream there is another online pond with a dam (Figure B-10) and concrete overflow chute with a 1 m drop at the bottom that creates an obvious fish barrier (Figure B-11). The total drop from the pond surface to the stream bed below is approximately 4 m. The removal of this dam should be a restoration priority because the habitat in this stream is high quality, both above and below the dam.

Revised Restoration:

Dam removal, protection.

Preliminary Restoration Assessment:

Protection, possible LWD, riparian restoration opportunities.

Special Considerations:

Dam removal would connect high quality habitat with downstream areas. However, the project will likely be expensive due to removal of the fine sediment impounded behind the dam. Access and equipment staging are excellent. There is a road and wide turnaround on the pond shoreline.

Species and Life Stage Benefit:

Spawning fish, egg incubation, and overwintering 0-age fish.

Prioritization Criteria Addressed

- Restores process and habitat and protects fully functioning habitat.
- There is a detailed road network throughout the drainage and great access near the dam site.
- Land ownership has not been verified.
- Relatively high Culturally Significant Resources score.
- There are likely relatively high Climate Change Amelioration benefits through dam removal and restoring connectivity.

Data Gaps/ Needs:

Land ownership is mixed in this area. Ownership and landowner willingness needs to be verified. Also, an engineering study and plan will be needed to quantify and dispose of fine sediments impounded behind the dam.

Project Name: Upper Columbia and Sanpoil Restoration **Project Rank 5**

Reach Name: Cornstalk 5C

Figure B-12. Overview of Cornstalk 5C reach. The stream drains from west to east through the lake at the center of the photo. The red line indicates the surrounding upslope areas that drain to the reach.

Figure B-13. Upper Cornstalk 5C reach drains through a cedar forest (left panel), and the lower portions drain through a wide valley wetland/lake ecosystem (right panel).

Location and Site Description: Cornstalk 5C drains approximately 11.8 km^2 and is approximately 11.5 km from the confluence with Lake Roosevelt. The priority reach is the mainstem Cornstalk Creek and is approximately 2,500 m long (Figure B-12). The top of the reach drains through dense riparian vegetation dominated by western red cedar (Figure B-13 left panel). The lower half of the reach is predominantly characterized by wide wetland valley, with substantial evidence of beaver activity that includes Round Lake (Figure B-13 right panel). Bankfull width of Cornstalk Creek is between approximately 2 m and 6 m, while floodplain width is between approximately 200 m and 1,100 m. Average channel gradient is approximately 0.6%. The downstream extent of the reach has side-by-side 2 m culverts that were dry on the day of our field visit but had evidence of flow in the not too distant past. It appears that the current lake outlet is a constructed channel that was excavated to reduce the size of the lake. There is approximately 1 km of stream between the lake outlet and these culverts that should be the target of any restoration actions. The rest of this reach should be protected.

Revised Restoration Objectives:

Protect wetland and riparian buffers, remeander/restore lake outlet.

Preliminary Restoration Assessment:

Protection (wetland), riparian restoration, remeander (lake outlet).

Special Considerations:

Upstream of the lake outlet, this reach should be protected. From the lake outlet to the road crossing, the stream could be remeandered with normal LWD loads installed or placed into its original channel. A prominent consideration is the frequency and duration of water in the channel downstream of the lake. On the day of our field visit, the channel was completely dry. Access and staging are excellent at the Round Lake Cultural Center.

Species and Life Stage Benefit:

Winter predation on age 1+ juveniles, food quality, and water quality.

Prioritization Criteria Addressed

- Restores riparian, wetland/floodplain process, and habitat and protects fully functioning habitat.
- At the Round Lake Cultural Center access and staging are very easy relative to the remeander project site downstream of the lake outlet.
- Land ownership has not been verified.
- There may be short-term impacts to Culturally Significant Resources if the Round Lake Cultural gathering center is disrupted by construction and staging activities. Remeandering the lake outlet should provide benefits by potentially restoring first foods.
- There may be Climate Change Amelioration benefits by protecting and restoring the intact lakeshore wetlands, restoring riparian zones, and remeandering the channel.

Data Gaps/ Needs:

A hydrology study is needed to verify if the timing and duration of flows between Round Lake and downstream areas creates hydrologic connectivity to perennially flowing stream habitat. Land ownership needs to be verified.

Project Name: Upper Columbia and Sanpoil Restoration **Project Rank 6**

Reach Name: Sanpoil 4A

Figure B-14. Overview of Sanpoil 4A reach. Note State Route 21 on the west side of the valley and the gravel road along the east side of the valley, with single-thread channel meandering across the valley. Red lines indicate the extent of lands draining to the study reach.

Figure B-15. Representative photo of Sanpoil 4A reach showing fire impacts to riparian forest, and the low gradient meandering stream. Note LWD in the channel here. Further downstream, there is relatively little LWD (see Figure B-16 below).

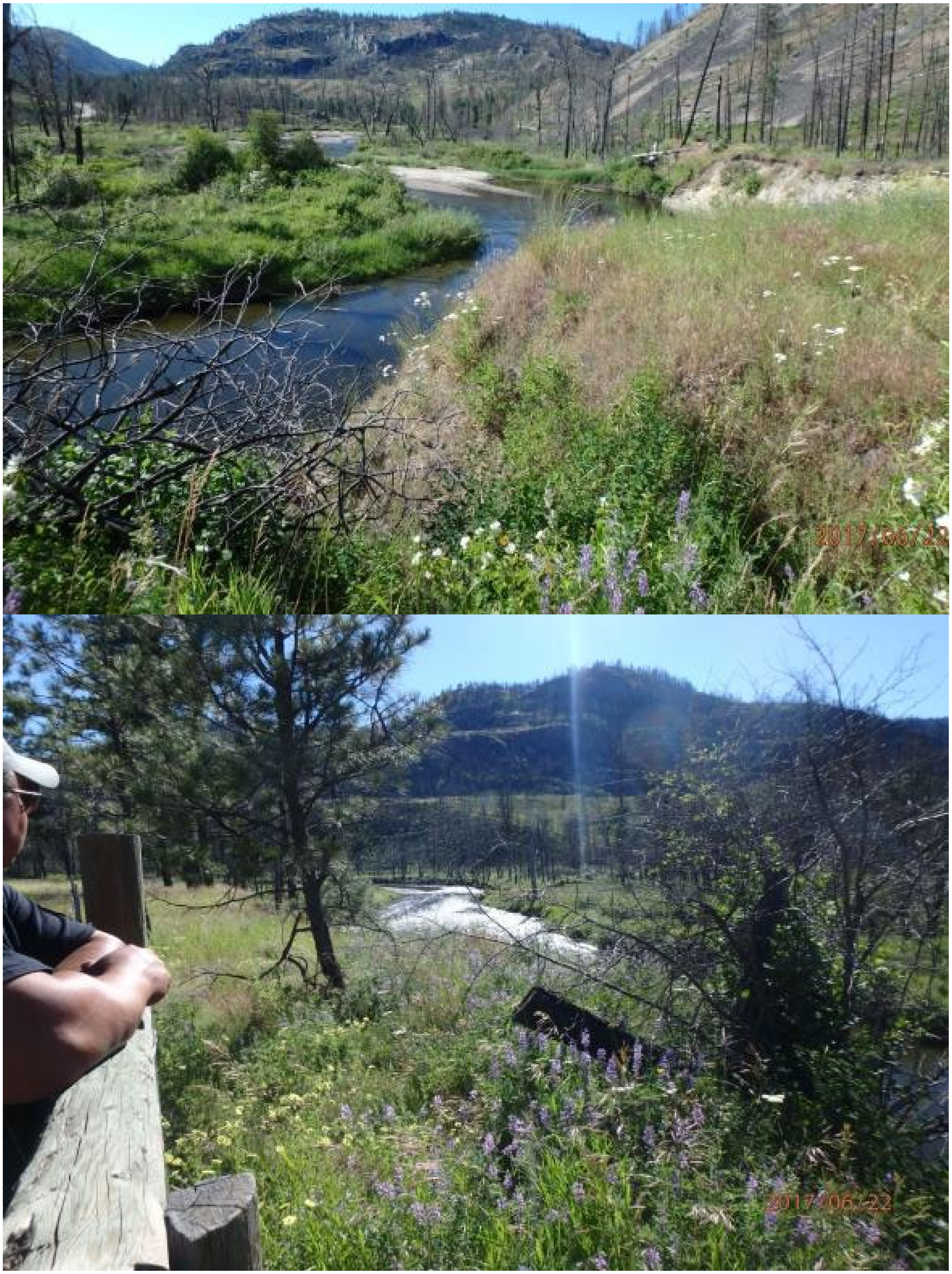


Figure B-16. Sanpoil 4A reach from the east side of the river near the bottom of the reach. Upper panel is looking upstream. Lower panel is looking downstream.

Location and Site Description: Sanpoil 4A drains approximately 3.3 km^2 and is approximately 40 km from the confluence with the Columbia River (Figure B-14). The priority reach is the mainstem Sanpoil and is approximately 1,700 m long. It is characterized by meandering, low gradient morphology with a wide active channel. Bankfull width exceeds 20 m on average, while floodplain width is approximately 400 m. Average channel gradient is approximately 0.2%. The EDTshed was burned completely in 2014 during the Devil's Elbow fire. There is virtually no live standing timber in the riparian zone, although the forbs and shrubs are recovering (Figure B-15, B-16). It appears that CCT Range Management personnel recently installed fencing near the downstream end of the reach (see the lower panel of Figure B-16) near a heavily used cattle staging area. It is clear cattle have ranged throughout the reach, but no evidence of recent activity was visible.

Because of the fire impacts, riparian restoration should be a priority here. In addition, because of the value of this reach as spawning habitat and the obvious lack of large wood in the channel, LWD or ELJ installations would increase the physical heterogeneity in this reach by encouraging more lateral channel movement, creating pool habitat, and encouraging connectivity with floodplain habitats. Approximately 0.6 km from the top of the reach would be a good location for an ELJ that would engage floodplain meander wetlands that are currently disconnected from the channel.

Revised Restoration Objectives:

Riparian restoration, LWD, possible ELJs.

Preliminary Restoration Assessment:

Riparian restoration, livestock exclusion, LWD.

Special Considerations:

There is easy access and staging on both sides of the river throughout this reach. The banks are low, making it easy to reach the channel with equipment.

Species and Life Stage Benefit:

Spawning, holding for pre-spawn adult fish, and egg incubation.

Prioritization Criteria Considered:

- Restores fire-impacted riparian and instream habitat.
- There is excellent access and staging throughout the reach.
- Land ownership is unknown.
- Relatively high Culturally Significant Resources score and provides benefits by potentially restoring first foods.
- There may be Climate Change Amelioration benefits by protecting the intact riparian wetland, restoring riparian habitat at the bottom of the reach, and increasing habitat complexity.

Data Gaps/ Needs:

Landownership has not been verified.

Project Name: Upper Columbia and Sanpoil Restoration **Project Rank 7**

Reach Name: Sanpoil 5C

Figure B-17. Overview of Sanpoil 5C reach. This reach has changed dramatically due to the April 2017 floods relative to this 2016 photo. Red lines indicate the upslope area that drains to this reach.

Figure B-18. Highly complex habitat including off channel habitat, gravel bars, pools, and LWD in the channel resulting from the April 2017 flood. This should represent target restoration conditions for other mainstem Sanpoil River reaches.

Figure B-19. Bottom end of Sanpoil 5C reach. Note LWD jams storing gravel on both banks. This habitat condition should be used to target restoration conditions in other reaches of the mainstem Sanpoil River.

Location and Site Description: Sanpoil 5C drains approximately 1.1 km^2 and is approximately 55 km from the confluence with the Columbia River. The priority reach is the mainstem Sanpoil River and is approximately 1,000 m long (Figure B-17). This reach was heavily altered by the April 2017 flood that caused dramatic changes in channel geomorphology, and sediment and LWD loads. Given the high-quality condition of habitat in this reach, we recommend changing the prioritization of this reach from restoration to protection. These conditions may represent restoration targets for other mainstem Sanpoil River reaches. It is characterized by a meandering channel with expansive gravel bars deposited in meanders and channel margins associated with LWD. Bankfull width is approximately 19 m, while floodplain width is between approximately 50 m and 135 m. Average channel gradient varies between approximately 0.3% and 1%. The top of the reach coincides with the 21 Mile Campground, which would provide easy access and staging opportunities for restoration. The top of this reach is approximately 10 km downstream of the confluence of the West Fork Sanpoil, which roughly doubles the mainstem discharge. In addition, recent fires in the West Fork Sanpoil have destabilized large areas, contributing to sediment delivery. Also, the record flooding during April 2017 caused substantial disturbance to this reach, resulting in very heterogeneous habitat, lots of sediment, and LWD jam deposition in the channel and floodplain (Figure B-18, B-19). Connectivity between channel and floodplain habitats in this reach currently exceeds what could reasonably be accomplished with restoration actions. We suggest simply protecting this reach unless conditions threaten road infrastructure in the future.

Revised Restoration Objectives:

Protection.

Preliminary Restoration Assessment:

LWD, riparian restoration, livestock exclusion.

Special Considerations:

The April 2017 floods renewed and created habitat areas and connectivity with floodplain habitats in this reach. Current conditions are likely as good as any in the mainstem Sanpoil River and could serve as restoration targets for other reaches. Prior to the April 2017 flood, our assessment based on existing surveys was that this reach would benefit from LWD and riparian improvements. Our current assessment is that this area should be protected as is.

Species and Life Stage Benefit:

Spawning, egg incubation, and holding pre-spawn adult.

Prioritization Criteria Addressed

- Protects fully functioning habitat.
- Access and staging should not be an issue in this reach.
- Land ownership has not been verified.
- Very high Culturally Significant Resources score.
- There may be limited additional Climate Change Amelioration benefits.

Data Gaps/ Needs:

Land ownership needs to be verified.

Project Name: Upper Columbia and Sanpoil Restoration **Project Rank 8**

Reach Name: Sanpoil 3D

Figure B-20. Overview of Sanpoil 3D reach. The reach meanders across the valley floor between State Highway 21 to the west and East Sanpoil Road to the east. Bridge Creek Road crosses the river near the bottom of the reach. Red lines indicate the extent of upslope lands draining to the reach.

Figure B-21. Representative photo of habitat quality in Sanpoil 3D reach. Note single-thread channel with relative lack of riparian zone.

Location and Site Description: Sanpoil 3D is a mainstem Sanpoil reach that drains approximately 16 km^2 and is roughly 34 km upstream of the confluence with the Columbia River. The priority reach is approximately 2,800 m long. It is characterized predominantly by island-braided and meandering channel morphologies, with gravel stored in the active channel on meander bends, point bars, and islands (Figure B-20). Bankfull width is approximately 21 m, while floodplain width varies between approximately 500 m and 600 m. Average channel gradient varies between approximately 0.2% and 0.9%. On the west side of the river, there are some agricultural/ranching operations and associated houses and other buildings. This reach appears to be downstream of the massive sediment slug delivered to the river system during the April 2017 flood. There are disconnected wetlands in the floodplain near the top of the reach that are visible from Highway 21, separated from the river by pasture lands. Riparian condition alternates between conifer-dominated mature forest and pasture throughout the reach (Figure B-21). In most places, there is a noticeable lack of LWD in the channel.

Revised Restoration:

LWD, riparian restoration, livestock exclusion, floodplain reconnection, floodplain (wetland) restoration.

Preliminary Restoration Assessment:

LWD, riparian restoration, livestock exclusion, floodplain reconnection, floodplain (wetland) restoration.

Special Considerations:

The river in this reach is island-braided and meandering, both of which respond well to large wood where it is in the channel. The upper portion of the reach is devoid of LWD and exhibits heavy damage due to livestock grazing in the riparian zone. This reach has lots of meander scars in the floodplain, indicating active lateral movement history. Riparian restoration is necessary, particularly in upper portions of the reach. The caveat for this reach is that it appears that the large amount of sediment being processed by the river has not yet made it down to this reach. As more sediment makes its way to the reach, the lateral migration of the channel will likely increase. Restoration actions that may be desirable would include ELJs and other LWD installations to protect human infrastructure on the west side of the valley. These installations could be designed to engage floodplain habitats that are currently isolated on both sides of the river.

Species and Life Stage Benefit:

Spawning, holding habitat for pre-spawn adult fish, and egg incubation.

Prioritization Criteria Addressed

- Restores riparian and floodplain processes and increases habitat complexity.
- Excellent access and staging from the east side. Access from the west side may depend on landowner.
- Land ownership is unknown.
- Medium Culturally Significant Resources score.

- There will likely be substantial Climate Change Amelioration benefits by restoring this reach through reduced temperatures, floodplain restoration, and improved habitat complexity.

Data Gaps/ Needs: Land ownership has not been verified. Also, it is not known what the effects of the increased sediment load will be when the sediment slug from the April 2017 flood begin to work through this reach.

Project Name: Upper Columbia and Sanpoil Restoration **Project Rank 9**

Reach Name: Sanpoil 5E

Figure B-22. Overview of Sanpoil 5E reach. State Highway 21 runs along the west side of the river for the length of this reach. In addition, a gravel road runs along the east side of the river, although in much of this section, it is considerably upslope from the river. The red lines indicate the upslope area that drains to this reach.

Figure B-23. Sanpoil 5E reach detail. Upper panel shows large jam in the center of the channel that engaged and created floodplain habitat (lower panel).

Figure B-24. Floodplain habitats in Sanpoil 5E reach. Left panel shows deep (>1 meter) pool used by amphibians and salmonid fish. Right panel shows large jam stored in the floodplain east of the main channel.

Location and Site Description: Sanpoil 5E drains approximately 4.3 km^2 and is approximately 60 km from the confluence with the Columbia River. This reach is just over 2 km downstream of the confluence with the West Fork Sanpoil (Figure B-22). This reach was heavily altered by the April 2017 flood that caused dramatic changes in channel geomorphology, sediment, and LWD loads. Given the high-quality condition of habitat in this reach, we recommend changing the prioritization of this reach from restoration to protection. The priority reach is the mainstem Sanpoil River and is approximately 3,400 m long. It is characterized by meandering and confined morphologies. Bankfull width is approximately 19 m, while floodplain width is between approximately 50 m and 100 m. Average channel gradient varies between approximately 0.2% and 0.3%. This reach received a massive sediment load during the April 2017 floods that caused lateral channel movement and overbank flows that recruited LWD to the channel, scoured out and connected floodplain habitats, and stored substantial amounts of gravel. During the flood, the entire valley bottom between the State Highway and the toe of the mountain was engaged in flood conveyance. Aside from the road infrastructure in this reach, there is nothing that could be negatively impacted by the LWD in this reach or by high flows that may engage the floodplain in the future. Our suggestion is to leave this reach alone for now and perhaps use it to generate restoration target conditions for other reaches of the mainstem and West Fork Sanpoil Rivers.

Revised Restoration Objectives:

Protection.

Preliminary Restoration Assessment:

LWD, riparian restoration.

Special Considerations:

None.

Species and Life Stage Benefit:

Spawning, holding pre-spawn adult fish, and egg incubation.

Prioritization Criteria Addressed

- Protects fully functioning habitat.
- The lack of human infrastructure in this reach makes it a high priority for protection. No restoration actions are necessary.
- Land ownership has not been verified.
- Very high Culturally Significant Resources score.
- There may be limited Climate Change Amelioration benefits from protecting this reach.

Data Gaps/ Needs:

Land ownership needs to be determined.

Project Name: Upper Columbia and Sanpoil Restoration **Project Rank 10**

Reach Name: Hall 4

Figure B-25. Overview of Hall 4 reach. Hall Creek is a meandering alluvial system in this reach, with relatively high levels of habitat diversity associated with lateral channel migration. The current stream channel is east of a post-glacial wetland and former stream alignment.

Figure B-26. Photo of the downstream end of Hall 4 reach looking upstream. Note the healthy riparian community.

Location and Site Description: Hall 4 drains approximately 18.4 km^2 and is approximately 8.9 km from the confluence with the Columbia River. The priority reach is the mainstem Hall Creek and is approximately 5,000 m long (Figure B-25). It runs through a post-glacial valley dominated by forested and emergent wetland. The current creek alignment is largely disconnected from this wetland system on the surface. It is characterized by meandering and straight morphologies, with appropriate physical habitat diversity for a low gradient meandering stream characterized by pool-riffle sequences. Bankfull width averages 10.5 m, while floodplain width ranges from approximately 230 m to 440 m. Average channel gradient is approximately 1%. Despite the high-quality condition of the riparian zone through much of the reach, there is a noticeable lack of LWD in the channel—except in the bottom 1/3 of the reach where LWD loads are higher. At places, the riparian zone is severely impacted by agricultural and probably grazing operations. On the day of our field visit, the stream was highly turbid at the bottom of the reach (Figure B-26). The source of turbidity was not observed.

Revised Restoration Objectives:

LWD, riparian restoration (selected reaches), livestock exclusion, wetland reconnection.

Preliminary Restoration Assessment:

LWD, riparian restoration (selected reaches), livestock exclusion.

Special Considerations:

Some reaches are in good shape with lots of LWD, but others appear to be degraded. Impacts on agricultural lands are greatest. There appears to be heavy beaver activity in large wetland/stream areas to the west. The portion of this reach that lies roughly at the top of the bottom half, below the agricultural area (see Figure B-25), is high quality habitat and should be used to set restoration targets for the rest of the reach in terms of habitat diversity, LWD loadings, and connectivity with the riparian wetland system.

Species and Life Stage Benefit:

Spawning, holding pre-spawn adult fish, and egg incubation.

Prioritization Criteria Addressed

- Restores riparian process, habitat complexity (LWD), and wetland habitat.
- Access and staging are intermittent throughout the reach. Some landowners have better access to the stream than others. The large wetland that dominates the west side of the valley precludes access from that side for most of the reach length.
- Land ownership is unknown.
- Relatively high Culturally Significant Resources values.
- There may be Climate Change Amelioration benefits by protecting the intact riparian wetland, reconnecting it to the stream during high water events, restoring the riparian zone, and increasing habitat complexity.

Data Gaps/ Needs:

Land ownership is not known. The source of turbidity has not been confirmed but could be from agricultural lands adjacent to the stream or farm roads that cross the stream.

Project Name: Upper Columbia and Sanpoil Restoration **Project Rank 11**

Reach Name: Sanpoil 4G

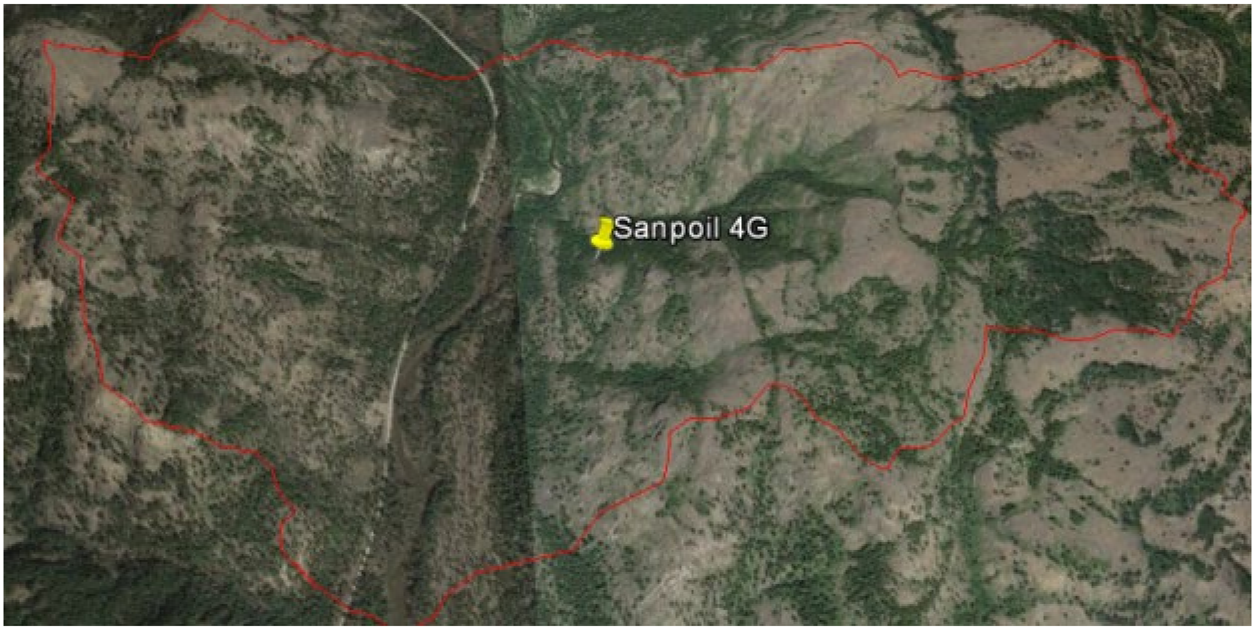


Figure B-27. Overview of Sanpoil 4G reach. The mainstem Sanpoil River runs between Highway 21 to the west and East Sanpoil Road to the east. The red lines indicate the extent of upslope lands that drain to the reach. Bear Creek comes enters near the bottom left of the photo, and 21 Mile creek drains near the "Sanpoil 4G" label in the upper center of photo.

Figure B-28. Upper end of Sanpoil 4G reach. Note fully intact riparian condition and large slug of sediment in the active channel resulting from the April 2017 flood.

Figure B-29. Representative photo taken near the middle of Sanpoil 4G reach. Note healthy riparian condition but also a relative lack of sediment and LWD in the active channel compared to Figure B-28.

Location and Site Description: Sanpoil 4G drains approximately 6 km^2 and is approximately 50 km from the confluence with the Columbia River. The priority reach is the mainstem Sanpoil River and is approximately 2,800 m long. The upper and lower-most one kilometer of the reach are characterized by a meandering channel with substantial sediment and LWD in the channel—particularly associated with meanders. The middle one kilometer is higher gradient and exhibits a more confined morphology. Overall in the reach, bankfull width is approximately 19 m, and floodplain width varies between approximately 50 m and 100 m. Average channel gradient varies between approximately 0.2% and 0.3%. This reach was heavily altered by the April 2017 flood that caused dramatic changes in channel geomorphology, sediment, and LWD loads. Given the high-quality condition of habitat in this reach, we recommend protection for the top and bottom one kilometer of the reach. This reach received a massive sediment load during the April 2017 floods that caused lateral channel movement and overbank flows that recruited LWD to the channel, scoured out and connected floodplain habitats, and stored massive amounts of gravel. During the flood, the entire valley bottom between the State Highway and the toe of the mountain was engaged in flood conveyance. The bottom of the reach is near the right bank confluence with Bear Creek and the upstream extent is just above 21 Mile Creek, which comes in on the left bank (Figure B-27). Twentyonemile Creek is known to be an important tributary to spawning fish.

Near the middle of the reach there is substantially less wood than in the adjacent reaches upstream and downstream. Although the river is processing a massive slug of sediment from the April 2017 flood (Figure B-28), the middle of the reach has less sediment stored in the channel and almost no LWD in the active channel (Figure B-29).

Revised Restoration:

Protection upstream and downstream, possible LWD in middle of reach.

Preliminary Restoration Assessment:

LWD, possibly riparian restoration.

Special Considerations:

There is easy access from Highway 21 near Bear Creek that also provides for good staging. The same is true across from the confluence of Twentyonemile Creek. In addition, East Sanpoil Road can be accessed upstream from the Twentyonemile Creek road, although we did not drive that road during our field visit and cannot verify that it is passable down to Sanpoil 4G reach. LWD installations in the lower half of this reach would be easy to accomplish and would provide considerable benefit as the sediment slug continues to process through the reach.

Species and Life Stage Benefit:

Spawning, holding pre-spawn adult fish, and egg incubation.

Prioritization Criteria Addressed

- Restores habitat and protects fully functioning habitat.
- Relatively easy access and staging in this reach from both sides of the river.
- Land ownership has not been verified.
- Relatively low Culturally Significant Resources score.
- There may be limited Climate Change Amelioration benefits through increasing habitat complexity.

Data Gaps/ Needs:

Land ownership has not been verified.

Project Name: Upper Columbia and Sanpoil Restoration **Project Rank 12**

Reach Name: NF Hall 1B

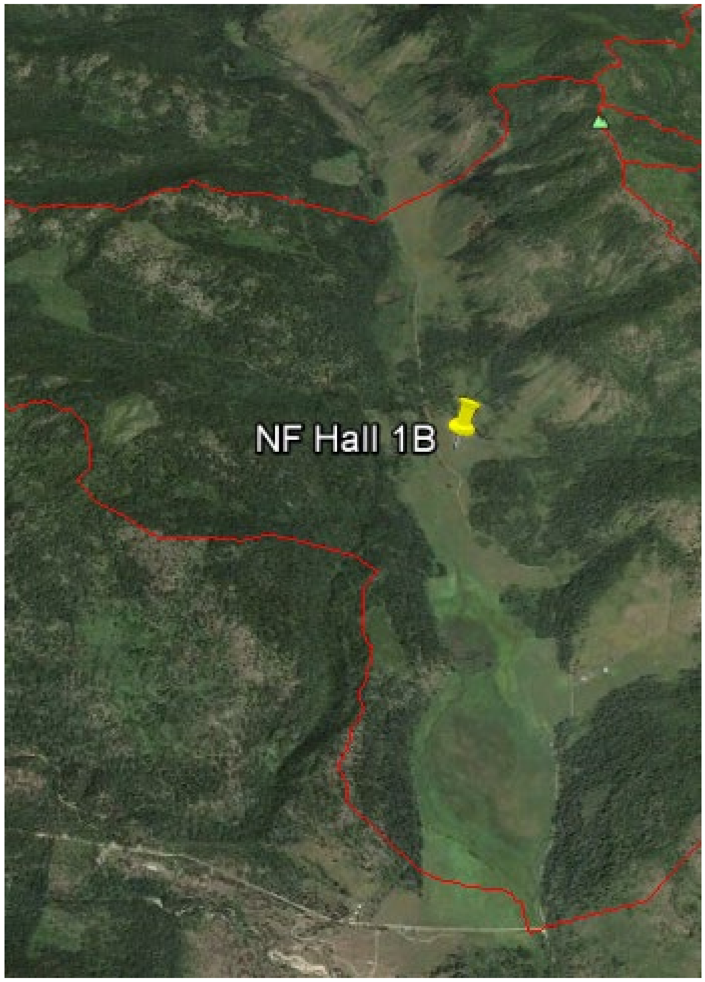


Figure B-30. Overview of NF Hall 1B reach. Hall Creek in this reach drains through a post-glacial wetland valley. Red lines indicate extent of upslope areas draining to the reach.

Figure B-31. Culverts at the top of NF Hall 1B reach. These culverts flow under a farm lane that does not appear to be necessary. Removal of these culverts or modification of the outlet with a boulder step configuration could be a relatively inexpensive and easy project.

Figure B-32. Beaver lodge and flooded wetland near the middle of NF Hall 1B reach (left panel). Reed canary grass monoculture choking the stream, with no visible flow at the bottom end of the reach (right panel).

Location and Site Description: NF Hall 1B is a tributary to Hall Creek and drains approximately 18 km^2 as it flows approximately 13.5 km to the confluence with Lake Roosevelt. The priority reach is approximately 5,100 m long (Figure B-30). The stream flows through a low-gradient post-glacial valley dominated by wetlands, with a floodplain width that varies between 250 m and 650 m. The upper portions of the reach are characterized by a closed, shrubby, riparian canopy (Figure B-31). Lower in the reach, wetlands dominate the valley (Figure B-32). The lower 2 km are characterized predominantly by a very low-gradient stream and marsh wetland ecosystem that lacks a clearly defined channel in places. The lower 1.5 km of the reach is a large wetland that is largely a monoculture of non-native Reed Canary Grass (Figure B-32 right panel). Upstream of that for approximately one kilometer, the stream is an artificially straightened single-thread channel that appears to have been modified to drain the adjacent wetland to convert it to pasture lands. Restoration actions should focus on this lower 3 km of the reach. Restoration actions should focus on local physical removal of the reed canary grass (*Phalaris arundinacea*), and willow and other riparian plantings to encourage beaver to flood this area and drown the reed canary grass. In addition, moving the stream away from the roadside and installing LWD will help remeander the stream into the wetland and create habitat complexity. The upstream 2 km exhibit a shrubby riparian zone with substantial beaver influence on the hydrology (Figure B-32 left panel). At the very top of the reach there is a farm lane with a blocking culvert that could potentially be fixed with the installation of small boulders used to construct steps that would allow fish to enter the pipe.

Revised Restoration:

Wetland restoration, riparian restoration, remeander channel, LWD, culvert removal.

Preliminary Restoration Assessment:

Riparian restoration, livestock exclusion, remeander channel, LWD.

Special Considerations:

There is excellent access and staging throughout this reach. Working in wetlands can create special challenges for heavy equipment that will need to be considered when planning specific restoration actions.

Species and Life Stage Benefit:

Overwintering 1-age, improving prey nutritional quality, and holding habitat for pre-spawn adult fish.

Prioritization Criteria Addressed

- Restores connectivity, riparian, and floodplain processes and improves habitat.
- Access and staging are excellent throughout the reach, but landowner willingness has not been assessed.
- Land ownership is unknown.
- Medium Culturally Significant Resources score.
- There will likely be substantial Climate Change Amelioration benefits through increased connectivity, reduced temperature, increased habitat complexity, and floodplain/wetland restoration.

Data Gaps/ Needs:

Land ownership is not known.

Project Name: Upper Columbia and Sanpoil Restoration **Project Rank 13**

Reach Name: Sanpoil 2F

Figure B-33. Overview of Sanpoil 2F reach. State Highway 21 runs along the west side of the valley and East Sanpoil Road runs along the east side of the valley. The red lines indicate the extent of upslope lands that drain to the reach.

Figure B-34. Gravel and LWD deposited in the channel during the 2017 flood event near the downstream end of Sanpoil 2F reach.

Figure B-35. Looking upstream from the park on the west side of the river just upstream of Bush Creek Road. Note the lack of LWD in the channel here. This is typical of the reach.

Location and Site Description: Sanpoil 2F drains approximately 6.2 km^2 and is approximately 20 km from the confluence with Lake Roosevelt. The priority reach is the mainstem Sanpoil River and is approximately 2,400 m long. It is characterized by meandering and confined morphologies, with a couple of short island-braided sections mediated by large LWD jams. Bankfull width is approximately 21 m, while floodplain width is between approximately 70 m and 210 m. Average channel gradient varies between approximately 0.4% and 0.5%. Habitat units are in general relatively homogeneous and on the order of 100 m in length or more. Much of the reach is riffle and glide, with some boulder runs as well. The riparian zone is dominated by deciduous shrubs and small trees interspersed with conifers farther away from the channel. Installing LWD (including ELJs), and implementing riparian restoration are appropriate throughout the reach. In particular, Campground 1104 at the upstream end appears to be a good place to install an ELJ to push the river into the left bank and engage floodplain habitat on the other side (see Figure B-35). Access and staging are very good here.

Revised Restoration Objectives:

Riparian restoration, LWD, possible ELJs.

Preliminary Restoration Assessment:

LWD, riparian restoration, livestock exclusion.

Special Considerations:

The channel is nearly devoid of LWD throughout the reach. There is excellent access and staging nearly everywhere on the east side of the river. Some buildings and roads suggest private ownership east of the river, and this needs to be verified. On the west side, the best access is at Campground 1104. Other land ownership and landowner willingness need to be verified.

Species and Life Stage Benefit:

Spawning, holding pre-spawn adult fish, and egg incubation.

Prioritization Criteria Addressed

- Restores riparian floodplain processes and habitat complexity.
- Access and staging are variable but possible from either State Highway 21 on the west or East Sanpoil Road on the east side of the river by way of the bridge at Silver Creek Road.
- Land ownership has not been verified, except in Campground 1104.
- Relatively high Culturally Significant Resources score.
- There are likely Climate Change Amelioration benefits from riparian and floodplain restoration, and from increased habitat complexity.

Data Gaps/ Needs:

Land ownership needs to be verified.

Project Name: Upper Columbia and Sanpoil Restoration **Project Rank 14**

Reach Name: Sanpoil 2J

Figure B-36. Overview of Sanpoil 2J reach. State Highway 21 runs north and south in the center of the figure. The river is east of the main highway with a gravel road east of the river. The red lines indicate the upslope area draining to the reach.

Figure B-37. Pool, glide, riffle sequence in the center of Sanpoil 2J reach. This level of habitat diversity is typical of the reach. Note nearly complete lack of LWD in the channel.

Figure B-38. Sanpoil 2J reach, looking upstream. Riparian zone is in fair condition but lacks mature trees throughout the reach.

Location and Site Description: Sanpoil 2J drains approximately 8 km^2 and is approximately 28 km from the confluence with the Columbia River. The priority reach is the mainstem Sanpoil River and is approximately 3,700 m long (Figure B-36). It is characterized by a confined channel that meanders across the floodplain. Bankfull width is approximately 21 m, and floodplain width is between approximately 70 m and 200 m. Average channel gradient varies between approximately 0.4% and 0.5%. The reach has some residences and agricultural land uses on the west side of the river and at the northern end of the reach (Figure B-36). The riparian zone is in fair condition, dominated by shrubs and forbs with a ponderosa pine overstory. There are large cutbanks at outside meander bends on both sides of the river that recruit gravel to the channel. Habitat diversity is good with relatively large (on the order of 100 m in length) pools, boulder riffles, and glides throughout. There is a noticeable absence of LWD in this reach. In addition, suspected grazing activity on the east side of the river may be implicated in the lack of overstory vegetation, although no cattle were observed during our field visit. Also, it is clear the sediment slug from the April 2017 flood had not been transported to this reach by the time of our field visit. We expect the channel to become much more dynamic once that sediment makes it down to this reach.

Revised Restoration Objectives:

Riparian restoration, LWD, possible ELJs.

Preliminary Restoration Assessment:

LWD, riparian restoration.

Special Considerations:

The channel is nearly devoid of LWD. There is potentially excellent access and staging throughout the reach on the east side of the river. On the west side, landowner cooperation would likely be necessary.

Species and Life Stage Benefit:

Spawning, egg incubation, and holding pre-spawn adult fish.

Prioritization Criteria Addressed

- Restores riparian processes and habitat complexity.
- Access and staging are generally very good.
- Land ownership has not been verified.
- Relatively high Culturally Significant Resources score.
- There may be Climate Change Amelioration benefits from riparian restoration and by installing LWD to facilitate sediment storage, hyporheic exchange, reduce temperature, and increase habitat complexity.

Data Gaps/ Needs:

There is evidence that livestock grazing occurs in this reach. However, cattle were not present during our field visit and most visible impacts were recovering. Verify if future grazing rotations are in the range management plan. Land ownership also needs to be verified.

Project Name: Upper Columbia and Sanpoil Restoration **Project Rank 15**

Reach Name: Stranger 7

Figure B-39. Overview of Stranger 7 reach. The creek in this area drains through a wide, low-gradient wetland valley bottom. Red lines indicate the extent of lands draining to the study reach.

Figure B-40. Beaver dam and failed culvert at the bottom of Stranger 7 reach. This photo is representative of low gradient stream meandering through densely vegetated wetland. Numerous juvenile salmonids were observed on the margins of the channel here.

Location and Site Description: Stranger 7 drains approximately 5.9 km^2 and is approximately 13 km from the confluence with Lake Roosevelt (Figure B-39). The priority reach is in Stranger Creek and is approximately 2,100 m long. It is characterized by wide, slow-meandering morphology as the stream winds through densely vegetated wetland (Figure B-40). Bankfull width is not readily determined here because in many places the channel is not well defined; though floodplain width is approximately 120 m. Average channel gradient is approaching 0%. In the upper half of the reach, the riparian zone is in great condition, consisting of mature conifer overstory with diverse shrub and forb understory. In the lower half of the reach, on the north side of the stream, the riparian zone is limited to the wetland area. Some buffer restoration in this area is necessary. New livestock fencing is planned for the southern side of the reach. It should be installed on the northern side as well. On the day of the field visit, cows were observed in the stream and grazing in the riparian zone—causing turbid conditions. It was apparent that failed fencing allowed them to access the property.

Revised Restoration Objectives:

Riparian restoration, livestock exclusion.

Preliminary Restoration Assessment:

Riparian restoration, livestock exclusion.

Special Considerations:

This reach should be protected. Fencing should be repaired and installed to keep livestock out of the riparian wetlands. Field observations verified a highly productive wetland/stream ecosystem. In fact, it is the kind of highly productive rearing habitat that restoration projects try to emulate.

Species and Life Stage Benefit:

Predation on 2+and 1+ age fish, and quality of prey items.

Prioritization Criteria Addressed

- Protects fully functioning riparian and restored riparian habitat.
- There is excellent access and staging on the north side at the bottom of the reach for riparian restoration and fencing.
- Land ownership is unknown.
- Relatively high Culturally Significant Resources score and provides benefits by potentially restoring first foods.
- There may be Climate Change Amelioration benefits by protecting the intact riparian wetland and restoring the riparian zone at the bottom of the reach.

Data Gaps/ Needs:

Land ownership is unknown. Property and structures on the north side at the downstream extent of the reach are apparently abandoned.

Project Name: Upper Columbia and Sanpoil Restoration **Project Rank 16**

Reach	**Name:**	Sanpoil	2I

Figure B-41. Overview of Sanpoil 2I reach. Note State Route 21 on the west side of the valley and the gravel road along the east side of the valley, with single-thread channel meandering across the valley. Red lines indicate the extent of lands draining to the study reach.

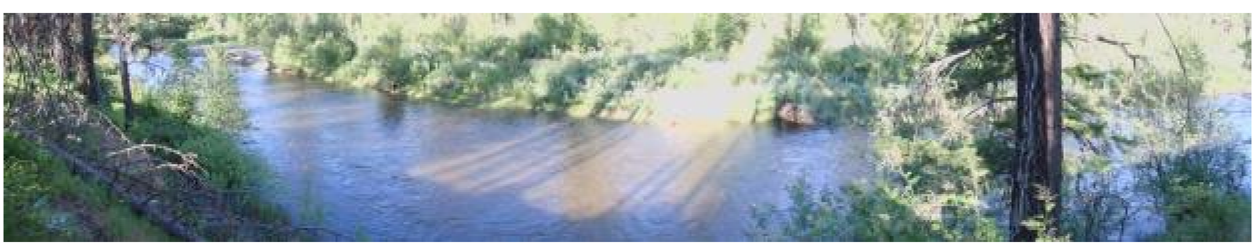


Figure B-42. Panoramic photo of a representative section of the study reach in the upper ½ of the reach. Note the relatively high quality riparian condition. Also, the river here is largely one large glide with very little LWD in the channel.

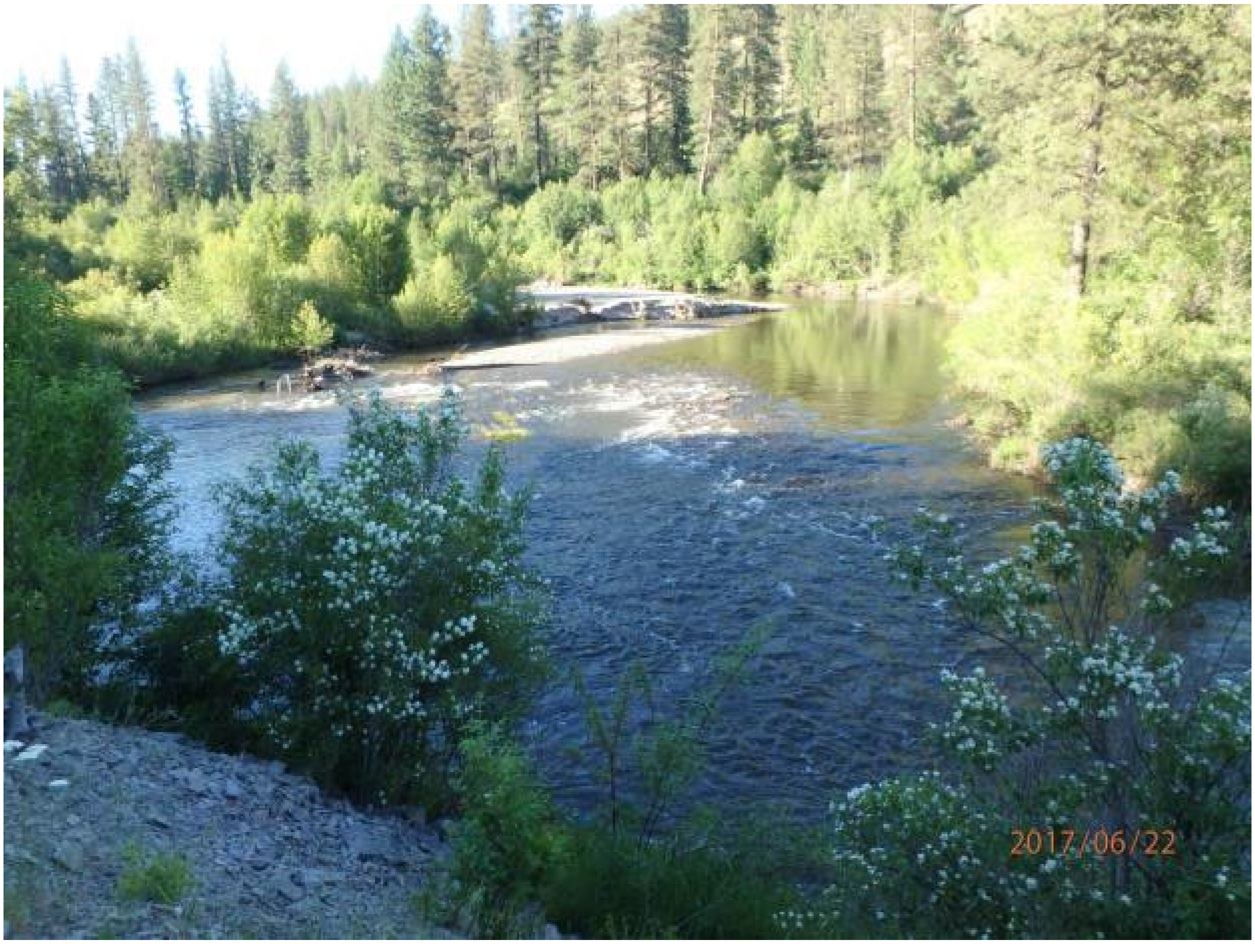


Figure B-43. Photo taken near SR 21 in the lower 1/3 of the study reach. This is a good candidate location for an engineered log jam installation to engage floodplain habitats on the other side of the channel and to protect the road on the near side.

Location and Site Description: Sanpoil 2I drains approximately 9.1 km^2 and is approximately 25.5 km from the confluence with the Columbia River. The priority reach is the mainstem Sanpoil and is approximately 3,500 m long. The upper and lower kilometer of the reach are characterized by a slightly higher gradient single-thread channel than the middle of the reach, which has more sediment and LWD deposited in the channel on meander bends and islands. Bankfull width exceeds 20 m on average, with floodplain width ranging from 80 m to 250 m. Average channel gradient is 0.3%. State Highway 21 runs along the west side of the valley for the entire length of the reach. Likewise, there is a gravel road that runs along the entire length of the east side of the valley. There are locations where the river is nearer to one road or the other, making access easier as it meanders across the valley. The upper half of the reach is basically one long glide with very little change in habitat condition and a noticeable lack of large wood (Figure B-42). There are localized areas in the reach in need of riparian restoration (replanting and livestock exclusion). There was no evidence of recent livestock grazing in the reach at the time of our field visit but clear impacts of historic grazing. The riparian zone is largely comprised of ponderosa pine (*Pinus ponderosa*) overstory with mixed young conifer and deciduous understory. The channel is largely single-thread for the length of the reach. Some engineered log jams could engage the channel and floodplain in key locations, particularly in the bottom 1/3 of the reach.

In the upper and lower portions of the reach, adding LWD would increase habitat complexity (e.g., more pools), provide cover, and affect sediment storage dynamics in the channel. This, in turn, could have positive benefits related to temperature in both summer and winter by facilitating hyporheic storage and exchange with surface waters. In the middle section of the reach, the channel is more physically heterogeneous, with gravel and LWD stored in the active channel. Here, strategically placed ELJs could engage floodplain habitat with higher frequency, creating access to important rearing habitats.

Revised Restoration Objectives:

Riparian restoration, livestock exclusion, and LWD installations.

Preliminary Restoration Assessment:

Riparian restoration, livestock exclusion.

Special Considerations:

Access and staging are excellent east of State Highway 21 in the upper 1/3 of the reach, and in the first kilometer at the bottom of the reach. East Sanpoil Road provides decent access along the east side of the valley. However, access to the floodplain may require temporary road building from the east side in most locations, or use of a helicopter. Approximately 0.5 km up from the bottom of the reach, it appears that off-channel water access has been developed for livestock. This presents an opportunity to fence in preferred access routes for cattle that would allow them access to water and keep them out of the rest of the riparian zone and river channel.

Species and Life Stage Benefit:

Spawning, holding for pre-spawn adult fish, and egg incubation.

Prioritization Criteria Considered:

- Restores riparian processes and improves instream habitat.
- There is excellent access and staging on the west side of the reach, but more variable from the east side.
- Land ownership is unknown.
- Relatively high Culturally Significant Resources score and provides benefits by potentially restoring first foods.
- There may be Climate Change Amelioration benefits by restoring the riparian zone, instream habitat diversity, and floodplain wetlands.

Data Gaps/ Needs:

Need landowner information for this reach to secure access and restoration partnerships.

Project Name: Upper Columbia and Sanpoil Restoration **Project Rank 17**

Reach Name: Sanpoil 3C

Figure B-44. Overview of Sanpoil 3C reach. Note State Route 21 on the west side of the valley and the gravel road along the east side of the valley, with single-thread channel meandering across the valley. Red lines indicate the extent of lands draining to the study reach.

Figure B-45. Representative photo of Sanpoil 3C reach showing intact riparian forest, single-thread riffle habitat, and the lack of instream LWD.

Location and Site Description: Sanpoil 3C drains an upslope area of approximately 6.6 km^2 and is approximately 33 km from the confluence with the Columbia River. The priority reach is the mainstem Sanpoil and is approximately 2,220 m long. Much of the reach is characterized by a single-thread, low gradient channel meandering across the valley floor. The channel is lower gradient in the upper 1.5 km of the reach, with more sediment stored in the active channel there. The bottom kilometer of the reach becomes more confined and meanders less across the valley floor (Figure B-44). Sediment in the reach is mostly cobble and gravel. Bankfull width exceeds 20 m on average, with floodplain width ranging from 330 m to 850 m. The riparian zone is largely intact mature forest, except near the private land adjacent to the lower end of reach (Figure B-45). Channel gradient varies between 0.2% and 0.5%.

Revised Restoration Objectives:

LWD and possible ELJ installations, riparian restoration, livestock exclusion.

Preliminary Restoration Assessment:

Riparian restoration, livestock exclusion.

Special Considerations:

The best access is near the upper extent of the reach where Bridge Creek Road crosses the river. Access and staging are potentially possible on both sides of the river here, depending on ownership and landowner willingness. Near the bottom of the reach on the west side, access and staging would be very easy if the landowners are cooperative. Depending on specific sites chosen for restoration, there is relatively good access to the reach near Bridge Creek Road. Below the road crossing, the river moves away from the road and there is more vertical separation between the road and stream elevations. There is an excellent potential staging area near the Bridge Creek Road crossing. However, access to the river in this area would require road building through riparian wetlands on the east bank. Access is easier from the west bank higher in the reach. In the lower section of the reach, access is difficult from the east side due to the road elevation and steep slope but would be very easy on the west side if the landowners are cooperative.

Because of the value of this reach as spawning habitat and the obvious lack of pools for holding—particularly in the lower half of the reach—LWD or ELJ installations should be the focus of restoration actions.

Species and Life Stage Benefit:

Spawning, holding for pre-spawn adult fish, and egg incubation.

Prioritization Criteria Considered:

- Protects fully functioning riparian habitat, restores riparian and instream habitat.
- Access is generally good, although variable depending on specific location.
- Land ownership is unknown.
- Very high Culturally Significant Resources score and provides benefits by potentially restoring first foods.

- There may be Climate Change Amelioration benefits by restoring the riparian zone, instream habitat diversity, and floodplain wetlands.

Data Gaps/ Needs:

Landowner access needs to be determined.

Project Name: Upper Columbia and Sanpoil Restoration **Project Rank 18**

Reach Name: Hall 2B

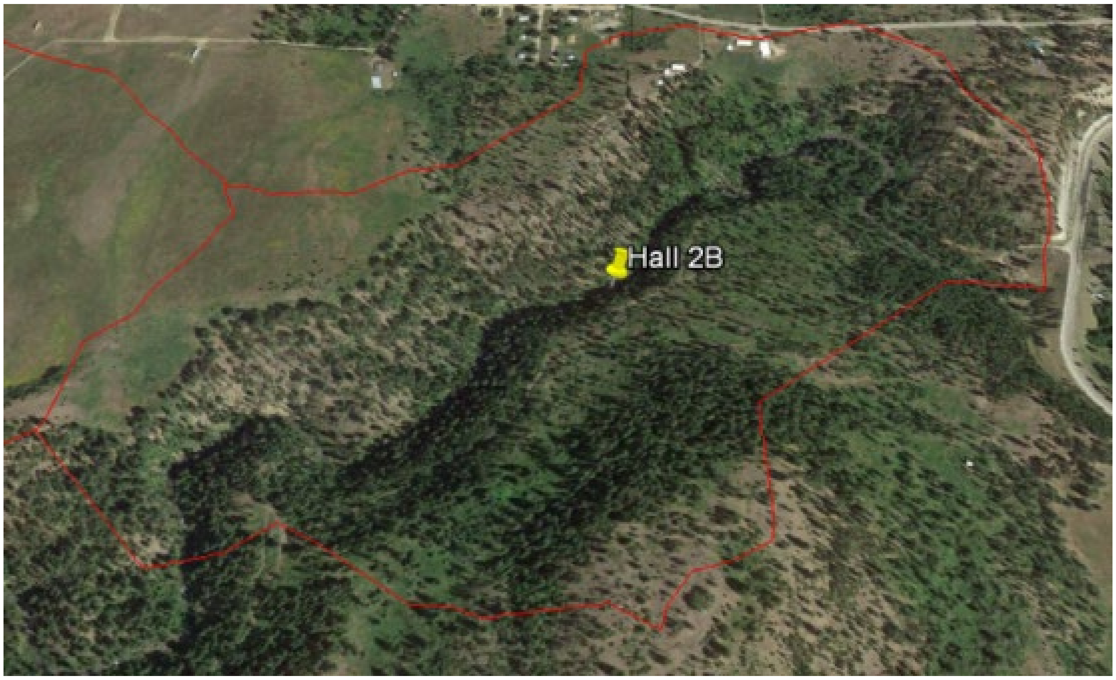


Figure B-46. Overview of Hall 2B reach. This reach is relatively steep and drains a canyon.

Figure B-47. Large culvert at the bottom of Hall 2B reach.

Figure B-48. Priority Hall 2b reach. This reach is characterized by large gravel and cobble substrate and relatively steep gradient. Note the lack of LWD in the channel.

Location and Site Description: Hall 2B drains a relatively small canyon (approximately 0.7 km^2) and is approximately one kilometer from the confluence with Lake Roosevelt (Figure B-46). The bottom of the reach is defined by the Inchelium Highway where the creek passes through a large culvert (Figure B-47). The priority reach is the mainstem Hall Creek and is approximately 1,600 m long. It is characterized by confined, meandering, and straight channel morphologies. Bankfull width is approximately 12 m, while floodplain width is between approximately 12 m and 100 m. Average channel gradient varies between approximately 0.5% and 3.8%. The reach is nearly devoid of LWD. However, installation of LWD should be done with caution in this reach owing to the single culvert and road prism that could cause water to back up if wood became hung up on the culvert.

Revised Restoration Objectives:

Protection, possible LWD.

Preliminary Restoration Assessment:

Barrier removal (bottom of reach), LWD.

Special Considerations:

LWD installations need to be designed to avoid movement in this reach. The risk of mobile LWD getting hung up on the Inchelium Highway culvert and causing a backwater flood should be considered. Also, access in this reach may be challenging everywhere except the very bottom of the reach. The stream is in a canyon that may require road building or use of a helicopter to get LWD into the channel.

Species and Life Stage Benefit:

Spawning, holding pre-spawn adult fish, and egg incubation.

Prioritization Criteria Addressed

- Protects functioning processes and improves habitat complexity.
- There is easy access and staging at the bottom of the reach. In addition, there is a gravel road along the top of the canyon on the south side of the reach.
- Land ownership has not been verified.
- Relatively high Culturally Significant Resources score.
- There may be some Climate Change Amelioration benefits to improving habitat complexity.

Data Gaps/ Needs:

Recommend an engineering assessment of LWD installation options. Land ownership needs to be verified.

Project Name: Upper Columbia and Sanpoil Restoration **Project Rank 19**

Reach Name: Lynx Trib 2A

Figure B-49. Overview of Lynx Trib 2A reach. This reach is slated for protection because of the intact drainage area which is defined by the red line.

Location and Site Description: Lynx Trib 2A drains a small upslope area of approximately 0.1 km^2 and is approximately 23 km from the confluence with Lake Roosevelt. The priority reach is the tributary Creek and is approximately 400 m long. It is characterized by plane bed channel with some step pool morphologies. Bankfull width is approximately 2 m, while floodplain width is between approximately 15 m and 50 m. Average channel gradient varies between approximately 2% and 10% at the upper end. We couldn't access this reach because of a landslide and road washout. We did view the reach from the other side of the Lynx Creek valley. The forest and riparian for Lynx Trib 2A are dominated by mature conifer forest, with some deciduous riparian vegetation near the confluence with Lynx Creek. This reach is identified as a high priority for protection. No restoration is necessary. There is a culvert downstream but it is not a barrier to fish passage.

Revised Restoration:

Protection.

Preliminary Restoration Assessment:

Protection, address downstream barrier?

Special Considerations:

None.

Species and Life Stage Benefit:

Rearing 2+-age resident fish, water quality (e.g., temperature) and obstructions (e.g., low flow) that may affect 2+-age resident rearing.

Prioritization Criteria Addressed

- Protects fully functioning habitat.
- There is no access to this site.
- Land ownership has not been verified.
- Relatively high Culturally Significant Resources score.
- There may be limited Climate Change Amelioration benefits to protecting this site.

Special Considerations:

None.

Data Gaps/ Needs:

We were not able to access this site during our field visit due to road washout. Ownership needs to be verified.

Project Name: Upper Columbia and Sanpoil Restoration **Project Rank 20**

Reach Name: WF Hall 2

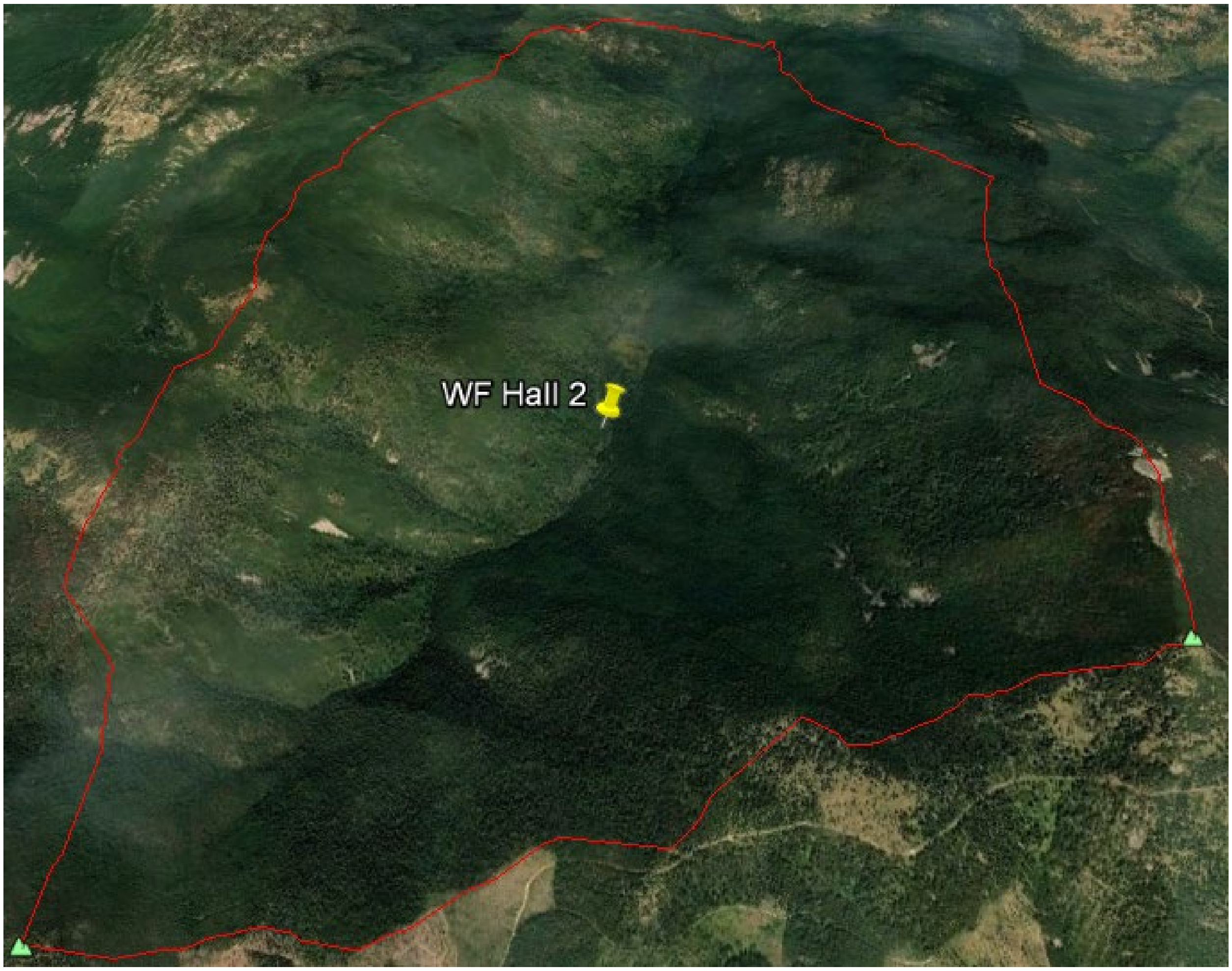


Figure B-50. Overview of WF Hall 2 reach. Note that roughly the western half of this EDTshed was logged completely in the last decade. Red lines indicate the upslope areas draining to the reach.

Location and Site Description: WF Hall 2 drains approximately 17 km^2 and is approximately 13.5 km upstream from the confluence with The Columbia River. The priority reach is the tributary Creek and is approximately 6,600 m long. The stream is characterized by meandering channel morphology through a fairly high elevation and steep watershed (Figure B-50). Peaks near the top of the watershed are more than 1,900 m. Bankfull width is approximately 22 m, while floodplain width is approximately 330 m. Average channel gradient is approximately 0.2%. We were not able to visit this reach during our field visit due to a road washout at GPS coordinates 48.43825, -118.41462.

Revised Restoration:

Protection.

Preliminary Restoration Assessment:

Protection (downstream barriers?).

Special Considerations:

No access to the reach until the road is repaired.

Species and Life Stage Benefit:

0-age resident rearing fish, overwintering habitat for 1-age, and overwintering habitat for 0-age fish.

Prioritization Criteria Addressed

- Protects fully functioning habitat.
- There is no access to this site due to road washout at GPS coordinates 48.43825, -118.41462.
- Land ownership has not been verified.
- Relatively high Culturally Significant Resources score.
- There may be limited Climate Change Amelioration benefits due to protecting this reach.

Data Gaps/ Needs:

We were not able to access the site during our field visit due to road washout. Land ownership needs to be confirmed.

Project Name: Upper Columbia and Sanpoil Restoration **Project Rank 21**

Reach Name: Barnaby 1

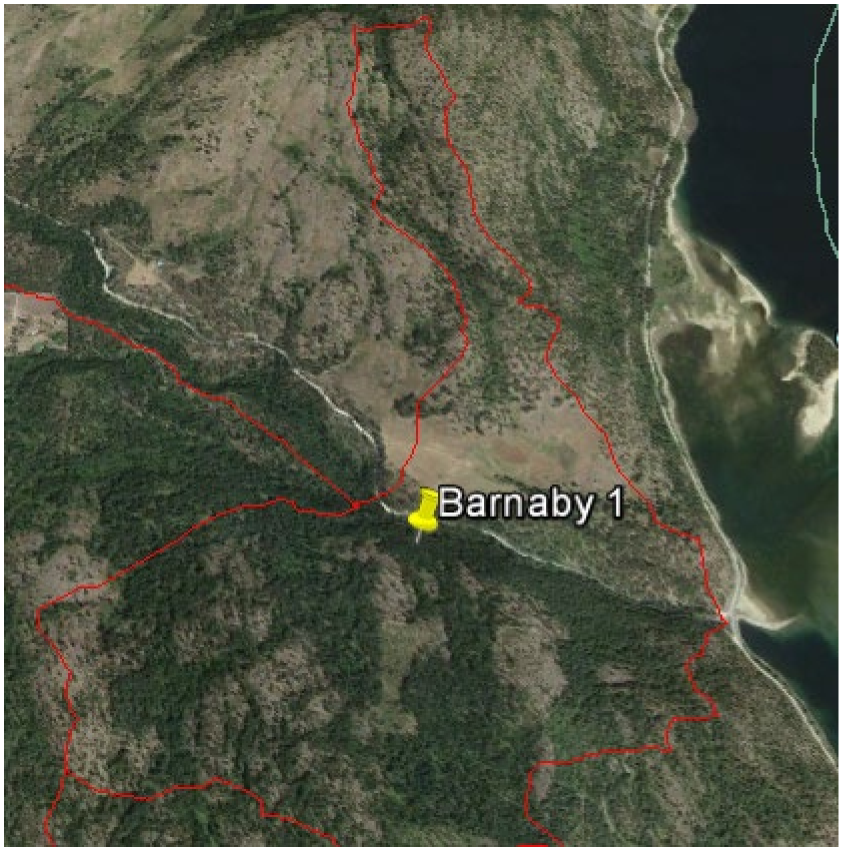


Figure B-51. Overview of Barnaby 1 reach. This reach drains directly to Lake Roosevelt. Red lines indicate the upslope areas draining to the reach. Land use is mostly forest with some agricultural/ranch lands north of the creek.

Figure B-52. Barnaby Creek near confluence with Lake Roosevelt. Upper panel is a panoramic of the pool impounded by the Inchelium Highway. Note the LWD and eroded bank. Lower panel is a view upstream from the pool at an active landslide that recruited trees to the channel during the April 2017 storm.

Figure B-53. Roadbed erosion caused during April 2017 storm (left panel). Right panel shows road sediments delivered across the forested riparian zone directly to Barnaby Creek.

Location and Site Description: Barnaby 1 drains approximately 4 km^2 and discharges directly to Lake Roosevelt. The priority reach is approximately 1,400 m long. It is characterized by plane-bed, pool-riffle, and step-pool channel morphology. Bankfull width is approximately 2 m, while floodplain width is approximately 25 m. Average channel gradient varies with channel type and ranges between approximately 3% and 12.5%. The bottom of the reach is in good condition due to recent landslide disturbance and LWD recruitment to the channel and pool upstream of the Inchelium Highway culverts (Figure B-52). The stream habitat and riparian vegetation in this reach are generally in high quality condition. The riparian zone is comprised of mature conifers throughout. There has been a history of logging throughout the lands that drain to this reach and some recent road failures were documented during our field visit. Just below the confluence with Cedar Creek, a substantial delivery of road sediment occurred, resulting from the April 2017 storm (Figure B-53). While this specific road failure is not within the study reach, sediment was transported across the riparian zone and was delivered directly to the stream channel. It's not known if this impact propagated downstream to the priority reach. Regardless, the road failure needs to be addressed.

Revised Restoration:

Road restoration, protection.

Preliminary Restoration Assessment:

Protection.

Special Considerations:

There is excellent access to the entire reach from Barnaby Creek Road, with good staging at the very top of the reach. Direct access to the stream can be difficult in places due to steep slope from the road down to the stream. Land ownership needs to be verified and landowner willingness assessed. Road failures propagated directly to the stream channel and this needs to be addressed as the highest priority for this reach.

Species and Life Stage Benefit:

Spawning fish, egg incubation, and overwintering 0-age fish.

Prioritization Criteria Addressed

- Restores sediment processes and protects fully functioning habitat.
- There is great access to this reach due to Barnaby Creek Road that runs adjacent to the stream throughout this reach.
- Land ownership has not been verified.
- Relatively low Culturally Significant Resources score.
- There are likely no additional Climate Change Amelioration benefits to this project.

Data Gaps/ Needs:

Active landslides and road failures due to the April 2017 storm delivered a lot of sediment to this system. It is not known if the proximity of Barnaby Creek Road results in a chronic source of fine sediment. Land ownership has not been verified. Some industrial forestry happens in this EDTshed and may be privately owned.

Project Name: Upper Columbia and Sanpoil Restoration **Project Rank 22**

Reach Name: Sanpoil 4C

Figure B-54. Overview of Sanpoil 4C reach. This mainstem reach meanders across the valley floor between State Highway 21 on the west side, and East Sanpoil Road on the eastern side of the valley.

Figure B-55. Representative habitat quality of Sanpoil 4C reach. Lots of gravel and LWD interactions are apparent as the river meanders across the valley floor.

Location and Site Description: Sanpoil 4C drains approximately 15 km^2 and flows approximately 43 km down to the confluence with the Columbia River. The priority reach is approximately 5,350 m long. It is characterized predominantly by meandering channel morphology (Figure B-54). Bankfull width is approximately 20 m, with a floodplain width of approximately 360 m. Average channel gradient varies with channel type and ranges between approximately 1% and 3%. There is no human infrastructure in the reach aside from the roads that run along both sides of the valley. Habitat quality is generally very high in this reach (Figure B-

55). This is in large part due to the massive sediment load being processed in this reach due to the April 2017 flood. Suggestions for restoration in this reach are limited to strategic ELJs that would keep the river away from the State Highway 21 road prism and encourage floodplain habitat engagement on the east side of the river.

Revised Restoration:

Protection, possible ELJs.

Preliminary Restoration Assessment:

LWD, riparian restoration, floodplain reconnection, upland forest restoration.

Special Considerations:

There is excellent access and staging at the top of the reach from either side of the river. Large wetlands adjacent to the channel make direct access to the channel less certain elsewhere in the reach. Land ownership has not been verified.

Species and Life Stage Benefit:

Holding habitat for pre-spawn adult fish, spawning, and egg incubation.

Prioritization Criteria Addressed

- Protects fully functioning habitat and restored floodplain processes.
- Access and staging are excellent at the top of the reach, but less certain downstream.
- Land ownership is unknown.
- Relatively high Culturally Significant Resources scores.
- There may be some limited Climate Change Amelioration benefits to this project, depending upon the extent of ELJ placement.

Data Gaps/ Needs:

Specific landowner information and willingness to participate in livestock fencing and riparian plantings needs to be gathered.

Project Name: Upper Columbia and Sanpoil Restoration **Project Rank 23**

Reach Name: Silver 1

Figure B-56. Overview of Silver 1 reach. The stream confluence with the Sanpoil Arm is in the lower left portion of the image. The red line indicates lands draining to the study reach.

Figure B-57. Photo taken near the top of Silver 1 study reach. Note the healthy and intact riparian zone. Also, there is substantial fine sediment in the channel (center of photo) from the nearby road or possibly from recent logging of steep slopes above the study reach.

Location and Site Description: Silver 1 drains an upslope area approximately 0.5 km^2 and is approximately 11.5 km from the confluence with the Columbia River. It is a small tributary watershed that drains to the Sanpoil Arm and is comprised of approximately 850 m of stream that is 2.5 m at bankfull width, with floodplain width ranging from 40 m to 130 meters. Average channel gradient ranges from 0.005% to 0.117%. There is a road that roughly parallels the stream and is relatively close to the stream in the upper reach. The road is paved near the bottom but then becomes gravel near the intersection with another road. There is a passable culvert under the road crossing approximately 200 m from the top of the reach. In some places the stream is relatively steep and incising as it heads downhill to the lake. In others, there are boulders that control the channel gradient. There is very little geomorphically effective large wood in the system. The stream is impacted from road sediment inputs, although it is not clear if the sediment is delivered at points or by overland flow through the riparian forest. We saw no obvious points of sediment introduction during our field visit, although there has been recent logging activity approximately 2 km above the reach on steep slopes. Overall, the riparian community is diverse and consists of snow berry (*Symphoricarpos albus*), red-osier dogwood (*Cornus stolonifera*), red alder (*Alnus rubra*), and young and mature conifers. As the stream approaches the Sanpoil Arm of Lake Roosevelt, the amount of road sediment is substantially decreased relative to upstream areas. There are no obvious recent grazing impacts to this reach.

Revised Restoration Objectives:

Control fine sediment sources, protect the riparian zone, LWD.

Preliminary Restoration Assessment:

Protection, LWD.

Special Considerations:

There is very little geomorphically functional LWD in the system. Sediment delivery from the major road is also a problem. It is not entirely clear where the road sediment enters the system, but there is clearly too much fine sediment from the road in the stream channel. In the upper part of the reach, access is relatively easy due to the road that parallels the stream for much of its length. In addition, approximately 0.5 km upstream from the confluence with the Sanpoil Arm, there is an intersection with Kuehne Rd that crosses the stream and roughly bisects the reach. This is a good location for equipment access. The road elevation is approximately 6.1 m (20 feet) above the stream elevation at this crossing. Approximately 200 m below that, Silver Creek Road veers away from the stream channel and slopes become very steep. There is no equipment access below this point. Also, both above and below the road crossing, there is very little LWD in the channel. In some places, the channel incision might be decreased with LWD in the channel to encourage bed aggradation, gravel storage, and pool formation. It is clear that the sediment load in this stream is impacted by sources from either the road or the upslope logging operations, or both. The amount of fine sediment can negatively impact spawning success, embryo incubation, and survival to emergence. In addition, sediment can fill pools and limit holding habitat for pre-spawn adult fish.

Species and Life Stage Benefit:

Spawning, holding for pre-spawn adult fish, and egg incubation.

Prioritization Criteria Considered:

- Protects fully functioning habitat, restores riparian and instream habitat.
- Access is generally good, although variable depending on specific location.
- Land ownership is unknown.
- Relatively high Culturally Significant Resources score and provides benefits by potentially restoring first foods.
- There may be Climate Change Amelioration benefits by restoring instream habitat diversity.

Data Gaps/ Needs:

Need landowner information for this reach to secure access and restoration partnerships.

Project Name: Upper Columbia and Sanpoil Restoration **Project Rank 24**

Reach Name: Sanpoil 1F

Figure B-58. Overview of Sanpoil 1F reach. This reach is between the town of Keller, Washington and the Sanpoil Arm of Lake Roosevelt on the Columbia River. The red line indicates the boundary of upslope lands that drain to the reach.

Figure B-59. Site of potential ELJ installation. In this location, the river has migrated into the road prism. An ELJ here would encourage the river to move into the floodplain on the opposite bank while protecting the road. Note high quality and diverse habitat in the channel and riparian conditions.

Location and Site Description: Sanpoil 1F drains approximately 1 km^2 of upslope area and is located at the top of the confluence with the Sanpoil Arm of the Columbia River. The priority reach is the mainstem Sanpoil River and is approximately 1,100 m long (Figure B-58). It is characterized by meandering, braided, and island-braided channel morphology. Bankfull width is approximately 150 m, while floodplain width is approximately 330 m. Average channel gradient is approximately 0.2%. This low-gradient section of river is laterally active, with lots of stored sediment in the channel associated with meander bends and islands. The habitat is fairly high quality with a meandering riffle/ glide channel form. The riparian zone is intact, with mixed coniferous and deciduous vegetation (Figure B-59). There are multiple cut banks and LWD jams in this reach. Aerial photo analysis indicates that this reach has always been laterally active, which generally coincides with good habitat quality for fish. There are roads along both sides of the reach that make access and staging relatively easy. The river meanders across the entire valley floor in this reach. Current conditions may also reflect the massive April 2017 flood that recruited LWD and sediment to the reach.

Revised Restoration:

Riparian restoration, LWD, possible ELJs.

Preliminary Restoration Assessment:

LWD, riparian restoration.

Special Considerations:

This reach is highly laterally active. This creates opportunities, but it can also be risky. An engineer should be consulted prior to installing structures in the channel where they might cause the river to interact with road infrastructure. ELJs may be appropriate to restore habitat in the channel as well as to divert flows away from eroding road prisms. The river is engaging the toe of the Silver Creek Road prism in several places in this reach, which may create cooperation opportunities with departments of transportation. LWD in a bio revetment installation would protect the toe, and strategic ELJs in the reach would facilitate moving the river away from the road in general. There are no bridges or buildings downstream that would be at risk. In addition, there is at least one large active landslide in the reach, with a house above it where another ELJ might be used to protect the toe of that slope.

Species and Life Stage Benefit:

0-age resident rearing fish, overwintering habitat for 1-age, and overwintering habitat for 0-age fish.

Prioritization Criteria Addressed

- Restores riparian and floodplain process and habitat complexity.
- Excellent access and staging in this reach.
- Land ownership has not been verified.
- Relatively low Culturally Significant Resources score.

- There may be some Climate Change Amelioration benefits to restoration in this reach.

Data Gaps/ Needs:

Land ownership needs to be verified. Engineering study is advisable in this reach for ELJ placement.

Project Name: Upper Columbia and Sanpoil Restoration **Project Rank 25**

Reach Name: Hall 3

Figure B-60. Overview of Hall 3 reach. This long (9.4 km) reach drains through a variety of private lands and others of unknown ownership. The red line indicates the upslope area that drains to the stream here.

Figure B-61. Looking downstream (left panel) and upstream (right panel) from the approximate center of Hall 3 reach. Conditions in this location are typical of the reach.

Figure B-62. Evidence of floodplain activation during April 2017 flood events. The road washed out here as the creek engaged a historic channel and sediment was delivered to the floodplain for several hundred meters downstream.

Location and Site Description: Hall 3 drains a large area (approximately 27 km^2) and is approximately 2.7 km from the confluence with Lake Roosevelt. The priority reach is the mainstem of Hall Creek and is approximately 7,100 m long (Figure B-60). It is characterized predominantly by meandering morphology, but exhibits both confined and island-braided morphologies as well, mostly in the lower extents. Bankfull width is approximately 12 m, while floodplain width is between approximately 30 m and 150 m. Average channel gradient varies between approximately 0.6% and 2.9%. There is a large, deep pool at the top of the reach upstream of the Lynx Creek Bridge. Inputs of road sediment are apparent from this bridge and road intersection. There is dense shrubby riparian vegetation throughout the reach (Figure B-61). However, there are some riparian impacts near the top of the reach where the stream abuts agricultural lands. In addition, there are clearly fine sediment inputs into the system here. LWD loads are moderate, on average. The channel is relatively straight with homogeneous habitat units, except where LWD is present in the channel (Figure B-61). During the April 2017 floods, overbank flows extended out into the floodplain and engaged historic channel features (Figure B-62).

Revised Restoration Objectives:

Riparian restoration, livestock exclusion, control fine sediment.

Preliminary Restoration Assessment:

Barrier removal (downstream), riparian restoration (buffer on ag. lands), LWD.

Special Considerations:

Stream channel is in decent shape, with a variety of habitat units in proximity to each other throughout the reach. In general, the upstream 4 kilometers are lower gradient and exhibit more lateral migration, and the downstream 2 kilometers are much steeper with the lowest kilometer in a canyon. There are some riparian impacts near the top of the reach and in other locations where agricultural lands impinge upon the channel. There is a suspected barrier at a 19% gradient waterfall near the bottom of the reach, but discussions with local landowners upstream indicated that there are existing populations of fish higher in the reach. It is unknown if the upstream fish are the result of stocking or natural migrations. We did not see the waterfall during our field visit because a road washout prevented access.

Species and Life Stage Benefit:

Spawning, holding pre-spawn adult fish, and egg incubation.

Prioritization Criteria Addressed

- Restores connectivity, riparian process, and habitat complexity.
- Access and staging are variable but possible from a variety of roads throughout the reach.
- Land ownership has not been verified but appears to consist of more private ownership here than along the Sanpoil River.
- Relatively high Culturally Significant Resources score.
- There may be limited Climate Change Amelioration benefits from riparian restoration, barrier removal, and increased habitat complexity.

Data Gaps/ Needs:

Aside from bridges, there were no direct sediment inputs observed during our field visit. It is uncertain if the waterfall near the downstream end of the reach creates a migration barrier under certain flow conditions, or if fish passage options should be considered. Land ownership needs to be determined.

Appendix C. Detailed Response to ISRP Comments

Response to the Preliminary ISRP Review (2020) – 199001800 Lake Roosevelt Habitat Improvement Project

The ISRP requested responses to the following questions in order to determine if the project meets scientific review criteria. Initial responses were provided to the ISRP on June 23, 2020. Updated responses are highlighted in grey and were added on April 11, 2022, after completion of revision of the Upper Columbia and Sanpoil Restoration Plan

1. **How are habitat restoration priorities linked to upslope processes that influence limiting factors? Are upslope watershed conditions included in the prioritization of restoration actions? Are upslope restoration actions considered as separate restoration alternatives?**

CCT Response: For project specific information on prioritization considerations regarding upslope processes and watershed conditions, see response below in #2.

The Upper Columbia and Sanpoil Restoration Plan included an assessment based on existing data which included land cover, land use, road crossing, and other factors. While the EDT modeling tends to focus most on reach or in-channel metrics, our assessment and follow up site visits in priority reaches looked at the entire area draining into a given priority reach (EDTshed). Thus, the restoration measures needed to address limiting factors and improve habitat were determined in part by looking at upslope conditions. For example, delivery of sediment from roads was identified as a potential cause of high levels of fine sediment in two priority reaches (Silver 1, and Barnaby 1) and road improvements and restoration measures are part of the suite of restoration actions recommended in these priority reaches. Upslope conditions were considered in the prioritization of restoration actions indirectly through identifying whether the restoration measures proposed restore processes (e.g., connectivity, hydrology, sediment).

On a watershed scale the current funding levels are insufficient to address many of the other upslope processes that influence limiting factors with direct restoration actions. However, participation in the CCT NEPA process allows opportunity to provide input to timber sale and range unit lease activities to minimize additional impacts where possible. In other instances project staff has provided coordination to aid the CCT Environmental Trust Department's (ETD) Watershed Restoration Specialist and Non-point Source Pollution Coordinator to identify roads in the LRHIP study area for closures and decommissioning to reduce open road density using grant funding. Other restoration actions performed by ETD that benefit LRHIP goals include: stream crossing removals or improvements; and road drainage improvements or relocation of stream adjacent roads where road density reduction is not possible.

2. **Are protection and restoration actions evaluated and prioritized concurrently in the prioritization process? For lands within the Colville Reservation, is land use regulation or specific protection status considered for protection priorities? Does the CCT have an overall land use plan for the Colville Reservation? For lands outside the Colville Reservation, is acquisition considered as a potential action in this project? The proposal**

states that protection of high-quality habitat is more effective than restoration of degraded habitat.

CCT Response: Yes, protection and restoration actions were prioritized along with restoration actions. For the study area, priority reaches were identified from the pool of all EDT reaches based on summaries of modeling results that predict Redband Trout population parameters. The summaries were used to rank the EDT reaches to identify high priority reaches for protection and restoration actions. The priority rankings (P_{rank}) were based on the summed EDT model outputs for the potential percent changes in Diversity (Div), Productivity (Prod), and Equilibrium abundance (N_{EQ}) reported in the EDT analysis (**Equation 1**).

Equation 1. $$P_{rank} = \Delta Div\% + \Delta Prod\% + \Delta N_{EQ}\%$$

Specific protection and restoration actions were not used to determine P_{rank}. Ranking the sums of percent change of the population parameters does bias priority reach selection towards potential for restoration of current to template conditions. However, a preliminary ranking of protection values for the Sanpoil Subbasin at the time of this response suggests a high level of congruity with selected priority reaches. The top five protection priority reaches for the Sanpoil Subbasin included the following Sanpoil River Mainstem reaches: Sanpoil 3D, Sanpoil 4B, Sanpoil 2I, Sanpoil 2J, and Sanpoil 4A. All five of these Sanpoil Subbasin protection priority reaches are among the top 25 priority reaches for the combined Sanpoil and Upper Columbia subbasins selected based on **Equation 1**. The response timeframe is not sufficient to revise the prioritization criteria and changes to the proposal Goals and Objectives, and Methods sections will create additional work needed to verify restoration and protection priorities before implementation.

As selected, all of the priority reaches were then evaluated both for restoration actions based on the model predictions of potential for *increased* diversity, productivity, and abundance under restoration of current conditions to the template condition scenario; and all priority reaches were also evaluated for protection actions based on model predictions of the potential for *reduced* diversity, productivity, and abundance under a degradation from the current condition scenario. Given the geographic extent and site specific conditions based on those metrics, some reaches were identified for both restoration and protection.

Following initial P_{rank} scoring, additional examination of datasets including: upslope conditions; habitat surveys; expected channel types and confinement; and riparian condition based on National Land Cover Database and aerial imagery were also used to develop recommendations for restoration and protection for priority reaches. Those recommendations required field verification to confirm modeling predictions and following site visits were revised as needed. Some priority reaches were reevaluated for protection during this process as they were largely high quality habitat.

With priority reaches identified using EDT modeling results and habitat restoration or protection objectives determined, the implementation strategy was then prioritized. Five criteria were used to prioritize implementation: 1) whether the action restores processes, 2) site access and logistics, 3) land ownership within 100 m of priority reach, 4) cultural significance and socioeconomics, and 5) whether the action has climate change amelioration benefits. Because priority reaches were already identified using EDT model results they were not included here again.

One shortcoming of this process is that the implementation score of priority reaches with multiple restoration/protection recommendations may not accurately reflect the relative benefit of each individual action and a better approach may be to first group reaches as high priority, moderate priority, and low priority based on P_{rank} then to prioritize specific restoration/protection measures individually within reaches based on the criteria above. The combination of a priority reach's P_{rank} and restoration/protection action prioritization score could then be combined to determine an overall hierarchy of implementation objectives.

To differentiate between protection actions that are intended to preserve high quality, intact habitat versus mitigating potential degradation of current conditions that could result in a reduction of N_{EQ}, a framework for determining specific protective actions to be implemented is included here (**Figure 14**). The distinction between protection action types is relevant because there can be a considerable difference in implementation costs and the investment of LRHIP funds do not reflect the true ecological value of restoration versus protection benefits.

At the present time, the four priority reaches with high quality, intact and functioning habitats specifically identified in the restoration plan and their associated upslope areas, the EDTsheds, which have been identified for protection, are largely located within Tribal Trust lands and fee parcels owned by the Colville Confederated Tribes with the exception of three privately owned fee parcels. The three parcels intersect approximately 220 m of the 3,400 m Sanpoil 5E reach and 600 m of the 1,000 m Sanpoil 5C reach. There may be potential future benefit to Sanpoil 5C by purchasing or encumbering a portion of a 125 ac fee parcel to the east at the downstream end of the reach. The remainder of these top tier priority reaches identified for protection would benefit most from policy and regulatory level protection measures as described below.

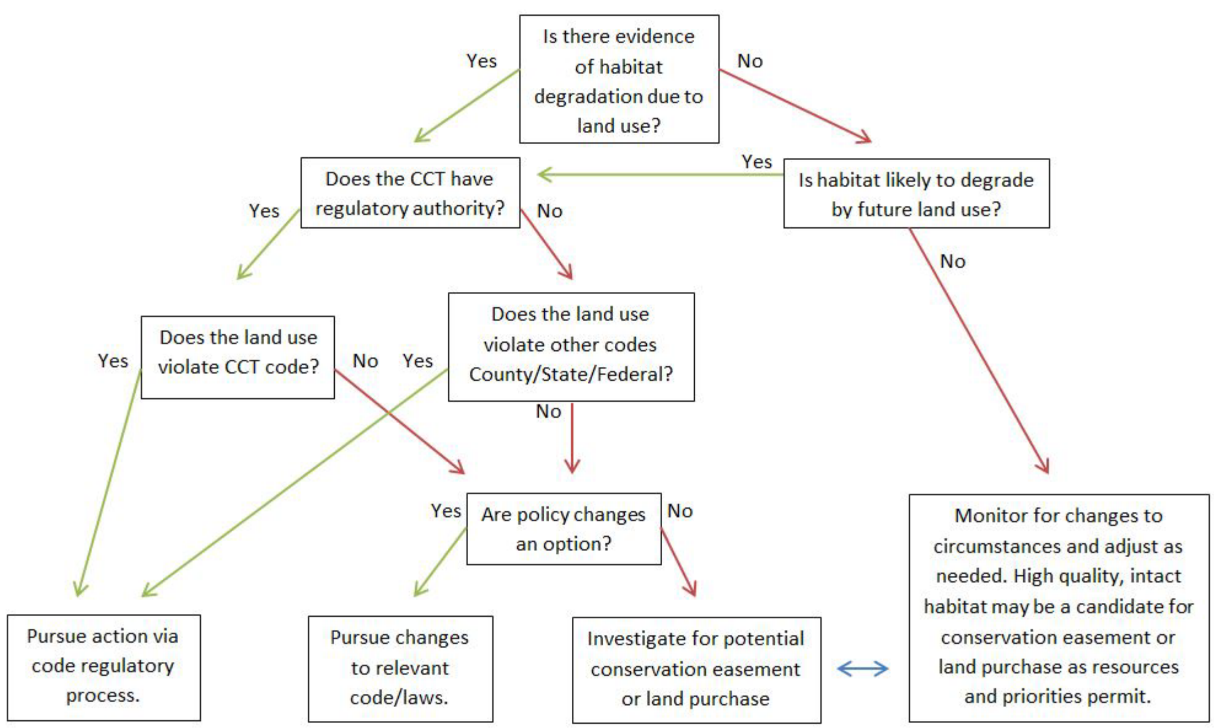


Figure 14. Decision tree matrix for determining specific protective measures for identified reaches.

Within the bounds of the reservation existing Colville Tribal Law and Order Code (CTLOC) outlines the authority for regulation of land use and protection status (CCT 2020). A number of relevant codes are found under Title 4: Natural Resources and Environment, which can effectively protect some priority reaches through passive means without requiring significant investment of project funding or staff time. Priority reach WF Hall 2 for example is entirely encompassed by the Grizzly Mountain Wilderness Area, a CCT land use designation which is intended to protect the area from anthropogenic disturbances and development specifically prohibiting; mining, timber harvest, grazing and associated infrastructure such as road building (CTLOC 4-3 Land use and Development). Any proposed changes to the Grizzly Mountain Wilderness Area land use that might degrade habitat in WF Hall 2 would require a permit review process before approval. Other CTLOC Title 4 sections such as; Fish, Wildlife and Recreation (4-1), Forest Practices (4-7), Water Quality Standards (4-8), Hydraulics Project Permitting (4-9), Rangeland Management (4-11) and others provide a basis that can be used to advocate for mitigating the impacts of land uses on fish habitat.

Priority reaches identified for protection to mitigate potential degradation of current conditions that could result in a reduction of N_{EQ}, are contained within CCT or public land ownership (e.g. USBR or USFS) for an average of 87% of the reach length with a range of 73% (Sanpoil 4C) to 100% (Sanpoil 4B). Priority reaches Cedar 1, Cornstalk 5C, and Silver 1 are not included as they have known or suspected barriers within or downstream that require additional investigation or removal first.

The CCT also relies on the Integrated Resource Management Plan (IRMP) to provide goals and objectives that guide multiple uses of the reservation forest, rangeland and water resources and also incorporates tribal revenue generating enterprises, habitat for fish and wildlife, and traditional cultural activities (CCT 2015). The LRHIP supports the IRMP Goals and Objectives specifically contributing to the following Fish and Wildlife Goals and Objectives:

Fish Goals and Objectives

Goal 1: Regional Planning. Work cooperatively and establish relationships with internal and external stakeholders to provide the best possible resource management of fish populations for the tribal membership throughout the Reservation and aboriginal territories.

Objectives: Participate in Columbia River Basin activities, committees and other natural resource management venues including fish and wildlife habitat conservation plans. Implementing habitat conservation plans. Participate in coordinated tribal natural resource management efforts through Project Planning Process to effectively manage resources and meet tribal goals and objectives.

Goal 3: Harvest. Conserve, enhance and restore native fish populations through harvest monitoring and management and provide appropriate opportunities for rightful ceremonial and subsistence harvest by the Colville tribal members.

Objectives: Expand tribal fishing opportunities in the Columbia River Basin, including *the Reservation and aboriginal territories.*

For priority reaches outside of the reservation boundary acquisition is a viable option for protection if warranted. Priority reach Lost 6 for example is a 4,475 m reach located north of the reservation and within the Okanogan National Forest for all but approximately 280 m at the upstream end. Further investigation would be required to weigh the relative benefit of purchasing or encumbering via conservation easement the relatively short segment located on private property versus restoration or protection activities in the national forest portion. Priority reach Sanpoil 7D which is also located outside of reservation lands was not identified for protection but the extensive agricultural impacts would likely require significant investment of restoration resources and the benefits of acquisition versus establishing a conservation easement to maintain restoration objectives would be dependent on the willingness of the landowners and the terms negotiated.

3. **Can the EDT model be used to estimate potential biological outcomes for Redband Trout? If so, the project could compare the relative benefits of protection actions with the benefits of restoration actions. The project should develop quantifiable biological objectives with explicit timeframes that could be evaluated in the future.**

CCT Response: Caution needs to be used when using EDT to set biological targets as estimates in capacity and abundance are relative to one another and their accuracy or precision is often unknown and many factors can influence adult abundance in particular (Mobrand et al. 1997; McElhany et al. 2010)[4]. However, as recommended, we were able to use EDT model outputs to set initial targets for juvenile abundance for priority EDT reaches. The method and approach is described in detail in the revised Upper Columbia and Sanpoil Restoration Plan. We view these as initial targets that need to be refined during the project design phase and prior to implementation. This is important for two reasons. First, while EDT helps identify limiting factors in a reach, capacity estimates are based on "template" conditions which assumes that a reach is restored to pristine or pre-human disturbance conditions. Second, during the design phase we will be able to determine the extent of the reach that will be treated, which will influence the biological target (juvenile Redband Trout capacity). Ensuring that the biological targets are reasonable is important particularly given that these targets and whether they are achieved will be one factor used to determine project effectiveness and assist with adaptive management of restoration for the Program.

As far as comparing protection vs restoration benefits, it is important to note that abundance, productivity as well as diversity were used to prioritize and identify the highest priority EDT

[4] McElhany, P., E. A. Steel, K. Avery, N. Yoder, C. Busack, and B. Thompson. 2010. Dealing with uncertainty in ecosystem models: lessons from a complex salmon model. Ecological Applications 20(2):465-482.

Mobrand, L. E., J. A. Lichatowich, L. C. Lestelle, T. S. Vogel. 1997. An approach to describing ecosystem performance "through the eyes of salmon". Canadian Journal of Fisheries and Aquatic Sciences 54(12): 2964-2973.

reaches both for restoration and protection. Thus, these biological outcomes were already used to help select the reaches[5].

4. **EDT projections should be evaluated after implementation with monitoring and evaluation. At the very least, implementation outcomes should be documented, and critical site conditions targeted for restoration should be assessed. Does the project plan to monitor its habitat restoration actions?**

CCT Response: We agree that monitoring and evaluation using EDT projections would be a valuable component to this project however funding level commitments limit our ability to implement effectiveness monitoring at a scale that could detect changes due to habitat restoration actions. Additionally, as stated in the ISRP response, BPA has not been willing to fund such evaluations. Unless there is some commitment from the agency to increase funding levels commensurate with this action, the CCT will not be able to implement M&E to that degree. With that said, the RM&E project (200810900) monitors overall population increases of Redband Trout from the Sanpoil subbasin that may be reflective of the LRHIP protection and restoration actions. The RM&E project is considering how to increase statistical power to detect changes in response to protection and restoration actions.

Implementation outcomes and critical site conditions targeted for restoration can be documented and assessed dependent on the type of restoration actions. Projects requiring engineering design services such as fish passage, floodplain connectivity, etc. will have as-built surveys completed post-implementation to insure that restoration objectives are met and documented. Riparian planting and livestock exclusion projects will have monitoring stations established at locations to be determined during individual restoration project planning phase.
The following types of data will be researched and implemented as feasible as part of the post implementation documentation and/or used during the assessment process:

- The CCT collected one meter resolution LiDAR data for the entire reservation between 2014-2016 which could be used as a baseline for comparison of pre/post implementation projects.
  - As remote sensing technology such as drone based LiDAR becomes more readily available some implementation outcomes could be documented to a higher degree of precision and assessed against the baseline LiDAR data.
- Aerial and terrestrial photography can be used to document and assess project reach scale restoration actions.
- The LRHIP is in the process of updating geospatial information for current and past projects and will incorporate new restoration and protection projects.
- Riparian restoration could be monitored using remote sensing, climate data, and cloud computing such as ClimateEngine.org. Alternatively or additionally existing land cover

[5] Note the original response to question 3 was retracted and replaced with this text.

classification such as LANDFIRE EVT could be compared to modeled historic land cover (LANDFIRE BpS).

5. **Are data on implementation and outcomes of this project included in the CCT Data Portal? Is this information publicly available? The proponents are asked to describe their plans to make their information available on the CCT Data Portal.**

CCT Response: The development of the Resident Fish Database (https://www.cctrfdata.org/) is ongoing. A portion of the database (stocking locations, species, numbers, and dates from the Resident Fish Hatchery) is available to the general public. The remainder of the database is also available to the general public, but a Keystone username and password is required to access it. Logins at this time are by request only and are approved through the CCT Chain of Command. Once logged in, more data is available, including data from other CCT Resident Fish Division projects including LRHIP. Data available on the database includes LRHIP stream habitat inventory survey data for the Upper Columbia tributaries and the Sanpoil Subbasin. As database development continues, more types of data will be uploaded and available for viewing.

6. **How does this project contribute to the implementation of the Lake Roosevelt Guiding Document?**

CCT Response: The Lake Roosevelt Habitat Improvement Project (LRHIP) interacts and coordinates with other projects within the CCT Resident Fish Program annually to review project specific goals and objectives, and to cross coordinate efforts between projects. The annual review consists of a Program Manager, Research Scientist, 3 Project Biologists, and a Hatchery Manager. The Lake Roosevelt fishery is co-managed by the Washington Department of Fish and Wildlife (WDFW), the Spokane Tribe of Indians (STOI), and the Colville Confederated Tribes (CCT). Representatives from each entity constituent the Lake Roosevelt Management Team (LRMT) and is guided by the draft Lake Roosevelt Guiding Document (https://spokanetribalfisheries.com/lrgd2020/). The LRMT makes decisions through a 3 tiered process (see matrix below) that includes a technical team, management team and a policy team. The LRHIP is part of a suite of technical projects identified in the Guiding Document directed at supplementation, research and monitoring, and habitat enhancement. Within the Guiding Document, the LRHIP has two identified goals:

1) Conserve, enhance, restore and monitor native aquatic species and reintroduced species in Lake Roosevelt and associated tributaries.
2) Provide and maintain subsistence fishing opportunities for Native American Tribes.

The Guiding Document further addresses objectives and strategies specific to the LRHIP. Those include:

Objective 2: Protect, restore, and enhance reservoir and tributary habitats necessary for all life stages and life history strategies of key fishes and aquatic organisms.

> ***Strategy 2.2***: Determine the quantity and quality of tributary habitats necessary for all life stages and life history strategies of key fishes and aquatic organisms.

Strategy 2.3**:** Implement projects and hydro-operations modifications to protect, restore, or enhance all reservoir and tributary habitats necessary for all life stages and life history strategies of key fishes and aquatic organisms.

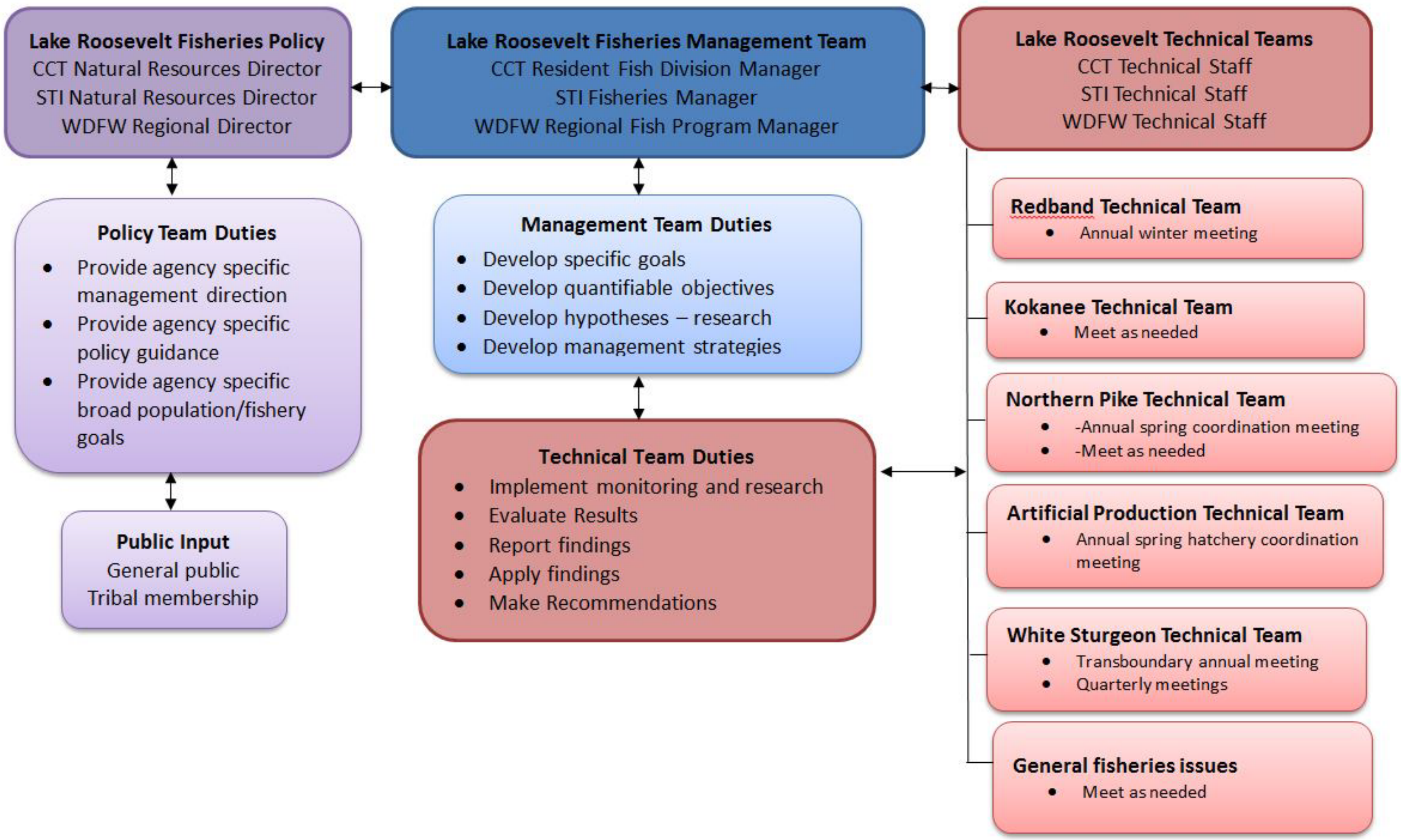
Objective 3: Identify all human created barriers, including those due to reservoir operations, to access to habitats by all life stages of key fishes and aquatic organisms within the reservoir and its tributaries.

Strategy 3.1**:** Where appropriate, restore access to all historical (pre-European settlement) habitats necessary for all life stages and life history strategies of key native fishes.

Strategy 3.2**:** Remove appropriate barriers preventing access to reservoir and tributary habitats.

The LRMT utilizes a number of actions to develop a robust native trout population and triploid Rainbow Trout harvest fishery. The Spokane and Sherman Creek hatcheries in conjunction with the Lake Roosevelt Net Pen Project provide up to 750,000 supplemented triploid Rainbow Trout for angler harvest. Angler possession limits are 5 per day for adipose clipped Rainbow Trout and adipose intact Rainbow Trout are to be released immediately. Harvest limits on predators was increased for Northern Pike (unlimited) and Walleye (16 fish and opening up Spokane Arm to harvest during spawning) and Northern Pike suppression programs were developed and conducted by the co-managers to protect native trout from predation. The Colville Business Council eliminated fishing by non-members in the Sanpoil River to protect the largest Redband Rainbow Trout population in the basin and to provide ample fishing opportunity for the tribal membership. To increase abundance of native trout in tributary habitats, the LRHIP and the Spokane Tribe of Indians implements restoration projects in their respective areas to improve native trout habitat. In summary, the current plan for native trout is to implement habitat restoration through the LRHIP and STOI projects, conduct predator removal through the Northern Pike Removal Projects (CCT, STOI and WDFW) and the Chief Josephs Kokanee Enhancement Project (predator removal), implement protective harvest regulations on Redband Rainbow Trout, and provide an augmented triploid Rainbow Trout fishery for angler harvest in Lake Roosevelt. These actions together should provide increases to the native trout populations over time.

Lake Roosevelt Fisheries Decision Matrix



7. Does the project have an explicit adaptive management plan? Is there an annual schedule for evaluating project actions and making decisions about actions for the coming year and adjustments to the project plans? Are the decisions documented and archived for future reference?

CCT Response: The project does not have an explicit adaptive management plan however, we agree that such a plan is necessary to summarize past events, evaluate project actions, make adjustments and decisions about future actions and to document restoration and protection actions taken overtime. In order to insure that the LRHIP is adaptable, accountable, and has a mechanism to measure whether habitat protection and restoration goals are being accomplished, we will first develop quantitative biological objectives so that there is a framework by which to evaluate project actions. Next we will outline a process by which project actions are evaluated for how they have performed relative to projected outcomes and goals and determine next steps based on the data. We recognize that a record of decisions made based on an explicit adaptive management plan would be of benefit considering the project biological staff turnover in recent years and the need for continuity and will work to accomplish the development of this task in the future.

Additional ISRP Specific Comments

In addition to the above specific questions, we noted that the ISRP in their detailed write up mentioned two other related questions. We provide concise responses to these two questions below.

Does the project include risks associated with potential for extreme weather events and regional climate and disturbance trends in the prioritization process?

CCT Response: The ability of a project to ameliorate the impacts of climate change was a key factor in prioritizing restoration actions as was whether the project restores processes. These were two of the five criteria used to reprioritize the 25 highest priority EDT reaches. Both these criteria are in part to focus on giving higher priority to those reaches that can be made more resilient to climate change and extreme weather conditions by restoring processes.

The proposal does not explain the long-term processes that will deliver wood to provide in channel and floodplain geomorphic function rather than relying on artificial ELJs and wood additions.

CCT Response: The preliminary restoration measure for the 25 highest priority reaches that included ELJs, floodplain reconnection, or channel remeandering are all designed to reconnect floodplain habitats. During the initial design phase, additional restoration measures will be identified and incorporated into the design to ensure floodplains are fully reconnected and riparian areas fully restored. This may include riparian planting to restore long-term sources of large wood with wood placement designed to provide adequate wood that is expected to last many decades. Moreover, while initially in some cases ELJs were identified, this is but one approach, but the best approach, which may include Stage 0, beaver enhancement, and other newer process-based restoration techniques will be considered.