RESTORATION OPPORTUNITY REPORT

SOUTH FORK SKYKOMISH RIVER BASIN RESTORATION FEASIBILITY PROJECT

King County
Department of Natural Resources and Parks
Water and Land Resources Division

Note:
Some pages in this document have been purposely skipped or blank pages inserted so that this document will copy correctly when duplexed.

RESTORATION OPPORTUNITY REPORT

SOUTH FORK SKYKOMISH RIVER BASIN RESTORATION FEASIBILITY PROJECT

Prepared for

King County

Department of Natural Resources and Parks
Water and Land Resources Division
201 S. Jackson Street
Seattle, Washington 98104

by

Herrera Environmental Consultants, Inc.
2200 Sixth Avenue, Suite 1100
Seattle, Washington 98121
Telephone: 206/441-9080

April 30, 2013

Acknowledgements

Funding for the project was provided by USFS, King County DNRP, King County Flood District, and the Snoqualmie Watershed Forum.

The document set was produced with the help of many people including:

- Karen Chang (USFS)
- Andy Bryden (USFS)
- Mark Ruebel (King County)
- Phyllis Meyers (King County)
- Sally King (King County)
- Clint Loper (King County)
- Josh Latterell (King County)
- Perry Falcone (King County)
- Janne Kaje (Snoqualmie Watershed Forum)
- Mike Rustay (Snohomish County)

CONTENTS

TABLES

FIGURES

INTRODUCTION

This report outlines the approach, analytical methods, and results of a study to identify restoration opportunities in the South Fork Skykomish River (the South Fork) basin (Figure 1) (see *Study Area Limits* section). It is the conclusion of a three phase feasibility study of salmonid habitat restoration projects within the South Fork basin conducted by King County (the County). The study was funded in part by the Natural Resources Damages (NRD) settlement made between Burlington Northern Santa Fe (BNSF) and the Washington State Department of Ecology (Ecology). Complementary funds were provided by the King County Flood District. Because of the source of funds for the study, the focus of the work is on salmonid habitat restoration projects, particularly those which have both habitat and flood benefits. The three-phase restoration feasibility study is intended to be the first step in a process to improve habitat conditions and reduce flooding of key infrastructure in the South Fork basin (i.e., South Fork and its major tributaries).

This salmonid habitat restoration feasibility study was implemented in three phases. Each phase built on the previous phase and has culminated in this final restoration feasibility report.

The first phase included a review of existing information and data for the South Fork Skykomish River basin. Agencies and organizations were contacted to obtain existing information on natural resource studies or restoration projects that had been completed for the basin. Data gaps were identified and potential future studies to fill those gaps were scoped. The findings are presented in the South Fork Skykomish River Salmon Habitat Information Review and Future Studies Scoping Summary Report that was completed in November 2012 (see Appendix B).

Based on the findings from the first phase, phase two included completion of three assessments to partially fill the data gaps identified in phase one, and to identify a preliminary list of salmonid habitat restoration project opportunities.

The following assessments were completed under phase two of this project. The assessments were conducted at varying levels of detail and intensity of field data collection that were constrained by the scope of the project and available funding:

- **Lower Miller River Restoration Feasibility Assessment:** This assessment covered the lowest 2 miles of the Miller River (referred to as the lower Miller) and entailed the most intensive analysis of all four assessments. In this area, a comprehensive habitat survey was performed, in addition to a catalog of existing human modifications. Also, a hydrologic analysis was performed on the Miller River as a whole. The hydrologic analysis was used to generate a two-dimensional hydraulic model that identified the extents of flooding and clarified the hydrology of alluvial fan channels observed in the field. The report includes a detailed description of in-channel and riparian habitat conditions, hydrologic analysis results, and identification of salmonid habitat restoration and flood protection opportunities (Appendix E).

- **South Fork Skykomish River Geomorphic Assessment**: This includes a geomorphic assessment of the South Fork basin and identification of restoration opportunities along the South Fork. A spatial survey of human modifications was made on the main channel, as well as a coarse-level in-water habitat survey. The final report included results of the geomorphic assessment for the basin, description and maps of human modifications confined to the South Fork mainstem, and identification of restoration opportunities on the mainstem. The report was completed by Herrera in December 2012 and is included in Appendix C.
- **Beckler and Rapid Rivers Habitat Restoration Opportunities Identification Study**: This assessment entailed a coarse-level identification of restoration opportunities along the Beckler and Rapid Rivers based on a 1-day rapid field reconnaissance, and review of existing literature and information about these rivers. This pilot assessment provided a guideline for reconnaissance assessments of other major tributaries (Miller, Foss, and Tye rivers, and Money and Index creeks) that were completed for the overall feasibility study (Appendix D).

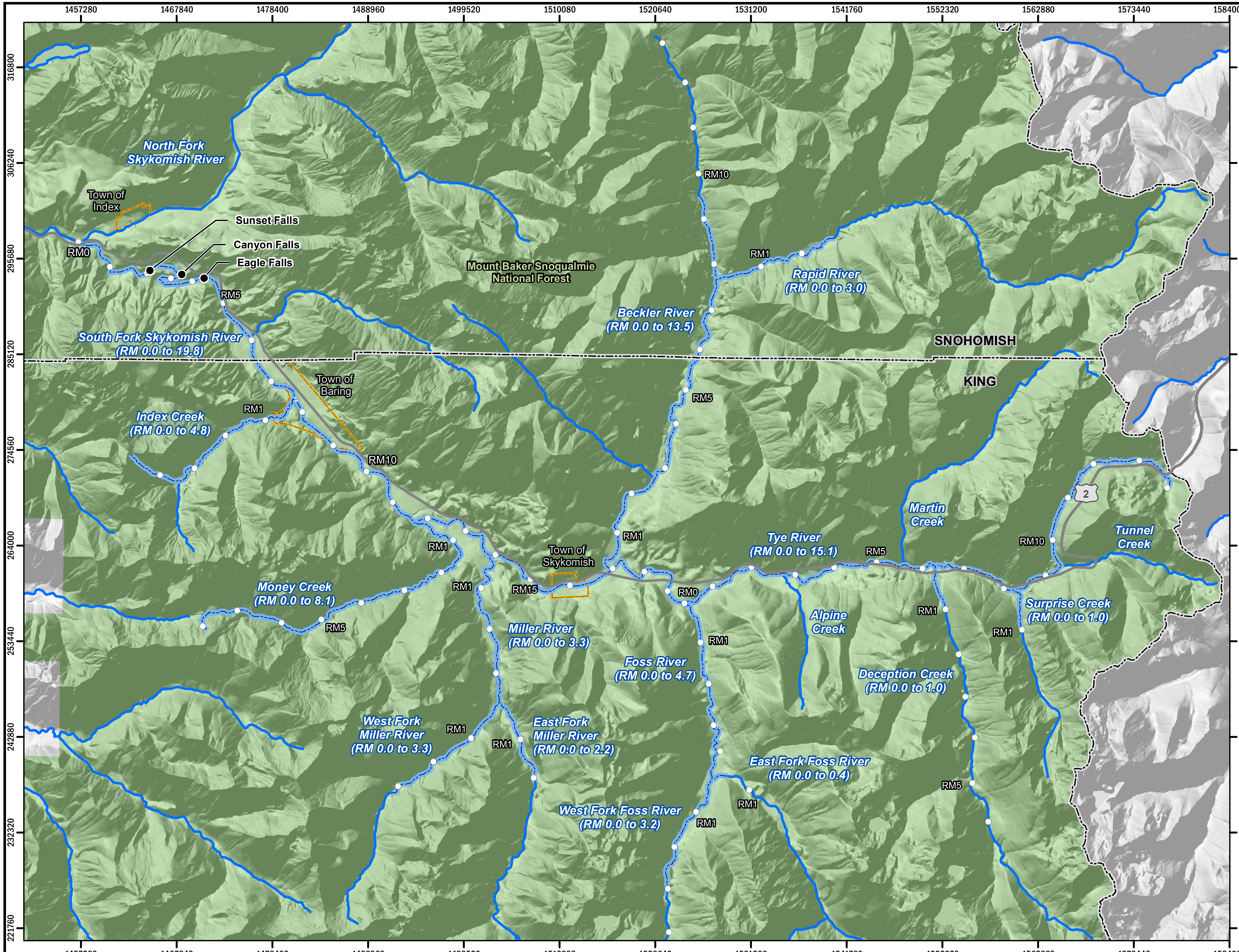
In addition to the above studies, a field reconnaissance and existing information assessment of remaining major tributaries was completed. One-day field reconnaissance trips were completed for the following tributaries: the upper Miller (above RM 2.0) and Foss rivers, the Tye River including the alluvial fans of Surprise and Deception creeks, and Money and Index creeks. Where available, existing literature was reviewed for these tributaries. Habitat conditions (where information was available) and restoration opportunities from these assessments are provided in this final restoration feasibility report and was not reported in any of the previous assessments (i.e., project opportunities in the tributaries mentioned above are all new and unique to this final report).

The third phase of this restoration feasibility study synthesizes information collected under phases one and two into one consolidated report (this feasibility study report). Restoration opportunities were consolidated into one list. These opportunities were prioritized using an All Known Available and Reasonable Technologies (AKART) analysis to determine the highest priority restoration projects that could potentially be implemented by King County in the future. The study area size (more than 70 miles of stream), the lack of existing data relevant to habitat restoration, and the relative inaccessibility of much of the study area precluded detailed analysis of attributes typically sought after in a restoration feasibility study. For instance, the study did not include a formal analysis of the hydrology of the entire basin, hydraulic modeling of any area outside the modern Miller River alluvial fan, a detailed analysis of the fish utilization of the area, or a survey of large woody debris (LWD).

Study Area Limits

The limits of the study area were determined in collaboration with the County and include 70 miles of stream. Of these 70 miles, 20 miles are on the mainstem of the South Fork and 50 miles include major tributaries to the South Fork as described below. They were determined based primarily upon the geomorphic transition from purely alluvial streams (included in the study) to colluvial (debris flow modulated) mountain streams (not included in the study), though accessibility (i.e., the presence of a road) also played a role. However,

Figure 1.
Study Area, South Fork Skykomish River Basin Restoration Feasibility Project, King County, Washington.



Legend

- Reach of interest
- River mile
- Community boundary
- Mount Baker Snoqualmie NF
- County line
- River
- Highway

N

0 1 2 4
Miles

HERRERA

Coordinates: NAD83 Washington State Plane North (feet)

Produced By: GIS
Project: K:\Projects\10-04766-008\Project\Area_of_Interest2.mxd (4/30/2013)

there were some areas (e.g., the West Fork Miller River, the upper Beckler River, etc.) that are not accessible by existing roads. The limits established also coincide with the approximate limits of anadromous fish presence, which are set primarily based upon the extent of steelhead in the system. The largest exception to this is the upper Tye River (i.e., above Alpine Falls, a fish barrier), which is easily accessible by road and has a large population of resident trout, but does not contain anadromous fish.

The limits of the study are shown graphically in Figure 1, but can also be summarized as:

- The entire main stem of the South Fork Skykomish River between its confluence with the North Fork Skykomish River (the North Fork) and the Tye and Foss Rivers
- The entire Beckler River, including the lower 3 miles of the Rapid River
- The entire Tye River, including the lowest mile of Surprise and Deception Creeks
- The Foss River up to RM 4.7, the lower 0.4 mile of the East Fork Foss River, and the lower 3.2 miles of the West Fork Foss River
- The lower Miller River from RM 0.0 to RM 2.0
- The upper Miller River from RM 2.0 to RM 3.3, the lower 2.2 miles of the East Fork Miller River, and on the lower 3.3 miles of the West Fork Miller River

METHODOLOGY

The following section presents a summary of the methodology used for the four previous assessments (Appendices B through E). The AKART methodology used to develop a prioritized list of the salmon habitat restoration opportunities is discussed. The methodology for the proposed implementation strategy is also provided.

Existing Information

Physical Setting

The geologic context for the physical setting was primarily provided by Tabor et al. (1993). Tabor et al. (1993) includes a map and associated text that provide information regarding the recent geologic past that serves as the basic template for the analysis performed as part of the study presented herein. Several historical references were examined, including a recent book that describes the early development of the study area (Carlson 2009), and annotated photo archives available from the University of Washington (UW 2012). General Land Office (GLO) surveys and survey notes were also examined (GLO 1895a, 1895b, 1899), as well as other peer reviewed publications on similar settings (e.g., Collins et al. 2002; Collins and Montgomery 2011). Professional experience and reconnaissance, by boat, foot, and car were used to field verify the conditions described in these resources, and observations from aerial photographic analysis.

Habitat Conditions

Fish Distribution and Habitat Use

The most recent information on fish distribution is limited to areas that have been surveyed by Wild Fish Conservancy and WDFW. Information was collected from King County (2012), WDFW (2012) and Streamnet (1998), which provided geodatabases and maps of fish distribution for the South Fork Skykomish basin. King County's database contains information on known, presumed, and historic presence of Chinook, coho, pink, and chum salmon; steelhead; and bull trout. The fish distribution GIS layer from King County was used to map fish distribution included in this report. WDFW and Streamnet data provide fish habitat use information including spawning, rearing, and migration information, where it is available.

Aquatic Habitat Conditions

Herrera obtained United States Forest Service (USFS) (1994, 1995a, 1995b, 2009a, 2009b) historic watershed plans and reach assessments (Cascades Environmental Services 1997a, 1997b; Merlin Biological 2000) that in some cases included a list of restoration opportunities for the South Fork, and the Beckler, Foss, and Miller rivers. Where relevant for these rivers, historic habitat conditions were obtained from these studies.

Previously Proposed Restoration Opportunities

Information on historic restoration projects that occurred during the years of 1998 through 2007 was obtained from the Interagency Restoration Database (IRDA) GIS files that are maintained by the US Forest Service (USFS) as well as from USFS hard copy records of restoration projects. USFS switched to using the Watershed Improvement Tracking (WIT) database to store information on restoration projects that occurred after 2007. These data were not available for this report, but will be available in the future. Additional information on projects implemented in 2010 or later was obtained from USFS staff.

Field Studies

Three different tiers of field work were performed throughout the course of the study. The most intensive was a full reconnaissance of the Miller River alluvial fan (Appendix E). The entire alluvial fan was surveyed and compared to earlier geomorphic analysis performed on the alluvial fan prior to a major avulsion of the primary channel, which took place in January 2011. This mapping included both habitat type and extent of human modifications. The next level of detail was obtained on reconnaissance of the South Fork, primarily by boat. In this effort, the spatial extents of human modifications and in-stream habitat elements were mapped, but survey was confined to the main stem of the South Fork. The most cursory effort was that associated with the major tributaries, including the Beckler, Foss, Tye, and upper Miller rivers, and Index and Money creeks. Field work in the tributaries primarily verified restoration opportunities identified beforehand in aerial photographs, as well as opportunities discovered in the field.

Habitat Impairments

Habitat impairments were mapped to varying degrees depending upon the level of reconnaissance mentioned above. Habitat impairments are those past human alterations to the landscape (e.g., rock or structure placement, deforestation, wood removal, etc.) that ultimately contribute to habitat degradation and loss. For the most intensive work on the Miller River, known habitat impairments were mapped, surveyed, and quantified to the extent that preliminary engineering cost estimates could be made to implement their removal. During the less intensive mapping exercise on the South Fork, all impairments observable from the river (primarily riprap and fill material) were mapped, but were only quantified with respect to their spatial extent (i.e., volume estimates of rock and fill were not possible). In the coarsest level of analysis, only obvious modifications observed first in aerials, and then from well-traveled roads were documented, for the purposes of identifying restoration projects. As such, no map of modifications in the tributaries could be constructed for the areas associated with the coarsest level of analysis.

Habitat Features

A reconnaissance of habitat features was completed at different levels of detail for these three areas: lower Miller River, the South Fork Skykomish, and the remaining tributary reaches in the study area. The most detailed field reconnaissance was completed for the lower Miller River where both instream and riparian habitat features and conditions were documented by walking the 2-mile reach, and then mapping the features in detail for that reach. The field reconnaissance of the 20 miles of the South Fork was conducted by raft and on foot below Sunset Falls (RM 2.0), and only included in-stream observations of riparian habitat. Lidar imagery was initially used to identify habitats, particularly off-channel habitat features (as defined below) and these were confirmed in the field where possible. The observed habitat features were then digitized in GIS, and mapped for this report. The aquatic habitat features were roughly mapped on aerial photographs during the float trip. The remaining 50 miles of tributaries in the study area were observed by driving roadways adjacent to the river and accessing the stream where possible, and for short distances on foot over 4 days. Only the general habitat conditions that could be seen from or near access roads were observed and noted as they related to project opportunities; habitat features (i.e., side channels, pools, riffles) for these tributaries were not mapped.

Regardless of the level of detail, classifications of aquatic habitat types were based on the classification approach used in Ecosystem Diagnosis and Treatment (EDT) as described in Lestelle et al. (2005); channel types and geomorphic units followed the system defined by Montgomery and Buffington (1997); and stream habitats were based on Bisson et al. (1982).

The aquatic habitat types identified within the study area are shown and described in the geomorphic assessment report in Appendix C and Miller River report in Appendix E. Aquatic habitat types are distinguished by whether they occur in-channel (i.e., on the main river) or off-channel (i.e., off main river).

Restoration Opportunities

A process-based approach was used in the identification of restoration opportunities (Kondolf et al. 2006). In addition, consideration was given to the watershed conditions (opportunities and constraints) to ensure a holistic approach to restoration of the entire study area. In particular, restoration opportunities were drawn from the human modifications and their impairments to habitat detailed above. The opportunities also focused on edge and off-channel (side channel and floodplain) habitat improvements, which have been identified by previous studies as the key limiting factors in the study area (Snohomish Basin Salmonid Recovery Technical Committee and National Marine Fisheries Service 2005). The focus of restoration opportunities is exactly what the name implies: restoration of predevelopment conditions. Because recent geological history has resulted in limitations on habitat (e.g., the incision of the South Fork into glaciolacustrine clays), there is also potential for habitat creation and augmentation that would result in habitat conditions that are somewhat different from those likely present before major human development (i.e., the construction of the railway, US-2, and the residences built along portions of their alignments). These opportunities that would create as opposed to restore habitat were generally not detailed because of their large number, and the availability of many other restoration projects that directly mitigate past human impacts.

Prioritization of Project Opportunities

The prioritization of project opportunities was completed in two steps. The first step took the project opportunities identified according to the methods described above and processed them using an AKART analysis, a common engineering tool for evaluating alternatives and engineering designs. The second step used the results of the AKART analysis and discussions with County and USFS staff and the Snohomish Basin Technical Committee to identify a strategy needed to pursue implementation of some of the restoration projects.

AKART Method

AKART is an adaptable tool that quantitatively scores different project elements based upon simple criteria that can be tailored to the particular goals of a particular project or program. Criteria were developed in collaboration with County and USFS staff and the Snohomish Basin Technical Committee, and the scoring itself was developed in collaboration with County staff. Although criteria can be weighted to emphasize the importance of different elements, it was not done in the process herein. The scoring was completed by the consultant team using assembled geographic resources and reviewed for consistency both by the consultant team and the County.

Strategy Development

The proposed strategy was developed in conjunction with County and USFS staff and the Snohomish Basin Technical Committee. The strategy centered on a geographic clustering of projects that would build upon one another. Most of the clustering of the projects was a natural consequence of the existing geomorphic conditions and the risks and impacts due to particular human activities. Their prioritization was based upon the types of restoration opportunities (e.g., floodplain reconnection, armor removal, etc.) and their varying relevance to the limiting factors described in the Snohomish River Basin Salmon Conservation Plan (Snohomish Basin Salmon Recovery Forum 2005).

RESULTS

The following section presents a summary of the results of the previous assessments, and the prioritization analysis of restoration project opportunities. The bulk of the results are found in in four related documents in Appendices B through E. The scoring of each of the 118 project opportunities are described in this section and listed in Appendix A. Preliminary conclusions, a proposed implementation strategy, data gaps, and proposed additional studies are provided in the sections following the results.

Existing Information

Existing information with regard to both physical and ecological information in the South Fork basin is extremely limited (Appendix A). Most of the data used in the analysis were obtained from existing USFS studies, and from the four assessments listed in the *Introduction* section and provided in Appendices B through E.

Physical Setting

The South Fork basin is a steep, predominantly bedrock river basin on the west slope of the Washington Cascades primarily dominated by marine intrusive bedrock in the west and continental metamorphic rock in the east. Other general information about the physical geography of the basin can be found in Appendix C, *South Fork Skykomish River Geomorphic Assessment*.

One common aspect to the basin at large is the regular occurrence of alluvial and colluvial fans. Alluvial fans are cone-shaped deposits of sediment that occur when a stream undergoes a dramatic drop in slope, typically associated with an abrupt lack of horizontal confinement. Colluvial fans are similar type deposits that made primarily from debris flows. Both alluvial and colluvial fans are sedimentologically active. Channel avulsions occur regularly, sometimes multiple times per year in response to every large precipitation event. They also present the hazard of debris flows, which can at a minimum destroy infrastructure, and possibly can injury or kill people that are on the alluvial or colluvial fans when debris flows occur.

South Fork

The South Fork extends from the confluence of the Foss River and Tye River (east of the Town of Skykomish) to the confluence with the North Fork Skykomish River near the Town of Index (Figure 1). Nearly the entire river is strongly influenced by its incision into lacustrine sediment and competent bedrock. The incision and the presence of bedrock have limited channel migration as compared to other western Washington rivers. LWD is also extremely limited in most locations, possibly due in part to the limited channel migration, but also probably due to intensive logging and clearing of wood from the stream. This may in turn cause a negative feedback process, because the lack of LWD and associated log jams limit the formation of hard points capable of inducing channel migration as well as accruing large volume of sediments. Further details about the geomorphology of the South Fork are provided in Appendix C.

Lower Miller River

The Miller River is a tributary to the South Fork with a confluence a few miles west of the Town of Skykomish. The alluvial fan is particularly dynamic due to the sharp break in along-channel slope at the confluence, which causes increased sediment deposition. There are a large number of human modifications on the alluvial fan due to the presence of a County road and the BNSF railway. Appendix E, Lower Miller River Restoration Feasibility Report, summarizes the geomorphic consequences of these modifications, and the general physical variables describing the alluvial fan.

Beckler-Rapid Basin

The Beckler River is controlled by the Evergreen Fault, a modern manifestation of the Straight Creek Fault that runs the north to south length of the Cascades. Because the river occupies a low lying portion of the fault, it is not as steep as other South Fork tributaries and is naturally straight. Like the South Fork, the Beckler River is largely devoid of wood in its lower reaches.

The Rapid River is a tributary of the Beckler River and extends well east and north towards the Cascade Crest. This part of the Cascades receives much less rainfall and much more snowfall than much of the rest of the basin. This means that the Rapid River has a much less flashy hydrology than the other tributaries, and has a strong, persistent freshet. It is also more remote and has an abundance of LWD. For further details about Beckler-Rapid Basin, see Appendix D, Beckler and Rapid Rivers Habitat Restoration Opportunities Identification Study.

Other Tributaries

The physical setting of the other smaller tributaries examined in this study has not been documented in the four complementary assessments in Appendices B through E. These tributaries are clearly influenced by the overarching geomorphic factors described in Appendix C, but most have unique features worth noting here. These geomorphic features have implications on the types of projects possible in these areas, as well as any habitat lift associated with possible projects.

Tye River

The Tye River is often thought of as the upstream extension of the South Fork. Having its headwaters at the Cascade Crest at Stevens Pass, the eastern portion of the basin is typical of these higher, snowier areas. As a result, it is more regulated by snowmelt, rather than the rain-on-snow events common in the tributaries further west. Below the upper basin, the river enters a bedrock gorge terminating at Alpine Falls, a natural fish barrier. The lower reaches of the Tye River are controlled by the Beckler Peak Rock Avalanche that occurred between 500 and 3,500 years ago. The mile above the avalanche is highly dynamic with a broad floodplain, due to the impoundment of sediments from the avalanche up to the downstream end of the gorge. The lowest 2 miles are incised into the avalanche deposit, with few to no side channels.

In addition to the complexities of the main stem of the Tye River, the river also has a wide variety of tributary fans. The Surprise Creek tributary fan is well developed, being the site of the Town of Scenic, upstream of the bedrock gorge in an alluvial reach of the Tye River. The relatively low gradient of the Tye River upstream of the gorge initiates a sharp break in slope as compared to the steeper Surprise Creek, which contributes to the dynamic nature of the alluvial fan. The Deception Creek tributary fan is markedly different, as it occurs within the confines of the bedrock gorge. As a result, the alluvial fan is less distinct and much coarser. However, it is also dynamic, with a potential avulsion likely near the confluence with the Tye River. It is likely that the other large alluvial fans in the basin (Tunnel Creek, Alpine Creek, and Martin Creek) are equally complex, but these areas were not visited in this study due primarily to their inaccessibility. For example, an unnamed creek just downstream from Martin Creek also has a large colluvial fan that is bisected by US-2, which is more colluvial (debris flow dominated) than alluvial (water flow dominated).

Foss River

The Foss River, like the Beckler River, occupies a valley defined by faulting associated with Straight Creek Fault. The slope of the Foss River is greater than the Beckler River, though a broad floodplain area exists near the confluence, which appears to be of lower gradient and contains extensive intermingling side channels. Below the confluence reach, the river is confined between numerous colluvial fans from both sides of the valley. The Foss River alluvial fan itself is small because the confluence with the Tye River is incised into the Beckler Peak Avalanche. Despite its size, there is a significant opportunity to improve conditions there because of the degree to which the alluvial fan has been altered by human activities.

Upper Miller River and Money Creek

The upper Miller River and Money Creek are probably the most active geomorphic regions in the South Fork basin. Though they are distinct and discharge to different places on the South Fork, there are a lot of physical similarities between the two basins. They also share a common tributary fan, although human alterations have caused the rivers to no longer intermingle. Both basins are geologically complex, but generally dominated by marine intrusive rocks (i.e., the Snoqualmie Batholith in their headwaters). Due to their western location, and each with a relatively low elevation pass to areas to the southwest, they are much more dominated by rainfall than the other tributaries. Large rainfall events in November 2006 and January 2009 reactivated many debris flow chutes and produced large amounts of sediment throughout the basin. Therefore, as compared with the other river and creek basins discussed in this report, the upper Miller River and Money Creek basins will likely be much more susceptible to hydrologic changes from climate change, particularly in the near term (i.e., the next 20 years). In addition to the extreme geomorphic activity, the upper portions of each basin contain numerous abandoned mines, a few of which are near active stream channels.

Fish Distribution

According to USFS (2009b), no anadromous fish species historically utilized habitat in the South Fork Skykomish River above Sunset, Canyon, and Eagle Falls, natural migration barriers located about 2 river miles above the confluence of the North and South Forks of the Skykomish River.

King County's database contains information on known and presumed fish presence within the 100-year floodplain of the river, and historic or potential presence of Chinook, coho, pink, and chum salmon; steelhead; and bull trout. Distribution of Chinook salmon, bull trout, and steelhead trout within the study area are depicted in Figures 2, 3, and 4, respectively, as well as Table 1. According to Streamnet (1998), fall/summer Chinook use the South Fork above Eagle Falls for spawning and rearing to RM 14.1 and then for migration to the confluence with the Foss River. Chinook also migrate and rear in the Foss, Beckler, and Rapid rivers and in the lower reaches of the Tye and Miller rivers and Money Creek (WDFW 2012; Streamnet 1998). Bull trout use the South Fork for rearing and migrating, and spawn in the upper reaches of tributaries to the South Fork where water tends to be cooler (Streamnet 1998). Summer steelhead trout trapped at Sunset Falls are deposited in the South Fork at approximately RM 6.8 and migrate, spawn, and rear up to its confluence with the Foss River. Steelhead trout also spawn and rear in the Beckler, Miller, Foss, and Rapid rivers and in the lower reaches of Money and Index creeks (Streamnet 1998). Additionally, coho and pink salmon migrate and rear in the South Fork, and spawn and rear in all the tributaries within the study area. Chum, native charr, and some stray sockeye also occur in more limited extents. Figure 5 shows the distribution of coho, pink and chum salmon.

The long-term annual average of returns for fish at the trap-and-haul facility at Sunset Falls ranges from approximately 20,000 for coho to 7,000 for pink (odd number years only), 600 to 800 for Chinook and for upstream migrating steelhead, and about 60 or less for chum, native charr, and some stray sockeye (USFS 2009b; WDFW 2002). Annual returns for coho and pink salmon (odd number years only) have increased substantially over the last decade compared to these long-term averages, averaging about 30,000 and 15,000 fish, respectively.

The South Fork basin comprises much of the Skykomish River Tier 1 Key Watershed, which serves as crucial refugia for maintaining and recovering the at-risk stocks of Chinook, bull trout, and steelhead in the greater Skykomish basin. Widespread impacts to estuarine habitats, as well as instream, riparian, and upland areas (especially downstream of the Mount Baker Snoqualmie National Forest boundary), have resulted in large reductions in the quantity and quality of spawning and rearing habitats of resident and anadromous fish stocks within the North and South Fork Skykomish watersheds, as well as elsewhere within the Snohomish Basin (Snohomish Basin Salmonid Recovery Technical Committee 1999, 2002; Snohomish Basin Salmonid Recovery Technical Committee and NMFS 2005; Snohomish Basin Salmon Recovery Forum 2005; USFS 1994, 1995a, 1995b, 2009b). Additionally, most of the South Fork basin has been designated as critical habitat for bull trout (see Appendix D for more information).

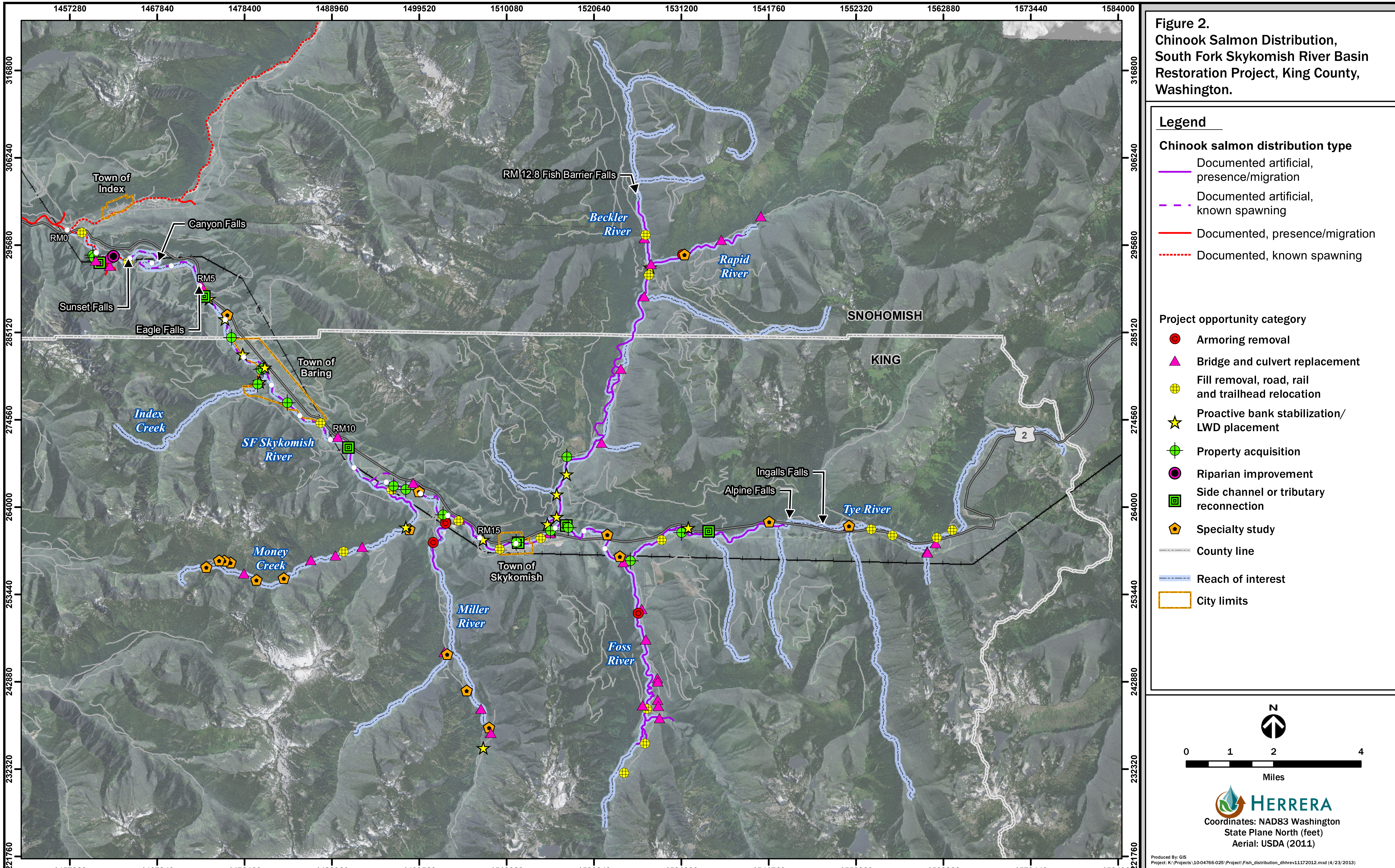


Figure 2.
Chinook Salmon Distribution, South Fork Skykomish River Basin Restoration Project, King County, Washington.

HERRERA

Coordinates: NAD83 Washington State Plane North (feet)
Aerial: USDA (2011)

Produced By: GIS
Project: K:\Projects\10-04766-025\Project\Fish_distribution_dhhrev11172012.mxd (4/23/2013)

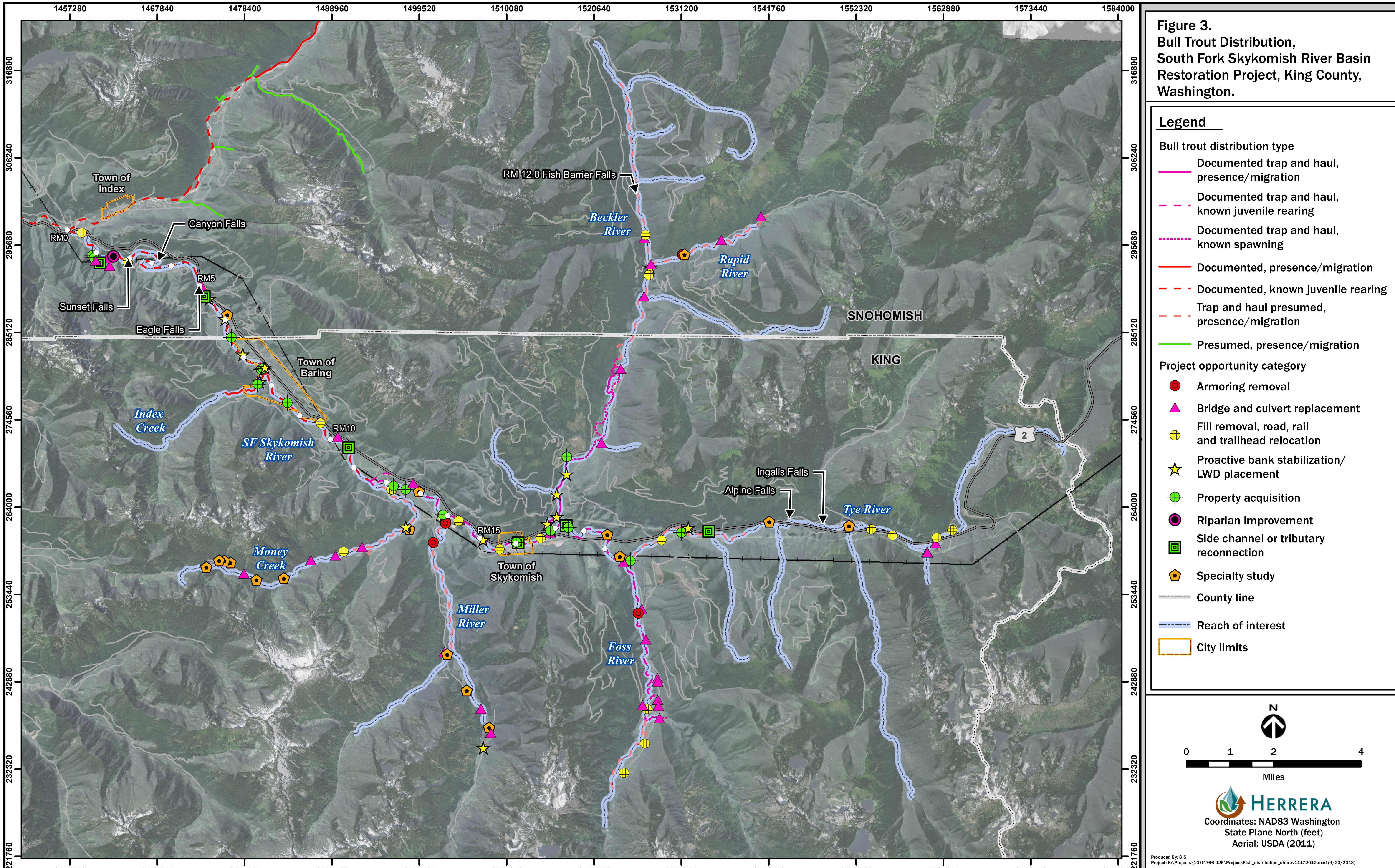


Figure 3.
Bull Trout Distribution, South Fork Skykomish River Basin Restoration Project, King County, Washington.

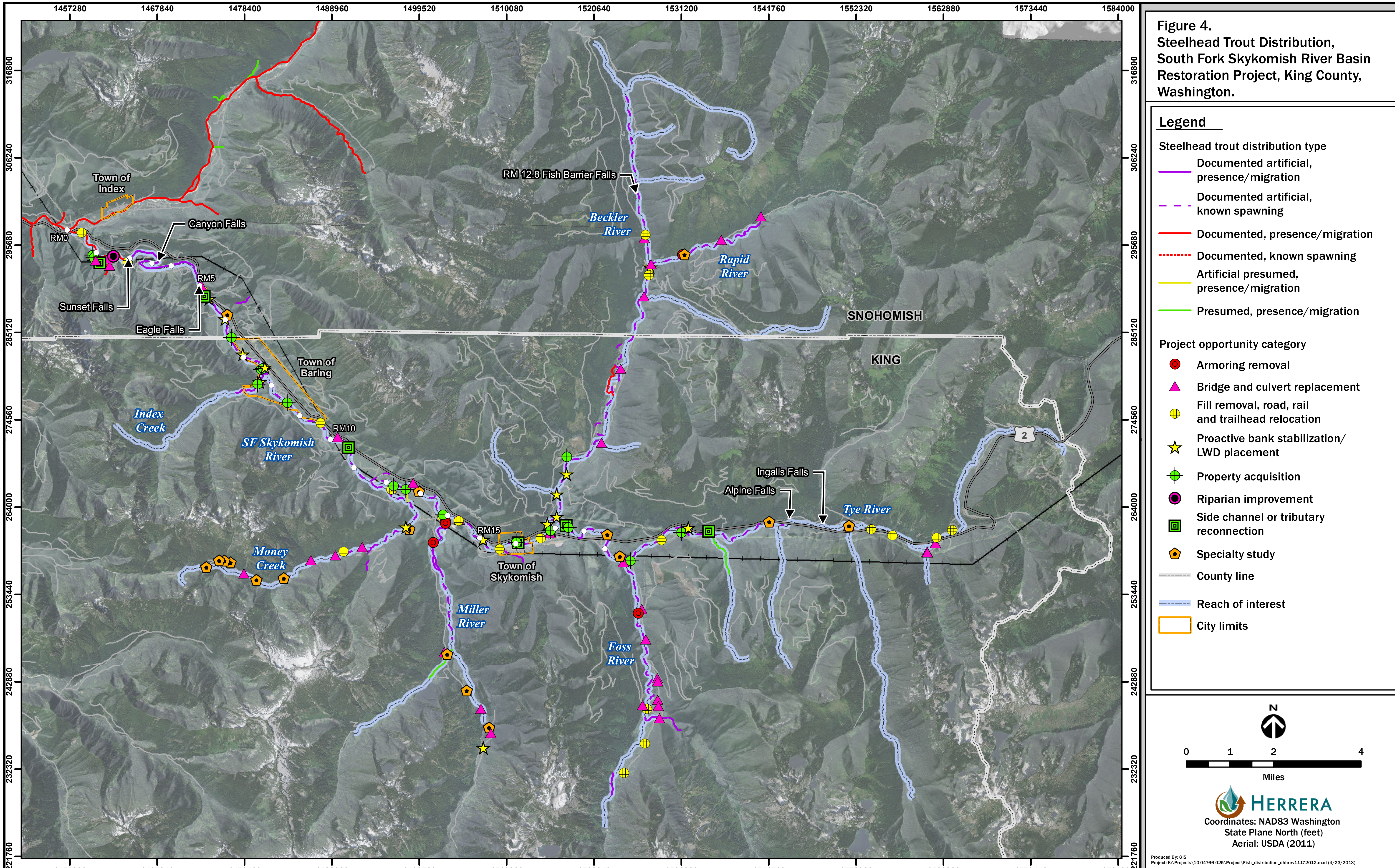


Figure 4.
Steelhead Trout Distribution, South Fork Skykomish River Basin Restoration Project, King County, Washington.

Figure 5.
Coho, Pink, and Chum Distribution, South Fork Skykomish River Basin Restoration Project, King County, Washington.

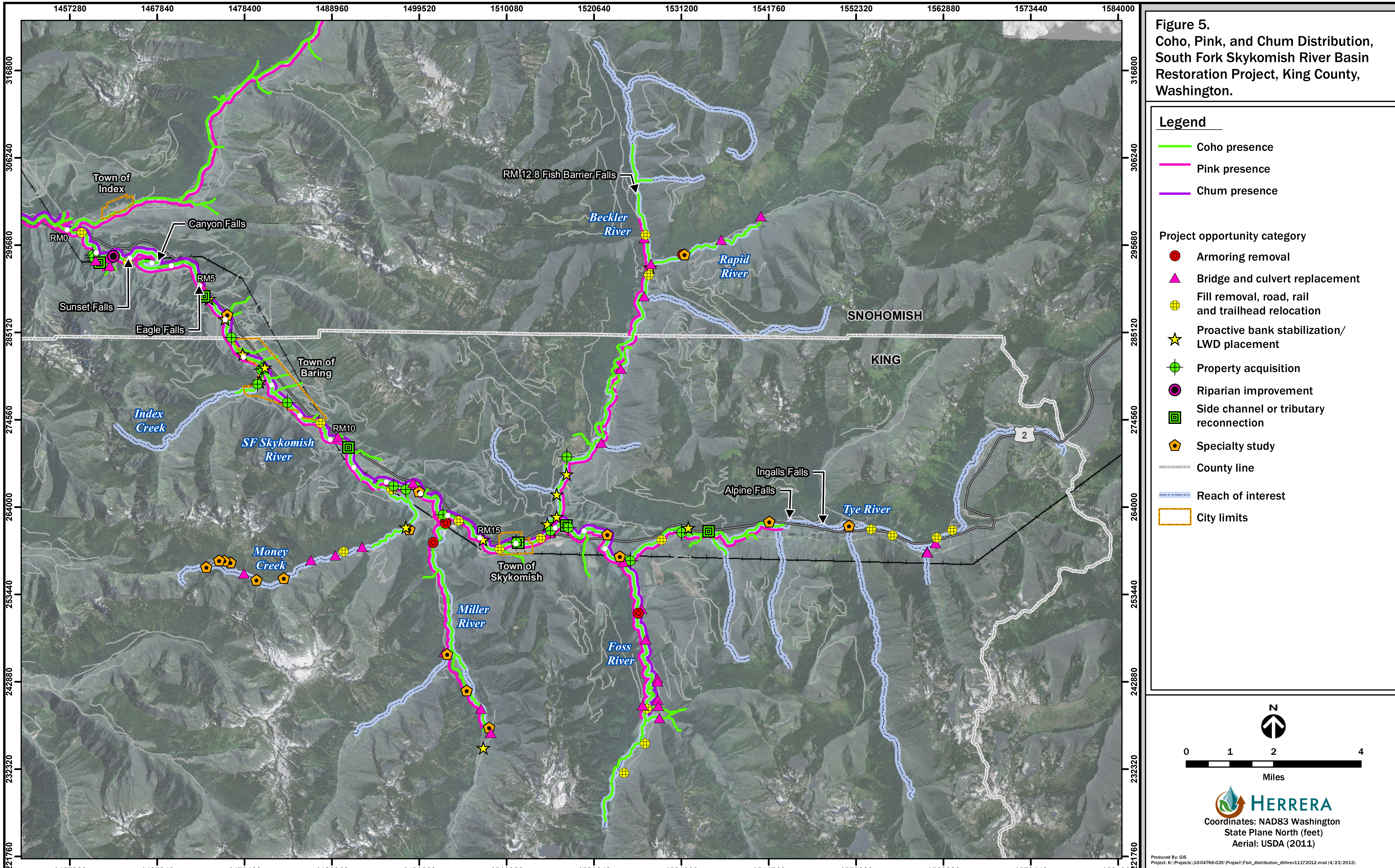


Table 1. Summary of Salmonid Use Within the South Fork Study Area.

Stream	Species	Run	Use Type	From (RM)	To (RM)
Beckler River	Chinook salmon	Fall	Migration only	0.0	9.6
Beckler River	Coho salmon	N/A	Rearing and migration	0.0	2.5
Beckler River	Coho salmon	N/A	Migration only	2.5	10.9
Beckler River	Steelhead	Summer	Spawning and rearing	0.0	12.3
Beckler River	Pink salmon	N/A	Spawning and rearing	0.0	8.7
Beckler River	Pink salmon	N/A	Migration only	8.7	9.2
Beckler River	Bull trout	N/A	Migration only	0.0	1.9
Beckler River	Bull trout	N/A	Spawning and rearing	1.9	5.3
Beckler River	Bull trout	N/A	Migration only	5.3	12.5
Foss River	Chinook salmon	Fall	Migration only	0.0	4.7
Foss River	Coho salmon	N/A	Migration only	0.0	4.7
Foss River	Steelhead	Summer	Spawning and rearing	0.0	4.7
Foss River	Chum salmon	Fall	Migration only	0.0	4.7
Foss River	Pink salmon	N/A	Migration only	0.0	4.7
Foss River	Bull trout	N/A	Rearing and migration	0.0	4.7
Index Creek	Coho salmon	N/A	Migration only	0.0	1.0
Index Creek	Steelhead	Summer	Migration only	0.0	1.0
Index Creek	Bull trout	N/A	Migration only	0.0	1.3
Miller River	Chinook salmon	Fall	Migration only	0.0	1.6
Miller River	Coho salmon	N/A	Migration only	0.0	3.7
Miller River	Steelhead	Summer	Migration only	0.0	1.7
Miller River	Steelhead	Summer	Spawning and rearing	1.7	3.4
Miller River	Steelhead	Summer	Rearing and migration	3.4	3.7
Miller River	Pink salmon	N/A	Spawning and rearing	0.0	3.7
Miller River	Bull trout	N/A	Migration only	0.0	3.7
Money Creek	Chinook salmon	Fall	Migration only	0.0	1.3
Money Creek	Coho salmon	N/A	Rearing and migration	0.0	1.3
Money Creek	Coho salmon	N/A	Migration only	1.3	2.8
Money Creek	Steelhead	Summer	Spawning and rearing	0.0	3.3
Money Creek	Steelhead	Summer	Migration only	3.3	3.5
Money Creek	Bull trout	N/A	Migration only	0.0	3.4
South Fork Skykomish River	Chinook salmon	Fall	Spawning and rearing	0.0	1.9

Table 1 (continued). Summary of Salmonid Use Within the South Fork Study Area.					
Stream	**Species**	**Run**	**Use Type**	**From (RM)**	**To (RM)**
South Fork Skykomish River	Chinook salmon	Fall	Spawning and rearing	1.9	14.2
South Fork Skykomish River	Chinook salmon	Fall	Migration only	14.1	19.9
South Fork Skykomish River	Coho salmon	N/A	Rearing and migration	0.0	1.9
South Fork Skykomish River	Coho salmon	N/A	Rearing and migration	1.9	19.9
South Fork Skykomish River	Steelhead	Summer	Migration only	0.0	1.9
South Fork Skykomish River	Steelhead	Summer	Migration only	1.9	6.8
South Fork Skykomish River	Steelhead	Summer	Spawning and rearing	6.8	19.9
South Fork Skykomish River	Steelhead	Winter	Spawning and rearing	0.0	1.3
South Fork Skykomish River	Steelhead	Winter	Migration only	1.3	1.9
South Fork Skykomish River	Chum salmon	Fall	Migration only	0.0	1.9
South Fork Skykomish River	Chum salmon	Fall	Migration only	1.9	19.9
South Fork Skykomish River	Pink salmon	N/A	Migration only	0.0	0.2
South Fork Skykomish River	Pink salmon	N/A	Spawning and rearing	0.2	1.9
South Fork Skykomish River	Pink salmon	N/A	Spawning and rearing	1.9	19.9
South Fork Skykomish River	Bull trout	N/A	Rearing and migration	0.0	11.7
South Fork Skykomish River	Bull trout	N/A	Rearing and migration	11.7	19.9
Tye River	Chinook salmon	Fall	Migration only	0.0	4.7
Tye River	Coho salmon	N/A	Migration only	0.0	4.7
Tye River	Steelhead	Summer	Spawning and rearing	0.0	4.7
Tye River	Pink salmon	N/A	Spawning and rearing	0.0	4.7
Tye River	Bull trout	N/A	Migration only	0.0	3.7

Source: Streamnet (1998)

Habitat Conditions

South Fork

The USFS (1995b) watershed study of the Skykomish Forks and the Snohomish Basin plans (Snohomish Basin Salmonid Recovery Technical Committee 1999, 2002; Snohomish Basin Salmonid Recovery Technical Committee and NMFS 2005; Snohomish Basin Salmon Recovery Forum 2005; USFS 1994, 1995a, 1995b, 2009b) contain information about the South Fork habitat conditions at a watershed scale. The latest habitat conditions information was presented in the Ecological Analysis for Salmon Conservation report (Snohomish Basin Salmonid Recovery Technical Committee and NMFS 2005), although it was pulled from earlier studies; it is summarized here (see Appendix C for more detailed information). Fish passage conditions (due to barriers) are moderately degraded (i.e., watershed processes and habitat structure have substantially diverged from natural conditions and impair the natural productivity of salmonids) in the South Fork subwatershed. Riparian habitat and quantity of instream LWD were ranked as moderately degraded, although more information was needed to confirm this below Sunset Falls. Hydrologic conditions, such as peak flow fluctuations, were ranked as intact (functioning at optimum conditions for salmonids) although insufficient information about this was available for the reach below Sunset Falls. Shoreline condition and connectivity to the floodplain were ranked as degraded throughout the South Fork. The study also identified a data gap in information about geomorphic and sedimentation conditions within the subwatershed.

Lower Miller River

The lower Miller River is very productive habitat within the South Fork Skykomish River Basin for fish. Large runs of salmonids have historically been observed at the mouth of the alluvial fan (see Appendix E). Habitat diversity and side channels provide rearing and potential spawning habitat for all salmonids in the study area. The alluvial fan provides an influx of cold water, nutrients, sediment, and potential food sources that attract fish. Appendix E provides detailed information about instream and riparian habitat conditions for the lower Miller River.

Beckler-Rapid Basin

Instream habitat quality within the Beckler River was rated overall good, although both the numbers of pools and pool diversity were rated moderate to low in a stream survey performed in 1997 (Cascades Environmental Services, Inc. 1997). Information regarding the conditions of the instream habitat for the Rapid River was not available.

Riparian habitat within the basin consists of mid-seral (20- to 75-year-old) forest stands that were harvested in the 1970s and 1980 until timber harvesting in riparian areas was regulated (USFS 1995b). Approximately half of the basin is now protected under the Wild Sky Wilderness Act that was established in 2008. Further information about the habitat in the Beckler-Rapid Basin is available in Appendix D.

Other Tributaries

The habitat conditions of the other smaller tributaries (i.e., all other tributaries other than the Tye and Foss rivers) examined in this study was not documented in the four complementary assessments. The habitat in these tributaries is formed by the overarching geomorphic processes and conditions that are described in general terms in Appendix C. A summary of specific habitat conditions based on previous studies was available for the Tye and Foss rivers and is provided in the next two subsections.

Tye River

Existing information regarding habitat conditions in the Tye River is limited. USFS completed a watershed study of the Tye River in 1994 that provides an overview of habitat conditions and these are summarized here (USFS 1994). Overall water quality is good within the watershed. While sedimentation is a concern in the lower watershed, more information is needed to determine its significance. There is a lack of snags and live large trees available for LWD recruitment in the managed riparian and upland areas, although this is expected to improve as the forests mature. This recovery has already been observed to occur upstream from the Beckler Peak Avalanche. The upland and riparian habitat has been fragmented due to human development, timber harvesting, and natural events such as fire and snow avalanches.

Foss River

Information on the habitat conditions in the Foss River is limited to a USFS (2009a) Miller-Foss River Watershed assessment. The following is a brief summary of the information from this assessment. As stated within this report, hydraulic (peak flows) and hydrologic information is lacking for the Foss River; however, the USFS reported that flows are not as flashy as those of the Miller and that low summer flows are adequate to support salmonids. The lower Foss becomes extremely shallow or dry in portions of some river reaches where the channel is hundreds of feet wide and braided over a substrate of thick alluvial deposits. Generally, water quality within the basin is good. Temperature data (the only water quality data that has been surveyed) for year 2000 show conditions at or below the Washington state water quality standards for char spawning of 12°C (53.6°F). Riparian habitat within the Foss River subwatershed is generally intact, but stands are immature due to historic timber harvesting practices. Riparian habitat is also disturbed by road building and residential development (in the lower reaches), and fires. The Mount Baker Snoqualmie National Forest Land and Resource Management Plan (USFS 1990) has a guideline that areas with more than 12 percent of early seral stage (immature) vegetation (due to disturbance or fragmentation), and less than about 70 percent crown closure may constitute levels of disturbance that could result in undesirable cumulative effects within the watershed stream systems. Neither the 70 percent crown closure level, nor the 12 percent disturbance level are meant to be used as firm thresholds, but as flags for areas of concern, and to prompt further study before future decisions about land management are made. The USFS (2009a) report states that the Foss and Miller subwatersheds do not exceed the 12 percent threshold level of immature forest, but they did not provide information on the crown closure.

Field Studies

This section describes findings from the limited field reconnaissance in the study area. The findings from the field work on the lower Miller River can be found in Appendix E, Lower Miller River Restoration Feasibility Report. The reconnaissance of the South Fork yielded a survey of human modifications and general habitat characteristics. This information can be found in Appendix C, South Fork Skykomish River Geomorphic Assessment. In the tributaries, no new information besides human impairments was obtained from the limited field reconnaissance. Observations of habitat conditions were limited to areas accessed by car over a 4-day period and are summarized in the following sections.

The field studies were tiered to focus effort on known high ecological lift areas based upon the fish use data presented in Figures 2 through 5. The field work is summarized in Table 2.

Table 2. Summary of Field Efforts.

Date of Visit	Mode of Access	Rivers Visited	Data Collected
August 16	Car	Beckler & Rapid rivers	Project site identification
August 21-23	Boat	South Fork (RM 5-19)	Project site identification, habitat (including LWD), human modifications
September 4	Car	North Fork (Index), South Fork (Skykomish)	Gage survey
September 7	Foot	South Fork (RM 0-2)	Project site identification, habitat (including LWD), human modifications
September 14	Car & Foot	Miller (RM 0-2)	Project site identification, habitat (including LWD), human modifications
September 19	Car	Miller (RM 1)	Gage installation
September 27	Car & Foot	Tye	Project site identification
October 4	Car & Foot	Miller & Foss rivers	Project site identification
October 5	Car	Money & Index creeks	Project site identification
December 7	Car	Miller (RM 1)	Gage retrieval

Note: All dates in 2012

Habitat Impairments

As previously stated, habitat impairments have not been exhaustively cataloged throughout the basin due to its size and relative inaccessibility. Channel modifications have been cataloged in the nearly 20 miles of the South Fork and the lowest 2 miles of the Miller River and the results of this are provided in Appendix C. Within the other tributaries, which constitute approximately 50 miles stream length, possible habitat impairments were identified only where project opportunities exist, and they are presented by tributary in the project opportunity descriptions in Appendix A. A comprehensive analysis of habitat impairments was not completed for these other tributaries.

Habitat Features

South Fork

In-channel and off- channel habitats were observed (where possible) during the field reconnaissance. This section presents a brief summary of the habitats; more detailed information is provided in Appendix C.

The South Fork has limited pool density and diversity, although the pool quality of existing pools was high. The density is low because of the general lack of large woody debris. It is likely the predevelopment pool density was much larger and more similar to other undisturbed large rivers in western Washington. Typically pools are formed on the South Fork in association with man-made structures or bedrock outcroppings. They are of high quality because they are typically very deep, slow moving, and often associated with riparian vegetation.

Bars comprised of a range of materials from large boulders (mean diameter in excess of 2 to 3 feet) to gravel were located throughout the study area, though the mechanisms that formed them vary widely. They are more limited in the developed areas around Skykomish and Baring. They are more expansive in the Money-Miller reach due to this being the least incised part of the river.

Active side channels are most extensive in the reach between the Miller River confluence and Eagle Falls than in any other reaches of the South Fork Skykomish River, and are used by juvenile fish as observed during the site reconnaissance. Side channel habitat was constricted and partially blocked by fill and revetments associated with US-2 and the BNSF railway near the towns of Skykomish and Baring, the largest set of human impacts in the South Fork (Appendix C).

The presence of LWD was extremely limited within the assessment area, relative to other western Washington rivers. This is due to numerous factors, including deforestation for timber harvesting and stream cleaning that occurred most extensively in the 1970s through early 1990s (Snohomish Basin Salmonid Recovery Technical Committee and National Marine Fisheries Service 2005; USFS 1995b). There may be other natural factors that contribute to the lack of the wood in the stream, primarily related to the river being simplified, incised, and having reduced channel migration.

Edge habitat is another key habitat type that has been identified as needing improvement in the study area (Snohomish Basin Salmonid Recovery Technical Committee and National Marine Fisheries Service 2005). Riprap and rock have been placed along at least nearly 5 miles of shoreline in the South Fork study area (for details see Figure 5 of Appendix C).

As described in the report in Appendix C, the South Fork Skykomish River is confined by bedrock and lacustrine clay in several areas. It does not often migrate through a wide floodplain like many other large rivers in the region. However, the reaches where incision is less pronounced (from the Miller River confluence to Eagle Falls, and near tributary fans) do have intact active side channel networks. Due to limited surveys of the riparian area and the geomorphic features of the river basin, only a few off-channel habitats were observed during the field investigation, which means that some side channels were likely missed. A wide channel migration zone was observed on the lidar imagery on the left bank of the river from RM 7.3 to RM 6.8 and on both sides of the river from RM 6.5 to RM 6.2. The Money-Miller Alluvial Fan Complex also contains numerous side channels, some of which are disconnected by fill and revetments associated with US-2 and the BNSF railway.

Lower Miller River

The lower Miller River is a dynamic environment with numerous side channels and a large amount of potential hyporheic flow. Habitat diversity and side channels provide rearing and potential spawning habitat for all salmonids in the study area, particularly since this area is close to the South Fork. Appendix E provides detailed information about the geomorphic and habitat features present on the lower Miller River.

Beckler-Rapid Basin

General habitat observations were made during the 1-day site reconnaissance where access by roads was possible. Habitat conditions were noted within the areas where human modifications had occurred and where restoration opportunities had been identified. Generally, the Beckler River particularly below its confluence with the Rapid River is lacking LWD. Riparian habitat is generally intact and is comprised of early seral (20 to 75 years in age) forest except in areas where roads, residences, and campground facilities exist. Private residential development and the Beckler Campground are in the lower reach of the Beckler. Instream spawning and rearing habitat is generally good where it exists; however, pool diversity and quantity appeared low particularly along armored reaches or at road crossings. Similar conditions to that of the Beckler River exist in the Rapid River. Further information regarding habitat conditions in the Beckler-Rapid Basin is available in Appendix D.

Other Tributaries

The habitat conditions of the other smaller tributaries including upper Miller and Foss rivers, and Money and Index creeks were not systematically investigated in this study. Conditions in these tributaries have also not been documented in complementary assessments. However, the habitat features in these tributaries are formed by the overarching geomorphic processes and conditions that are described in Appendix C. Due to very limited field observations in these streams, a brief summary is provided here. All of these streams have relatively intact riparian habitat that consists of a patchwork of early-seral to mid-seral coniferous and mixed coniferous/deciduous forest. The riparian areas, particularly in the lower reaches of these streams, are fragmented by residential development, roads, road crossings, historic timber harvest, and some on-going timber harvest on private lands. Due to historic timber practices, stream cleaning, and immature forest stands in the riparian areas, the lower reaches of these streams are lacking LWD although not to the extent lacking in the South Fork and Beckler Rivers, which have extremely low levels of LWD. As the gradient of these streams steepen and less development has occurred, more LWD log jams were observed. The lower reaches of Money Creek was particularly lacking in LWD of the four streams that were studied. Instream habitat was not studied in a formal or comprehensive manner. However, generally spawning and rearing habitat was intact and in good condition, except in areas where human modifications (armoring or road crossings) were present. As with the other streams in this study area, pool habitats were lacking in diversity and frequency, particularly in reaches lacking LWD or that were disturbed by human impairments.

Restoration Opportunities

One hundred and eighteen (118) restoration opportunities were identified in the assessment area and are summarized in project information sheets provided in Appendix A and shown on Figure 6. In most cases, little information was available to define the magnitude of the benefits described. Rather benefits are based on physical improvements observed at similar sites in western Washington. Habitat benefits are also broadly defined. Almost entirely, they are based upon the proximity to similar environments where fish can reasonably be expected to occur. They do not necessarily refer to habitat benefits directly on site (e.g., underneath a bridge that will be replaced). Because of the lack of information about the sites, oftentimes the solutions described are non-specific. This was because data was not available to identify clear alternatives, which would need to be developed through a more rigorous design process. Despite these caveats, all of the project sites were observed directly and there can be some assurance that if implemented properly there would be some habitat benefit associated with them all.

The opportunities could also benefit from being grouped programmatically. For example, culvert replacement projects in a particular basin or group of basins could be grouped, as their benefits may be the same, and the net improvement from all the culvert replacements would be significant (as opposed to individually where the ecological lift is arguably small). Programmatic actions would lessen permit efforts and could also be lumped to target a single large grant, which may possibly reduce design and planning costs.

The opportunities were evaluated according to the criteria shown in Table 2 in order to prioritize them for potential implementation. Each project was ranked and a total score was tallied. Those with the highest score rank as the higher priority projects based on the criteria. The results of the prioritization are summarized in Appendix A. While the AKART analysis provides a basis for making decisions about which projects are the highest priority, an implementation strategy drawn from overall conclusions of the feasibility study (including the complementary assessments) will also guide the implementation of project opportunities; this is discussed in the next section.

Figure 6.
Restoration Project Opportunities, South Fork Skykomish River Basin Restoration Feasibility Project, King County, Washington.

Legend

Project opportunity category

- Armoring removal
- Bridge and culvert replacement
- Fill removal, road, rail and trailhead relocation
- LWD placement
- Property acquisition
- Riparian improvement
- Side channel or tributary reconnection
- Specialty studies; Specialty study
- Countyline
- City limits
- Reaches of Interest
- Fall of interest
- Highway
- Railroad

N

0 1 2 4

Miles

HERRERA

Coordinates: NAD83 Washington State Plane North (feet)
Aerial: USDA (2011)

Produced By: GIS
Project: K:\Projects\10-04766-025\Project\Restoration_Opportunities+_12_18_12.mxd (4/29/2013)

Table 3. Criteria Used in AKART-based Prioritization of Restoration Opportunities.

Restoration of Predevelopment Geomorphic Processes (project type)	Ranking Criteria	Comment/Explanation
1	Infrastructure protection with habitat enhancement, LWD placement	Refers to projects such as proactive bank stabilization
2	Fish passage barrier removal and debris flow passage (culvert replacement)	Culvert replacement for both debris flows and fish barrier removal
3	River edge restoration (revetment removal or riparian improvement)	
4	Floodplain process restoration (levee or road removal/relocation)	
5	Preservation of intact habitat (property acquisition or easement)	
Species Use		
1	No fish use	
2	Non-listed fish	This criterion includes salmonids and other resident fish
3	Steelhead trout use only	
4	High priority Chinook and/or bull trout use	
5	High priority naturally occurring salmonid use	This refers to naturally occurring populations of salmonids below Sunset Falls
Habitat Benefit		
1	Remove geomorphic impediment	This refers to restoring debris and water flows but not directly restoring fish habitat.
2	Large wood enhancement or conservation project	Projects where LWD placement would be the main element
3	Small area of wetted edge habitat restored (< 300 lineal feet)	
4	Large area of wetted edge habitat restored (> 300 lineal feet) or small side channel restored (< 500 lineal feet)	
5	Large side channel restored (> 500 lineal feet) or floodplain (> 0.1 acres)	

Table 2 (continued). Criteria Used in AKART-based Prioritization of Restoration Opportunities.		
Restoration of Predevelopment Geomorphic Processes (project type)	**Ranking Criteria**	**Comment/Explanation**
Ease of Implementation		
1	Project would be difficult, if not impossible, to implement due to multiple private properties, requiring extensive analysis, and requires purchase of additional land	
2	Project would be difficult to implement, BNSF railroad ownership, requires purchase of additional land	
3	Project would be somewhat difficult to implement, single private owner, but requires additional analysis	
4	Project would be relatively easy to implement, public owner, but requires additional analysis	
5	Project would be easy to implement, public owner	
Permitting Complexity		
1	Project would be difficult, if not impossible, to permit, requiring off-site mitigation	
2	Project would be difficult to permit, possibly requiring off-site mitigation, requiring all environmental permits	
3	Project would require in-water permits, requiring most environmental permits	
4	Project would require some environmental permits	
5	Project would be simple to permit and may be exempt from in-water and would be exempt from other permits	
Construction Complexity		
1	Complex construction, difficult to contract, significant dewatering and fish exclusion, no road access	
2	Complex construction, difficult to contract, significant dewatering and fish exclusion, but with limited road access	

Table 2 (continued). Criteria Used in AKART-based Prioritization of Restoration Opportunities.		
Restoration of Predevelopment Geomorphic Processes (project type)	**Ranking Criteria**	**Comment/Explanation**
Construction Complexity (cont'd)		
3	Moderate construction and contracting complexity, equipment/materials needed require in-water work and fish exclusion, limited road access	
4	Straightforward construction and contracting, some work required in-water and some fish exclusion, good road access	
5	Simple contracting, work can be done with easily accessible machinery, limited possibly no in-water work, very easy road access	Contracts could be with volunteer organizations
Geomorphic Context		
1	Non-fish bearing small tributaries of tributaries or riparian enhancements of tributaries	These represent small streams that are non-fish bearing
2	Primary tributary mainstem of the SF Skykomish channel migration zone	This criterion is the channel migration zone of the mainstems of the SF Skykomish primary tributaries
3	SF Skykomish mainstem channel migration zone	
4	SF Skykomish mainstem side channel	
5	SF Skykomish River tributary fans at the mainstem	These are the major tributary fans of the SF Skykomish River

Recommended Implementation Strategy

The recommended implementation strategy is based on the results of this study (and previous assessments) and the collective professional judgment about the basin established during meetings between Herrera, County and USFS staff, and the Snohomish Basin Technical Committee. It is helpful to outline these conclusions below that resulted from the investigation and the vetting of the results by stakeholders mentioned above, as they guided the development of the recommended strategy.

- Tributary alluvial fans are one of the key habitat features in the South Fork basin. The Miller River alluvial fan, the largest tributary fan in the basin, has already been known anecdotally as a locus for salmonid presence and spawning (Herrera 2009). The analysis and observations made herein indicate that smaller tributary fans support similar ecological structure and communities, albeit smaller in scale. The group agreed that these areas should be a focus of restoration activities. Restoration on alluvial fans primarily consists of actions that allow the tributary to migrate throughout the fan, as would have occurred prior to development. Channel migration on a fan is principal mechanism by which habitat on alluvial fans is made and preserved.

- Geomorphology strongly regulates the presence and absence of hydraulic complexity in the basin. There are many places in the basin where there is limited channel migration because of the presence of surficial bedrock and lacustrine clays.

- The native runs of salmon below Sunset Falls are larger in number, and are not constrained in the same way as those runs above the falls due to the presence of this natural barrier. As such, restoration actions that would benefit these native runs were deemed of higher value.

- While there are excellent targets for restoration above Alpine Falls on the Tye River, the purpose of the study (i.e., improvement of salmonid habitat) meant that very little effort and emphasis was placed on opportunities in this area. Actions above Alpine Falls are included in Appendix A, but are not a focus of the restoration strategy discussion below.

- The strategy is guided by the results of the AKART analysis of individual projects (Table 1 of Appendix A). While the AKART analysis cannot necessarily discriminate the relative importance between two similar individual projects, the broad results from the analysis does provide the relative importance of groups of projects, and those projects in particular areas. The results of the AKART analysis in the case of this study corroborate some of the points above, as well as earlier decisions made by the restoration team.

The following elements (collections of project opportunities) should be included in any strategy of restoration in the South Fork basin. They are described roughly in order of their degree of improvement to habitat, and their ease of implementation as identified in the AKART prioritization process.

Miller River Alluvial Fan

A suite of projects on the Miller River Alluvial Fan have already been analyzed in detail due to the maintenance and subsequent failure of the Old Cascade Highway (Herrera 2009, see Appendix E). From this analysis, it is known that the Miller River Alluvial Fan has significant ecological lift potential. Also, because of recent acquisition efforts by the County, the property needed to construct the restoration projects is largely in public hands, simplifying implementation of the projects. The projects will continue to be constrained by the BNSF railway at the north end of the alluvial fan and Miller River Road, a key access point to the Alpine Lakes Wilderness Area.

Mt. Index Riversites Projects

The large private development called Mt. Index Riversites is located primarily on the left bank of the South Fork downstream of Sunset Falls. Reconnaissance on foot within the river and on the public roads in the area indicated that there were a large number of restoration project opportunities that would have both ecological and flood hazard benefits. River-based reconnaissance also indicated that existing juvenile salmonid use was relatively high in this area (compared to above the falls), suggesting that ecological lift of those activities would be great. Further, there could be additional projects not identified in this study because not all of the area was surveyed due to lack of access. Lidar was also not available. At a minimum, it is recommended that Snohomish County and the USFS engage private landowners in the development, possibly through the Snohomish Conservation District, to prevent future habitat impacts from occurring.

Property Acquisition and Conservation in Vicinity of Baring

Due to its geological setting and a general lack of LWD, there are limited side channels throughout the South Fork. However, in the vicinity of Baring, there are several intact side channels. Many of these side channels are in private ownership and undeveloped. Therefore, to preserve what little habitat exists, it is highly recommended that these private parcels be acquired and placed into conservation. Like at Mt. Index Riversites development, it may be possible to work collaboratively with the King County Department of Natural Resources and Parks or private non-profit land conservancy organizations to acquire conservation easements where public acquisition is not possible.

Tributary Fan Restoration Projects

Virtually every large tributary fan in the study area has at least one restoration project opportunity associated with it. These are often the first areas to be developed, despite their hazards, as they are flat, close to a source of water, and typically ecologically productive (i.e., they have abundant fish). As such, human impacts have often complicated hazard management and infrastructure maintenance, often to the detriment of aquatic habitat.

The potentially high ecological lift possible in these areas makes them a focus of future restoration, and this is largely reflected in the prioritization in Appendix A. Because the alluvial fans were identified using remotely sensed data only, it may be prudent to perform a more exhaustive field analysis of these features to fully identify and develop opportunities in these areas.

Road Removal and Realignment in the Beckler-Rapid Basin

The Beckler and Rapid Rivers have been used extensively for access for logging and recreation in the recent past. These activities have been dramatically reduced with the establishment of the Wild Sky Wilderness Area. As such there are a number of logging roads that are no longer needed. Because these roads often constitute fill in the floodplain, their removal can expand existing habitat and restore predevelopment geomorphic conditions in otherwise impacted reaches. There are several project opportunity sites where this would occur in the Beckler-Rapid Basin, including the removal of nearly a mile of floodplain road (FS Road 6550) in the floodplain of the Beckler River upstream of the Rapid River confluence.

LWD Survey

While no formal LWD survey was completed during the course of this study, it is clear from the preliminary work done as part of the South Fork geomorphic assessment that lack of LWD is an important limitation on habitat quality, quantity, and complexity in the South Fork, and the lower reaches of the major tributaries, particularly the Beckler River. A formal study would be extremely helpful to better assess and identify restoration opportunities involving the placement of LWD. In particular, the study should be designed to identify all woody debris in the stream (i.e., identify geomorphic situations where LWD accumulates), and existing riparian conditions in order to locate key locations where channel migration can occur to increase LWD debris accumulation in the stream. Because the problem appears most acute on the South Fork and Beckler River below its confluence with the Rapid River, these areas should be targeted first. Other major tributaries (e.g., Miller and Foss rivers, Money and Index creeks), which are generally in better shape, could be studied at a later date.

Culvert Replacements and Expansion in Upper Portions of Southern Tributary Basins

Probably the largest subset of projects by number is the replacement of culverts in the upper reaches of Money Creek, Miller River, and the Foss River. Money Creek and the Miller and Foss rivers are highly dynamic systems with copious amounts of sediment delivered along their length. The sediment often arrives to the river via debris flows propagating perpendicular to the channels and clogs the culverts along the roads located in the valley bottom. These debris flows form literally dozens of colluvial fans along the roadways. The unstable dynamics of these slopes have high potential for damage to infrastructure as they generate large quantities of sediment.

In addition to damage to infrastructure, routine culvert placement and replacement can have a variety of habitat impacts. They include:

- Sediment accumulation upstream of a small culvert creates an unnaturally steep drop through the culvert and across the roadway such that a fish barrier can be created.
- In rare cases, sediment can completely clog the culvert, causing the flow to run over the road, which creates a fish barrier and a source of in-stream pollution.
- Often riparian vegetation is either removed directly during maintenance activities or indirectly as result of sediment being impounded above an insufficient crossing. Removal of riparian vegetation has a number of impacts to fish habitat including, but not limited to, temperature increases and loss of macroinvertebrate food sources.
- The insufficient and poor design of culverts necessitates regular maintenance which has habitat impacts, even if work is done within a "work window" (i.e., time window when fish are not present). In the maintenance activities, fines are produced and delivered to the tributary and ultimately the main channel. These fines are delivered to the stream ordinary low-water periods during spawning. These fines are thereby capable of smothering redds and degrading water quality. In-water noise can also be an impact to fish during maintenance construction activities.

Therefore, an important task should be to evaluate whether the trunk roads (FS Roads 68, 6410, 6412, 6420, and 6422) in these remote locations are necessary. Taken individually these projects to improve culvert crossings are generally low priority. However, if the roads are to remain, then these projects could be implemented collectively (grouped by stream or subwatershed), to increase overall habitat benefits to the river and creek systems and reduce maintenance over the long term.

SUMMARY OF FINDINGS

Summary of Physical Factors

There are many physical factors that were identified and used to generate restoration projects contained within Appendix A. Most of these were local in scale, and relevant only to a particular restoration project. However, a few key global factors guided most of these projects. They are:

- The South Fork Skykomish floodplain occupies only a fraction of the apparent base of the Skykomish valley due to post-glacial incision into bedrock, and lacustrine sediments from glacial Lake Skykomish.
- The South Fork and Beckler River contain less LWD and hydraulic complexity than predevelopment conditions, which results in highly simplified channel geometry in most locations. It is unclear the degree to which the system is impaired because of the uncertainty of the amount of wood and channel complexity present prior to development.
- The single largest human modifications in the South Fork basin are the prisms and armoring associated with US-2, the BNSF railway, and trunk USFS roads in the tributaries.
- Tributary fans are a key geomorphic element, and vary in size, structure and composition throughout the basin.
- The Money-Miller Alluvial Fan Complex is the largest alluvial fan complex in the basin. It is also very dynamic and has a large number of restoration opportunities associated with it because of its extensive history of development.

Summary of Ecological Factors

As with the physical factors, there are many ecological factors that were identified and used to generate restoration projects contained within Appendix A. Most of these were local in scale and relevant only to a particular restoration project. However, a few key global factors guided most of these projects:

- An extensive amount of suitable habitat (approximately 70 miles of streams) exists for salmonids including habitat for the three ESA-listed species Chinook salmon, steelhead, and bull trout.
- Fish use of habitat in the South Fork below the natural passage barrier at Sunset Falls was observed to be high compared to the habitat above the falls.

- Tributary fans within the South Fork basin are ecologically rich because they provide a diversity of habitats, and an influx of dissolved oxygen, cold water, nutrients, and potential food sources.

- Pool and edge habitat, particularly in the South Fork, Beckler, lower Foss, and Lower Miller rivers and lower Money Creek were found to be moderately degraded because the channel geometry has been simplified due to the lack of LWD, bank armoring, and road density.

Data Gaps

Data gaps in the basin are significant. Very little information exists on nearly every environmental variable important for restoration projects (see Appendix B). A brief listing of the data gaps is included below along with a description of the utility of the information in light of the results of this feasibility study.

- Hydrologic analysis – The work on the Miller River, which had to indirectly describe the hydrology of the upper South Fork and the North Fork, is the first quantitative attempt to assess the site-specific hydrology of any part of the South Fork basin. It indicates that while the Miller River largely mimics well known trends in the long record of data collected on the main stem of the Skykomish River in Gold Bar, there are distinct patterns in the South Fork basin in the distribution of runoff, particularly the starvation of moisture as one moves east in the range. Therefore to support further restoration efforts in the South Fork basin, it is recommended that all of the major tributaries be analyzed (i.e., at a minimum the Tye, Beckler, and Foss rivers). From the experience of the Miller River work, it is recommended that these analyses be based upon water level observations (rather than hydrologic modeling) in those tributaries. The dearth of precipitation data at higher elevations, and the complexities of physical processes there (i.e., primarily the dynamics of rain-on-snow events), make any hydrologic modeling effort difficult. However, without accurate, calibrated hydrology, it is impossible to reliably predict habitat benefits from future restoration actions. Further, without knowing hydrologic forcing, no flood protection project can accurately quantify the expected flood benefits achieved from a particular engineering design, or assess flood risk from any action in the South Fork floodplain.

- Geomorphic analysis – Aside from the Skykomish geologic map and the geomorphic assessment of the South Fork (Appendix C), there have been no geomorphic analyses done in the South Fork basin. Geomorphic analyses provide the landscape context for restoration actions by identifying what predevelopment conditions and what range of habitat outcomes are possible given a set of physical inputs. Without these analyses, it is possible that restoration engineering design will fail to meet project objectives over the long term. It is recommended that geomorphic analyses be performed on all of the major tributaries (i.e., the upper Miller, Tye Beckler, and Foss rivers) to better inform restoration projects in these areas.

- LWD survey – As mentioned in the Recommended Implementation Strategy section earlier in this document, it is clear from an informal survey of wood in the geomorphic assessment of the South Fork (Appendix C) that the river system is deprived of wood, both as compared to historical conditions and other river systems in the Pacific Northwest. As such, a formal survey of LWD and its sources should be undertaken throughout the lower reaches of the basin to better understand the origin of wood deprivation and formulate strategies to ameliorate the habitat impacts of the lack of LWD.

- Hydraulic modeling – There has been no modern hydraulic modeling in any part of the basin, with the exception of the two-dimensional modeling performed on the Miller River fan as a part of this feasibility study (Appendix E). An earlier flood study of the basin conducted by the Federal Emergency Management Agency (FEMA) that established initial base-flood elevations is likely out-of-date with respect to both standard hydraulic methods and the hydrology it is based upon. Hydraulic modeling will be necessary to complete some of the restoration projects identified in Appendix A. Hydraulic modeling may also be helpful in identifying the benefits of various restoration and flood protection strategies (e.g., Timber Lane Village) and identifying impacts to nearby landowners from any engineering action.

- Riparian assessment – While some existing information is available on the riparian condition for the South Fork, Beckler, Miller, and Foss rivers (USFS studies in 1990s), this information was collected at the watershed scale and is outdated. A targeted study of the riparian areas along the South Fork, and key tributaries would provide updated information on the current conditions including off-channel habitats in these areas. This study would complement the LWD study proposed above.

- Targeted fish use assessment – Fish presence surveys (Wild Fish Conservancy, WDFW) have been completed in the South Fork, lower Tye, Beckler, Miller, and Foss rivers, and the lower reaches of Money and Index creeks, but have been limited to Chinook, coho, pink, and chum salmon; steelhead; and bull trout. Fish habitat use surveys tied to areas where high benefit restoration opportunities have been identified or areas of high ecological value (tributary fans) would inform how projects are designed and implemented. Also, there is evidence that the basin is used by resident trout, but information is lacking on the extent of the use. A study of resident fish in targeted streams such as the upper Tye River would also inform the design and implementation of restoration projects.

Highest Priority Restoration Project Opportunities

Once the prioritization was completed and shared with County staff, County staff determined the seven highest priority projects, mostly based upon the scores shown in Appendix A. Some additional consideration was given to geographically balancing the projects between the South Fork and the tributaries. A more complete description of each of these highest priority projects is given below, along with design and construction costs where applicable, and a figure illustrating project constraints and potential actions. The projects appear in no particular order.

FS Road 6550 (ID: BR-13)

Return to Figure 6

FS Road 6550 extends north and east from FS Road 65 just after its crossing of Fourth of July Creek on the Beckler River in Snohomish County. As observed in the field and shown on the USFS road map, FS Road 6550 dead ends at Bullbucker Creek (Beckler River RM 9.6: Figure 7). Originally the road continued to the north to connect with FS Road 65 and FS Road 63 that runs along the North Fork Skykomish River. The abandoned roadbed north of Bullbucker Creek has been reclaimed by vegetation and wetland seeps, but is still elevated above the floodplain. Several dispersed campsites are located along the 1.3-mile maintained road spur. A low bridge over the Beckler River at RM 8.8 is undersized and appears to be in danger of being washed out. The river is confined by the fill along this spur road that starts on the west side of the river, and then crosses to the east side. The roadbed cuts the river off from its floodplain throughout much of the length of the spur.

Since FS Road 6550 is within the floodplain of the Beckler River, it has a significant impact on fish habitat in the Beckler River system. In particular, all three listed species (bull trout, Chinook, and steelhead) could use the area opened by this project. Removal of the road fill and bridge could restore predevelopment floodplain functions within a 10- to 15-acre area because of the intact mature vegetation in the valley.

The project would entail abandonment of 1.3 miles of FS Road 6550, removal of the road fill from the floodplain, and removal of the bridge at RM 8.8. Additional roadbed that was previously abandoned could also be removed. Although it may be necessary to survey the road if the project were to go out to bid, a recent report discussed the relative costs of road decommissioning by the USFS (Duensing 2004). From this report, it is found that decommissioning can cost up to $30,000 on USFS lands if the road is completely removed, but as little as $1,000 if the road is simply abandoned, as the portion of FS Road 6550 beyond Bullbucker Creek currently is. Survey and design costs would likely be comparable to the total amount required for complete removal if effort was taken to identify and then survey the portion of the 1.3 miles of road that is within the floodplain (see below). Therefore a simpler strategy would be to use USFS or County Roads crews to completely remove the 1.3 miles of road that remains without doing further analysis. Assuming the high end of the estimate (to account for removal of the bridge and multiple culverts) and a 3 percent escalation rate from the time of Duensing’s (2004) report publication, the approximate construction cost in this scenario is $51,000.

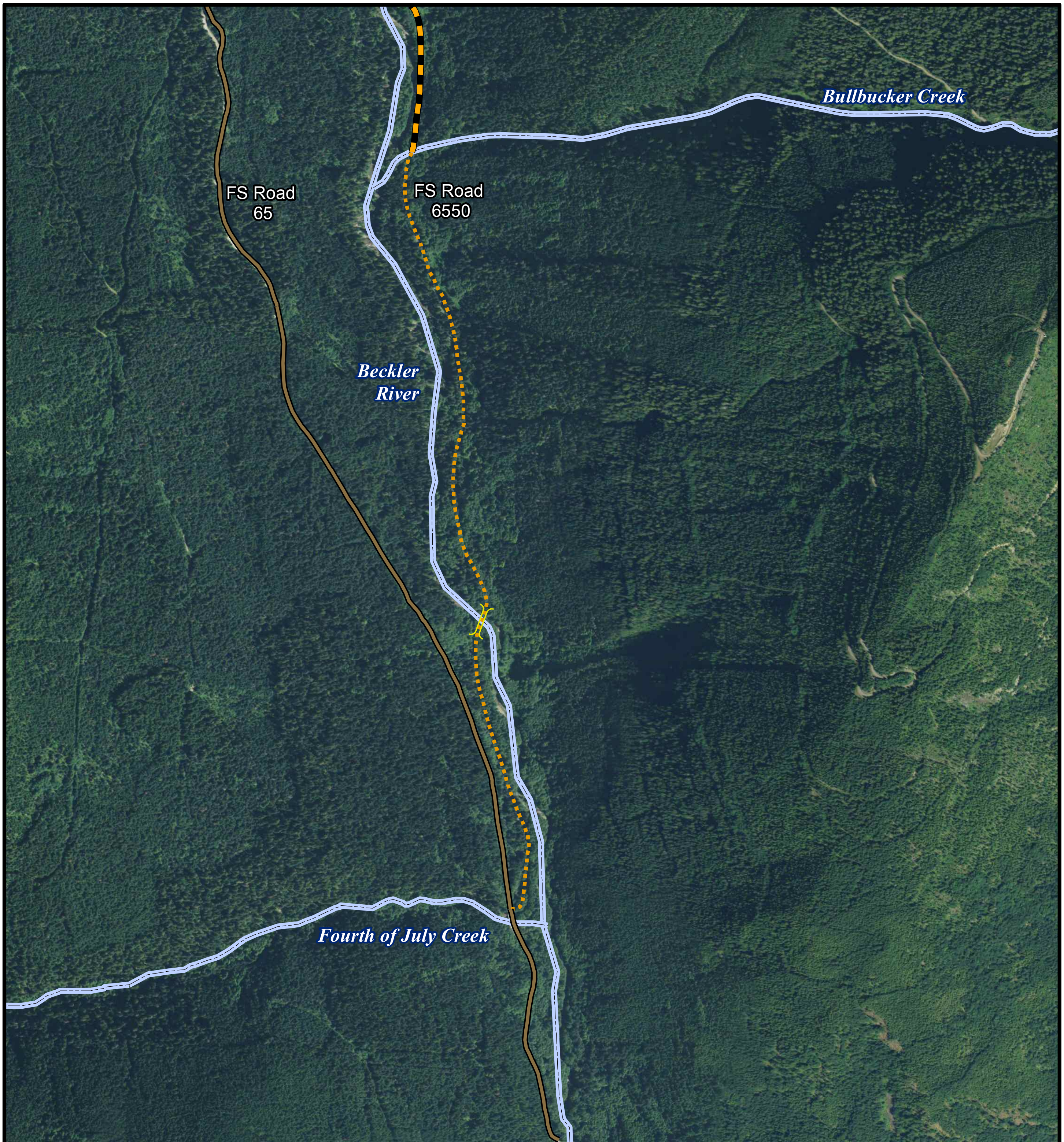
Approximate Design Cost If Surveyed: $50,000

Approximate Construction Cost If Performed by USFS or County Roads Crews: $51,000

Old Cascade Highway (ID: MR-9)

Return to Figure 6

In January 2011, Old Cascade Highway was obliterated by an avulsion of the Miller River just west of the historic bridge crossing. Now most of the flow goes through avulsion site (see photo in Appendix A with the simpler project description) and the road has been closed indefinitely. The highway had considerable rock along its prism to protect it from attack by the river, which would be removed and relocated to the edges of the alluvial fan (Figure 8).



Legend

- Road
- Road to be removed
- Decommissioned road
- Bridge
- Stream

Figure 7. FS Road 6550 Project Conceptual Plan.

N

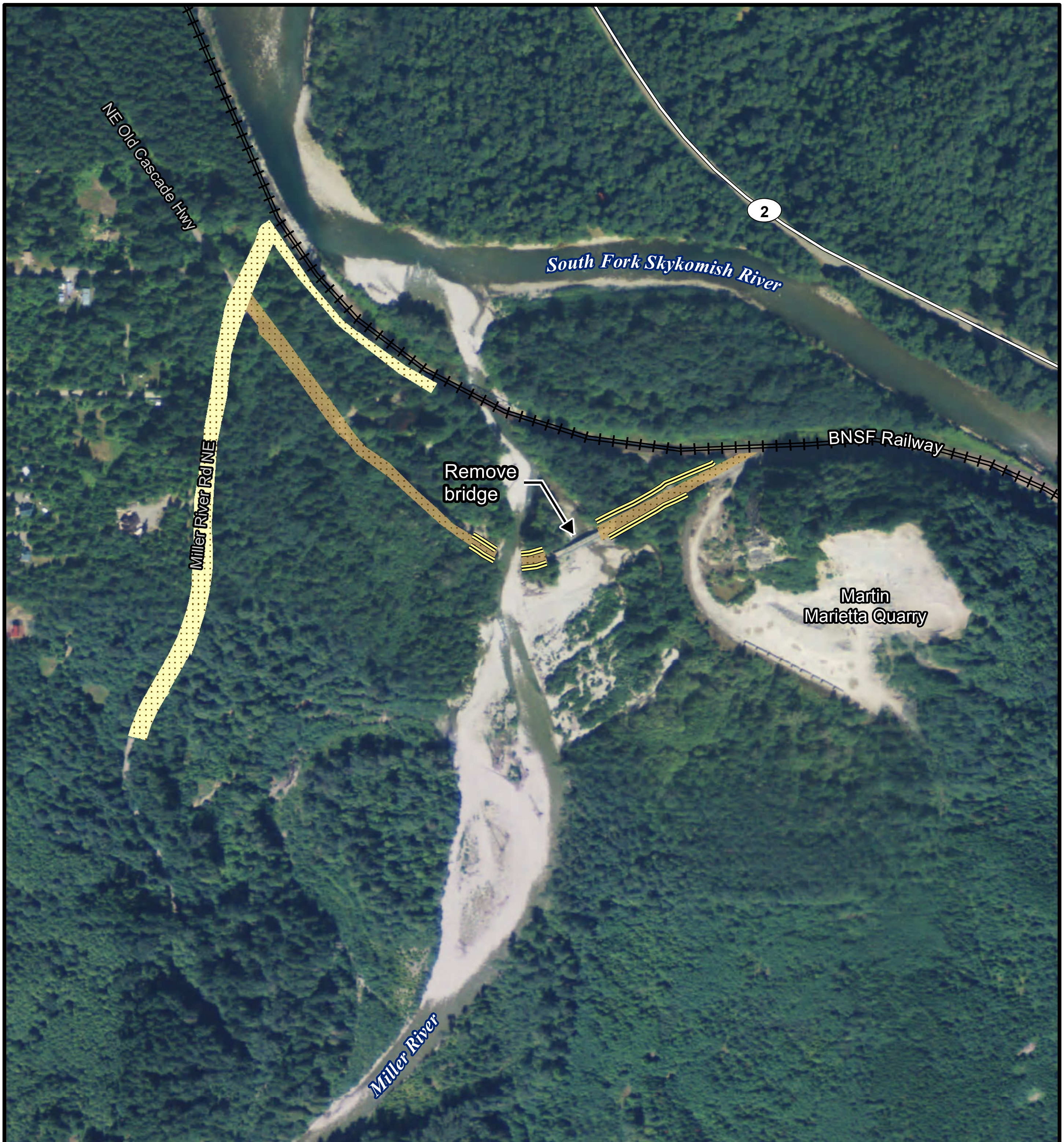
0 625 1,250 2,500

Feet

HERRERA

Aerial: USDA (2011)

K:\Projects\10-04766-025\Project\Conceptual_Plans\FS_road_6550.mxd (4/26/2013)



Legend

- Existing fill to be removed
- Highway
- Railroad
- Placed fill and rock
- Levee or revetment to be removed

Figure 8. Old Cascade Highway Project Conceptual Plan.

N

0 250 500 1,000

Feet

HERRERA

Aerial: USDA (2011)

K:\Projects\10-04766-025\Project\Conceptual_Plans\old_cascade_highway.mxd (4/29/2013)

The highway also inadvertently protected the railroad, which is now the only significant infrastructure that is intact and crosses the fan.

The benefits of this project would be large. Approximately 11 acres of disconnected floodplain and 1,700 linear feet of side channels will be reconnected if this project is implemented. There will also be an improvement of aquatic habitat complexity and quality in 200 linear feet of the main channel complex. Over time, it is likely that one of the disconnected side channels may eventually become the new thalweg. This would allow the avulsion channel and the former main channel to aggrade, revegetate, and become an ecologically productive side channels. In short, habitat on the fan would be expanded greatly if the road were to be removed.

The Old Cascade Highway project involves removing the existing fill and rock associated with the Old Cascade Highway and Bridge abutments (approximately 2,000 cubic yards of riprap and almost 25,000 cubic yards of fill), and placing the riprap along 650 feet on the upstream side of the currently unarmored railroad embankment on the Miller River left bank that is at current risk to failure (Figure 8). As part of this riprap placement design, and due to the channel avulsion potential described above, consideration should be given to the possibility of the main channel migrating to the northwest and flowing between the remaining segment of the Old Cascade Highway and the railroad. If this were to happen, the remaining segment of the Old Cascade Highway as well as any unarmored segment of the railroad embankment could be compromised. Design and construction costs are estimated to be $1,408,325 (for details, see Appendix E-1). The cost estimate includes removal of road fill, but does include disposal of asphalt or the bridge itself.

The road has, and will continue to protect the railway so long it is in place, though there is clear evidence that it has been and will continue to be gradually lost due to natural processes. The railway prism west of the existing Miller River main channel crossing is not armored. Hydraulic modeling results indicate high velocities (in excess of 10 feet per second: Appendix E) in this area, which was corroborated by significant geomorphic changes observed following recent high flows in the vicinity of the left bank railway bridge abutment.

There is a greater potential for encountering hazardous or culturally significant materials than any of the other high priority projects. The road has been in place, in some form, for nearly 100 years, and it may have been located at a historical Native American crossing point. The bridge is relatively newer than the road itself, so there may be old creosote-treated wooden abutments from the original bridge buried in the road prism. The bridge itself is also potentially a historic resource and the extent to which the abutments would be included in that determination is unknown.

Approximate Design and Construction Cost: $1,408,325 (see Appendix E-1 for details)

Miller River Road Revetment (ID: MR-11)

Return to Figure 6

A rock revetment extends along Miller River Road at the apex of the Miller River Alluvial Fan. The revetment extends 150 feet beyond the road, blocking a former side channel. There are several private properties downstream in the formerly active channels. At this location, there is also another side channel on the far side of the channel way, adjacent to Miller River Road.

The Miller River Fan is one of the most productive alluvial fans in the study area. The Miller River Road Revetment blocks 5 acres of floodplain on the alluvial fan from being engaged by the river. This limits rearing and spawning opportunities for Chinook, coho, and steelhead. The benefits of this project would be to reengage a set of side channels at the extreme west edge of the alluvial fan. These side channels have mature native vegetation along them, as well as hyporheic water input. Some (but not all) of this area is already developed. Therefore, acquiring these developed properties, demolishing existing structures, and revegetating the area would increase the ecological performance of this project.

The core of the Miller River Road Revetment project involves removing 150 lineal feet of the existing riprap and fill material that is the Miler River Road revetment. This revetment is currently being eroded by the river and blocking a former side channel (Figure 9). The wasted rock would be used to construct a 350-foot long setback revetment in order to protect the roadway and communities and property on the left bank. Alternatively, the private properties in question (called out in Figure 8) could be acquired, but their acquisition is not included in the cost estimate. Combined design and construction cost associated with this work is estimated at $2,630,320 (for details, see Appendix E). It is important to note that the acquisition of the private properties might result in minor construction cost savings because the rock acquired from the removal of the Miller River Road revetment could then be end dumped along Miller River Road (well above the ordinary high water mark) rather than placed in a new levee. Moving the rock to the road might also provide a greater habitat benefit by reengaging a set of former side-channels that run through these properties.

Approximate Design and Construction Cost: $2,630,320 (see Appendix E-1 for details)

Miller River Curve Revetment (ID: MR-10)

Return to Figure 6

A large revetment called the Miller River Curve Revetment primarily protects the Old Cascade Highway from attack by the main stem of the Miller River. It also secondarily protects a collection of small private properties on the east side of Miller River Road (Figure 10). The cross-section of the revetment is large (on the order of dozens of square yards), with a considerable amount of large rock. It extends for 750 feet. A full accounting of the conditions on the alluvial fan is summarized in Appendix E.

The benefits of this alternative are significant. The alternative would reconnect 5.5 acres of disconnected floodplain and approximately 1,000 linear feet of side channels. It would also improve of aquatic habitat complexity and quality in 50 linear feet of the existing main stem. Removing this revetment would reengage these channels, even without removing the road (i.e., the Old Cascade Highway project), though implementing the Old Cascade Highway project would improve the performance of this alternative.

The Miller River Curve Revetment project involves removing approximately 3,400 cubic yards of existing riprap and 48,100 cubic yards of fill that is on the Miller River Curve revetment, and placing that riprap on the east side of the Miller River Road prism. If done in conjunction with the Old Cascade Highway project, some of the fill and rock can be reused to protect the railway, particularly since it is larger than most of the rock placed along the highway. Design and construction costs associated with the proposed work are estimated at $2,885,510 (for details, see Appendix E-1).

Legend

- Placed rock and fill
- Levee or revetment to remain
- Levee or revetment for removal
- Road

Figure 9. Miller River Road Revetment Conceptual Plan.

N

0 125 250 500

Feet

HERRERA

Aerial: USDA (2011)

K:\Projects\10-04766-025\Project\Conceptual_Plans\miller_river_road_revetment.mxd (4/29/2013)

Legend

- Levee or revetment
- Levee or revetment to be removed
- Parcels to acquire
- Placed fill and rock*

*** Possible to waste rock and fill along BNSF Railway if project done in conjunction with Old Cascade Highway removal**

Figure 10. Miller River Curve Revetment Conceptual Plan.

N

0 150 300 600

Feet

HERRERA

Aerial: USDA (2011)

K:\Projects\10-04766-025\Project\Conceptual_Plans\miller_river_curve_revetment.mxd (4/29/2013)

The Miller Curve Revetment serves as secondary flood protection to the railway, though its impacts to the railway are mixed. The removal of the revetment would increase the probability of a channel forming that would directly impact the unarmored railway prism. However, removing the revetment would reduce the risk of debris flow from reaching the railway by engaging most of the modern alluvial fan. Removal may also reduce flood elevations at the bridge itself. Because the construction activities would only be removing relatively recent placed fill (though the date of placement is uncertain), the probability of encountering cultural resources or hazardous materials is small.

Approximate Design and Construction Cost: $2,885,510 (see Appendix E-1 for details)

Foss River Alluvial Fan (ID: TR-1)

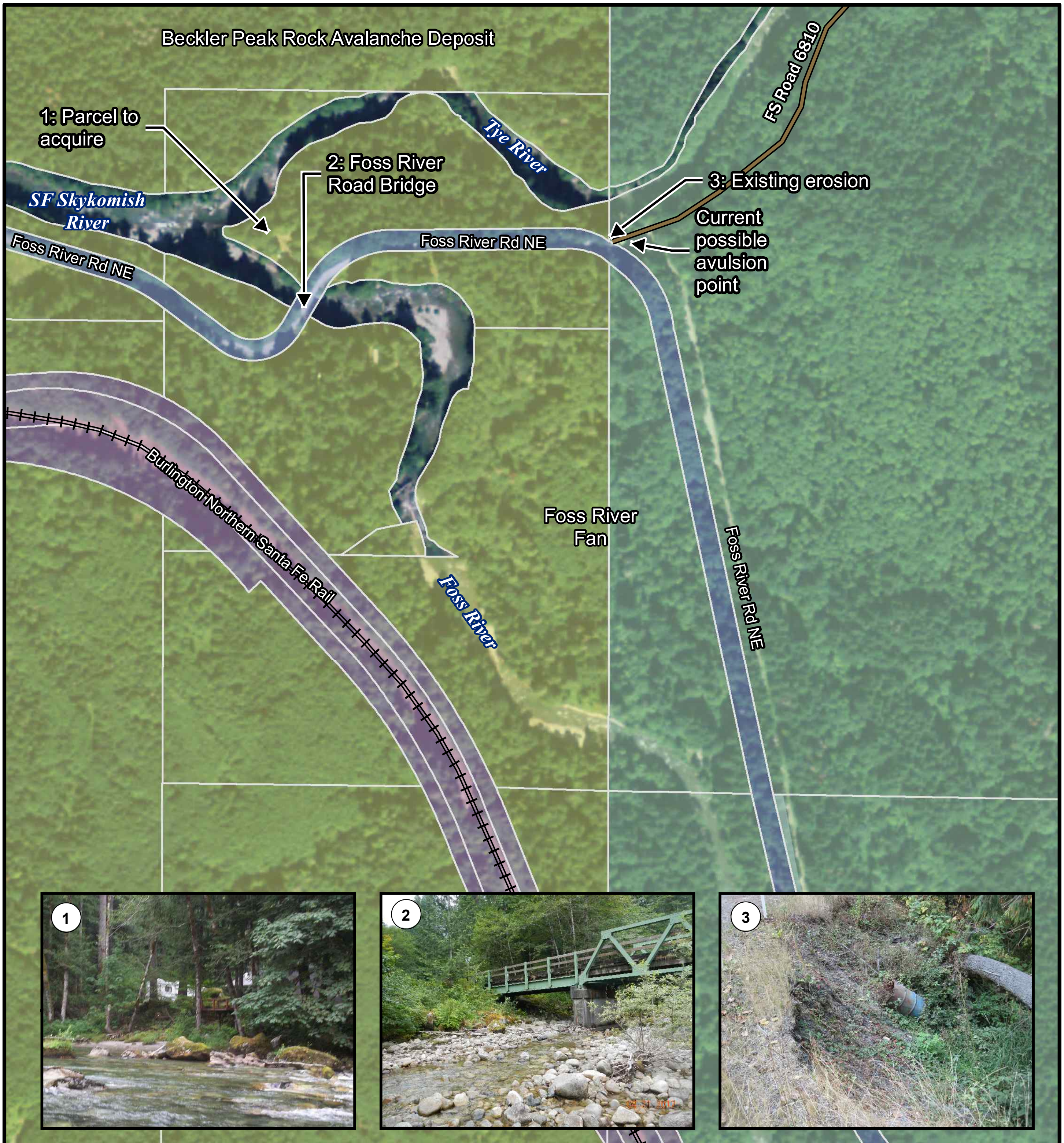
Return to Figure 6

Foss River Road bisects the Foss River Alluvial Fan just upstream from the confluence of the Foss and Tye rivers. The road also bridges the river in a way that constricts the floodplain of the river. The Foss River Alluvial Fan is naturally incised and constrained because it is generally inset into the Beckler Peak Rock Avalanche deposit. However, the road and the fill associated with it unnaturally direct the flow to two locations: the current main channel and another low spot near the junction of Foss River Road and FS Road 6810. The low spot does not have a culvert, and all of the flow currently overtops the road. Though an avulsion is not imminent at this time, it is likely that as the fan aggrades more flow will be directed to the road junction. Continued overtopping will act to scour the road prism and potentially eventually cause the loss of both Foss River Road and FS Road 6810 (Figure 11).

The project would investigate the solutions potentially available to restore predevelopment geomorphic processes to all or part of the fan. The study would determine if simple solutions could be implemented to improve habitat conditions on the alluvial fan and decrease erosive risk on the roadway. Examples of these simple solutions include (but are not limited to) placing a culvert or bridge near the junction of Foss River Road and FS Road 6810 or placing large woody debris to deflect flow away from the Foss River Road). Another purpose of the study will be to determine if two-dimensional hydraulic modeling will be required to further design these simple solutions. Like most of the rest of South Fork basin, the hydrology of the Foss River is largely unknown. Therefore any modeling effort would need to estimate first the hydrology of the basin. Finally, the project would investigate the feasibility of moving the road to another location that would be beneficial from habitat, flooding, and road maintenance perspectives.

The Foss River Alluvial Fan provides important habitats for three listed species (Chinook, steelhead, and bull trout). The alluvial fan is currently impaired in several ways by the road crossing in the middle of the alluvial fan. The objective of the project is to reengage a larger portion the Foss River Alluvial Fan and the rearing habitat it potentially possesses. Another objective is to prevent future access disruptions and environmental impacts from flooding and road maintenance. Proposed improvements may increase channel length and floodplain engagement, improving rearing conditions, but also expanding spawning habitat area.

Approximate Geomorphic Assessment Cost: $15,000



Legend

Road

Railroad

Parcel

BNSF

Private

USFS

Public (county)

Figure 11. Foss River Fan Project Conceptual Study.

N

0 200 400 800

Feet

HERRERA

Aerial: USDA (2011)

K:\Projects\10-04766-025\Project\Conceptual_Plans\foss_river_fan.mxd (4/26/2013)

South Fork RM 16.9 Right Bank (ID: SFSR-42)

Return to Figure 6

The Beckler River confluence with the South Fork Skykomish River is located at approximately RM 16.9 on the right bank. The river now crosses under US-2 downstream of the Beckler River confluence at RM 16.8. A side channel cuts through the Beckler River fan floodplain on the left bank of the Beckler River where it bends sharply southeast towards the South Fork Skykomish River. This area is near the site of an historic landslide from Beckler Peak that pushed the Beckler River to the west. The floodplain in this area is intact and forested, and the right bank of both rivers is in private ownership (Figure 12).

The parcel in question is probably one of the largest single private parcels on the major (named) alluvial fans in the basin. Alluvial fans, particularly those of the major tributary rivers, are important for all of the listed species in the area (Chinook, steelhead, and bull trout). Acquiring and restoring the parcel provides valuable rearing habitat for all of these species. It can also expand spawning for steelhead and Chinook by allowing the fan to develop alternate channels through the floodplain, as they did prior to development.

The project would entail purchasing the private parcel on the right bank of the South Fork Skykomish River between RM 16.9 and RM 17.1 and the Beckler River. The purpose would be to preserve and protect the side channel and floodplain in this area. A portion of this parcel has been cleared and could be revegetated, even though the cleared area is likely outside of the floodplain. Acquisition of the parcel could also enable a larger range of bridge replacement options that would have significant ecological benefits, since the bridge is near the end of its design life and will need to be replaced within the next several years.

Approximate Acquisition Cost from King County Tax Records: $187,000*
*does not include costs associated with building demolition and revegetation

South Fork RM 7.5 Left Bank (ID: SFSR-19)

Return to Figure 6

The inlet of large forested side channel is currently in small-parcel private ownership near the Town of Baring. The area could theoretically all be developed despite that most of the nine small parcels are in the floodplain and possess a side channel. The project includes all of the properties north and west of the junction of NE 190th Street and 637th Avenue NE. Two of the parcels are already developed with small recreational cabins. Based upon photographs in King County tax records, these structures are built on stilts, suggesting that the parcels are inundated regularly. The other parcels are all currently in private hands and could be developed, and further negatively affect rearing areas and reduce riparian and floodplain vegetation (Figure 13).

Very few active side channels exist on the South Fork. Even fewer have adjacent (riparian) mature forest associated with them, like in this area. Further the side channel is associated with the Index Creek Alluvial Fan, one of the focus points for the three listed species in the area (Chinook, steelhead, and bull trout).

The project would acquire these precarious, yet ecologically valuable parcels and place them in a conservation easement. Following acquisition, the three developed parcels would have the recreational buildings currently on them demolished and then reforested. A longer-term

Legend

- Parcel to acquire
- Parcel boundary
- Highway
- Railroad

Figure 12. RM 16.9 Right Bank Acquisition Plan

N

0 175 350 700
Feet

HERRERA

Aerial: USDA (2011)

K:\Projects\10-04766-025\Project\Conceptual_Plans\rm16.9_right_bank_acquisition.mxd (4/21/2013)

Legend

- Parcels to be acquired
- Side channel
- Stream
- Highway
- Road
- Railroad

Figure 13. RM 7.5 Left Bank Acquisition Plan.

N

0 175 350 700

Feet

HERRERA

Aerial: USDA (2011)

K:\Projects\10-04766-025\Project\Conceptual_Plans\rm7.5_left_bank_acquisition.mxd (4/26/2013) program of acquisition could continue to acquire parcels further upstream to buffer this unusual feature.

Approximate Acquisition Cost from King County Tax Records: $259,000*
*does not include costs associated with building demolition and revegetation

References

Beechie, T.J., D.A. Sear, J.D. Olden, G.R. Pess, J.M. Buffington, H. Moir, P. Roni, and M.M. Pollock. 2010. Process-based Principles for Restoring River Ecosystems. *BioScience* 60(3):209-222.

Bisson, P.A., J.L. Nielsen, R.A. Palmason, and L.E. Grove. 1982. A system of naming habitat types in small streams, with examples of habitat utilization by salmonids during low streamflow. Pages 62-73 in N.B. Armantrout, editor. Acquisition and utilization of aquatic habitat inventory information. Proceedings of a symposium held 28-30 October, 1981, Portland, Oregon. Western Division, American Fisheries Society.

Carlson, W. and the Skykomish Historical Society. 2009. *Images of America: Upper Skykomish Valley*. Arcadia Publishing, San Francisco.

Cascades Environmental Services, Inc. 1997a. Beckler River Stream Survey Level II, Version 9.6 for Region 6, Final Report. Prepared for US Forest Service, Mount Baker Snoqualmie National Forest, Skykomish Ranger District, Skykomish, Washington. November 12, 1997.

Cascades Environmental Services, Inc. 1997b. Tye River Stream Survey Level II, Version 9.6 for Region 6, Final Report. Prepared for US Forest Service, Mount Baker Snoqualmie National Forest, Skykomish Ranger District, Skykomish, Washington. November 12, 1997.

Collins, B.D. and D.R. Montgomery. 2011. The legacy of Pleistocene glaciation and the organization of lowland alluvial process domains in the Puget Sound region. *Geomorphology* 126:174-185.

Collins, B.D., D.R. Montgomery, and A.D. Haas. 2002. Historical changes in the distribution and functions of large wood in Puget Lowland rivers. *Canadian Journal of Aquatic and Fishery Sciences* 59:66-76.

Duensing, L. 2004. Groundtruthing Forest Service Road Decommissioning. Prepared for Wildlands CPR.

General Land Office (GLO). 1895a. Township No. 26 North Range No. 10 East Willamette Meridian, Washington. Olympia, Washington, US Surveyor General's Office.

General Land Office (GLO). 1895b. Township No. 26 North Range No. 11 East Willamette Meridian, Washington. Olympia, Washington, US Surveyor General's Office.

General Land Office (GLO). 1899. Township No. 27 North Range No. 10 East Willamette Meridian, Washington. Olympia, Washington, US Surveyor General's Office.

Herrera. 2009. Miller River Fan Geomorphic Assessment. Prepared for King County Department of Natural Resources and Parks, Water and Land Resources Division, River and Floodplain Management Section, by Herrera Environmental Consultants, Inc., Seattle, Washington. December 2009.

King County. 2012. GIS data layer of fish distribution for South Fork Skykomish River Basin. Obtained from King County GIS on November 8, 2012.

Kondolf, G.M. and 13 others. 2006. Process-based ecological river restoration: Visualizing three-dimensional connectivity and dynamic vectors to recover lost linkages. *Ecology and Society* 11(2):5.

Lestelle, L.C., W.E. McConnaha, G. Blair, and B. Watson. 2005. Chinook Salmon Use of Floodplain, Secondary Channel, and Non-Natal Tributary Habitats in Rivers of Western North America: Application to the Willamette River (Oregon) and Formulation of Species-Habitat Rules for EDT Analysis. Mobrand-Jones and Stokes, Vashon, Washington and Portland, Oregon. September 28, 2005.

Merlin Biological. 2000. Foss River Stream Survey Level II, Version 2.0 for Region 6, Final Report. Prepared for US Forest Service, Mount Baker Snoqualmie National Forest, Skykomish Ranger District, Skykomish, Washington. August 2000.

Montgomery, D.R., and J.M. Buffington. 1997. Channel-reach morphology in mountain drainage basins. *Geological Society of America Bulletin* 109:596-611.

Snohomish Basin Salmon Recovery Forum. 2005. Snohomish River Basin Salmon Conservation Plan. Snohomish County Department of Public Works, Surface Water Management Division, Everett, Washington. June 2005.

Snohomish Basin Salmonid Recovery Technical Committee and National Marine Fisheries Service. 2005. Snohomish River Basin Ecological Analysis for Salmon Conservation. May 2004, Updated June 2005.

Snohomish Basin Salmonid Recovery Technical Committee. 1999. Initial Snohomish River Basin Chinook Salmon Conservation/Recovery Technical Work Plan. October 6, 1999.

Snohomish Basin Salmonid Recovery Technical Committee. 2002. Snohomish River Basin Salmonid Habitat Conditions Review. September 2002.

Streamnet. 1998. StreamNet Database (Version 98.3) [database downloaded to disk]. Portland (OR): StreamNet, April 1998. [17 May 1998]. URL: http://www.streamnet.org/accesstable.html.

Tabor, R.W., V.A. Frizzell, Jr., D.B. Booth, R.B. Waitt, J.T. Whetten, and R.E. Zartman. 1993. Geologic map of the Skykomish River 30- by 60-minute quadrangle. US Geologic Survey, Map I-1963.

USFS. 1990. Mount Baker Snoqualmie National Forest Land and Resource Management Plan. US Forest Service.

USFS. 1994. Tye River Watershed Analysis, Mt. Baker-Snoqualmie National Forest, Skykomish Ranger District. US Forest Service.

USFS. 1995a. Watershed Analysis - Beckler River, Skykomish Ranger District. US Forest Service.

USFS. 1995b. Skykomish Forks Watershed Analysis, Mt. Baker-Snoqualmie National Forest. US Forest Service.

USFS. 2009a. Miller-Foss Watershed Analysis, Mt. Baker-Snoqualmie National Forest. US Forest Service.

USFS. 2009b. Watershed Action Plan for the National Forest System Lands of the North and South Fork Skykomish 5th-Field Focused Watersheds. A Framework for Prioritizing Restoration. Skykomish Ranger District Mt. Baker – Snoqualmie National Forest. US Forest Service. September 2009.

UW. 2012. University of Washington Libraries Digital Collections.

WDFW. 2002. Salmonid Stock Inventory (SaSI) reports, WRIA 7 Snohomish Basin. Obtained from website on May 24, 2012: http://wdfw.wa.gov/conservation/fisheries/sasi/search.php?searchby=WRIA&search=07&orderby=Species%20ASC,%20StockName%20ASC.

WDFW. 2012. GIS data layer of fish distribution for South Fork Skykomish River Basin. Obtained from WDFW GIS website electronic database download on November 9, 2012.

APPENDIX A

Summary of Restoration Project Opportunities and Prioritization

The project description sheets are intended for the purposes of pursuing grant funding. In most cases, very little information was available to define the magnitude of the benefits described. But all of the projects have restorative benefits. It is acknowledged that infrastructure protection would likely accompany most of the projects and it could be infrastructure updates that motivate or fund the restoration actions mentioned here. Habitat benefits are based on the physical improvements observed at similar sites in western Washington. Habitat benefits are also broadly defined. Almost entirely, they are based upon the proximity to similar environments where fish can reasonably be expected to be present. They often do not necessarily refer to habitat benefits directly on site (e.g., underneath a bridge that will be replaced). Because of the lack of information about the sites, oftentimes the solutions described are non-specific. This was because data was not available to identify clear alternatives, which would need to be developed through a more rigorous design process.

The opportunities could also benefit from being grouped programmatically. For example, culvert replacement projects in a particular basin or group of basins could be grouped, as their benefits may be the same, and the net improvement from all the culvert replacements would be significant (as opposed to individually where the ecological lift is arguably small). Programmatic actions would lessen permit efforts and could also be lumped to target a single large grant, which may possibly reduce design and planning costs.

To aid in the development of a strategy for implementation, a prioritization analysis was also performed. This analysis, in addition to identification of those projects that could have flood benefits, is included as Table A-1.

Table A-1. Prioritization Scores of Project Opportunities Using AKART Criteria.

Site Number	ID #	River Name	Site Name	Opportunity Category	Flood Protection Nexus [a]
1	BR-1	Beckler River	RM 0.1 Beckler River	LWD placement	Yes
10	BR-10	Beckler River	RM 7.6 Dispersed Campsite	LWD placement	No
11	BR-11	Beckler River	USFS Road 65 at Rapid River	Bridge and culvert replacement	No
12	BR-12	Beckler River	Fourth of July Creek Bridge	Bridge and culvert replacement	No
13	BR-13	Beckler River	USFS Road 6550	Fill removal, road, rail and trailhead relocation	No
2	BR-2	Beckler River	Powerline - Beckler River	LWD placement	No
3	BR-3	Beckler River	Bolt Creek	LWD placement	No
4	BR-4	Beckler River	Beckler River Campground	LWD placement	No
5	BR-5	Beckler River	RM 1.9 Upland	Property acquisition	No
6	BR-6	Beckler River	RM 2.9 Unnamed Stream	Bridge and culvert replacement	No
7	BR-7	Beckler River	RM 3.5 - 5.0	Specialty Study	No
8	BR-8	Beckler River	Johnson Creek Bridge	Bridge and culvert replacement	Yes
9	BR-9	Beckler River	RM 7.4 - 7.6	Fill removal, road, rail and trailhead relocation	No
1	FR-1	Foss River	RM 1.3 Tributary	Bridge and culvert replacement	No
10	FR-10	Foss River	FS Road 6800-010	Bridge and culvert replacement	No
11	FR-11	Foss River	FS Road 6835	Fill removal, road, rail and trailhead relocation	No
12	FR-12	Foss River	West Fork Foss Trailhead	Fill removal, road, rail and trailhead relocation	No
2	FR-2	Foss River	Railway Bridge	Armoring removal	No
3	FR-3	Foss River	RM 2.2 Colluvial Fan	Bridge and culvert replacement	No
4	FR-4	Foss River	RM 3.2 Tributary	Bridge and culvert replacement	No
5	FR-5	Foss River	Necklace Valley Trailhead	Bridge and culvert replacement	No
6	FR-6	Foss River	FS Road 68 Bridge	Fill removal, road, rail and trailhead relocation	No
7	FR-7	Foss River	RM 4.2 Tributary, FS Road 68	Bridge and culvert replacement	No
8	FR-8	Foss River	RM 4.2 Tributary, FS Road 6835	Bridge and culvert replacement	No

Table A-1. Prioritization Scores of Project Opportunities Using AKART Criteria.

Site Number	ID #	River Name	Site Name	Opportunity Category	Flood Protection Nexus [a]
9	FR-9	Foss River	East Fork Bridge	Bridge and culvert replacement	No
1	IC-1	Index Creek	637th Ave NE Bridge	Bridge and culvert replacement	Yes
2	IC-2	Index Creek	Skylandia Development	Property acquisition	No
3	IC-3	Index Creek	RM 0.3 Index Creek	LWD placement	No
4	IC-4	Index Creek	RM 0.5 Index Creek	Property acquisition	No
1	MC-1	Money Creek	FS Road 6031	Fill removal, road, rail and trailhead relocation	No
10	MC-10	Money Creek	RM 5.7 - 5.8	Specialty studies	No
11	MC-11	Money Creek	RM 6.1 Tributary	Bridge and culvert replacement	No
12	MC-12	Money Creek	RM 6.4 Tributary	Bridge and culvert replacement	No
13	MC-13	Money Creek	RM 6.6 Tributary	Specialty studies	No
14	MC-14	Money Creek	RM 6.8 Tributary	Specialty studies	No
15	MC-15	Money Creek	RM 7.2 Tributary	Specialty studies	No
2	MC-2	Money Creek	FS Road 6031 Residences	Property acquisition	No
3	MC-3	Money Creek	USFS Road 6422	Specialty studies	No
4	MC-4	Money Creek	RM 1.7	LWD placement	No
5	MC-5	Money Creek	RM 3.0	Bridge and culvert replacement	No
6	MC-6	Money Creek	RM 3.8	Bridge and culvert replacement	No
7	MC-7	Money Creek	RM 3.5 - 4.6	Fill removal, road, rail and trailhead relocation	No
8	MC-8	Money Creek	RM 4.3 Tributary	Bridge and culvert replacement	No
9	MC-9	Money Creek	RM 4.8 Tributary	Specialty studies	No
1	MR-1	Miller River	RM 2.1 Culvert	Bridge and culvert replacement	No
10	MR-10	Miller River	Miller River Curve Revetment	Armoring removal	Yes
11	MR-11	Miller River	Miller River Road Revetment	Armoring removal	Yes
2	MR-2	Miller River	Confluence Tributary	Bridge and culvert replacement	No

Table A-1. Prioritization Scores of Project Opportunities Using AKART Criteria.

Site Number	ID #	River Name	Site Name	Opportunity Category	Flood Protection Nexus [a]
3	MR-3	Miller River	West Fork Miller Mine	Specialty studies	No
4	MR-4	Miller River	East Fork Miller RM 1.1	Specialty studies	Yes
5	MR-5	Miller River	East Fork Miller RM 1.7	Bridge and culvert replacement	No
6	MR-6	Miller River	FS Road 6412 Bridge Right Bank	Specialty studies	No
7	MR-7	Miller River	East Fork Miller RM 2.2 Tributary	Bridge and culvert replacement	No
8	MR-8	Miller River	East Fork Miller RM 2.7	LWD placement	No
9	MR-9	Miller River	Old Cascade Highway	Fill removal, road, rail and trailhead relocation	Yes
14	RR-14	Rapid River	RM 0.8 Rapid River	Armoring removal	No
15	RR-15	Rapid River	Evergreen Mountain Side Channel	Specialty studies	No
16	RR-16	Rapid River	RM 1.8 Tributary	Bridge and culvert replacement	No
17	RR-17	Rapid River	RM 3.2 Colluvial Fan	Bridge and culvert replacement	No
1	SFSR-1	SF Skykomish River	Foss River Bridge	Bridge and culvert replacement	Yes
10	SFSR-10	SF Skykomish River	RM 14.3 Side Channel	Bridge and culvert replacement	No
11	SFSR-11	SF Skykomish River	RM 14.3 Railroad	Fill removal, road, rail and trailhead relocation	Yes
12	SFSR-12	SF Skykomish River	Miller River Alluvial Fan	Fill removal, road, rail and trailhead relocation	No
13	SFSR-13	SF Skykomish River	Money Creek Campground	Specialty study	Yes
14	SFSR-14	SF Skykomish River	RM 12.5 Railroad Bridge	Bridge and culvert replacement	No
15	SFSR-15	SF Skykomish River	RM 10.5	Side channel or tributary reconnection	No
16	SFSR-16	SF Skykomish River	RM 10.2	Bridge and culvert replacement	No
17	SFSR-17	SF Skykomish River	RM 9.5	Fill removal, road, rail and trailhead relocation	No
18	SFSR-18	SF Skykomish River	RM 8.6	Property acquisition	No
19	SFSR-19	SF Skykomish River	RM 7.5 Left Bank	Property acquisition	No
2	SFSR-2	SF Skykomish River	Timber Lane Village	Specialty study	Yes
20	SFSR-20	SF Skykomish River	RM 7.5 Right Bank	Armoring removal	No

Table A-1. Prioritization Scores of Project Opportunities Using AKART Criteria.					
Site Number	**ID #**	**River Name**	**Site Name**	**Opportunity Category**	**Flood Protection Nexus [a]**
21	SFSR-21	SF Skykomish River	RM 7.0	LWD placement	No
22	SFSR-22	SF Skykomish River	RM 6.4	Property acquisition	No
23	SFSR-23	SF Skykomish River	RM 6.0	LWD placement	No
24	SFSR-24	SF Skykomish River	Barclay Creek Alluvial Fan	Specialty study	Yes
25	SFSR-25	SF Skykomish River	RM 5.4	LWD placement	No
26	SFSR-26	SF Skykomish River	Upper Eagle Falls Tributary	Side channel or tributary reconnection	No
27	SFSR-27	SF Skykomish River	Lower Eagle Falls	Specialty study	Yes
28	SFSR-28	SF Skykomish River	Lower Eagle Falls Tributary	Bridge and culvert replacement	No
29	SFSR-29	SF Skykomish River	Sunset Falls Tailout	Fill removal, road, rail and trailhead relocation	No
3	SFSR-3	SF Skykomish River	RM 17.4	Side channel or tributary reconnection	No
30	SFSR-30	SF Skykomish River	Mt. Index Riversites Floodplain	Side channel or tributary reconnection	No
31	SFSR-31	SF Skykomish River	Mt. Index Riversites Riparian Improvement	Riparian improvement	No
32	SFSR-32	SF Skykomish River	Mt. Index Riversites Right Bank Floodplain	Property acquisition	No
33	SFSR-33	SF Skykomish River	McCall Creek Alluvial Fan	Property acquisition	No
34	SFSR-34	SF Skykomish River	McCall Creek Culvert	Bridge and culvert replacement	No
35	SFSR-35	SF Skykomish River	Bridal Veil Creek	Bridge and culvert replacement	Yes
36	SFSR-36	SF Skykomish River	Paytan Creek	Bridge and culvert replacement	Yes
37	SFSR-37	SF Skykomish River	Mt. Index Road	Property acquisition	No
38	SFSR-38	SF Skykomish River	RM 0.3	Fill removal, road, rail and trailhead relocation	No
39	SFSR-39	SF Skykomish River	RM 12.0 - 12.4 Left Bank	Property acquisition	No
4	SFSR-4	SF Skykomish River	Beckler River Alluvial Fan	LWD placement	No
40	SFSR-40	SF Skykomish River	RM 13.8 - 14.0 Right Bank	Property acquisition	No
41	SFSR-41	SF Skykomish River	RM 16.0 Right Bank	Property acquisition	Yes
42	SFSR-42	SF Skykomish River	RM 16.9 Right Bank	Property acquisition	No

Table A-1. Prioritization Scores of Project Opportunities Using AKART Criteria.

Site Number	ID #	River Name	Site Name	Opportunity Category	Flood Protection Nexus [a]
43	SFSR-43	SF Skykomish River	RM 17.4 - 18.0 Right Bank	Property acquisition	No
5	SFSR-5	SF Skykomish River	US 2 RM 16.8	Bridge and culvert replacement	No
6	SFSR-6	SF Skykomish River	RM 16.6	Fill removal, road, rail and trailhead relocation	No
7	SFSR-7	SF Skykomish River	RM 16.0	Side channel or tributary reconnection	No
8	SFSR-8	SF Skykomish River	Maloney Creek	Fill removal, road, rail and trailhead relocation	No
9	SFSR-9	SF Skykomish River	RM 15.1 - US 2	LWD placement	No
1	TR-1	Tye River	Foss River Alluvial Fan	Property acquisition	Yes
10	TR-10	Tye River	RM 7.1 Tributary	Fill removal, road, rail and trailhead relocation	No
11	TR-11	Tye River	Surprise Creek Railroad Culvert	Fill removal, road, rail and trailhead relocation	No
12	TR-12	Tye River	Surprise Creek FS Road Bridge	Bridge and culvert replacement	No
13	TR-13	Tye River	BNSF Staging Area	Bridge and culvert replacement	No
14	TR-14	Tye River	FS Road 6099	Fill removal, road, rail and trailhead relocation	No
15	TR-15	Tye River	Tunnel Tributary	Fill removal, road, rail and trailhead relocation	No
2	TR-2	Tye River	RM 1.2 Tributary	Fill removal, road, rail and trailhead relocation	No
3	TR-3	Tye River	Upstream Beckler Peak Rock Avalanche	Property acquisition	No
4	TR-4	Tye River	RM 1.9	LWD placement	No
5	TR-5	Tye River	RM 2.4	Side channel or tributary reconnection	No
6	TR-6	Tye River	RM 4.1 Tributary Colluvial Fan	Specialty study	Yes
7	TR-7	Tye River	Deception Falls Side Channel	Specialty study	No
8	TR-8	Tye River	Deception Falls Pedestrian Bridge	Bridge and culvert replacement	No
9	TR-9	Tye River	RM 6.6 Tributary	Fill removal, road, rail and trailhead relocation	No

[a] Would generally score greater than a value of 20 using King County Flood Control District Project Prioritization Criteria, where critical infrastructure includes all County roads, US-2, the BNSF railway and BPA utility corridor, but not FS or private roads and driveways

Opportunity Name	**BR #1: RM 0.1 Beckler River**
Activity	**LWD Placement**

Project sponsor	USFS
Target habitat	Adult and juvenile salmonid migration and rearing
Current ownership	USFS
Hydrogeomorphic classification	Mainstem riverbank
Project size	~100 feet of riverbank
Strategy	LWD Placement

Existing conditions	Beckler Road runs along the right bank (west side) of the Beckler River at this site location. The road serves as the primary connector route from US Route 2 to the North Fork of the Skykomish and to recreational sites and timber production lands. At RM 0.1, the river makes a sharp turn to the southeast due to a bedrock outcrop. The river has scoured out the road embankment just upstream of the bedrock and is starting to undermine the road (see photo). Riprap was placed in this area, but has failed and has been mostly carried downstream during large storm events. While some large woody debris has collected where the bedrock is located, the bank is still unstable.
Project description	The project would entail placement of LWD and vegetation to both secure the bank and to provide fish habitat complexity along the edge of the river. Another option would be to move the road to the west, away from the river and then add LWD and vegetation on the bank to prevent further erosion, break up river flows, and provide refugia and cover for fish.
Future threats	Further erosion of the channel, undermining the road, and potential road collapse into the channel necessitating a less habitat friendly fix. This would result in loss and damage of fish habitat and fish habitat diversity in this reach, and likely cause debris to enter the channel.
Project rationale	The road fill impairs this reach of the river, where it would typically overtop the banks into the floodplain. If LWD were placed within the erosion area and the bank was revegetated, it would break up the flow, provide habitat diversity, and prevent the road debris from entering the channel. Setting back the road, removing the fill, placing LWD, and revegetating the bank would also restore floodplain functions, habitat diversity, and vegetative cover to this reach of the river.
Functions restored	Floodplain connection, greater juvenile salmonid habitat diversity, refugia and cover, and some additional shading of the shoreline. Additionally, localized water quality improvement would be provided by the project implementation.

<table>
<tr><td>Opportunity Name</td><td colspan="3">BR #2: LWD Placement</td></tr>
<tr><td>Activity</td><td colspan="3">Power line - Beckler River</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>USFS</td></tr>
<tr><td>Target habitat</td><td>Adult and juvenile salmonid rearing and refugia</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Mainstem riverbank</td></tr>
<tr><td>Project size</td><td>~200 feet of riverbank</td></tr>
<tr><td>Strategy</td><td>LWD Placement</td></tr>
<tr><td>Existing conditions</td><td colspan="3">Bonneville Power Administration (BPA) power lines cross perpendicularly over the Beckler River at approximately RM 0.5. To maintain the utility alignment, the vegetation is periodically cut down within a 100 foot swath below the power lines. Due to the loss of forested riparian habitat and the erosive force of the river, the steep left bank of the river is eroding under the power lines (see photo). Bank armoring at this location was not observed during the field investigation and erosion is likely to continue to occur over time.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would entail placement of LWD and vegetation to both secure the bank and to provide localized fish habitat complexity.</td></tr>
<tr><td>Future threats</td><td colspan="3">Entrainment of the stream along the bank and armoring with rock or other means by BPA. Further erosion of the embankment would cause more slumping of the bank into the river and may cause a perception of risk to the power line poles. Since no LWD is present at this location, erosion will continue to occur, potentially causing embeddedness within spawning gravels, loss of fish habitat diversity, and loss of riparian vegetation and cover. Rock armor would further degrade stream conditions.</td></tr>
<tr><td>Project rationale</td><td colspan="3">The loss of riparian vegetation along the power line corridor has resulted in erosion and instability of the bank. Placing LWD and revegetating the eroding bank would break up the flow, increase habitat diversity, and restore riparian cover, which provide critical functions to maintaining good salmonid habitat.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Greater salmonid habitat diversity, refugia and cover, moderating the delivery of sediment to the channel, and providing some additional shading of the shoreline. Additionally, localized water quality improvement would be provided by the project implementation.</td></tr>
</table>

Opportunity Name	**BR #3: Bolt Creek**		
Activity	**LWD Placement**		
		**Project sponsor**	USFS
		Target habitat	Adult and juvenile salmonid rearing and refugia
		Current ownership	USFS
		Hydrogeomorphic classification	Tributary streambank
		Project size	~75 feet of riverbank
		Strategy	LWD Placement
Existing conditions	FS Road 65 crosses over Bolt Creek, a tributary to the Beckler River, via a bridge. The bridge abutments adequately span the channel so that no scouring appears to be occurring. As part of the bridge installation, riprap armoring was placed along the right bank of the stream. The riprap extends approximately 75 feet downstream of the bridge. The riprap appeared to have been at this location for long enough to allow vegetation to grow over the riprap.		
Project description	The project would entail removal of fill and riprap and replacement with LWD and vegetation to both secure the bank and to provide fish habitat complexity.		
Future threats	Entrainment of the river against the armored bank due to the lack of roughness. Potential future bank failure and then localized erosion of the embankment. Additional threats include erosion and sedimentation causing embeddedness within spawning gravels, greater loss of fish habitat diversity, and loss of riparian vegetation and cover.		
Project rationale	Hard armored embankments typically entrain the river against the bank, which results in erosion and eventually bank failure. Placing LWD and revegetating the eroding bank would restore critical functions to maintaining good salmonid habitat.		
Functions restored	Greater salmonid habitat diversity, refugia and cover, stabilizing the bank, and providing some additional shading of the shoreline. Additionally, localized water quality improvement would be provided by the project implementation.		

<table>
<tr><td>Opportunity Name</td><td colspan="3">BR #4: Beckler River Campground</td></tr>
<tr><td>Activity</td><td colspan="3">LWD Placement, Campsite Relocation</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>USFS</td></tr>
<tr><td>Target habitat</td><td>Adult spawning and juvenile salmonid edge habitat; side channel habitat</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Mainstem riverbank and side channel</td></tr>
<tr><td>Project size</td><td>~300 feet of riverbank</td></tr>
<tr><td>Strategy</td><td>LWD Placement, campsite relocation</td></tr>
<tr><td>Existing conditions</td><td colspan="3">The USFS Beckler River Campground is set on the banks of the Beckler River at about RM 1.5. The car-based campground contains 27 campsites, of which approximately five are located at the water's edge. Two of the five campsites located at the river's edge, have been nearly cleared of vegetation and are eroding into the river (see photo). Some log armoring has been placed along the riverbank at the campsite closest to the entrance of the campground and the other campsite contains more vegetation. Also, a high-flow side channel exists at the north end (upstream end) of the campground.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would entail placement of stable LWD, and planting of vegetation to both secure the bank and to provide fish habitat complexity, or alternatively relocating the campsites to a location that is farther from the water's edge. If feasible, an existing partially connected side channel could be better reconnected with the river as part of the project.</td></tr>
<tr><td>Future threats</td><td colspan="3">The campsites are in the process of eroding away, and they may be eroded into the river at some time. Bank failure would cause more localized sedimentation of the river and eventually result in loss of riparian habitat. Since no LWD or riparian vegetation exists in this area, erosion of imported fine sediment will continue to occur, potentially causing embeddedness of spawning gravels. The bank may be riprapped to prevent erosion and this would result in, loss of fish habitat diversity on the edge of the channel. The side channel may be abandoned, if campgrounds are being threatened with flooding and armoring measures are taken.</td></tr>
<tr><td>Project rationale</td><td colspan="3">The campground is in danger of being flooded and the campsites eroded away. The embankments could be stabilized through a combination of relocating campsites and then adding LWD and vegetation to the riverbank. This would also prevent fish habitat disturbance and improve edge habitat diversity. If campsites are relocated, then the side channel could be reconnected, improving rearing and refugia habitat.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Greater salmonid habitat diversity, refugia and cover, slowing the delivery of fine sediment to the channel, and providing some additional shading of the shoreline. Additionally, localized water quality improvement (temperature and turbidity) would be provided by the project implementation.</td></tr>
</table>

Opportunity Name	BR #5: RM 1.9 Upland
Activity	**Upland Property Acquisition**

Project sponsor	USFS
Target habitat	Adult spawning and juvenile salmonid rearing
Current ownership	USFS
Hydrogeomorphic classification	Mainstem riverbank
Project size	~90 acres
Strategy	Property acquisition

Existing conditions	FS Road 6510 extends north and west from the FS Road 65 (Beckler Road) and provides access to private timber harvest properties and recreation. Active timber harvest activities were observed along this road during the field investigation. A large clear-cut was observed approximately 1 mile north of FS Road 65 and can be seen in the aerial above. From the aerial photograph, the area is estimated to be approximately 90 acres in size and within 150 feet of the active channel. This area consists of a patchwork of USFS and private land. The 90-acre clear-cut area is surrounded by USFS land.
Project description	The project would entail property acquisition of the timber harvest area (approximately 90 acres) or possibly a larger area.
Future threats	More timber harvesting and road building could occur within this area, causing potential debris flows and sedimentation in the river (and thus embeddedness of spawning gravels) and loss of intact forest habitat within the watershed. Additional timber harvesting reduces the amount of LWD that is available for possible recruitment within the stream.
Project rationale	The forests in the lower Beckler River watershed continue to be actively harvested on private lands. Acquiring this property would prevent further clear-cutting, and forest practices could be applied to move the forest towards old growth succession characteristics with the target of restoring the watershed.
Functions restored	Riparian vegetation functions including improving water quality, dampening peak flood flows, and providing LWD for recruitment into the river.

Opportunity Name	BR #6: RM 2.9 Unnamed Stream
Activity	**Culvert Replacement**

Project sponsor	USFS
Target habitat	Adult spawning
Current ownership	USFS
Hydrogeomorphic classification	Tributary colluvial fan
Project size	~50 lineal feet of tributary stream
Strategy	Culvert replacement

Existing conditions	FS Road 65 crosses an Unnamed Creek that flows through an undersized culvert at RM 2.9. A large debris flow of large boulders was observed on the upstream side of the culvert. The stream was also observed to be intermittent as it was dry at the time of the field investigation. These boulders were not able to pass through the culvert due to the size (36 inches). Anadromous fish are not likely present in this small tributary. The culvert is currently a hanging culvert and would be a fish barrier because it is hanging above the streambed on the downstream side of the culvert, although the steepness of the stream would also be a barrier to fish passage.
Project description	The project would entail a culvert replacement with a properly sized bottomless culvert or bridge.
Future threats	Additional debris flows could cause blockage of the existing culvert and cause flooding of FS Road 65, and also additional sedimentation of the stream and the Beckler River. Boulders and LWD would not be able to pass through the culvert to the Beckler River during a large storm event.
Project rationale	Predevelopment debris flows like the one observed at RM 2.9 are blocked from reaching their final destination – the Beckler River. Also, the culvert could become plugged resulting in a washout of the culvert, damage to the road, and sedimentation of the Beckler River, initiating emergency actions that may endanger wildlife. Restoring predevelopment geomorphic processes would improve habitat within the tributary and the Beckler River.
Functions restored	Predevelopment geomorphic processes. It would improve downstream transport of spawning-size gravel.

<table>
<tr><td>Opportunity Name</td><td colspan="3">BR #7: RM 3.5 – RM 5.0</td></tr>
<tr><td>Activity</td><td colspan="3">Specialty Study - LWD placement</td></tr>
<tr><td colspan="2" rowspan="6">No photo is available for this project because it covers a large area and the location is uncertain.</td><td>Project sponsor</td><td>USFS</td></tr>
<tr><td>Target habitat</td><td>Adult spawning and juvenile salmonid rearing, Edge and instream pool/riffle habitat</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>River edge, pool/riffle</td></tr>
<tr><td>Project size</td><td>~1.5 RM of instream habitat improvements</td></tr>
<tr><td>Strategy</td><td>Specialty Study</td></tr>
<tr><td>Existing conditions</td><td colspan="3">The lower reach of the Beckler River is devoid of LWD within the stream. Braided channels are located between RM 3.5 and RM 5.0 in the lower Beckler River. While this reach, because it is braided, has a higher diversity of habitat types than other reaches of the river, the habitat is still moderately degraded. This area has very little LWD due to previous timber harvesting, road construction, and stream cleaning. The instream habitat is moderately degraded and the instream river geomorphology is simplified due to the lack of LWD.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would entail conducting a study to determine where the best placement of LWD would bring the most benefit to fish habitat.</td></tr>
<tr><td>Future threats</td><td colspan="3">Instream habitat will continue to degrade and channel geomorphology will remain or become increasingly simplified. Deleterious incisement of the stream may occur over the long term.</td></tr>
<tr><td>Project rationale</td><td colspan="3">The instream habitat is moderately degraded and the instream river geomorphology is simplified due to the lack of LWD. Braided channels provide a wide variety of instream habitats and improving this habitat would have high benefit to salmonids.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Improved fish habitat diversity (pool/riffle habitat, edge habitat), restored predevelopment geomorphic processes, and improved spawning and rearing habitat.</td></tr>
</table>

Opportunity Name	**BR #8: Johnson Creek Bridge**
Activity	**Bridge Replacement and Fill Removal**

Project sponsor	USFS
Target habitat	Adult spawning and juvenile salmonid rearing
Current ownership	USFS
Hydrogeomorphic classification	Tributary alluvial fan
Project size	~75 foot bridge span
Strategy	Bridge replacement

Existing conditions	FS Road 65 crosses Johnson Creek that flows into the Beckler from the east at RM 6.9. The bridge is undersized for the volume of flows that pass under the bridge. Scouring of the bridge abutments and adjacent riverbank was observed indicating the bridge is undersized. Also a pressure crack was observed at each end of the bridge indicating instability of the bridge (see photo). Fill has been placed within the stream in order to accommodate construction of the bridge. The bridge is a pinch point in the stream that will continue to erode over time.
Project description	The project would entail determining the appropriate size bridge to construct at the site, replacing the bridge with a properly sized bridge, and removing fill from the old bridge and reengaging lost floodplain. Also, the stream bank will be treated with LWD and vegetated with native vegetation to both stabilize the bank and provide improved fish habitat.
Future threats	The river will continue to entrain against the left bank of the bridge. Over time the bridge abutment will scour, which could cause the bridge to fail, and the bank will continue to erode behind the abutments. This will require more riprap fill to be placed on the bank and within the stream to protect the bank and bridge, and may initiate emergency actions that could further endanger wildlife. Fish habitat diversity in this area will continue to decrease and would continue to allow the potential of predation (due to the lack of LWD for cover). Scouring of the streambank both up and downstream of the bridge may also occur. Sedimentation of downstream spawning gravel may occur due to the erosion.
Project rationale	The bridge is undersized and at some point in the future could fail. Currently, the bridge is having a negative effect on fish habitat within this reach. A bridge replacement would be proactive before failure happens, and would restore properly functioning fish habitat.
Functions restored	Improved fish habitat diversity, restored predevelopment flow regime, stabilized banks, and reduced potential sedimentation of spawning gravels.

Opportunity Name	**BR #9: RM 7.4 -7.6**
Activity	**LWD Placement and/or Road Relocation**

Project sponsor	USFS
Target habitat	Adult and juvenile salmonid habitat complexity and access to off-channel habitats
Current ownership	USFS
Hydrogeomorphic classification	Mainstem riverbank
Project size	~2,000 feet of streambank
Strategy	LWD placement and/or road relocation

Existing conditions	FS Road 65 is close to the Beckler River between RM 7.4 and 7.6, just downstream of its confluence with the Rapid River. Upstream of RM 7.6, the river bends east towards the road, and then bends south along the road. Since the river flows towards the road at this location, riprap has been placed on the riverbank to protect it from erosion. The road and riprap bank confine and straighten the stream at this location. Alders that were 10 to 20 years old were observed growing out of the riprap, indicating the bank armoring has been present and stable for that period.
Project description	The project would entail two potential options: 1) remove some or all of the riprap, incorporate LWD into the bank, and plant native vegetation, or 2) relocate the road to the east (connecting it to FS Road 6520), remove the riprap, and then incorporate LWD and vegetation along the riverbank.
Future threats	The river will continue to entrain against the left bank along the road due to the riprap. Over time, the riprap is likely to fail and the bank will scour, or more riprap will be placed along the river. As a result, the fish habitat within this reach will continue to degrade. Riprap banks would continue to allow the potential of predation (due to the lack of LWD for cover). Erosion of the bank would cause sedimentation of downstream spawning gravel.
Project rationale	Riprap armoring results in the threats that are listed under the Future Threats section above, as well as maintains poor riparian conditions. Fish habitat is continuing to degrade under current conditions. The incorporation of LWD and vegetation within this reach will improve habitat functions. If the road was relocated away from the river, this would provide habitat benefits, and allow the river to move freely within its floodplain within this reach.
Functions restored	Improved fish habitat diversity, increased food sources for fish, additional riparian cover provided, restored predevelopment flow regime, reconnected floodplain with the stream, and reduced potential sedimentation of spawning gravels.

Opportunity Name	BR #10: RM 7.6 Dispersed Campsite
Activity	Dispersed Campsite Decommission

Project sponsor	USFS
Target habitat	Adult spawning and juvenile salmonid edge habitat
Current ownership	USFS
Hydrogeomorphic classification	Rapid River alluvial fan
Project size	0.3 acres
Strategy	LWD placement

Existing conditions	A small spur road off of FS Road 65 heads toward the Beckler River to a dispersed campsite at RM 7.6. The river bends south along the FS Road 65 just downstream of this location (see opportunity # 9 for more details). An approximate 15,000 square foot area is cleared of vegetation to allow cars and camping. The vegetation on the riverbank and has been cleared and trampled at the campsite.
Project description	The spur road and campsite area would be blocked off, and revegetated with native shrubs and trees.
Future threats	Use of the campsite would continue to result in trampling and clearing of riparian vegetation. Due to the loss of vegetation, erosion would occur that could result in sedimentation of downstream spawning gravels. Also, bank failure may occur, and the river may avulse through the campsite. The loss of vegetation also results in the loss of shade, cover, and food sources for fish. Riprap may be placed at this location to stop bank erosion. Pollutant contamination of the stream from vehicular traffic at the river's edge may occur.
Project rationale	Dispersed camping at the river's edge at this location adversely affects fish habitat as described in the Future Threats section. This potential project opportunity would complement opportunity #9 and would restore this reach to predevelopment conditions.
Functions restored	Improved fish habitat diversity, restoration of the riparian cover would increase food sources and cover for fish, and shade for the stream, reduced potential sedimentation of spawning gravels, and improved water quality.

Opportunity Name	BR #11: USFS Road 65 at Rapid River
Activity	Bridge Replacement and Fill Removal

Project sponsor	USFS
Target habitat	Juvenile salmonid edge habitat and habitat complexity
Current ownership	USFS
Hydrogeomorphic classification	Rapid River alluvial fan
Project size	~100 foot bridge span
Strategy	Bridge replacement

Existing conditions	FS Road 65 crosses the Rapid River approximately 300 feet upstream of its confluence with the Beckler River. Scouring along the banks and bridge abutments was observed indicating the bridge is undersized. Fill has been placed within the river in order to accommodate construction of the bridge, causing disconnection of the river with the rest of its alluvial fan. The bridge is a pinch point in the stream that will continue to erode over time.
Project description	The project would entail determining the appropriate size bridge to construct at the site, replacing the bridge with a properly sized bridge, and removing fill from the old bridge. In addition, LWD and native vegetation will be incorporated into the riverbanks for stabilization, and to provide improved fish habitat.
Future threats	The river will continue to scour the banks and bridge abutments, potentially causing bridge and bank failure. Over time, this will require more fill to be placed on the bank and within the stream to protect the bank and bridge, and may initiate emergency actions that endanger wildlife habitat. Fish habitat diversity in this area will continue to degrade, and would continue to allow the potential of predation (due to the lack of LWD for cover). Scouring of the stream bank both up and downstream of the bridge will continue to occur. Sedimentation of downstream spawning gravels may occur due to the erosion.
Project rationale	The bridge is undersized and at some point in the future could fail. Currently, the bridge and fill within the stream is having a negative effect on fish habitat within this reach. Bridge replacement that removes the abutments and fill from the stream before failure would restore the predevelopment processes to the stream, prevent more damage to fish habitat in the future, and prevent complete bridge failure. The remainder of the alluvial fan may be reconnected.
Functions restored	Improved fish habitat complexity, restored predevelopment geomorphic conditions, stabilized banks and reduced potential sedimentation of spawning gravels, restored riparian vegetation resulting in improved shade, cover, and increased food sources for fish.

Opportunity Name	**BR #12: Fourth of July Creek**
Activity	**Bridge replacement and fill removal**

Project sponsor	USFS
Target habitat	Adult spawning and juvenile salmonid edge habitat and habitat complexity
Current ownership	USFS
Hydrogeomorphic classification	Tributary alluvial fan
Project size	~75 foot bridge span
Strategy	Bridge replacement

Existing conditions	FS Road 65 crosses Fourth of July Creek at RM 8.3 of the Beckler River. The bridge is undersized for the volume of flows that pass under the bridge. Scouring along the banks and bridge abutments was observed indicating the bridge is undersized. Also, a stress crack (see photo) between the bridge and the road connector was observed. Fill has been placed within the stream in order to accommodate construction of the bridge. The bridge is a pinch point in the stream that will continue to erode over timed and continue to disconnect the creek from its alluvial fan.
Project description	The project would entail determining the appropriate size bridge to construct at the site, replacing the bridge with a properly sized bridge, and removing fill from the old bridge. Also, LWD and native vegetation will be incorporated into the riverbanks for stabilization and to provide improved fish habitat.
Future threats	The river will continue to scour the banks and bridge abutments, potentially causing bridge and bank failure. Over time, this will require more fill to be placed on the bank and within the stream to protect the bank and bridged and may initiate emergency actions that endanger wildlife Fish habitat diversity in this area will continue to degrade and would continue to allow the potential of predation (due to the lack of LWD for cover). Scouring of the stream bank both up and downstream of the bridge will continue to occur. Sedimentation of downstream spawning gravels may occur due to the erosion.
Project rationale	The bridge is undersized and at some point in the future is likely to fail. Currently, the bridge and fill within the stream is having a negative effect on fish habitat within this reach by disconnecting the creek from its alluvial fan and floodplain. Bridge replacement that removes the abutments and fill from the stream before failure would restore the predevelopment processes to the stream, prevent more damage to fish habitat in the future, and prevent complete bridge failure.
Functions restored	Improved fish habitat diversity, restored predevelopment geomorphic conditions, stabilized banks and reduced potential sedimentation of spawning gravels, restored riparian vegetation resulting in improved shade, cover, and increased food sources for fish.

<table>
<tr><td>Opportunity Name</td><td colspan="3">BR #13: USFS Road 6550</td></tr>
<tr><td>Activity</td><td colspan="3">Road and Fill Removal Feasibility Analysis</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>USFS</td></tr>
<tr><td>Target habitat</td><td>Adult and juvenile salmonid habitat complexity and access to off-channel habitats</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Mainstem floodplain</td></tr>
<tr><td>Project size</td><td>~1.3 miles of stream and 15 acres of floodplain</td></tr>
<tr><td>Strategy</td><td>Road and fill removal feasibility analysis</td></tr>
<tr><td>Existing conditions</td><td colspan="3">FS Road 6550 extends east from FS Road 65 just after its crossing of Fourth of July Creek. As observed in the field and shown on the USFS road map, FS Road 6550 dead ends at Bullbucker Creek (Beckler River RM 9.6). Originally the road continued to the north to connect with FS Road 65 and FS Road 63 that runs along the North Fork Skykomish River. The abandoned roadbed north of Bullbucker Creek has been reclaimed by vegetation and wetland seeps, but is still elevated above the floodplain. Several dispersed campsites are located along the 1.3 mile maintained existing road spur. A low bridge over the Beckler River at RM 8.8 is undersized and appears to be in danger of being washed out in the next flood. The river is confined by the road fill along this spur road that starts on the west side of the river, and then crosses to the east side. The roadbed cuts the river off from its floodplain.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would entail abandonment of 1.3 miles of FS Road 6550, removal of the road fill from the floodplain, and removal of the bridge at RM 8.8. Additional roadbed that was previously abandoned could also be removed. Due to the large size of this project, a feasibility study of this large floodplain reconnection and fill removal project would need to be completed in order to determine its elements.</td></tr>
<tr><td>Future threats</td><td colspan="3">The river will continue to be cut off from its floodplain on both sides of the river where the road is located. The road fill confines the channel, causing downcutting and straightening of the channel, and eliminating off-channel refugia. This results in degradation of the fish habitat and disruption of predevelopment geomorphic processes within the floodplain. The bridge at RM 8.8 further restricts the channel at that location.</td></tr>
<tr><td>Project rationale</td><td colspan="3">Since FS Road 6550 is within the floodplain of the Beckler River, it has the largest impact on fish and riparian habitat of any of the other human modifications that were observed within the study reach (with the possible exception of Beckler Road on the lower river). Removal of the road fill and bridge could restore predevelopment floodplain functions within a 10- to 15-acre area.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Improved fish access to off-channel habitats, habitat diversity, additional riparian cover provided that would result in increased shade for the stream, and cover, and food sources for fish, restored predevelopment flow regimes, reconnected floodplain and stream, increased off-channel refugia and reduced potential sedimentation of spawning gravels.</td></tr>
</table>

<table>
<tr><td>Opportunity Name</td><td colspan="3">RR #14: RM 0.8 Rapid River</td></tr>
<tr><td>Activity</td><td colspan="3">Bank Armoring and Fill Removal</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>USFS</td></tr>
<tr><td>Target habitat</td><td>Adult and juvenile salmonid edge habitat</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Mainstem riverbank</td></tr>
<tr><td>Project size</td><td>~75 feet of streambank</td></tr>
<tr><td>Strategy</td><td>Armoring removal</td></tr>
<tr><td>Existing conditions</td><td colspan="3">FS Road 6530 crosses the Rapid River via a bridge at RM 0.8. The bridge completely spans the river and floodplain at this location and does not warrant replacement. However, bank armoring and fill along the right bank are present.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would entail removing the bank armoring and incorporating LWD into the bank. The bank would also be vegetated with native vegetation. LWD and native vegetation would be incorporated into the riverbanks for stabilization, and to provide improved fish habitat.</td></tr>
<tr><td>Future threats</td><td colspan="3">The river will continue to scour the banks and be entrained along the riprap, potentially causing bank failure. Over time, this will require more fill to be placed on the bank and within the stream to protect the bank and bridge, and may initiate emergency actions that endanger wildlife. Fish habitat diversity in this area will continue to degrade and would continue to allow the potential of predation (due to the lack of LWD for cover). Scouring of the stream bank both up and downstream of the bridge will continue to occur. Sedimentation of downstream spawning gravels may occur due to the erosion.</td></tr>
<tr><td>Project rationale</td><td colspan="3">Currently, the armored banks are having a negative effect on fish habitat within this reach. Replacement of the riprap with LWD, and adding native vegetation to the banks will restore predevelopment processes to the stream, prevent more damage to fish habitat in the future, and prevent potential slope failure.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Improved fish habitat diversity, restored predevelopment flow regime, stabilized banks and reduced potential sedimentation of spawning gravels, restored riparian vegetation resulting in improved shade, cover, and increased food sources for fish.</td></tr>
</table>

Opportunity Name	**RR #15: Evergreen Mountain Side Channel**		
Activity	**Feasibility Analysis**		
		**Project sponsor**	USFS
		Target habitat	Adult/ juvenile off-channel habitat access and complexity
		Current ownership	USFS
		Hydrogeomorphic classification	Mainstem riverbank and floodplain
		Project size	~1.3 miles of stream
		Strategy	Bridge, road, and fill removal feasibility analysis
Existing conditions	FS Road 6530 crosses the Rapid River via bridges at RM 1.0 and then again at RM 1.3. An unnamed tributary joins the river from the west at RM 1.2. Another tributary joins the river from the east just upstream of RM 1.3. At RM 1.3, the Rapid River curves sharply to the west and under the bridge and then winds back around to the southeast until it passes back under the bridge at RM 1.0. Riprap armoring and fill is present along the left bank of the curve at RM 1.3 (see photo). Field observations revealed FS Road 6530 was constructed within a side channel of the Rapid River between the two bridges, and the bank armoring and fill at RM 1.3 prevents the river from avulsing through the bank to the old side channel where FS 6530 is now present. The bridges are both slightly undersized at each location.		
Project description	A feasibility study would need to be completed to understand the complexities of the potential road relocation and removal of one or both bridges and alternative road options. It is possible that the road could be relocated to higher ground and reconnected upstream of the RM 1.3 bridge. The side channel could then be restored by removing the armoring at RM 1.3, the roadbed within the channel, and stabilizing and vegetating the banks.		
Future threats	The river may avulse through the bank armoring at RM 1.3 and damage FS Road 6530, potentially causing one of the bridges to fail, and initiate emergency actions that endanger wildlife. This would damage fish habitat by adding debris and sediment to the channel. The side channel will continue to be cut off, reducing the rearing habitat, and potentially spawning and refugia habitat that could be available for fish. Bridge crossing and road confinement of the Rapid River will continue to disrupt the predevelopment hydraulic and geomorphic processes within the floodplain.		
Project rationale	Since FS Road 6530 is within the floodplain of the Rapid River, it has the largest impact on fish and riparian habitat of any of the other human modifications that were observed on the Rapid River. Restoration of the side channel would provide 0.3 miles of potential rearing, spawning, and refugia habitat to this segment of the river.		
Functions restored	Increased available stream habitat, improved fish habitat diversity, reconnected side channel and floodplain with the river, increased off-channel and side-channel refugia, additional riparian cover provided, which would result in increased shade for the stream, cover and food sources for fish, restored predevelopment flow regimes, and reduced potential sedimentation of downstream spawning gravels.		

Opportunity Name	**RR #16: RM 1.8 Tributary Culvert Replacement**
Activity	**Culvert Replacement**

Project sponsor	USFS
Target habitat	Adult and juvenile salmonid passage
Current ownership	USFS
Hydrogeomorphic classification	Tributary colluvial fan
Project size	~100 lineal feet of stream
Strategy	Culvert replacement

Existing conditions	FS Road 6530 crosses an unnamed creek that flows from the north through an undersized culvert at RM 1.8 of the Rapid River. The tributary flows down the steep slopes to the north of the Rapid River valley, where debris flows are frequent. The culvert is not sized large enough to pass large boulders and wood carried by the stream to the Rapid River, and the culvert has effectively disconnected the stream from its colluvial fan.
Project description	The project would entail a culvert replacement with a properly sized culvert or bridge.
Future threats	Additional debris flows could cause blockage of the existing culvert, cause flooding or damage of FS Road 6530, and initiate emergency actions that could endanger wildlife. The undersized culvert will continue to disrupt the predevelopment hydraulic and geomorphic processes of sediment and debris flows into the Rapid River and continue to disconnect the stream from its colluvial fan.
Project rationale	Predevelopment debris flows like the one observed at RM 1.8 are blocked from reaching their final destination – the Rapid River. Also, there is potential that the roadbed and culvert could end up in the Rapid River during a large storm event. Allowing the predevelopment hydraulic and geomorphic processes to be restored will improve conditions for fish on the tributary colluvial fan.
Functions restored	Fish passage, predevelopment hydraulic and geomorphic processes, stabilized streambank, additional riparian habitat provided that would result in improved cover, shade, and food sources for fish.

<table>
<tr><td>Opportunity Name</td><td colspan="3">RR #17: RM 3.2 Colluvial Fan</td></tr>
<tr><td>Activity</td><td colspan="3">Culvert Replacement</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>USFS</td></tr>
<tr><td>Target habitat</td><td>Adult and juvenile salmonid passage and juvenile off-channel refugia.</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Tributary colluvial fan</td></tr>
<tr><td>Project size</td><td>~1 acre of colluvial fan</td></tr>
<tr><td>Strategy</td><td>Culvert replacement</td></tr>
<tr><td>Existing conditions</td><td colspan="3">Forest Road 6530 crosses two unnamed creeks that flow from the north through an undersized culvert and a ford at RM 3.2 of the Rapid River. The two tributaries to the Rapid River combine to form an colluvial fan as they flatten out at the base of the slope along the road. colluvial fans typically provide sediment and gravel to the stream in the floodplain valleys below the slopes. The culvert is not sized large enough to pass the potentially large amount of sediment and debris and the ford exposing the stream of vehicular pollution. Culverts at the base of the slopes of colluvial fans often fill up with sediment if they are undersized.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would entail a culvert replacement with a properly sized set of culverts or bridges that can accommodate the sediment flows of the colluvial fan.</td></tr>
<tr><td>Future threats</td><td colspan="3">Over time the undersized culvert could become blocked with sediment and other debris. Once blocked, the stream may start undermining the area around the culvert and could result in culvert failure. Culvert failure may initiate emergency actions that could endanger wildlife. The undersized culvert will continue to disrupt predevelopment geomorphic processes. The ford exposes the stream to vehicular pollution.</td></tr>
<tr><td>Project rationale</td><td colspan="3">Fish will continue to be adversely affected by the undersized culvert. The culvert could be blown out in a storm and end up in the Rapid River during a large storm event. Allowing the predevelopment hydraulic and geomorphic processes to be restored will improve conditions for fish in both the tributary and the Rapid River, and expand off-channel refugia.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Predevelopment geomorphic processes, stabilized streambank, additional riparian habitat provided that would result in improved cover, expanded off-channel refugia, shade, and food sources for fish.</td></tr>
</table>

<table>
<tr><td>Opportunity Name</td><td colspan="3">FR #1: RM 1.3 Tributary</td></tr>
<tr><td>Location</td><td colspan="3">Culvert replacement</td></tr>
<tr><td colspan="2" rowspan="7"></td><td>Project sponsor</td><td>USFS</td></tr>
<tr><td>Target habitat</td><td>Salmonid spawning and rearing habitat</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Tributary colluvial fan</td></tr>
<tr><td>Project size</td><td>~0.25 acre of tributary colluvial fan</td></tr>
<tr><td>Strategy</td><td>Culvert replacement</td></tr>
<tr></tr>
<tr><td>Existing conditions</td><td colspan="3">FS Road 68 crosses an unnamed tributary to the Foss River at approximately RM 1.3 of the Foss River. The tributary drains through a 5 foot CMP culvert under the road and then travels downslope into the Foss River. The culvert is perched at three to four feet above the stream on the downstream side of the road. The tributary channel is 20 to 30 feet wide and the culvert is undersized for the stream flows and debris that would pass under the road, impairing predevelopment geomorphic and hydraulic processes. The tributary contains potentially suitable steelhead and bull trout spawning and rearing habitat.</td></tr>
<tr><td>Project description</td><td colspan="3">The undersized culvert would be replaced with either with box culverts or possibly a bridge to accommodate debris flows.</td></tr>
<tr><td>Future threats</td><td colspan="3">The road will continue to impair the predevelopment geomorphic and hydraulic processes. The culvert may blow out and the road may be undermined and fail.</td></tr>
<tr><td>Project rationale</td><td colspan="3">The undersized culvert is perched and is a fish barrier. Undersized culverts such as these along FS Road 68 block debris flows and delivery of sediment and water to the mainstem. Replacing the culverts would restore fish passage and restore or partially restore predevelopment geomorphic and hydraulic processes.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Predevelopment geomorphic and hydraulic processes, and upstream fish passage.</td></tr>
</table>

<table>
<tr><td>Opportunity Name</td><td colspan="3">FR #2: Railway Bridge</td></tr>
<tr><td>Location</td><td colspan="3">Armoring removal</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>USFS</td></tr>
<tr><td>Target habitat</td><td>Salmonid rearing; edge habitat</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Mainstem edge habitat</td></tr>
<tr><td>Project size</td><td>~400 feet of edge habitat</td></tr>
<tr><td>Strategy</td><td>Armoring removal</td></tr>
<tr><td>Existing conditions</td><td colspan="3">FS Road 68 makes a hairpin turn over the Foss River and heads back to the north. A BNSF railroad trestle crosses the Foss River at this point. The piers of the trestle are on concrete pads and bedrock in the river channel. The piers that are in the channel are being scoured. Sandbags were observed around and along the piers to protect them from additional scour. The fill from the piers and sandbags is constricting the channel at this location. Fish habitat diversity is low and degraded in this area.</td></tr>
<tr><td>Project description</td><td colspan="3">The piers need to be reconstructed and placed on bedrock and the armoring removed from the channel. If possible, LWD will be placed along the bank to improve the diversity of the habitat along the edge of the river at this location.</td></tr>
<tr><td>Future threats</td><td colspan="3">The fill in the channel will continue to impair the predevelopment geomorphic and hydraulic processes. Fish habitat will continue to be simplified and degraded. The piers will continue to scour and potentially fail in the future, although the threat was not imminent.</td></tr>
<tr><td>Project rationale</td><td colspan="3">The piers could be moved or reconstructed so that they are not within the channel. Removal of the fill in the channel will restore geomorphic and hydraulic processes and edge habitat.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Predevelopment geomorphic and hydraulic processes, increase in habitat diversity and edge habitat.</td></tr>
</table>

<table>
<tr><td>Opportunity Name</td><td colspan="3">FR #3: RM 2.2 Colluvial Fan</td></tr>
<tr><td>Location</td><td colspan="3">Culvert replacement</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>USFS</td></tr>
<tr><td>Target habitat</td><td>Salmonid spawning habitat - indirectly</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Tributary colluvial fan</td></tr>
<tr><td>Project size</td><td>~0.25 acre of tributary</td></tr>
<tr><td>Strategy</td><td>Culvert replacement</td></tr>
<tr><td>Existing conditions</td><td colspan="3">An colluvial fan and associated debris flows was observed along FS Road 68 at RM 2.2. A 3-foot CMP culvert drains an unnamed intermittent tributary that is also the debris chute. The culvert is undersized for passage of the large rock debris that slides down the chute. The culvert was perched approximately 20 to 30 feet above the tributary on the downstream side of the road. No fish are likely to migrate up to the road crossing due to steepness of the gradient; however, they may use the mouth of the tributary for refugia. The road and culvert are blocking delivery of sediment, and LWD to the Foss River.</td></tr>
<tr><td>Project description</td><td colspan="3">The project entails replacing the culvert with either a box culvert or possibly a bridge to accommodate the debris flows.</td></tr>
<tr><td>Future threats</td><td colspan="3">The road and the undersized culvert will continue to impair the predevelopment geomorphic processes. The culvert may blow out and the road may be undermined and fail and end up in the Foss River.</td></tr>
<tr><td>Project rationale</td><td colspan="3">Undersized culverts such as this one along FS Road 68 block debris flows and delivery of sediment and water to the mainstem. Replacing the culvert would restore or partially restore these processes.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Predevelopment geomorphic and hydraulic processes, with a potential indirect improvement to spawning habitat in the mainstem river.</td></tr>
</table>

<table>
<tr><td>Opportunity Name</td><td colspan="3">FR #4: RM 3.2 Tributary</td></tr>
<tr><td>Location</td><td colspan="3">Culvert replacement</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>USFS</td></tr>
<tr><td>Target habitat</td><td>Salmonid spawning habitat - indirectly</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Tributary colluvial fan</td></tr>
<tr><td>Project size</td><td>~0.25 acre of tributary</td></tr>
<tr><td>Strategy</td><td>Culvert replacement</td></tr>
<tr><td>Existing conditions</td><td colspan="3">An colluvial fan was observed along FS Road 68 approximately 3 miles to the north of the parking lot for the Necklace Valley trailhead. Two culverts (3-foot CMPs) drain two tributaries that also are debris flow chutes. The culverts are perched and are undersized for the size of the debris and storm flows. Evidence of water overtopping the road was observed. No fish are likely to access these tributaries up to the road crossing due to steepness of the gradient; however, they are a source of sediment and water to the Foss River.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would replace the culverts either with box culverts or possibly a bridge to accommodate debris flows.</td></tr>
<tr><td>Future threats</td><td colspan="3">The road will continue to impair the predevelopment geomorphic processes. Culverts may blow out and the road may be undermined and fail.</td></tr>
<tr><td>Project rationale</td><td colspan="3">Undersized culverts such as these along FS Road 68 block debris flows and delivery of sediment and water to the mainstem. Replacing the culverts would restore or partially restore these processes.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Predevelopment geomorphic processes, with an indirect improvement to spawning habitat.</td></tr>
</table>

<table>
<tr><td>Opportunity Name</td><td colspan="3">FR #5: Necklace Valley Trailhead</td></tr>
<tr><td>Location</td><td colspan="3">Culvert replacement</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>USFS</td></tr>
<tr><td>Target habitat</td><td>Salmonid spawning habitat - indirectly</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Tributary colluvial fan</td></tr>
<tr><td>Project size</td><td>~0.25 acre of tributary colluvial fan</td></tr>
<tr><td>Strategy</td><td>Culvert replacement</td></tr>
<tr><td>Existing conditions</td><td colspan="3">An colluvial fan was observed along FS Road 68 near its intersection with the parking lot for the Necklace Valley trailhead. Three culverts (two are 3-foot HDPE, one is 5-foot CMP) drain three tributaries that also are debris flow chutes. The culverts are perched and are undersized for the size of the debris and storm flows (one culvert was damaged). Evidence of water overtopping the road was observed. No fish are likely to access these tributaries up to the road crossing due to steepness of the gradient; however they are a source of sediment and water to the Foss River.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would replace the culverts either with box culverts or possibly a bridge to accommodate debris flows.</td></tr>
<tr><td>Future threats</td><td colspan="3">The road will continue to impair the predevelopment geomorphic processes. Culverts may blow out and the road may be undermined and fail.</td></tr>
<tr><td>Project rationale</td><td colspan="3">Undersized culverts such as these along FS Road 68 block debris flows and delivery of sediment and water to the mainstem. Replacing the culverts would restore or partially restore these processes.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Predevelopment geomorphic processes, with an indirect improvement to spawning habitat.</td></tr>
</table>

<table>
<tr><td>Opportunity Name</td><td colspan="3">FR #6: FS Road 68 Bridge</td></tr>
<tr><td>Location</td><td colspan="3">Riprap fill removal, LWD placement</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>USFS</td></tr>
<tr><td>Target habitat</td><td>Chinook rearing, steelhead, and bull trout spawning rearing; edge habitat</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Tributary</td></tr>
<tr><td>Project size</td><td>~0.3 acre of floodplain</td></tr>
<tr><td>Strategy</td><td>Fill removal</td></tr>
<tr><td>Existing conditions</td><td colspan="3">The FS Road 68 Bridge (built in 1998) over the mainstem of the Foss River approximately 0.2 mile downstream of its confluence with the East Fork has a significant amount of fill on the right bank abutment, although the bridge does not constrict the floodplain. The existing bridge opening spans the floodplain. Riprap fill appears to have been placed in the channel, possibly from an older bridge installation.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would replace the bridge so that the abutments are out of the floodplain. Rock fill in the floodplain would be removed.</td></tr>
<tr><td>Future threats</td><td colspan="3">The riprap in the floodplain and channel degrades the local fish habitat in this reach and this would continue. Salmonids are more open to predation in these habitats.</td></tr>
<tr><td>Project rationale</td><td colspan="3">Chinook salmon rear in this reach and steelhead and bull trout rear and spawn in this reach. While the expansion of the floodplain is small, this reach is used by the three ESA-listed salmonids and would be of high value for that reason.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Expanded Chinook salmon rearing habitat, expanded steelhead and bull trout rearing and spawning habitat, improved edge habitat.</td></tr>
</table>

Opportunity Name	FR #7: RM 4.2 Tributary, FS Road 68
Location	Bridge replacement

Project sponsor	USFS
Target habitat	Salmonid rearing and spawning habitat, edge habitat
Current ownership	USFS
Hydrogeomorphic classification	Tributary
Project size	~1 acre of floodplain
Strategy	Bridge replacement

Existing conditions	The FS Road 68 Bridge (built in 1998) over a tributary to the Foss River approximately 0.2 mile downstream of its confluence with the East Fork has a significant amount of fill on the right bank abutment and constricts the floodplain, particularly to the west. The existing bridge opening is about 60 feet, but active channel migration zone is over 80 feet wide. The thalweg impacts the rock on the right abutment. Riprap appears to have been placed multiple times to protect the right abutment.
Project description	The project would replace the bridge so that the abutments are out of the floodplain. Rock fill in the floodplain would be removed.
Future threats	The thalweg is flowing against the right bank abutment and is being scoured. Although it does not appear to be in imminent risk of failure, the bridge may become at risk if the river becomes increasingly trapped by the rock on the right abutment, causing failure. Fill and armoring within the floodplain is degrading the local fish habitat.
Project rationale	The project would expand the bridge opening, reengaging the floodplain currently cut off by the existing bridge opening. The confluence of these streams is a productive rearing and spawning area for coho salmon and steelhead and bull trout, so even though the expansion of active floodplain would be small and restoration of predevelopment geomorphic conditions would not be complete, the benefit would be significant.
Functions restored	Expanded coho salmon, steelhead, and bull trout rearing habitat.

<table>
<tr><td>Opportunity Name</td><td colspan="3">FR #8: RM 4.2 Tributary, FS Road 6835</td></tr>
<tr><td>Location</td><td colspan="3">Bridge replacement</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>USFS</td></tr>
<tr><td>Target habitat</td><td>Salmonid rearing and spawning habitat, edge habitat</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Tributary</td></tr>
<tr><td>Project size</td><td>~1 acre of floodplain</td></tr>
<tr><td>Strategy</td><td>Bridge replacement</td></tr>
<tr><td>Existing conditions</td><td colspan="3">The FS Road 6835 Bridge (built in 1998) over a tributary to the East Fork Foss River near its confluence with the East Fork has fill on the right bank abutment and constricts the floodplain, particularly to the north. The existing bridge opening is about 60 feet, but active channel migration zone is over 80- feet wide. The thalweg impacts the rock on the right abutment. Riprap appears to have been placed multiple times to protect the right abutment.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would replace the bridge so that the abutments are out of the floodplain. Rock fill in the floodplain would be removed.</td></tr>
<tr><td>Future threats</td><td colspan="3">The thalweg is flowing against the right bank abutment and is being scoured. Although it does not appear to be in imminent risk of failure, the bridge may become at risk if the river becomes increasingly trapped by the rock on the right abutment, causing failure. Fill and armoring within the floodplain is degrading the local fish habitat.</td></tr>
<tr><td>Project rationale</td><td colspan="3">The project would expand the bridge opening, reengaging the floodplain currently cut off by the existing bridge opening. The confluence of these streams is a productive rearing and spawning area for coho salmon, and potentially for steelhead and bull trout (bull trout are presumed to be up this far in the system), so even though the expansion of active floodplain would be small and restoration of predevelopment geomorphic conditions would not be complete, the benefit would be significant.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Expanded coho salmon and steelhead rearing and spawning habitat, and potentially bull trout rearing and spawning habitat.</td></tr>
</table>

Opportunity Name	**FR #9: East Fork Bridge**
Location	**Bridge replacement**
	
Project sponsor	USFS
Target habitat	Salmonid rearing and spawning habitat, edge habitat
Current ownership	USFS
Hydrogeomorphic classification	Confluence
Project size	~2 acres of floodplain
Strategy	Bridge replacement
Existing conditions	The FS Road 6835 Bridge over the East Fork Foss River near the confluence with the West Fork has a significant amount of fill on the right bank abutment and constricts the floodplain, particularly to the north. The existing bridge opening is large (about 120 feet), but active channel migration zone is over 200 feet wide. The thalweg impacts the rock on the right abutment. Several generations of rock on the right abutment were observed.
Project description	The project would expand opening of the bridge at this location, possibly with another separate span to the north. Rock fill at the abutments and along the bank would be removed.
Future threats	The right bank abutment is being attacked. Although it does not appear to be in imminent risk of failure because of large span of the bridge, it may become at risk if the river becomes increasingly trapped by the rock on the right abutment.
Project rationale	The project would expand the bridge opening, reengaging the floodplain currently cut off by the existing bridge opening. The confluence of the forks is a highly productive rearing and spawning area for Chinook, coho, steelhead and bull trout, so even though the expansion of active floodplain would be small and restoration of predevelopment geomorphic conditions would not be complete, the benefit would be significant.
Functions restored	Expanded Chinook, coho, steelhead rearing and spawning habitat, and potentially bull trout rearing and spawning habitat.

Opportunity Name	FR #10: FS Road 6800-010
Location	Bridge replacement, road removal

Project sponsor	USFS
Target habitat	Salmonid spawning
Current ownership	USFS
Hydrogeomorphic classification	Tributary
Project size	12 acres of floodplain
Strategy	Bridge replacement, road removal

Existing conditions	An unnamed creek crosses FS Road 6800-010 near the confluence of the forks of the Foss River. The crossing is on the hillside approximately 500 feet above the floodplain of the forks confluence. FS Road 6800-010 is extremely disturbed and has several generations of culverts and destroyed fords. Even during the site visit where runoff was nonexistent, flow from the stream went over the road and generated fine sediment and turbidity in the stream. There are no recreational facilities accessible beyond this crossing.
Project description	The project would either place a sufficient culvert or bridge over the unnamed stream or remove the road entirely.
Future threats	The road in its current state will likely fail during the next rainy season. This will generate copious amounts of fine sediment in a highly productive salmonid rearing and spawning area. Restoration of access will produce even more impacts.
Project rationale	The project will reduce or eliminate fine sediment and auto pollution from being discharged to a highly productive salmonid rearing and spawning area.
Functions restored	Improved Chinook salmon and steelhead trout spawning and rearing habitat, and potentially bull trout spawning habitat. Predevelopment geomorphic functions, improved water quality, and passage of flood and debris flows.

<table>
<tr><td>Opportunity Name</td><td colspan="3">FR #11: FS Road 6835</td></tr>
<tr><td>Location</td><td colspan="3">Fill removal, road relocation or removal</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>USFS</td></tr>
<tr><td>Target habitat</td><td>Juvenile salmonid rearing and refugia</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Floodplain</td></tr>
<tr><td>Project size</td><td>3,000 feet of floodplain edge</td></tr>
<tr><td>Strategy</td><td>Fill removal, road relocation or removal</td></tr>
<tr><td>Existing conditions</td><td colspan="3">FS Road 6835 skirts the edge of the West Fork Foss River floodplain approximately one mile from the West Fork Foss Trailhead. The road is on fill in what appears to be floodplain for approximately 3000 feet. Conditions in the floodplain adjacent to the road are pristine.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would remove the fill from the floodplain and either relocate the road up on the hillside east of the floodplain or remove the road entirely and move the West Fork Foss Trailhead one mile downstream onto the gently sloping hillside.</td></tr>
<tr><td>Future threats</td><td colspan="3">The road could become at risk and compromise habitat in a significant way if the thalweg migrated to the east side of the floodplain.</td></tr>
<tr><td>Project rationale</td><td colspan="3">The confluence area of the forks of the Foss is a highly productive nursery for a wide range of salmonids. The main channels are also a prime spawning area. The proposed project is simple to implement and would result in a clear expansion of high quality habitat.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Expanded Chinook and coho salmon and steelhead trout rearing habitat and potentially bull trout rearing habitat, predevelopment geomorphic conditions.</td></tr>
</table>

<table>
<tr><td>Opportunity Name</td><td colspan="3">FR #12: West Fork Foss Trailhead</td></tr>
<tr><td>Location</td><td colspan="3">Fill and road removal</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>USFS</td></tr>
<tr><td>Target habitat</td><td>Salmonid rearing, spawning and refugia</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Low-gradient tributary confluence</td></tr>
<tr><td>Project size</td><td>50 feet of tributary</td></tr>
<tr><td>Strategy</td><td>Fill and road removal</td></tr>
<tr><td>Existing conditions</td><td colspan="3">A ford for an unnamed creek exists about 1000 feet north of the West Fork Foss Trailhead on FS Road 6835. No flow was observed on the site visit. The ford is immediately adjacent to the floodplain of the West Fork Foss.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would either place a sufficient culvert or bridge over the unnamed stream or remove the road entirely, relocating the West Fork Foss Trailhead about 1000 feet further north.</td></tr>
<tr><td>Future threats</td><td colspan="3">Ongoing fine sediment to a productive salmonid rearing and spawning area.</td></tr>
<tr><td>Project rationale</td><td colspan="3">The project will reduce or eliminate fine sediment from being discharged to a productive salmonid rearing and spawning area.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Improved Chinook, coho and steelhead rearing and/or spawning habitat, and potentially bull trout rearing habitat Predevelopment geomorphic conditions, Improved water quality and processing of flood and debris flows.</td></tr>
</table>

Opportunity Name	**IC #1: 637th Ave NE Bridge**
Activity	**Bridge replacement or removal**

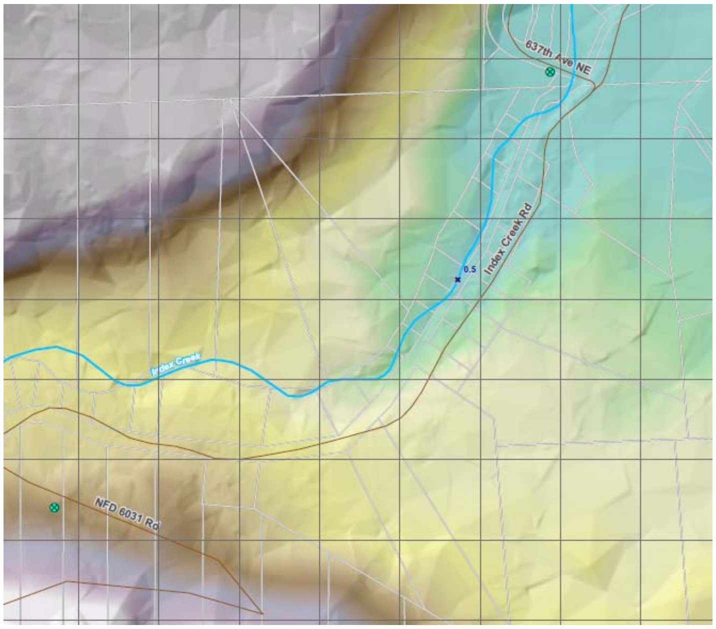
Project sponsor	King County
Target habitat	Bull Trout/Steelhead spawning or rearing
Current ownership	Private
Hydrogeomorphic classification	Tributary crossing
Project size	200 feet of tributary
Strategy	Bridge replacement

Existing conditions	Index Creek, a large tributary to the South Fork Skykomish River, is crossed by a poorly constructed 160 foot wooden bridge at 637th Avenue NE. The bridge has wooden pilings on concrete and the middle piers (pilings) are precariously perched on a rock in the middle of the braided stream. The bridge looks in danger of being damaged by high water and constricts the channel at its location. The stream splits around a small island at this location and contains highly diverse pool/riffle habitat above and below the bridge. The bridge leads to a private residential community that is within the floodplain of Index Creek. Bull trout and steelhead trout have been documented by WDFW in the lower mile of this stream.
Project description	The project would replace the bridge with a steel bridge or causeway that spans beyond the floodplain of the stream and does not constrict or leave fill within the channel. If this project was combined with Index Creek #IC-2 project to purchase the residences that are accessed by this bridge to remove them from the floodplain, then the bridge would be removed.
Future threats	The bridge will fail within the next few years, as it already shows signs of scour and earlier repairs. The failure of the bridge would result in debris in the stream, further constricting the stream in this location. This would also cause bank erosion at either end of the bridge resulting in an increase of fine sediment in the stream, which can clog spawning gravels.
Project rationale	This bridge is the only access to the residential community. The bridge is unstable and confines the channel in its current condition. The bridge pilings constitute fill material within the channel. If the bridge failed it would require emergency action and will likely trigger an emergency action that will necessarily have significant in-water impacts.
Functions restored	Predevelopment geomorphic and hydraulic processes, which will improve conditions in the main stem of Index Creek; improvement of steelhead and bull trout rearing and spawning habitat.

Opportunity Name	**IC #2: Skylandia Development**
Activity	**Property acquisition**
	
Project sponsor	King County
Target habitat	Chinook salmon spawning, Bull Trout/Steelhead spawning and rearing
Current ownership	Private
Hydrogeomorphic classification	Floodplain
Project size	~15 acres of floodplain
Strategy	Property acquisition
Existing conditions	The Skylandia residential development is at the mouth Index Creek along the South Fork Skykomish River. This development is accessed via 637th Avenue NE off of Index Creek Road (see IC #1 above). Skylandia is a private community and access was not granted during the site visits to this area. Based on the LIDAR, the residential development is within the active 100-year floodplain and would likely be flooded out during large storm events. Approximately 40 parcels are in within the floodplain. From review of aerial photographs, the area contains immature forest except where residential houses, driveways, and lawns are present, although it could not be determined if houses are on all 40 parcels.
Project description	All or part of the Skylandia residential development would be purchased. Houses and roads could be removed and restored to forested floodplain habitat. This project could be combined with IC #1 and the bridge could be removed and the road to the Skylandia community could be abandoned.
Future threats	It is likely that all 40 parcels contain residences and more development is likely to occur in this area. More clearing of the forested habitat within the floodplain would occur to accommodate increased development. Increased development would increase disruption of floodplain processes such as overbank flooding and potential side channel formation. The development may also impair floodplain movement of Index Creek. The community may flood during high storm events, potentially causing them to armor their properties to prevent flooding. Armoring of these residences may result in disconnection of the floodplain from the South Fork Skykomish River.
Project rationale	The Skylandia development is within the active floodplain and is currently impairing floodplain processes and side channel and wetland formation. More development in this area is likely to occur, further impairing the floodplain processes. The confluence of a tributary is important habitat for salmonids as it provides additional areas for spawning and rearing, a cold water source, nutrients, and food sources.
Functions restored	Predevelopment floodplain processes, which will improve conditions in the main stem of South Fork and the mouth of Index Creek. Improvement of steelhead and bull trout rearing and spawning habitat, and Chinook salmon spawning habitat.

<table>
<tr><td>Opportunity Name</td><td colspan="2">IC #3: RM 0.3 Index Creek</td></tr>
<tr><td>Activity</td><td colspan="2">Soft armoring enhancement</td></tr>
<tr><td colspan="2" rowspan="6">
</td><td>Project sponsor</td><td>King County</td></tr>
<tr><td>Target habitat</td><td>Bull Trout/ Steelhead rearing, edge habitat</td></tr>
<tr><td>Current ownership</td><td>Private</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>River edge</td></tr>
<tr><td>Project size</td><td>~200 lineal feet of riverbank</td></tr>
<tr><td>Strategy</td><td>Soft armoring enhancement</td></tr>
<tr><td>Existing conditions</td><td colspan="3">Approximately 0.3 mile upstream of the 637th Avenue NE bridge (see IC #1 above), the right bank has been riprapped to prevent erosion and potential damage of Index Creek Road. The stream curves towards the road that this location. Index Road is approximately 50 feet from the riprapped bank. Index Road is within the 100-year floodplain at this project location.</td></tr>
<tr><td>Project description</td><td colspan="3">The riprapped bank would be enhanced by the addition of LWD into the riprap, or the riprap could be removed and replaced with LWD. The bank would need to be stabilized using soft armoring techniques.</td></tr>
<tr><td>Future threats</td><td colspan="3">More riprap may be placed along this section of road to prevent future erosion, particularly if all or some of the bank armoring failed and was washed downstream. Additional armoring beyond this site may occur, further impairing floodplain processes.</td></tr>
<tr><td>Project rationale</td><td colspan="3">Riprap typically entrains the river against the armored bank and reduces fish habitat diversity along the river edge. Adding LWD to the bank breaks up the flows of the river and improves river edge habitat diversity. The road is at risk of being undermined in the future.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Improvement of river edge habitat and potential increase in steelhead and bull trout rearing habitat.</td></tr>
</table>

Opportunity Name	**IC #4: RM 0.5 Index Creek**
Activity	**Property acquisition**



Project sponsor	King County
Target habitat	Bull Trout/Steelhead spawning and rearing
Current ownership	Private
Hydrogeomorphic classification	Floodplain
Project size	~15 acres of floodplain
Strategy	Property acquisition

Existing conditions	At RM 0.5 of Index Creek, seven private properties on the right bank are within the floodplain. No access to these private parcels was available and it could not be determined whether the riverbank along them is armored. Houses and driveways on these properties are within the floodplain, although not all parcels contain houses. Index Creek Road is also in the floodplain in this area.
Project description	This project entails purchasing all or some of the private properties on the right bank in this area. Houses and roads could be removed and restored to forested floodplain habitat.
Future threats	Only about half of 7 parcels contain residences and more development is likely to occur in this area. More clearing of the forested habitat within the floodplain may occur to accommodate increased development. Increased development would, in turn, increase disruption of floodplain processes such as overbank flooding and potential side channel formation. Flooding of the properties may occur.
Project rationale	These private parcels are within the active floodplain and are impairing floodplain processes or possibly cutting off the floodplain from the creek. These properties are likely to be flooded and damaged at some time in the future.
Functions restored	Predevelopment floodplain processes, which may improve spawning and rearing habitat in this lower reach of Index Creek.

<table>
<tr><td>Opportunity Name</td><td colspan="3">MC #1: FS Road 6031</td></tr>
<tr><td>Activity</td><td colspan="3">Property acquisition, road and fill removal</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>King County</td></tr>
<tr><td>Target habitat</td><td>Chinook salmon rearing, Bull Trout/Steelhead spawning and rearing</td></tr>
<tr><td>Current ownership</td><td>USFS, County, and Private</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Floodplain and tributary</td></tr>
<tr><td>Project size</td><td>~4 acres of floodplain</td></tr>
<tr><td>Strategy</td><td>Road and fill removal and property acqusition</td></tr>
<tr><td>Existing conditions</td><td colspan="3">Forest Service Road 6031 is located between the mainstem of the South Fork Skykomish River and Money Creek. The road provides access to a few residential properties and extends to Index Creek Road. From County Road 64, FS Road 6031 turns south and crosses an unnamed tributary and then turns west past an intersection with FS Road 6030 that has been abandoned. FS Road 6031 crosses Money Creek within about 4,800 feet from the intersection of the two roads. Newly constructed 100-foot bridges have been constructed by the USFS in 2011 at both stream crossings. The bridge over Money Creek is gated and was closed at the time of the field investigation. Approximately 100 feet west of the Money Creek bridge, a connector road meets FS Road 6031 from the south. Just west of this connector road, two new culverts were constructed under FS Road 6031 to provide drainage of a tributary and wetland seeps to the South Fork Skykomish River. This area contains early-seral mixed forest that has been disturbed by the road and new construction of the bridge and culverts and residential development. This area is also within the active Money Creek Alluvial Fan.</td></tr>
<tr><td>Project description</td><td colspan="3">This project entails abandonment and removal of at least 4,800 feet of FS Road 6031 between the intersection with the spur road and the intersection with the connector road to the west of Money Creek bridge. An alternate route that is outside the floodplain could be constructed between County Road 6420 (that connects with County Road 64) and the connector road that would allow access to the remaining section of FS Road 6031. Alternatively, all of FS Road 6031 could be abandoned and/or removed, if the private properties were acquired.</td></tr>
<tr><td>Future threats</td><td colspan="3">While most of the property along FS Road 6031 is publicly owned, there are 6 private parcels near the unnamed tributary at the east end of the road. More development could occur along the road further filling the floodplain. FS Road 6031, bridges, and culverts will continue to impair the predevelopment hydrologic and geomorphic processes within the floodplain.</td></tr>
<tr><td>Project rationale</td><td colspan="3">A 4,800-foot section of FS Road 6031 is within active floodplain and alluvial fan of Money Creek. Two tributaries cut through the alluvial fan and are affected by the bridges and culverts along this road. The roads, culverts, and bridges are impairing predevelopment floodplain processes. An access road that is outside the floodplain could be constructed to replace this section of road.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Predevelopment floodplain processes, which may improve spawning and rearing habitat in this lower reach of Money Creek and its tributaries, and the mainstem of the South Fork Skykomish River.</td></tr>
</table>

Opportunity Name	MC #2: FS Road 6031 Residences
Activity	**Property acquisition**

Project sponsor	King County
Target habitat	Chinook salmon rearing, Bull trout/ Steelhead trout spawning and rearing
Current ownership	USFS, County, and Private
Hydrogeomorphic classification	Floodplain and tributary
Project size	~2 acres of floodplain
Strategy	Property acquisition

Existing conditions	Forest Service Road 6031 provides access to a six residential parcels at the east end of the road. A description of the conditions within this area is described under the Money Creek #2 project opportunity.
Project description	This project entails purchasing the parcels along FS Road 6031. Residences and driveways would be removed and the floodplain habitat would be restored. The tributary that flows through these properties would also be restored, if necessary.
Future threats	Based on aerial photographic review, not all of the six private parcels contain residences. More development could occur in this floodplain area since a road is maintained. The tributary that flows through the residential parcels could be impaired by filling or armoring as a result of development in the area. The residences and roads within the floodplain will continue to impair the predevelopment hydrologic and geomorphic processes.
Project rationale	The private parcels are within active floodplain and alluvial fan of Money Creek and are impairing the predevelopment floodplain processes. An unnamed tributary flows through the private parcels and if armored would impair side channel processes and the edge habitat of the stream. Also, these properties are likely to be flooded and damaged at some time in the future since they are in the floodplain.
Functions restored	Predevelopment floodplain and side channel processes, which may improve spawning and rearing habitat in the lower reach of unnamed tributary, and the South Fork Skykomish River.

<table>
<tr><th>Opportunity Name</th><th colspan="3">MC #3: FS Road 6422</th></tr>
<tr><td>Activity</td><td colspan="3">Specialty studies</td></tr>
<tr><td colspan="2" rowspan="6">
</td><td>Project sponsor</td><td>King County</td></tr>
<tr><td>Target habitat</td><td>Bull trout/Steelhead trout spawning and rearing</td></tr>
<tr><td>Current ownership</td><td>King County</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Floodplain, tributaries, riparian</td></tr>
<tr><td>Project size</td><td>~1 acre of floodplain, 4 acres of riparian improvement, 200 feet of river edge</td></tr>
<tr><td>Strategy</td><td>Specialty studies</td></tr>
<tr><td>Existing conditions</td><td colspan="3">FS Road 6420 crosses Money Creek via a 160 foot long bridge. Just east of the bridge, FS Road 6420 intersects with FS Road 6422 that cuts south and east from the floodplain to the slopes above the stream. FS Road 6422 was likely previously used for recreation and timber harvesting and now terminates in approximately one mile at a washout near Kimball Creek. The slopes both above and below the road are unstable. Several debris flows (see photo) have occurred above and below the road partly due to undersized culverts and the roadbed is washed out in several places. Due to the instability of the soils on the road slopes, it is generating fine sediment into Money Creek. The road is only passable by high clearance four wheel drive vehicles and appears to have infrequent use due to its condition. Additionally, the right bank of Money Creek at the lower end of FS Road 6422 is armored to prevent damage to the road.</td></tr>
<tr><td>Project description</td><td colspan="3">This project entails abandoning and possible removal of all or part of FS Road 6422. At a minimum, the culverts could be removed from the road and it could be vegetated. Removal of the fill within the floodplain near the FS Road 6420 bridge could occur. More analysis is needed to determine the extent and elements of the project.</td></tr>
<tr><td>Future threats</td><td colspan="3">In its current condition, FS Road 6422 generates fine sediment that discharges to Money Creek and potentially fills in spawning gravels. As the culverts continue to fail and more of the road washes out, sedimentation of Money Creek will increase. The slopes above Money Creek in this area are steep and debris flows are common, but the road blocks the predevelopment geomorphic process of debris flows and this will continue. Culverts may blow out during large storm events and end up as fill within the creek. Riprap armoring along the right bank of Money Creek for protection of FS Road 6422 will continue to degrade edge habitat and may cause bank failure.</td></tr>
<tr><td>Project rationale</td><td colspan="3">FS Road 6422 appears to be unmaintained and has washed out at approximately one mile above the stream. The road is generating fine sediment that washes into Money Creek and it is also impairing the predevelopment geomorphic and hydrologic processes. These processes could be restored if the road was abandoned and removed. Sedimentation could also be reduced by vegetating the abandoned road. Additionally, riprap armoring along the right bank of Money Creek to protect FS Road 6422 could be removed.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Predevelopment geomorphic and hydrologic processes, restoration of floodplain processes, and edge habitat improvement.</td></tr>
</table>

Opportunity Name	MC #4: RM 1.7
Activity	**LWD placement**

Project sponsor	USFS
Target habitat	Bull trout/ Steelhead trout rearing
Current ownership	USFS
Hydrogeomorphic classification	River edge
Project size	~300 feet of river edge
Strategy	LWD placement

Existing conditions	Approximately 200 feet to the west of the FS Road 6420 bridge crossing of Money Creek, the left bank is riprapped to prevent bank failure. A 24-inch corrugated metal pipe extends out of the bank and drains stormwater collected on the opposite side of the road into the stream. The stream curves towards the road at this location and is entrained against the riprap. The edge habitat is monotypic and impaired. Since the stream is so close to the road, it is devoid of riparian vegetation for approximately 500 feet.
Project description	This project entails removing some or all of the riprap and adding LWD to the bank. This will improve and diversify the edge habitat along this reach. Also, this will add LWD to the stream, which is lacking throughout most of the stream, but particularly in the lower reaches.
Future threats	The road armoring will continue to impair the edge habitat along this reach of the stream. The stream is entrained along the riprap and could cause bank failure, which would result in fill within the stream. The lack of LWD along the riprap armored bank is concomitant with lack of cover for fish, making them more susceptible to predation.
Project rationale	The habitat along the riprapped bank is simplified and degraded. The stream is lacking LWD, particularly in the lower reaches. Adding LWD would improve edge habitat.
Functions restored	Restoration of edge habitat diversity, which would improve steelhead and bull trout rearing habitat.

<table>
<tr><th>Opportunity Name</th><th colspan="3">MC #5: RM 3.0</th></tr>
<tr><td>Activity</td><td colspan="3">Culvert replacement</td></tr>
<tr><td colspan="2" rowspan="6">
</td><td>Project sponsor</td><td>USFS</td></tr>
<tr><td>Target habitat</td><td>Resident trout spawning, and rearing</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Tributary colluvial fan</td></tr>
<tr><td>Project size</td><td>~100 feet of tributary</td></tr>
<tr><td>Strategy</td><td>Bridge and culvert replacement</td></tr>
<tr><td>Existing conditions</td><td colspan="3">A repetitive landslide area was identified along FS Road 6420 at RM 3.0 at an unnamed tributary. Jersey barriers have been placed along the road to prevent debris from spilling into the road. An undersized 36-inch PVC culvert under the road drains the tributary, but was plugged by large boulders from the landslide. The predevelopment geomorphic processes are interrupted by the road. The gradient of the tributary is too steep for fish passage from Money Creek.</td></tr>
<tr><td>Project description</td><td colspan="3">This project entails replacing the culvert with a box culvert or bridge that can accommodate the size of the debris that is deposited by debris flows. Jersey barriers could be removed once the new culvert or bridge was in place.</td></tr>
<tr><td>Future threats</td><td colspan="3">The undersized culvert may cause undermining of the road and a washout. The road and undersized culvert will continue to impair the predevelopment geomorphic process of debris flows and deposition of boulders, gravel, and sediment into the stream.</td></tr>
<tr><td>Project rationale</td><td colspan="3">The undersized culvert under the road is impairing or blocking the periodic delivery of landslide debris into stream, which is important for continued replenishment of boulders, gravel and sediment. The landslide debris or water getting backed up behind the road due to a plugged culvert could damage the road, possibly resulting in failure.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Predevelopment geomorphic processes that may improve trout spawning and rearing habitat.</td></tr>
</table>

<table>
<tr><td>Opportunity Name</td><td colspan="3">MC #6: RM 3.8</td></tr>
<tr><td>Activity</td><td colspan="3">Culvert placement</td></tr>
<tr><td colspan="2" rowspan="6">
</td><td>Project sponsor</td><td>USFS</td></tr>
<tr><td>Target habitat</td><td>Resident trout spawning, and rearing</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Tributary colluvial fan</td></tr>
<tr><td>Project size</td><td>~100 feet of tributary</td></tr>
<tr><td>Strategy</td><td>Bridge and culvert replacement</td></tr>
<tr><td>Existing conditions</td><td colspan="3">A repetitive landslide area was identified along FS Road 6420 at RM 3.8 at an unnamed tributary. Jersey barriers have been placed along the road to prevent debris from spilling into the road. No culvert has is located here. The predevelopment geomorphic processes are interrupted by the road. The gradient of the tributary is too steep for fish passage from Money Creek.</td></tr>
<tr><td>Project description</td><td colspan="3">This project entails placing a properly sized new box culvert or a bridge that can accommodate the size of the debris that is deposited by debris flowsat this location. Jersey barriers could be removed once the new culvert or bridge was in place.</td></tr>
<tr><td>Future threats</td><td colspan="3">No culvert is present at this location and water crossing the road washes fine sediment into Money Creek. Potential sedimentation of spawning gravels may occur. Also, the water may undermine the road and a wash it out, resulting in increased fine sediment into the stream. The road will continue to impair the predevelopment geomorphic process of debris flows and deposition of boulders, gravel, and sediment into the stream.</td></tr>
<tr><td>Project rationale</td><td colspan="3">Water is flowing over the road and debris flows are occurring on the slopes on the land side of the road. A box culvert could restore the predevelopment geomorphic and hydrologic processes to this colluvial fan and tributary. The landslide debris and water that gets backed up behind the road could damage the road, possibly resulting in failure, and more fine sediment in the stream.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Predevelopment geomorphic processes that may improve spawning and rearing habitat.</td></tr>
</table>

Opportunity Name	MC #7: RM 3.5 - 4.6
Activity	Fill removal, road relocation

Project sponsor	USFS
Target habitat	Resident trout rearing habitat
Current ownership	USFS
Hydrogeomorphic classification	Floodplain
Project size	~6+ acres of floodplain
Strategy	Fill removal, road, rail and trailhead relocation

Existing conditions	FS Road 6420 drops into the floodplain of Money Creek from approximately RM 3.5 to RM 4.6. The roadbed constitutes fill material within the 100-year floodplain. The road could be relocated to a moderate slope above the road to the north that is out of the 100-year floodplain.
Project description	This project entails relocating approximately one mile of FS Road 6420 to the slopes above the floodplain to the north. The old road bed could be removed and then the area could be vegetated with native shrubs and trees.
Future threats	Fill in the floodplain will continue to impair predevelopment floodplain processes by blocking the river from flooding this area. The road would block the potential future formation of side channels or wetlands in this area.
Project rationale	Relocating the road out of the floodplain would potentially restore 6 or more acres of floodplain habitat that is currently blocked by the road. A side channel or wetland could be created or be formed if the road was relocated outside the floodplain. The predevelopment floodplain processes could be restored.
Functions restored	Restoration of floodplain processes; side channel or wetlands may also be formed, improving rearing habitat for resident trout.

<table>
<tr><td>Opportunity Name</td><td colspan="3">MC #8: RM 4.3 Tributary</td></tr>
<tr><td>Activity</td><td colspan="3">Bridge or culvert replacement</td></tr>
<tr><td colspan="2" rowspan="6">
</td><td>Project sponsor</td><td>USFS</td></tr>
<tr><td>Target habitat</td><td>Resident trout spawning, and rearing</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Tributary colluvial fan</td></tr>
<tr><td>Project size</td><td>~100 feet of tributary</td></tr>
<tr><td>Strategy</td><td>Bridge and culvert replacement</td></tr>
<tr><td>Existing conditions</td><td colspan="3">An colluvial fan was identified along FS Road 6420 at RM 4.3 at an unnamed tributary. An undersized 60 inch CMP culvert under the road drains the tributary, but has been plugged by large boulders from the colluvial fan The predevelopment geomorphic processes are interrupted by the road. The gradient of the tributary is too steep for fish passage from Money Creek.</td></tr>
<tr><td>Project description</td><td colspan="3">This project entails replacing the culvert with a box culvert or bridge that can accommodate the size of the debris that is deposited by debris flows.</td></tr>
<tr><td>Future threats</td><td colspan="3">The undersized culvert may cause undermining of the road and a washout. The road and undersized culvert will continue to impair the predevelopment geomorphic process of debris flows and deposition of boulders, gravel, and sediment into the stream.</td></tr>
<tr><td>Project rationale</td><td colspan="3">The undersized culvert under the road is impairing or blocking the periodic delivery of debris flows into the stream, which is important for replenishment of boulders, gravel, and other sediment types. The landslide debris or water getting backed up behind the road due to a plugged culvert could damage the road, possibly resulting in failure.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Predevelopment geomorphic processes that may improve trout spawning and rearing habitat.</td></tr>
</table>

Opportunity Name	**MC #9: RM 4.8 Tributary**
Activity	**Alluvial fan debris flow monitoring**

Project sponsor	USFS
Target habitat	Resident trout spawning, and rearing
Current ownership	USFS
Hydrogeomorphic classification	Tributary colluvial fan
Project size	~200 feet of tributary
Strategy	Specialty study

Existing conditions	An colluvial fan was identified along FS Road 6420 at RM 4.8 at an unnamed tributary. A 15-foot long concrete vented ford that contains twin 2-foot HDPE culverts with debris racks has been installed at this location. The ford is supposed to allow debris and water to pass over the road during large storm events and the culverts discharge low flows. The predevelopment geomorphic processes are interrupted by the road, however, debris may be moving into the stream much more frequently and easily than through a single culvert. However, the ford may not allow LWD to pass over the road into Money Creek below. The gradient of the tributary is too steep for fish passage from Money Creek.
Project description	This project would be a specialty study to monitor the passage of debris during large and small storm events to determine the effectiveness of the ford. If the ford is not effective at passing debris into Money Creek, or blocks LWD from passage, then the County will determine if it should be replaced with a bridge or another solution.
Future threats	The culverts in the ford may become blocked and cause undermining of the road and a washout. The road may continue to impair the predevelopment geomorphic process of debris flows and deposition of boulders, gravel, sediment, and LWD into the stream.
Project rationale	Insufficient information is available to determine to what extent if any does the vented ford restrict or block the periodic delivery of debris into the stream. This project would entail monitoring the effectiveness of the ford at passing boulders, gravel, and LWD into the stream. This information could then inform whether any further action should be taken to replace the ford with some other structure.
Functions restored	Predevelopment geomorphic processes and LWD recruitment that may improve trout spawning and rearing habitat.

Opportunity Name	MC #10: RM 5.7 - 5.8
Activity	**LWD placement - Specialty study**

Project sponsor	USFS
Target habitat	Resident trout spawning, and rearing
Current ownership	USFS
Hydrogeomorphic classification	Tributary colluvial fan
Project size	~600 feet of riparian area and 100 feet of tributaries
Strategy	Specialty study

Existing conditions	Debris flows occur in the vicinity of two tributaries along FS Road 6420 at approximately RM 5.7 and 5.8. A colluvial fan exists at RM 5.7. Debris flows on this colluvial fan have blocked the undersized 24-inch CMP culvert at this location. At RM 5.8, another debris flows within a tributary channel has damaged a 30-inch CMP culvert at this location. These unstable slopes are part of an colluvial fan at this location. The gradients of the intermittent tributaries are very steep (>60 percent slope) and are therefore are not fish passable.
Project description	This project entails a specialty study to determine what size culvert or bridge or multiple culverts or bridges would need to be replaced at this location. Also, further analysis is needed to determine the slope stabilization techniques that will work best at this location.
Future threats	Debris flows will continue to erode the slope above the road. The geomorphic processes will continue to be blocked or impaired by the road.
Project rationale	Insufficient information is available to determine how best to prevent mass wasting into the stream at this location and to best benefit fish habitat. More analysis is needed to determine the best method to stabilize the slope and provide habitat improvement.
Functions restored	Predevelopment geomorphic processes; riparian improvement; and possibly edge habitat improvement.

Opportunity Name	MC #11: RM 6.1 Tributary
Activity	Culvert replacement

Project sponsor	USFS
Target habitat	Resident trout spawning, and rearing
Current ownership	USFS
Hydrogeomorphic classification	Tributary colluvial fan
Project size	~100 feet of tributary
Strategy	Bridge and culvert replacement

Existing conditions	An colluvial fan was identified along FS Road 6420 at RM 6.1 at an unnamed tributary. An undersized 36-inch CMP culvert under the road drains the tributary, but has been plugged by large boulders and debris from the debris flows that crosses the road. The debris flow deposits appeared to have been frequently cleared from the road to keep it passable. The predevelopment geomorphic processes are interrupted by the road. The gradient of the tributary is too steep for fish passage from Money Creek.
Project description	This project entails replacing the culvert with a box culvert or bridge that can accommodate the size of the debris that is deposited by debris flows.
Future threats	The undersized culvert may cause undermining of the road and a washout. The road and undersized culvert will continue to impair the predevelopment geomorphic process of deposition of boulders, gravel, and sediment into Money Creek.
Project rationale	The undersized culvert under the road is impairing or blocking the periodic delivery of debris flows into the stream, which is important for replenishment of boulders, gravel and sediment. The landslide debris or water getting backed up behind the road due to a plugged culvert could damage the road, possibly resulting in failure.
Functions restored	Predevelopment geomorphic and hydrologic processes that may improve trout spawning and rearing habitat in Money Creek.

Opportunity Name	**MC #12: RM 6.4 Tributary**
Activity	**Culvert replacement**

Project sponsor	USFS
Target habitat	Resident trout spawning, and rearing
Current ownership	USFS
Hydrogeomorphic classification	Tributary colluvial fan
Project size	~100 feet of tributary
Strategy	Bridge and culvert replacement

Existing conditions	An colluvial fan was identified along FS Road 6420 at RM 6.4 at an unnamed tributary. The road at this location is approximately 600 feet above the steep canyon-like slopes of Money Creek. The landslide started on the upslope side of the road and crossed the road as it continued downslope towards Money Creek. The road had been cleared of debris, but based on the young vegetation at this debris flow, disturbance has been frequent. An undersized 36-inch CMP culvert under the road drains the tributary, but has been plugged by large boulders and debris from the repeated debris flows. The predevelopment geomorphic processes are interrupted by the road. The gradient of the tributary is too steep for fish passage from Money Creek.
Project description	This project entails replacing the culvert with a box culvert or bridge that can accommodate the size of the debris that is deposited by debris flows.
Future threats	The undersized culvert may cause undermining of the road and a washout. The road and undersized culvert will continue to impair the predevelopment geomorphic process of deposition of boulders, gravel, and sediment into Money Creek.
Project rationale	The undersized culvert under the road is impairing or blocking the periodic delivery of debris flows into the stream, which is important for replenishment of boulders, gravel, and other sediment types. The road may also block the transport of LWD into Money Creek. The landslide debris or water getting backed up behind the road due to a plugged culvert could damage the road, possibly resulting in failure.
Functions restored	Predevelopment geomorphic and hydrologic processes that may improve trout spawning and rearing habitat in Money Creek.

<table>
<tr><td>Opportunity Name</td><td colspan="3">MC #13: RM 6.6 Tributary</td></tr>
<tr><td>Activity</td><td colspan="3">Culvert replacement</td></tr>
<tr><td colspan="2" rowspan="6">
</td><td>Project sponsor</td><td>USFS</td></tr>
<tr><td>Target habitat</td><td>Resident trout spawning, and rearing</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Tribuary colluvial fan</td></tr>
<tr><td>Project size</td><td>~100 feet of tributary</td></tr>
<tr><td>Strategy</td><td>Bridge and culvert replacement</td></tr>
<tr><td>Existing conditions</td><td colspan="3">An colluvial fan or landslide was identified along FS Road 6420 at RM 6.6 at an unnamed tributary. The road at this location is approximately 600 feet above the steep canyon-like slopes of Money Creek. The landslide started on the upslope side of the road and crossed the road as it continued downslope towards Money Creek. The road had been cleared of debris, but based on the young vegetation at this debris flow, disturbance has been frequent. An undersized 36-inch CMP culvert under the road drains the tributary, but has been plugged by large boulders and debris. The predevelopment geomorphic processes are interrupted by the road. The gradient of the tributary is too steep for fish passage from Money Creek.</td></tr>
<tr><td>Project description</td><td colspan="3">This project entails replacing the culvert with a box culvert or bridge that can accommodate the size of the debris that is deposited by debris flows.</td></tr>
<tr><td>Future threats</td><td colspan="3">The undersized culvert may cause undermining of the road and a washout. The road and undersized culvert will continue to impair the predevelopment geomorphic process of deposition of boulders, gravel, and sediment into Money Creek.</td></tr>
<tr><td>Project rationale</td><td colspan="3">The undersized culvert under the road is impairing or blocking the periodic delivery of debris flows into the stream, which is important for replenishment of boulders, gravel, and sediment. The road may also block the transport of LWD into Money Creek. The landslide debris or water getting backed up behind the road due to a plugged culvert could damage the road, possibly resulting in failure.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Predevelopment geomorphic and hydrologic processes that may improve trout spawning and rearing habitat in Money Creek.</td></tr>
</table>

Opportunity Name	MC #14: RM 6.8 Tributary
Activity	Culvert replacement

Project sponsor	USFS
Target habitat	Resident trout spawning, and rearing
Current ownership	USFS
Hydrogeomorphic classification	Tribuary colluvial fan
Project size	~100 feet of tributary
Strategy	Specialty study

Existing conditions	An colluvial fan or landslide was identified along FS Road 6420 at RM 6.8 at an unnamed tributary. The road at this location is approximately 600 feet above the steep canyon-like slopes of Money Creek. The landslide started on the upslope side of the road and crossed the road as it continued downslope towards Money Creek. The road had been cleared of debris, but based on the young vegetation at this debris flow, disturbance has been frequent. An undersized 60-inch CMP culvert under the road drains the tributary, has been plugged by large boulders and debris. The predevelopment geomorphic processes and transport of LWD are interrupted by the road. The gradient of the tributary is too steep for fish passage from Money Creek.
Project description	This project entails an analysis of the best method for allowing large debris to pass over or under the road. A bridge or vented ford may work at this location. More analysis is needed to determine the best design for this project.
Future threats	The undersized culvert may cause undermining of the road and a washout. The road and undersized culvert will continue to impair the predevelopment geomorphic process of deposition of boulders, gravel, and sediment into Money Creek.
Project rationale	The undersized culvert under the road is impairing or blocking the periodic delivery of debris flows into the stream. In particular at this site, LWD has been blocked from transport to Money Creek. The landslide debris or water getting backed up behind the road due to a plugged culvert could damage the road, possibly resulting in failure.
Functions restored	Predevelopment geomorphic and hydrologic processes that may improve trout spawning and rearing habitat in Money Creek. LWD recruitment functions may be restored.

Opportunity Name	MC #15: RM 7.2 Tributary
Activity	**Culvert replacement**

Project sponsor	USFS
Target habitat	Resident trout spawning, and rearing
Current ownership	USFS
Hydrogeomorphic classification	Tributary colluvial fan
Project size	~100 feet of tributary
Strategy	Specialty study

Existing conditions	A colluvial fan was identified along FS Road 6420 at RM 7.2 at an unnamed tributary. The road at this location is approximately 600 feet above the steep canyon-like slopes of Money Creek. The landslide started on the upslope side of the road, crossed the road and damaged a 24-inch CMP culvert that crossed under the road. The bank on the Money Creek side of the road also appeared to have failed. The culvert was undersized for the size of debris passing over the road. A USFS construction crew was replacing the culvert with a new 36-inch HDPE culvert at the time of the site investigation, blocking passage beyond that point. While a new culvert was being installed at this location, the culvert was still undersized for the size of debris that is flowing through this area. The predevelopment geomorphic processes and transport of LWD are interrupted by the road. The gradient of the tributary is too steep for fish passage from Money Creek.
Project description	This project entails an analysis of the best method for allowing large debris to pass over or under the road and for stabilizing the bank with the goal of providing the highest benefit to fish habitat and restoring geomorphic processes. A vented ford may work at this location or a large box culvert. More analysis is needed to determine the best design for this project.
Future threats	The undersized culvert may cause undermining of the road and a washout, as it did previously. The road and undersized culvert will continue to impair the predevelopment geomorphic process of deposition of boulders, gravel, sediment, and LWD into Money Creek.
Project rationale	According to the USFS installing the new culvert at this site, replacement of culverts along this road is a frequent (annual) occurrence. The undersized culvert under the road is impairing or blocking the periodic delivery of debris flows including LWD into Money Creek. Debris flows are common along this road and the best solution for restoring the predevelopment geomorphic processes in this system while still maintaining recreational access on this road is important. A solution at this site may be used at other downstream sites.
Functions restored	Predevelopment geomorphic and hydrologic processes that may improve trout spawning and rearing habitat in Money Creek. LWD recruitment functions may be restored.

<table>
<tr><td>Opportunity Name</td><td colspan="3">MR #1: RM 2.1 Culvert</td></tr>
<tr><td>Activity</td><td colspan="3">Culvert replacement</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>King County</td></tr>
<tr><td>Target habitat</td><td>Steelhead spawning</td></tr>
<tr><td>Current ownership</td><td>King County</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Tributary crossing</td></tr>
<tr><td>Project size</td><td>100 feet of tributary</td></tr>
<tr><td>Strategy</td><td>Culvert replacement</td></tr>
<tr><td>Existing conditions</td><td colspan="3">A tributary to the Miller River crosses Miller River Road immediately downstream the USFS group campsite through a 36-inch culvert in the Miller River floodplain. The stream is clearly capable of transporting material as large as the existing culvert (see photo). As a result the culvert needs to be made larger to avoid road failure. Steelhead have been documented to spawn in this part of the Miller River.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would replace the culvert either with a much larger box culvert or bridge.</td></tr>
<tr><td>Future threats</td><td colspan="3">The culvert will fail within the next few years, as it is already plugged with recent debris. The failure of the culvert will likely cause the road to fail, thus causing disturbance and increasing fine-sediment supply to the main stem Miller River.</td></tr>
<tr><td>Project rationale</td><td colspan="3">This culvert is downstream of the group camp in a heavily used portion of the road. Current conditions are unsustainable and will likely trigger an emergency action that will necessarily have significant in-water impacts.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Fish passage during runoff periods, restoration of predevelopment geomorphic processes, which will improve conditions in the main stem Miller River, in particular steelhead spawning habitat.</td></tr>
</table>

<table>
<tr><td>Opportunity Name</td><td colspan="3">MR #2: Confluence Tributary</td></tr>
<tr><td>Location</td><td colspan="3">Culvert replacement</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>King County</td></tr>
<tr><td>Target habitat</td><td>Steelhead spawning</td></tr>
<tr><td>Current ownership</td><td>King County</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Tributary crossing</td></tr>
<tr><td>Project size</td><td>100 feet of riverbank</td></tr>
<tr><td>Strategy</td><td>Culvert replacement</td></tr>
<tr><td>Existing conditions</td><td colspan="3">A tributary to the Miller River crosses Miller River Road near the confluence of the East and West forks. The crossing is made through five-foot corrugated metal culvert. The stream is clearly capable of transporting material as large as the existing culvert. The downstream end is perch over two feet above the channel below. The culvert needs to be made larger to avoid road failure and to correct for the step in the profile. Steelhead have been documented to spawn in this part of the Miller River.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would replace the culvert either with a much larger box culvert or bridge.</td></tr>
<tr><td>Future threats</td><td colspan="3">The culvert will fail within the next few years, as it is already plugged with recent debris. The failure of the culvert will likely cause the road to fail, thus causing in-stream disturbance and artificially increasing fine-sediment supply to the main stem Miller River.</td></tr>
<tr><td>Project rationale</td><td colspan="3">This culvert is in a heavily used portion of the road. Current conditions are unsustainable and will likely trigger an emergency action that will necessarily have significant in-water impacts.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Fish passage during runoff periods, restoration of predevelopment geomorphic processes, which will improve conditions in the main stem Miller River, in particular steelhead spawning habitat.</td></tr>
</table>

Opportunity Name	MR #3: West Fork Miller Mine
Activity	**Mine reclamation**

Project sponsor	USFS
Target habitat	All in-water habitats
Current ownership	USFS
Hydrogeomorphic classification	West Fork riverbank and side channel
Project size	Unknown
Strategy	Mine reclamation

Existing conditions	An assumed abandoned mine site exists with decaying infrastructure approximately one-half mile up abandoned FS Road 6410 (now the West Fork Miller Trail). Staining of the rocks in a stream that exits the mine indicates that there is potential for contamination of West Fork Miller waters. There are many abandoned mine sites in the West Fork Miller River basin, but it is likely that this site is only one that discharges potentially contaminated water directly into an area that could be visited by anadromous fish.
Project description	The project would be phased to determine the existence and extent of contamination at this relatively low elevation mine site. If contamination is found, reconnaissance of the entire site and the sources of effluent should be cataloged. According USFS maps of the area, the mine site extends several hundred feet upslope above easy access of the trail. A full analysis should be undertaken to determine the best means reduce or eliminate future water contamination.
Future threats	Contamination, if present, could continue to contaminate additional areas of the Miller, including spawning areas below the confluence of the forks. This contamination would contribute to bioaccumulation of metals in fish.
Project rationale	Contamination is often one of, access. As compared to other mine sites, this project site is reasonably accessible.
Functions restored	Improved water quality, reduction/elimination of contamination.

Opportunity Name	MR #4: East Fork Miller RM 1.1
Activity	Hazard analysis

Project sponsor	USFS
Target habitat	Steelhead spawning and rearing
Current ownership	USFS
Hydrogeomorphic classification	East Fork riverbank and floodplain
Project size	~12 acres
Strategy	Hazard analysis

Existing conditions	A small stream drains the north tip of Cascade Mountain and crosses FS Road 6412. In 2009 it was the site of major debris flow that destroyed the road and extended all the way into the main channel of the East Fork Miller River. Currently the stream has no low flow expression across the crossing. It also has no obvious culvert. During runoff periods, it is likely that material from above road will continue to come down from above the road. There is also a high probability of another large failure given the clear signs of past rockslides in the same location.
Project description	The project would examine the costs, both financial and environmental, of maintaining a road in this location and compare those to the recreational opportunities afforded by continuing to maintain the road beyond this point.
Future threats	Based upon the pattern of disturbance and vegetation and the geomorphic setting (multiple side channels originate in this area), it is clear that this debris flow / rockslide chute is a site of repetitive rock slides and debris flows. This is common in certain geologic settings where slopes are inherently unstable. As such, it should be expected that debris flows will continue to occur regularly at this location. These events input large quantities of fine material into the stream from the road into the channel. These have the potential to embed spawning gravels in the area and impair predevelopment conditions to numerous side channels used by juvenile fish that originate in this area.
Project rationale	The project site is a site that will continue to have rockslides destroy it in the future, which will necessitate major reconstruction of the road at regular intervals. The scale of the reconstruction is significant both in terms of financial costs and its impacts to the stream in this location. While the stream ecosystem in some sense is adapted to heavy disturbance in this area, the addition of fines and the regular use of machinery in the vicinity of the stream will continue to impair ecological function in the area.
Functions restored	Predevelopment geomorphic processes and reduction in man-made disturbance if it is determined that the road no longer needs to extend beyond this location, or that some other solution can be found to avoid a crossing at the particular site.

Opportunity Name	MR #5: East Fork Miller RM 1.7
Activity	Culvert replacement
	
Project sponsor	USFS
Target habitat	Steelhead habitat
Current ownership	USFS
Hydrogeomorphic classification	Tributary colluvial fan
Project size	150 feet of tributary
Strategy	Culvert replacement
Existing conditions	A small unnamed stream discharges to the East Fork near RM 1.7. Although there is a 36-inch corrugated plastic pipe in the roadway near the crossing, there are many signs that flow and sediment discharge over the road in other locations, including a side chute about 50 to 100 feet to the south of the main crossing. One indication is that the size of the material in transport (up to more than three-foot in diameter) is large compared to the size of culvert.
Project description	The project would entail a culvert replacement with a properly sized bottomless box culvert or bridge.
Future threats	The crossing will be a point of failure of the road in the future. Fine sediment from the road and disturbance will continue to occur to repair the road.
Project rationale	Improving the crossing will reduce future maintenance and disturbance to the tributary and the East Fork.
Functions restored	Predevelopment geomorphic processes. It would improve downstream transport of spawning-size gravel.

Opportunity Name	**MR #6: FS Road 6412 Bridge Right Bank**
Activity	**Hazard analysis**

Project sponsor	USFS
Target habitat	Steelhead habitat
Current ownership	USFS
Hydrogeomorphic classification	Tributary colluvial fan
Project size	~300 feet of unnamed tributary
Strategy	Hazard analysis

Existing conditions	FS Road 6412 is on the tributary colluvial fan of a major unnamed tributary that drains the west side of Maloney Ridge. The bridge itself clears the active channel way and is not at risk or impairing habitat in any way. However, it appears that a major tributary that used to discharge downstream of the bridge on the colluvial fan is avulsing to the center and upstream portions of the colluvial fan, which would then cross the road on the right bank next to the bridge, instead of downstream of the roadway. New culverts placed upgradient on the colluvial fan are allowing large volumes of floodwater to erode a new channel on the colluvial fan. This channel would cut across the road in at least two locations. Given the height of prism at the downstream location, it is likely that fixing the road would be prohibitively expensive due to large volumes of lost fill.
Project description	The project would analyze the value of having the road extend beyond this location. It is likely that for the road to remain in place a plan needs to be developed to mitigate the potential avulsion. The piecemeal nature of modifications to date is potentially counterproductive and encouraging more future maintenance that increases in-water disturbance and supply of anthropogenic fine sediment to the stream.
Future threats	The potential for avulsion of the tributary through the road is extremely high. If this occurs, the road will likely be lost, and significant disturbance will occur downstream from the avulsion point. The scale of the avulsion is relatively large and would likely embed spawning gravels much further downstream and disturb habitat in general.
Project rationale	The road will likely be lost if the stream fully avulses, but it only serves a single trailhead. Thoughtful removal of the road or a planned strategy around the management of the creek is required to prevent a large disturbance to the East Fork.
Functions restored	Predevelopment geomorphic conditions, reduced disturbance and fine sediment supply to the river if the road removed, relocated or better managed.

<table>
<tr><td>Opportunity Name</td><td colspan="3">MR #7: East Fork RM 2.2 Tributary</td></tr>
<tr><td>Activity</td><td colspan="3">Culvert replacement or bridge placement</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>USFS</td></tr>
<tr><td>Target habitat</td><td>Steelhead habitat</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Tributary</td></tr>
<tr><td>Project size</td><td>~75 foot bridge span</td></tr>
<tr><td>Strategy</td><td>Culvert replacement</td></tr>
<tr><td>Existing conditions</td><td colspan="3">FS Road 6412 crosses an unnamed tributary to the East Fork Miller River near RM 2.2. There are two stacked culverts (one three feet, the other four feet in diameter) that cross the road at this location. The culverts are perched on the downstream side by more than 10 feet.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would entail replacing the culverts with a bridge.</td></tr>
<tr><td>Future threats</td><td colspan="3">The culverts in their current arrangement are unsustainable and will likely fail in the future. Failure would induce large volumes of road sediment into the East Fork.</td></tr>
<tr><td>Project rationale</td><td colspan="3">The culverts are undersized and at some point in the future could fail. Failure of the road and culvert would likely introduce large volumes of fine sediment to the East Fork.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Predevelopment geomorphic processes, which will improve conditions in the East Fork Miller River.</td></tr>
</table>

<table>
<tr><td>Opportunity Name</td><td colspan="3">MR #8: East Fork RM 2.7</td></tr>
<tr><td>Activity</td><td colspan="3">Armoring removal</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>USFS</td></tr>
<tr><td>Target habitat</td><td>Resident trout habitat</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>East Fork riverbank</td></tr>
<tr><td>Project size</td><td>~150 feet</td></tr>
<tr><td>Strategy</td><td>Armoring removal</td></tr>
<tr><td>Existing conditions</td><td colspan="3">FS Road 6412 is immediately next to the right bank of the East Fork on the side of a steep cliff. Between 1998 and 2003, a rock revetment was placed on the right bank of the East Fork to protect the roadway from erosion. There is a small amount of floodplain on the left bank, which is undeveloped and owned by the USFS.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would entail removing rock revetment and placing secured wood upstream of the site towards the undeveloped left bank. A geotechnical analysis should be performed prior to construction to ensure that removing the rock would not make the slope unstable. A hazard analysis may also be performed to determine if the risk to habitat from the project, ongoing disturbance or future hazards is worth the expense for the relatively small amount of recreational benefit the roadway currently provides.</td></tr>
<tr><td>Future threats</td><td colspan="3">The river will be attracted to the smooth rocked bank and will remain next to the road and the rock for the future. This will likely cause the river to erode a large pool at the revetment further disconnecting it from the left bank floodplain.</td></tr>
<tr><td>Project rationale</td><td colspan="3">The rock revetment simplifies the river hydraulics and attracts the river towards the road. The limited vegetation in the footprint of the revetment compromise riparian habitat shading. Adding wood to the stream upstream will reengage the floodplain on the left bank and increase hydraulic complexity.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Improved edge and riparian habitat for resident trout. Reengagement of the left bank floodplain at high flows.</td></tr>
</table>

Opportunity Name	**MR #9: Old Cascade Highway Removal**		
Location	**Road and armoring removal**		
		**Project sponsor**	King County
		Target habitat	Adult and juvenile salmonid rearing and refugia
		Current ownership	King County
		Hydrogeomorphic classification	Alluvial fan
		Project size	10 acres of floodplain
		Strategy	Road and armoring removal
Existing conditions	In January 2011, Old Cascade Highway was obliterated by an avulsion. Now most of the flow goes through avulsion site (see photo) and the road has been closed indefinitely. The highway had considerable rock along the side of it to protect it from attack by the river. The highway also protected the railroad, which is now the only significant infrastructure that crosses the alluvial fan. A full accounting of the conditions is summarized in the lower Miller River restoration feasibility report in Appendix E.		
Project description	The project would remove the asphalt and road prism. Due to the level of protection that the highway provided the railroad, it may be necessary to relocate some of the rock to protect the railroad. If this is deemed unnecessary, the rock should be removed from the floodplain entirely. This project would need to be approved by King County Roads, who have yet to analyze the feasibility of road removal.		
Future threats	As described in detail in Herrera (2009), the road cuts and limits the development side channels on the alluvial fan, thus limiting spawning and rearing habitat. The road also limits the extent to which flood and debris can spread out on the alluvial fan, quickening and concentrating its release to the South Fork.		
Project rationale	The Miller River Alluvial Fan is one of the most ecologically productive alluvial fans in the study area. The Old Cascade Highway prism blocks 10 acres of floodplain from being engaged by the river. This limits rearing and spawning opportunities for Chinook, coho, and steelhead.		
Functions restored	Greatly expanded Chinook, coho, and steelhead rearing and spawning habitat. Some restoration of predevelopment conditions, improved water quality and processing of flood and debris flows.		

<table>
<tr><td>Opportunity Name</td><td colspan="3">MR #10: Miller River Curve Revetment</td></tr>
<tr><td>Location</td><td colspan="3">Armoring removal</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>King County</td></tr>
<tr><td>Target habitat</td><td>Adult and juvenile salmonid refugia, juvenile rearing, adult spawning</td></tr>
<tr><td>Current ownership</td><td>King County</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Alluvial fan</td></tr>
<tr><td>Project size</td><td>12 acres of floodplain</td></tr>
<tr><td>Strategy</td><td>Armoring removal</td></tr>
<tr><td>Existing conditions</td><td colspan="3">A large revetment called the Miller River Curve Revetment protected the floodplain above the Old Cascade Highway. The cross-section is large (see photo), with a considerable amount of angular rock. It extends for 750 feet. A full accounting of the conditions is summarized in Herrera (2012).</td></tr>
<tr><td>Project description</td><td colspan="3">The project would remove the revetment and rock from the junction with Miller River Road to the Martin Marietta Quarry either entirely from the floodplain or place it along Miller River Road to ensure that the road prism remains intact. If the rock is not relocated to the road prism and the road prism is not removed (i.e., MR-9 is not implemented), the road prism will likely be lost increasingly over time.</td></tr>
<tr><td>Future threats</td><td colspan="3">The curve revetment will continue to barricade a significant portion of the Miller River Alluvial Fan from the river. This impairs and limits the rearing and spawning habitat that can be achieved on the alluvial fan. The revetment also increases hazards by concentrating the flow unnecessarily through the active channel way.</td></tr>
<tr><td>Project rationale</td><td colspan="3">The Miller River Alluvial Fan is one of the most productive alluvial fans in the study area. The Miller River Curve Revetment blocks 12 acres of floodplain from being engaged by the river. This limits rearing and spawning opportunities for Chinook, coho and steelhead.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Greatly expanded Chinook, coho and steelhead rearing and spawning habitat. Some restoration of predevelopment conditions, improved water quality and capacity for flood and debris flows.</td></tr>
</table>

Opportunity Name	MR #11: Miller River Road Revetment
Location	Armoring removal, property acquisition

Project sponsor	King County
Target habitat	Adult and juvenile salmonid rearing and refugia
Current ownership	King County
Hydrogeomorphic classification	Alluvial fan
Project size	5 acres of floodplain
Strategy	Armoring removal and property acquisition
Existing conditions	A rock revetment extends along Miller River Road at the apex of the Miller River Alluvial Fan. The revetment extends 150 feet beyond the road, blocking a former side channel. There are several private properties downstream in the channel that the revetment currently protects. At this location there is another side channel on the far side of the channel way. A full accounting of the conditions is summarized in Herrera (2012).
Project description	The project would remove the 150-foot spur that extends beyond the edge of the road. A side project could be to place wood upstream of the road crossing itself and direct more flow into the channel on the undeveloped side of the valley. It is likely that one or more of the properties would need to be acquired to complete the project.
Future threats	The spur will continue to block valuable side channel habitat on the alluvial fan. The spur also concentrates flow and debris increase hazard risk downstream.
Project rationale	The Miller River Alluvial Fan is one of the most productive alluvial fans in the study area. The Miller River Road Revetment blocks five acres of floodplain from being engaged by the river. This limits rearing and spawning opportunities for Chinook, coho and steelhead.
Functions restored	Greatly expanded Chinook, coho and steelhead rearing and spawning habitat. Some restoration of predevelopment conditions, improved water quality and capacity for flood and debris flows.

<table>
<tr><td>Opportunity Name</td><td colspan="3">SFSR #1: Foss River Road Bridge</td></tr>
<tr><td>Activity</td><td colspan="3">Property acquisition, bridge replacement, road relocation, and/or fill removal</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>King County</td></tr>
<tr><td>Target habitat</td><td>Spawning, juvenile salmonid edge and rearing habitats, side channel habitat</td></tr>
<tr><td>Current ownership</td><td>Private & King County</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Foss River Alluvial Fan</td></tr>
<tr><td>Project size</td><td>~300 feet of riverbank</td></tr>
<tr><td>Strategy</td><td>Bridge replacement, property acquisition</td></tr>
<tr><td>Existing conditions</td><td colspan="3">Foss River Road Bridge crosses the Foss River on the Foss River Alluvial Fan approximately 300 feet upstream from its confluence with the Tye River and the headwaters of the South Fork. The right bank abutment contains a large amount of fill (approximately 100 feet of linear road). The fill prohibits migration of the river and engagement of the alluvial fan. It also protects a single residence on the alluvial fan that is located within the floodplain.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would acquire the property, remove any structures, and remove the fill associated with the road. This would necessitate extending the bridge approximately 100 feet on the right bank, or relocating the crossing to a site outside of the alluvial fan.</td></tr>
<tr><td>Future threats</td><td colspan="3">The current configuration of the crossing limits migration of the river corridor. The current crossing configuration also places the road, a County road, at risk to failure over time, which could also endanger local residents. This is already starting to occur near the road junction at the east end of the alluvial fan, and will likely be more critical in the future.</td></tr>
<tr><td>Project rationale</td><td colspan="3">The Foss River Road Bridge is at risk as aggradation of coarse material continues to accumulate at a single location on the alluvial fan. Former off-channel floodplain areas could be reconnected and reengaged. Failure of the bridge would not only compromise access to the Foss River valley, but it could endanger local residents.</td></tr>
<tr><td>Project benefits</td><td colspan="3">Greater salmonid habitat diversity, refugia, and habitat cover, expanded spawning habitat, increased hydraulic complexity, and restoration of predevelopment geomorphic conditions on the alluvial fan.</td></tr>
</table>

Opportunity Name	SFSR #2: Timber Lane Village
Activity	Hazard analysis

Project sponsor	King County
Target habitat	Adult and juvenile salmonid edge habitat
Current ownership	Private and USFS
Hydrogeomorphic classification	Mainstem riverbank
Project size	~4,000 feet of riverbank
Strategy	Hazard analysis to identify habitat-friendly protection strategies

Existing conditions	A large number of residences are located on the inside of a large meander on the South Fork in the Beckler reach. The substrate in this location is glaciodeltaic sediments, which is prone to erosion and sliding (see photo). These residences are located on the opposite bank. The slides push the river towards the residences, which requires armoring to protect the homes. Not all of the banks in the area are armored, which contributes to differential erosion and channel migration. The County has already acquired several properties to mitigate these risks. Due to the presence of the armor, riparian vegetation is compromised. The Anthracite Creek Alluvial Fan occurs at the west end of the development. The alluvial fan heightens the dynamic nature of the area and interacts with mainstem channel migration and the landsliding.
Project description	The proposed project would conduct a hazard analysis to determine the risk of future geomorphic change to the area. The analysis would identify which properties are most at risk and assemble a plan that would mitigate these risks and improve habitat, which may include further property acquisition.
Future threats	Failure of armoring and erosion of developed areas. Migration of the river into developed areas. Future armoring and clearing that would further compromise already degraded edge habitat.
Project rationale	The analysis would seek to determine which residences were most at risk and devise a strategy to protect and/or purchase those residences. This would decrease the future flood and habitat risk (from emergency actions) and would improve bank conditions in general. It may also result in long-term savings to the King County through hazard reduction.
Project benefits	Refugia and cover for juvenile salmonids along the riverbank.

Opportunity Name	**SFSR #3: RM 17.4**
Activity	**Side channel reconnection**

Project sponsor	USFS
Target habitat	Adult spawning and juvenile salmonid edge habitat; side channel habitat; flood refugia
Current ownership	USFS
Hydrogeomorphic classification	Side channel
Project size	~3,000 feet of side channel
Strategy	Side channel reconnection using LWD

Existing conditions	There is a large cutoff side channel complex on the right bank near RM 17.4. The entire area is in USFS ownership and contains relatively mature forest.
Project description	The project would entail placement of stable LWD on the left bank to force more flow into the right bank side channel network. If feasible, an existing partially connected side channel could be better reconnected with the river as part of the project.
Future threats	Numerous side channels in this area have been cut off by the Town of Skykomish, creating a limitation of rearing and high flow refugia areas, and a general loss of quality edge habitat.
Project rationale	The side channel complex on the right bank at RM 17.4 appears to be cut off recently because of the relatively low banks. The cutoff may be a result of stream wood cleaning and other development in the area. Placing LWD on the left bank would force flow away from the more developed left bank and increase the rearing opportunities for juvenile salmonids.
Project benefits	Greater salmonid habitat diversity, refugia, and habitat cover; providing some additional shading of the active shoreline. Additionally, there may be flood hazard reduction benefits.

<table>
<tr><th>Opportunity Name</th><th colspan="3">SFSR #4: Beckler River Alluvial Fan</th></tr>
<tr><td>Activity</td><td colspan="3">Riprap removal, property acquisition LWD placement</td></tr>
<tr><td colspan="2" rowspan="6">
</td><td>Project sponsor</td><td>WSDOT or King County</td></tr>
<tr><td>Target habitat</td><td>Adult spawning and juvenile salmonid edge habitat; side channel habitat</td></tr>
<tr><td>Current ownership</td><td>Private</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Mainstem riverbank</td></tr>
<tr><td>Project size</td><td>~400 feet of riverbank</td></tr>
<tr><td>Strategy</td><td>Riprap removal, property acquisition and/or proactive bank stabilization</td></tr>
<tr><td>Existing conditions</td><td colspan="3">The bank opposite of the Beckler River Alluvial Fan (i.e., the left bank of the South Fork) is armored with rock protecting a series of residences on the left bank. The right bank in this area is undeveloped and part of the active portion of the Beckler River Alluvial Fan.</td></tr>
<tr><td>Project description</td><td colspan="3">The riprap at these residences could be removed and replaced with engineered LWD, or the properties could be acquired and the riprap removed.</td></tr>
<tr><td>Future threats</td><td colspan="3">The riprap on this bank continues to degrade the riparian conditions in this area.</td></tr>
<tr><td>Project rationale</td><td colspan="3">The riprap along these residences would be replaced by engineered LWD structures. This would improve habitat on this bank and encourage migration of the river channel toward the undeveloped portions of the Beckler River Alluvial Fan.</td></tr>
<tr><td>Project benefits</td><td colspan="3">Improved edge habitat, habitat cover, and hydraulic complexity for juvenile salmonids. Some restoration of predevelopment geomorphic conditions. There could be modest flood hazard benefit by encouraging migration of the South Fork into the Beckler River Alluvial Fan.</td></tr>
</table>

<table>
<tr><td>Opportunity Name</td><td colspan="3">SFSR #5: US 2 RM 16.8</td></tr>
<tr><td>Activity</td><td colspan="3">US 2 Bridge replacement and fill removal</td></tr>
<tr><td colspan="2" rowspan="6">
</td><td>Project sponsor</td><td>WSDOT</td></tr>
<tr><td>Target habitat</td><td>Spawning, adult and juvenile salmonid edge habitat; side channel habitat</td></tr>
<tr><td>Current ownership</td><td>WSDOT</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Beckler River Alluvial Fan</td></tr>
<tr><td>Project size</td><td>~600 feet of fill</td></tr>
<tr><td>Strategy</td><td>Bridge replacement and fill removal, property acquisition</td></tr>
<tr><td>Existing conditions</td><td colspan="3">The US 2 Bridge at RM 16.8 has a large armored fill prism on the right bank. It fills the floodplain and inhibits natural geomorphic processes and greatly reduces the active portion of the Beckler River Alluvial Fan. It also blocks flood flows from that may flood a private residence on the alluvial fan.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would entail replacing the right bank abutment of the US 2 Bridge at this location with a causeway that would span the active alluvial fan.</td></tr>
<tr><td>Future threats</td><td colspan="3">The Beckler River Alluvial Fan at this location is severely restricted, making a large portion of it completely inaccessible to fish. Eventually the concentration of deposition of sediment in the area will raise flood water surface elevations and pose a risk to both the roadway and adjacent residences that could necessitate emergency actions that would be detrimental to habitat.</td></tr>
<tr><td>Project rationale</td><td colspan="3">The US 2 Bridge, particularly its right bank abutment, would be replaced with a causeway that would span the potentially active portion of the Beckler River Alluvial Fan, which would reconnect a large portion of the now-inactive Beckler River Alluvial Fan.</td></tr>
<tr><td>Project benefits</td><td colspan="3">Predevelopment geomorphic conditions on Beckler River Alluvial Fan. This will improve edge habitat and expand floodplain connectivity and rearing opportunities for juvenile salmonids. It may also increase spawning opportunities by establishing new alluvial fan side channels.</td></tr>
</table>

<table>
<tr><td>Opportunity Name</td><td colspan="3">SFSR #6: RM 16.6</td></tr>
<tr><td>Activity</td><td colspan="3">LWD placement, rail line relocation</td></tr>
<tr><td colspan="2" rowspan="6">
</td><td>Project sponsor</td><td>BNSF</td></tr>
<tr><td>Target habitat</td><td>Adult spawning and juvenile salmonid edge habitat</td></tr>
<tr><td>Current ownership</td><td>BNSF</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Mainstem riverbank</td></tr>
<tr><td>Project size</td><td>~2,000 feet of riverbank</td></tr>
<tr><td>Strategy</td><td>LWD placement, rail line relocation</td></tr>
<tr><td>Existing conditions</td><td colspan="3">The BNSF rail line is at the left bank edge of the South Fork Skykomish River from RM 16.2 to RM 16.8 within the Town of Skykomish. The railroad confines the river at this location and the river flows next to the riprap-armored bank. The riprap has failed in several places, and portions of the bank are eroding. US 2 crosses via a bridge from the right bank (north side) of the river to the left bank at RM 16.8 and parallels the railroad. A culvert under the railroad was observed in this location indicating drainage from the floodplain on the landward side of the railroad is needed.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would entail placement of stable LWD and planting of vegetation both to secure the bank and to provide fish habitat complexity, or alternatively relocating the railroad to a location that is farther from the water's edge. More study would be needed to determine the new location of the railroad.</td></tr>
<tr><td>Future threats</td><td colspan="3">The river bank along the railroad is in the process of eroding away despite the armoring, and may eventually undermine the railroad and fail. The use of riprap for bank stabilization will continue to cause damage or loss of fish habitat diversity on the edge of the channel. The railroad will continue to restrict the channel from movement, impairing geomorphic and hydraulic processes (such as overbank flooding).</td></tr>
<tr><td>Project rationale</td><td colspan="3">Riprap armored banks result in loss of fish habitat diversity and cover. The bank may fail at this location and damage the railroad. Bank failure would cause localized sedimentation of the river (and thus spawning habitat and salmon redds). Predevelopment geomorphic processes of river movement are being restricted at this location. Fish habitat diversity along the edge of the channel and riparian vegetation could be restored along the channel with the incorporation of LWD. Moving the railroad would restore the predevelopment geomorphic and hydraulic processes to this reach.</td></tr>
<tr><td>Project benefits</td><td colspan="3">Greater salmonid habitat diversity, refugia, and habitat cover, slowing the delivery of fine sediment to the channel, and providing some additional shading of the shoreline. Additionally, localized water quality improvement (temperature and turbidity) would be improved. Geomorphic and hydraulic processes could be restored if the railroad was setback further from the river.</td></tr>
</table>

Opportunity Name	SFSR #7: RM 16.0
Activity	LWD placement

Project sponsor	King County
Target habitat	Side channel habitat; juvenile rearing habitat
Current ownership	Private
Hydrogeomorphic classification	Side channel
Project size	~1,500 feet of side channel
Strategy	LWD placement and side channel reconnection

Existing conditions	An artificially disconnected (at lower flows) side channel due to the placement of infrastructure associated with the Town and the Fifth Street Bridge is located between RM 16.1 and RM 15.9 along the right bank of the Town of Skykomish just upstream of the bridge entering the Town from US 2. The side channel is within an undeveloped forested parcel between the river and US 2. The left bank at this location is heavily developed and armored.
Project description	The project would entail placement of stable LWD at strategic locations within the channel to force the river to flow into the side channel. Excavation of the entry to the side channel may also be needed. LWD may also be placed within the side channel if it would improve fish habitat.
Future threats	This is a highly developed and straightened reach of the river with little refugia for both adult and juvenile fish. The side channel area could become fully blocked off due to deposition or due to future development of the area. The side channel could be lost if future development fills in the area.
Project rationale	Side channel and refugia are very limited in the South Fork Skykomish River, particularly in this highly developed reach. Restoring side channel habitat would provide additional refugia habitat for both adults and juvenile and rearing habitat for juveniles.
Project benefits	Greater salmonid habitat diversity, refugia, and habitat cover; restored side channel habitat; restored predevelopment hydraulic processes to this reach; and restored juvenile rearing habitat.

<table>
<tr><td>Opportunity Name</td><td colspan="3">SFSR #8: Maloney Creek</td></tr>
<tr><td>Activity</td><td colspan="3">LWD placement, riprap removal, rail line relocation</td></tr>
<tr><td colspan="2" rowspan="6">
</td><td>Project sponsor</td><td>BNSF</td></tr>
<tr><td>Target habitat</td><td>Side channel habitat; juvenile rearing habitat; refugia; spawning habitat</td></tr>
<tr><td>Current ownership</td><td>BNSF</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Mainstem riverbank and side channel</td></tr>
<tr><td>Project size</td><td>~500 feet of tributary, side channel and off-channel wetlands</td></tr>
<tr><td>Strategy</td><td>LWD placement, riprap removal, rail line relocation</td></tr>
<tr><td>Existing conditions</td><td colspan="3">Maloney Creek joins the South Fork Skykomish River at approximately RM 15.6. The railroad is at the river's edge at this location and crosses over the mouth of Maloney Creek. The left bank is armored from RM 15.5 to RM 15.3. A side channel landward of the railroad is disconnected from the river. Culverts were observed under the railroad discharging drainage (see photo) from south of the railroad suggesting the presence of wetland floodplain areas, but they are perched well above ordinary water levels</td></tr>
<tr><td>Project description</td><td colspan="3">The project would entail relocating the railroad landward and out of the wetland and floodplain. The riprap armor along the bank would be removed and replaced with LWD and vegetation and the side channel would be reconnected.</td></tr>
<tr><td>Future threats</td><td colspan="3">This is a highly developed and straightened reach of the river with little refugia for both adult and juvenile fish. The lack of refugia and habitat cover will continue. Riprap bank armoring will continue to degrade fish habitat diversity along the edge of the river channel. Bank armoring will continue to disrupt geomorphic and hydraulic processes and isolate the potentially productive side channel and floodplain.</td></tr>
<tr><td>Project rationale</td><td colspan="3">Side channel and refugia are very limited in the South Fork Skykomish River, particularly in this developed reach. Restoring side channel habitat would provide additional refugia for both adults and juvenile and rearing habitat for juveniles. The river is confined by the railroad and the geomorphic and hydraulic processes at this location are being disturbed.</td></tr>
<tr><td>Project benefits</td><td colspan="3">Greater salmonid habitat diversity, side channel reconnection, refugia and habitat cover; restored predevelopment hydraulic processes to this reach; and restored juvenile rearing habitat. Restored riparian habitat that will provide shade, cover, and food sources for fish.</td></tr>
</table>

Opportunity Name	**SFSR #9: RM 15.1 – US 2**
Activity	**LWD placement, riprap removal**

Project sponsor	WSDOT
Target habitat	Juvenile rearing habitat; adult and juvenile spawning habitat
Current ownership	WSDOT
Hydrogeomorphic classification	Mainstem riverbank
Project size	~500 feet riverbank
Strategy	LWD placement, riprap removal

Existing conditions	US 2 abuts the right bank of the South Fork Skykomish River bank between RM 15.0 and RM 15.2. The right bank is armored with blast rock to protect the steep riverbank from erosion. The river flows adjacent to the riprap. No LWD or vegetation is located along this section of the riverbank and thus lack habitat complexity, though fish were observed at a nearby logjam, approximately 500 feet upstream.
Project description	The project would entail replacing the riprap armor with LWD and vegetation.
Future threats	This is a developed reach of the river with little edge habitat and refugia for both adult and juvenile fish. The lack of refugia and habitat cover will continue to be problematic. Riprap bank armoring will continue to degrade fish habitat diversity along the edge of the river channel and attract the river along the entire length of the roadway, causing further loss of intact floodplain area. Bank failure may occur, potentially causing sedimentation of the river and eventually embeddedness of spawning gravels.
Project rationale	Edge habitat diversity is low in this developed reach of the South Fork Skykomish River. The river is confined by the road and the geomorphic and hydraulic processes at this location are impaired. The riprap on the bank entrains the river against it and is likely to fail in the future.
Project benefits	Greater salmonid habitat diversity, restored predevelopment hydraulic processes, and, riparian habitat that will provide shade, cover, and food sources for fish.

Opportunity Name	**SFSR #10: RM 14.3 Side Channel**
Activity	**Bridge placement, side channel reconnection**

Project sponsor	King County or WSDOT
Target habitat	Side channel habitat; juvenile rearing habitat; adult and juvenile refugia
Current ownership	Private and WSDOT
Hydrogeomorphic classification	Side channel
Project size	~1,000 feet of side channel
Strategy	Bridge placement, LWD placement

Existing conditions	US 2 blocks off the inlet to a side channel that is located between RM 14.2 and RM 14.1 along the right bank. The side channel is within an undeveloped forested parcel on the north side of US 2. The river is constricted and artificially straight between US 2 and the BNSF railway that is located on the left bank.
Project description	The project would entail reconnecting the side channel with the river by placing a bridge over the entry location of the side channel. Excavation of the entry to the side channel may also be needed. LWD and vegetation would be placed where needed to prevent erosion and create additional fish habitat diversity and riparian cover. LWD may also be placed within the side channel if it would improve fish habitat or couldn't be provided by existing conditions.
Future threats	This is a developed and straightened reach of the river with little refugia for both adult and juvenile fish and limited juvenile rearing habitat. The side channel area will continue to be blocked off from fish access, and limit refugia and rearing habitat. The side channel could be lost if future development fills in the area or develops around it.
Project rationale	Side channel and refugia are very limited in the assessment area, particularly in this developed reach. Restoring side channel habitat would provide additional refugia habitat for both adults and juvenile and rearing habitat for juveniles.
Project benefits	Greater salmonid habitat diversity, refugia, and habitat cover; restored side channel habitat; restored predevelopment hydraulic processes to this reach; and restored juvenile rearing habitat.

Opportunity Name	SFSR #11: RM 14.3 Railroad
Activity	LWD placement, rail line relocation

Project sponsor	BNSF
Target habitat	Spawning habitat, edge habitat
Current ownership	BNSF
Hydrogeomorphic classification	Mainstem riverbank
Project size	~500 feet of riverbank
Strategy	Proactive bank stabilization, rail line relocation

Existing conditions	The railroad abuts the left bank of the South Fork Skykomish River at approximately RM 14.3. The left bank is unarmored and the raw fill prism is exposed and rapidly eroding. The river is pinched between US 2 and the railway, exacerbating the erosion risk. US 2 in this area is unarmored and protected by bedrock.
Project description	The project would entail relocating the railroad landward from the edge of the river or proactively stabilizing the bank with LWD. Vegetation may be added if appropriate.
Future threats	Ongoing erosion, as soon as this winter, could necessitate an emergency action to protect the railway in this location. Any added bank armoring will continue to disrupt geomorphic and hydraulic processes. The emergency action may have other detrimental impacts to wildlife.
Project rationale	The river is confined by the railroad and US 2. Because the road lies on bedrock, erosion is concentrated at the railway, exposing fine-grained materials in the railway fill prism. Relocating the railroad would allow the river to reconnect with the floodplain currently cut off by the railway. Bank failure will continue occur in the future, compromising local spawning habitat. The river completely lacks riparian vegetation and LWD in this reach.
Project benefits	Greater salmonid habitat diversity, create additional edge habitat (if the railway is moved), and restored predevelopment hydraulic and geomorphic processes to this reach. Restored riparian habitat that will provide shade, cover, and food sources for fish.

Opportunity Name	**SFSR #12: Miller River Alluvial Fan**
Activity	**Debris removal**

Project sponsor	King County
Target habitat	Spawning habitat
Current ownership	Private, King County and BNSF
Hydrogeomorphic classification	Miller River Alluvial Fan
Project size	N/A
Strategy	Debris removal

Existing conditions	Considerable concrete and metal debris has accumulated on the downstream end of the Miller River Alluvial Fan from the avulsion of the Miller River across Old Cascade Highway. In addition to the avulsion debris, other broken concrete and a former wellhead was found in the active channel. There are several other opportunities to improve conditions on the Miller River Alluvial Fan that relate to the avulsion that are discussed in detail in Herrera (2012).
Project description	This project would remove the deleterious debris observed from the main stem South Fork. This area was not included in the analysis of Herrera (2012).
Future threats	The debris will continue to impact healthy geomorphic function and preclude spawning in its footprint.
Project rationale	Edge habitat and cover is limited in this reach of the South Fork Skykomish River due to development. The bank is eroding at this time and a much larger landslide could occur in the future.
Project benefits	Spawning habitat in and around the debris removal and predevelopment geomorphic conditions everywhere the debris currently exists.

<table>
<tr><td colspan="2">Opportunity Name</td><td colspan="2">SFSR #13: Money Creek Campground</td></tr>
<tr><td colspan="2">Activity</td><td colspan="2">Feasibility analysis to restore impaired habitat</td></tr>
<tr><td colspan="2" rowspan="7">
</td><td>Project sponsor</td><td>USFS</td></tr>
<tr><td>Target habitat</td><td>Side channel habitat; juvenile rearing habitat; adult and juvenile refugia and adult spawning habitat</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Side channel, floodplain, mainstem riverbank</td></tr>
<tr><td>Project size</td><td>~1,000 feet of side channel, 2,000 feet riverbank</td></tr>
<tr><td>Strategy</td><td>Feasibility analysis</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Existing conditions</td><td colspan="3">Money Creek Campground is located on land between FS Road 6030 and the left bank of the South Fork Skykomish River between RM 13.0 and RM 12.5. The river bends to the north at this location and then back under the BNSF railroad crossing. The campground straddles the railway. The Money Creek confluence is south of the campground and joins the South Fork Skykomish River just downstream of the railroad trestle. Riprap armoring and a couple of cabled logs were placed along the riverbank to stop erosion from occurring on the left bank downstream of the trestle. Two small side channels are disconnected from the river by the armoring at this location. The river channel is also constricted by the armoring and US 2 on the opposite bank.</td></tr>
<tr><td>Project description</td><td colspan="3">This project would entail a study of the best options to maintain campground development, but restore impaired habitat. The project could entail reconnecting the side channel with the river by removing the riprap armoring, allowing flow into the channel, and taking pressure off the constricted reach in between the Old Cascade Highway and US 2. Riprap could be replaced with strategically placed LWD to prevent erosion and improve edge habitat for fish. The banks would be vegetated to prevent erosion further erosion and provide riparian cover. LWD may also be placed within the side channel if it would improve fish habitat. The feasibility study would also allow for optimal operation of the facility for improved habitat conditions.</td></tr>
<tr><td>Future threats</td><td colspan="3">Armoring to protect the campground, roads, and railroad have resulted in limited edge habitat and habitat degradation in this area and this will continue. Riparian cover has also been cleared and more will become cleared if further development occurs. The side channel area will continue to be blocked off from fish access.</td></tr>
<tr><td>Project rationale</td><td colspan="3">Side channel and refugia are very limited in the South Fork, particularly in this developed reach. Restoring side channel habitat would provide additional refugia habitat for both adults and juvenile and rearing habitat for juveniles. Replacing riprap armoring with LWD and vegetation will restore edge habitat and improve habitat diversity.</td></tr>
<tr><td>Project benefits</td><td colspan="3">Greater salmonid habitat diversity, refugia, and habitat cover; restored side channel habitat; restored predevelopment hydraulic processes to this reach; restored juvenile rearing habitat; and restored edge habitat.</td></tr>
</table>

<table>
<tr><td>Opportunity Name</td><td colspan="3">SFSR #14: RM 12.5 Railroad Bridge</td></tr>
<tr><td>Activity</td><td colspan="3">Bridge replacement or extension, fill removal</td></tr>
<tr><td colspan="2" rowspan="6">
</td><td>Project sponsor</td><td>BNSF</td></tr>
<tr><td>Target habitat</td><td>Adult spawning habitat; edge habitat for adult and juvenile salmonids</td></tr>
<tr><td>Current ownership</td><td>BNSF</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Floodplain, mainstem riverbank</td></tr>
<tr><td>Project size</td><td>~2,000 feet of fill removal</td></tr>
<tr><td>Strategy</td><td>Bridge replacement or extension, fill removal</td></tr>
<tr><td>Existing conditions</td><td colspan="3">BNSF railroad crosses the South Fork Skykomish River just downstream of Money Creek Campground at RM 12.5 on the combined Money-Miller Alluvial Fan. Money Creek flows into the south end of the campground and joins the South Fork Skykomish River just downstream of the railroad trestle. The old railroad trestle has a pier in the center of the channel on a bar, and the abutments are on a large amount of fill within the channel and in the floodplain. The trestle bridge is severely constricting the channel at this location.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would entail removing the fill associated with the railroad trestle bridge, and replacing the bridge with a longer bridge that spans the river and some of the floodplain or spans currently filled areas. Riprap would be replaced with strategically placed LWD to prevent erosion and improve edge habitat for fish. The banks would be vegetated to prevent further erosion and provide riparian cover.</td></tr>
<tr><td>Future threats</td><td colspan="3">The railroad trestle constricts the channel and is impairing geomorphic and hydraulic processes in this reach. In addition, the fill associated with the bridge has resulted in limited edge habitat and habitat degradation in this area and this will continue. Riparian cover has also been cleared and more become cleared if further development occurs.</td></tr>
<tr><td>Project rationale</td><td colspan="3">The railroad trestle constricts the channel and is impairing both fish habitat and predevelopment geomorphic and hydraulic processes and causing the loss of floodplain connection. Replacing the bridge, removing the fill in the channel, and restoring the bank with LWD and vegetation will improve fish habitat diversity and spawning habitat for adults. Replacing riprap armoring with LWD and vegetation will restore edge habitat, increase connection with the floodplain and improve habitat diversity.</td></tr>
<tr><td>Project benefits</td><td colspan="3">Greater salmonid habitat diversity, refugia, and habitat cover. Restored predevelopment geomorphic and hydraulic processes to this reach; and improved edge and floodplain habitat.</td></tr>
</table>

Opportunity Name	**SFSR #15: RM 10.5**
Location	**LWD placement, side channel reconnection**

Project sponsor	King County or BNSF
Target habitat	Side channel habitat, juvenile rearing habitat, adult and juvenile refugia,
Current ownership	BNSF and Private
Hydrogeomorphic classification	Tributary alluvial fan
Project size	~2,500 feet of side channel; 300 feet mainstem riverbank
Strategy	LWD placement, side channel reconnection and property acquisition

Existing conditions	A 2,500-foot side channel is located between RM 10.5 and RM 9.9 along the left bank of the South Fork Skykomish River on the Lowe Creek Alluvial Fan. Armoring and fill has limited the access to the side channel at the upstream end by attracting the thalweg of the river to the right bank. The armoring has failed despite multiple placements, and the bank is eroding and contacting the main channel even further upstream. While the channel is still active at higher flows, it could strand fish during low flows. The side channel is within an undeveloped privately owned forested parcel. The side channel contains excellent slack water habitat and habitat cover.
Project description	The project would entail reconnecting the side channel with the river by replacing armoring with engineered LWD on the right bank and/or in the middle of the channel to force flows towards and into the side channel. Excavation of the entry to the side channel may also be needed. LWD and vegetation would be placed where needed to both prevent erosion and avulsion to the side channel. LWD may also be placed within the side channel if it would improve fish habitat. Property acquisition of the private parcel may need to occur for the project to be completed.
Future threats	This side channel is on private property and could be developed further cutting off the side channel or resulting in loss of the channel. Bank erosion could continue to occur possibly resulting in emergency actions that would endanger wildlife.
Project rationale	Side channel and refugia are very limited in the South Fork Skykomish River, particularly in this developed reach. This project would improve connection to 2,500 feet of side channel. Restoring side channel habitat would provide additional refugia habitat for both adults and juveniles and rearing habitat for juveniles.
Project benefits	Greater salmonid habitat diversity, refugia, and habitat cover; restored side channel habitat; restored predevelopment hydraulic processes to this reach; restored juvenile rearing habitat, and restored edge habitat along the mainstem.

<table>
<tr><td>Opportunity Name</td><td colspan="3">SFSR #16: RM 10.2</td></tr>
<tr><td>Activity</td><td colspan="3">Bridge placement, tributary reconnection</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>WSDOT or BNSF</td></tr>
<tr><td>Target habitat</td><td>Adult spawning habitat; juvenile rearing habitat; adult and juvenile refugia</td></tr>
<tr><td>Current ownership</td><td>WSDOT and BNSF</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Tributary confluence</td></tr>
<tr><td>Project size</td><td>5,000 feet of two tributaries</td></tr>
<tr><td>Strategy</td><td>Bridge placement, tributary reconnection</td></tr>
<tr><td>Existing conditions</td><td colspan="3">Two tributaries are cut off from the right bank of the South Fork at RM 10.2. No apparent outlet of these streams exists under US 2. US 2 abuts the river at this location and the bank is armored for most of its length.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would entail reconnecting the tributaries by constructing at least one bridge across US 2 and the BNSF railway. LWD and vegetation would be placed along the bank to both stabilize the bank and improve habitat diversity. Rock could be removed where appropriate.</td></tr>
<tr><td>Future threats</td><td colspan="3">The tributary will continue to be cut off from the mainstem acting as a barrier to fish passage and impairing the predevelopment hydraulic processes that occurred at this location. Bank armoring will also continue to degrade fish habitat diversity. Since these tributaries are quite large and steep, there is a long-term risk to both the highway and the railway.</td></tr>
<tr><td>Project rationale</td><td colspan="3">Tributary connections are often disturbed or cut off due to US 2 and the railroad in the South Fork Skykomish River. This project would reconnect the river to 5,000 feet of tributary, restoring the floodplain connection on the opposite side of US 2. Restoring habitat would provide additional habitat for both adults and juvenile and potential rearing habitat for juveniles.</td></tr>
<tr><td>Project benefits</td><td colspan="3">Greater salmonid habitat diversity, refugia, and habitat cover, restored potential adult spawning habitat; restored predevelopment hydraulic processes to this reach and the tributaries; restored juvenile rearing habitat, and improved floodplain connection. It will also improve habitat access for salmonids.</td></tr>
</table>

<table>
<tr><td>Opportunity Name</td><td colspan="3">SFSR #17: RM 9.5</td></tr>
<tr><td>Activity</td><td colspan="3">Side channel reconnection, armoring removal</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>BNSF</td></tr>
<tr><td>Target habitat</td><td>Adult and juvenile edge habitat, rearing habitat</td></tr>
<tr><td>Current ownership</td><td>BNSF</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Mainstem riverbank</td></tr>
<tr><td>Project size</td><td>1,400 feet of riverbank</td></tr>
<tr><td>Strategy</td><td>Rock removal and engineered LWD placement</td></tr>
<tr><td>Existing conditions</td><td colspan="3">Approximately 1,400 feet of the right bank of the mainstem South Fork between RM 9.4 and 9.7 has a large rock revetment that protects the BNSF railway. The left bank is undeveloped. As is typical with rock revetments, the thalweg of the river has locked in against the revetment and continues to be attracted at its upstream end to the smooth wall presented by the revetment, causing more rock to be placed there. The area is immediately adjacent to one of the largest side channel complexes on the entire South Fork, which could be at risk to be eroded if the river continues moving towards the revetment.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would replace the existing rock revetment with engineered log structures that would improve habitat and force the river away from the railway. The habitat gains from this action would be magnified by the existing adjacent high functioning side channel complex.</td></tr>
<tr><td>Future threats</td><td colspan="3">The railway will continue to be at risk to erosion, while intact side channel habitat will be lost. This will cause a slow but progressive loss of one of the best examples of an intact side channel network on the South Fork.</td></tr>
<tr><td>Project rationale</td><td colspan="3">Engineered LWD jams will force the river away from the railway and engage floodplain on the undeveloped left bank. The prism could be then be protected by a combination of vegetation and secured LWD.</td></tr>
<tr><td>Project benefits</td><td colspan="3">Greater salmonid habitat diversity, refugia, and habitat cover, restored predevelopment hydraulic processes, improved floodplain connection, and arrest of the the ongoing loss of intact side channel areas upstream.</td></tr>
</table>

<table>
<tr><td>Opportunity Name</td><td colspan="4">SFSR #18: RM 8.6 Right Bank</td></tr>
<tr><td>Activity</td><td colspan="4">Property acquisition</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>King County</td></tr>
<tr><td>Target habitat</td><td>Juvenile rearing habitat, adult and juvenile refugia and edge habitat</td></tr>
<tr><td>Current ownership</td><td>Private</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Side channel and mainstem riverbank</td></tr>
<tr><td>Project size</td><td>500 feet of mainstem riverbank, 100 feet of side channel</td></tr>
<tr><td>Strategy</td><td>Property acquisition</td></tr>
<tr><td>Existing conditions</td><td colspan="4">Several properties at the edge of a large development near Baring abut a side channel complex and are opposite of a large colluvial fan originating on Palmer Mountain between RM 8.6 and 8.8. It is unclear whether the property immediately adjacent to side channel is developed, but several properties further away have been developed, but have not been armored. The side channel complex likely developed from channel migration from sediment output on the colluvial fan on the opposite bank. These homes not only threaten to harm habitat by the installation of new rock, but they are also at risk of catastrophic loss if the debris fan were to become active again.</td></tr>
<tr><td>Project description</td><td colspan="4">The project would entail purchasing properties and deconstructing residences (where they occur), with those properties closest to the side channel and the colluvial fan being the highest priority.</td></tr>
<tr><td>Future threats</td><td colspan="4">Side channels are rare on the South Fork, particularly those that are already well forested. The side channel on this site appears to be in good condition, but it could be compromised if armoring along it takes place. Also the homes could be in danger if the colluvial fan were to reactivate.</td></tr>
<tr><td>Project rationale</td><td colspan="4">Acquire properties to conserve existing habitat, prevent future habitat loss and reduce risk to property and human life from future geomorphic risks.</td></tr>
<tr><td>Project benefits</td><td colspan="4">Conserve salmonid habitat diversity, refugia, and habitat cover; conserve potential adult spawning habitat; conserve juvenile rearing habitat and floodplain connection.</td></tr>
</table>

<table>
<tr><td>Opportunity Name</td><td colspan="3">SFSR #19: RM 7.5 Left Bank</td></tr>
<tr><td>Activity</td><td colspan="3">Property acquisition</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>King County</td></tr>
<tr><td>Target habitat</td><td>Juvenile rearing, juvenile adult edge habitat</td></tr>
<tr><td>Current ownership</td><td>Private</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Side channel</td></tr>
<tr><td>Project size</td><td>~1,200 feet of side channel</td></tr>
<tr><td>Strategy</td><td>Property acquisition</td></tr>
<tr><td>Existing conditions</td><td colspan="3">The inlet of large forested side channel is currently in private ownership and could theoretically be developed despite that most of several (nine) small parcels are in the floodplain and possess an intermittent side channel. Three of the parcels have already been built on with structures built on stilts.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would acquire these precarious and ecologically valuable parcels and place them in a conservation easement. A program of acquisition could continue to acquire parcels further and further upstream to buffer this unusual feature.</td></tr>
<tr><td>Future threats</td><td colspan="3">Very few active side channels exist on the South Fork. Even fewer have adjacent mature forest associated with them. Some are currently in private hands and could be developed, further negatively affecting rearing areas and riparian vegetation.</td></tr>
<tr><td>Project rationale</td><td colspan="3">Some of the parcels in question are likely in the floodplain and cannot be legally developed; however, they could be if sold in association with other adjacent parcels, or developed illegally. These small parcels are in private hands and could easily be altered to degrade habitat.</td></tr>
<tr><td>Project benefits</td><td colspan="3">Greater salmonid habitat diversity, conserve edge and rearing habitat and cover. Conserve riparian habitat that will provide shade, cover, and food sources for fish.</td></tr>
</table>

Opportunity Name	**SFSR #20: RM 7.5 Right Bank**
Activity	**Armoring removal**

Project sponsor	King County
Target habitat	Adult and juvenile edge habitat
Current ownership	Private
Hydrogeomorphic classification	Mainstem riverbank
Project size	~1,200 feet of riverbank
Strategy	Rock removal and LWD placement

Existing conditions	Three large parcels exist on the right bank near RM 7.5. These parcels have homes, but they are set well away from the top of bank. Despite the setback, there is rock placed at the toe of bank that has been there a long time. The site is opposite a high quality intact forested side channel (see Opportunity #19).
Project description	The project would entail removal of the bank toe rock and placement of stable LWD and vegetation along the eroding bank to both stabilize the bank and provide improved fish habitat and diversity at this location. The project would have the side benefit of forcing flow into a high side channel system on the left bank.
Future threats	The rock and draws flow away from the intact forested side channel on the left bank. The project would be greatly improved if it were combined with Opportunity #19.
Project rationale	Edge habitat and cover is limited in this reach of the South Fork Skykomish River due to development. The rock at the toe of the bank discourages wood storage, and encourages trapping of flow near the smooth, straight rocked bank. The homes are also not at risk.
Project benefits	Greater salmonid habitat diversity, restored edge habitat and improved cover. Restored and improved riparian habitat that will provide shade, cover, and food sources for fish, reconnect a high quality forest side channel.

Opportunity Name	SFSR #21: RM 7.0
Activity	**LWD Placement**

Project sponsor	King County
Target habitat	Adult and juvenile edge habitat
Current ownership	Private
Hydrogeomorphic classification	Mainstem riverbank
Project size	~800 feet of riverbank
Strategy	LWD placement

Existing conditions	A group of homes on the right bank at RM 7.0 are currently unprotected from ongoing erosion at their bank. Signs of recent erosion were plentiful. Some of the homes are extremely close to the edge of bank (less than 20 feet). The left bank is private, but completely undeveloped.
Project description	The project would entail placement of stable LWD and vegetation along the eroding bank to both stabilize the bank and provide improved fish habitat and diversity at this location, while at the same time prevent emergency actions that could be detrimental to habitat. It would encourage migration of the primary and towards and into an intact side channel complex on the left bank.
Future threats	The eroding bank could continue to fail causing a land slump or slide and a loss of riparian habitat, possibly necessitating emergency actions that could endanger wildlife. Erosion could also endanger human life and property.
Project rationale	Edge habitat and cover is limited in this reach of the South Fork Skykomish River due to development. The bank is eroding at this time and adding wood instead of emergency rock would avoid future habitat impacts. Risks to the other bank are minimal.
Project benefits	Greater salmonid habitat diversity, restored edge habitat and improved cover. Restored riparian habitat that will provide shade, cover, and food sources for fish. Enhance activation of left bank side channel.

<table>
<tr><td>Opportunity Name</td><td colspan="3">SFSR #22: RM 6.4</td></tr>
<tr><td>Activity</td><td colspan="3">Property acquisition</td></tr>
<tr><td colspan="2" rowspan="6">
</td><td>Project sponsor</td><td>King County or Snohomish County</td></tr>
<tr><td>Target habitat</td><td>Juvenile rearing habitat, adult and juvenile edge habitat</td></tr>
<tr><td>Current ownership</td><td>Private</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Side channel</td></tr>
<tr><td>Project size</td><td>~1,800 feet of side channel</td></tr>
<tr><td>Strategy</td><td>Property acquisition</td></tr>
<tr><td>Existing conditions</td><td colspan="3">Nine parcels, which are mostly undeveloped, straddle a reasonably intact high-flow side channel on the right bank between RM 6.5 and 6.2, just north of the county line. Conditions within the side channel appear to be reasonably good, but the apparent new development in the area and the proximity of the site to US 2 indicates that development pressure is high.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would acquire undeveloped properties and place them in a conservation easement. Over a longer term, the few developed properties could be acquired, the structures could be removed, and the floodplain corridor restored.</td></tr>
<tr><td>Future threats</td><td colspan="3">Development within this unusual side channel feature would degrade and may limit. It is clear from the disturbance in the channel itself that flows are significant and could present a risk to property and human life. These risks could initiate future homeowners to place rock that would degrade habitat or trigger emergency actions that would endanger wildlife.</td></tr>
<tr><td>Project rationale</td><td colspan="3">Side channel habitat is limited in this reach of the South Fork. This intact side channel could be developed, but that development would pose risks to both human health and habitat. Acquisition of the properties and placement in conservation easements would allow this side channel to provide both habitat and flood reduction function, without endangering people or wildlife.</td></tr>
<tr><td>Project benefits</td><td colspan="3">Greater salmonid habitat diversity, conserve rearing edge habitat and cover. Conserve riparian habitat that will provide shade, cover, and food sources for fish.</td></tr>
</table>

Opportunity Name	**SFSR #23: RM 6.0**
Activity	**Bank armoring removal**

Project sponsor	Public Utility or USFS
Target habitat	Adult and juvenile edge habitat
Current ownership	USFS
Hydrogeomorphic classification	Mainstem riverbank
Project size	~150 feet of riverbank
Strategy	Armoring removal

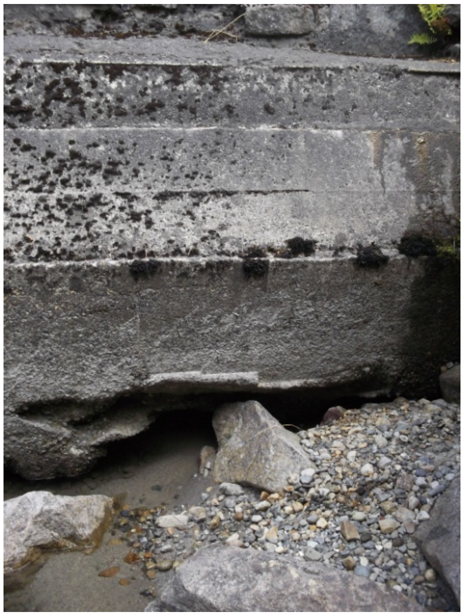
Existing conditions	In the power line crossing at RM 6.0, the public utility operating the power lines placed riprap along the unvegetated left bank. The orientation of the rock has directed the river to become more in contact with US 2 and several homes are precariously located on the right bank on the Barclay Creek Alluvial Fan.
Project description	The project would remove the bank armoring, as the river is not endangering power line infrastructure at this time.
Future threats	The rock degrades habitat in this already compromised area. The orientation of the rock directs flow towards US 2, possibly increasing the probability of emergency actions, and armoring on the right bank. Although there is bank erosion at this unvegetated site the first tower is extremely far from the river bank and not generally at risk.
Project rationale	Edge habitat and cover is limited in this reach of the South Fork Skykomish River due to development. The rock placed in the current orientation places increased risks to right bank landowners and US 2. The rock is not necessary to protect power line towers from destruction.
Project benefits	Greater salmonid habitat diversity, restored edge habitat and cover. Restored more natural channel migration patterns that would move the river away from other adjacent infrastructure.

<table>
<tr><td>Opportunity Name</td><td colspan="3">SFSR #24: Barclay Creek Alluvial Fan</td></tr>
<tr><td>Activity</td><td colspan="3">Feasibility analysis</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>Snohomish County or WSDOT</td></tr>
<tr><td>Target habitat</td><td>Rearing, spawning and adult and juvenile edge habitat</td></tr>
<tr><td>Current ownership</td><td>Private and WSDOT</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Tributary alluvial fan</td></tr>
<tr><td>Project size</td><td>About 1 acre</td></tr>
<tr><td>Strategy</td><td>Feasibility analysis</td></tr>
<tr><td>Existing conditions</td><td colspan="3">The Barclay Creek Alluvial Fan is dissected by US 2 and several residences on small properties surrounded on several sides by the South Fork, Barclay Creek and an unnamed tributary. Barclay Creek and the unnamed tributary form a tributary alluvial fan that has been highly altered due to adjacent infrastructure, primarily US 2. Both of the tributaries have bridges over them that were not examined in this analysis. Either of them could be constricting, and could compromise habitat in these critical areas.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would entail a feasibility analysis to determine what properties are most at risk and to develop a strategy to improve habitat conditions and reduce flood and geological risks to remaining infrastructure and homes.</td></tr>
<tr><td>Future threats</td><td colspan="3">The Barclay Creek Alluvial Fan is highly degraded due to development, armoring and bridge crossings. Alluvial fans are notoriously dangerous because of the high frequency of stream avulsions and their generally high level of activity. This is particularly true for steep alluvial fans, like the Barclay Creek Alluvial Fan, which could also produce debris flows, and debris floods can endanger human life both on the developed properties and the highway itself.</td></tr>
<tr><td>Project rationale</td><td colspan="3">The alluvial fan is highly degraded and constricted due to past development and the placement of US 2 across its lowest reaches. A feasibility analysis will develop a plan of action to improve habitat conditions while protecting vital infrastructure and improving flooding conditions at this complicated, interrelated, and potentially ecologically productive site.</td></tr>
<tr><td>Project benefits</td><td colspan="3">Restored predevelopment geomorphic functions, improve riparian and alluvial fan habitat that will provide shade, cover, and food sources for fish. Spawning habitat will be improved by delivering gravel and cobble to the lower portions of the tributaries and side channels of the South Fork in a more natural way.</td></tr>
</table>

<table>
<tr><td>Opportunity Name</td><td colspan="3">SFSR #25: RM 5.4</td></tr>
<tr><td>Activity</td><td colspan="3">Bank armoring removal</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>Snohomish County or USFS</td></tr>
<tr><td>Target habitat</td><td>Rearing, adult and juvenile edge habitat</td></tr>
<tr><td>Current ownership</td><td>Private and USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Mainstem riverbank</td></tr>
<tr><td>Project size</td><td>~400 feet of mainstem riverbank</td></tr>
<tr><td>Strategy</td><td>Riprap removal and LWD placement</td></tr>
<tr><td>Existing conditions</td><td colspan="3">Near RM 5.4 just upstream from Eagle Falls, there is a length of right bank riverbank that is armored, with little to no riparian vegetation. The channel is also highly simplified in this area. The left bank is undeveloped USFS land.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would entail replacing the existing riprap with engineered LWD, attempting to force the river towards the undeveloped left bank and away from existing infrastructure.</td></tr>
<tr><td>Future threats</td><td colspan="3">The lack of riparian vegetation and smooth rock banks will continue to attract the thalweg to the developed right bank. Over time, this could further endanger the structures on the right bank and the people who live in them.</td></tr>
<tr><td>Project rationale</td><td colspan="3">The South Fork is naturally hydraulically simple, but the smooth rock banks and removal of wood and riparian vegetation in the project site exacerbate these natural impairments and cause abandonment of forested side channels, and highly degraded habitat conditions. Adding engineered log structures to push the thalweg away from development towards the left bank, which is completely intact, will improve conditions significantly.</td></tr>
<tr><td>Project benefits</td><td colspan="3">Restored predevelopment geomorphic functions, engage side channel and floodplain habitat on the left bank that will provide shade, cover, and food sources for fish.</td></tr>
</table>

<table>
<tr><td>Opportunity Name</td><td colspan="3">SFSR #26: Upper Eagle Falls Tributary</td></tr>
<tr><td>Activity</td><td colspan="3">Blast rock removal, tributary reconnection</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>USFS</td></tr>
<tr><td>Target habitat</td><td>Rearing, spawning and adult and juvenile edge habitat; habitat access</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Tributary alluvial fan</td></tr>
<tr><td>Project size</td><td>About one acre</td></tr>
<tr><td>Strategy</td><td>Blast rock removal and tributary reconnection</td></tr>
<tr><td>Existing conditions</td><td colspan="3">At the upstream end of Eagle Falls there is a large deposit comprised of highly angular blast debris from previous blasting of the upper falls. This debris blocks a small unnamed tributary outlet effectively acting as a dam between the stream and the mainstem. Although there is wood at the tributary outlet (see photo), only during times of higher water is there sufficient water surface elevation to connect the mainstem to the tributary outlet. At low flows the rock is likely a fish barrier. Other than the blast debris the tributary is in excellent condition. The entire area is owned by the USFS.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would remove blast debris and re-contour the area to maximize the interaction of the tributary with the main stem.</td></tr>
<tr><td>Future threats</td><td colspan="3">The tributary is currently more or less disconnected from the main stem because of the large size of the blast debris. It will continue to be disconnected so long as the (very stable) blast debris stays in place.</td></tr>
<tr><td>Project rationale</td><td colspan="3">The alluvial fan is essentially cut off from the South Fork. As such it is not available for rearing except at the highest flows. This disconnects what would have been a highly biologically productive tributary alluvial fan. The blast debris also degrades geomorphic functions of the mainstem, though to a lesser degree.</td></tr>
<tr><td>Project benefits</td><td colspan="3">Restored predevelopment geomorphic function of the tributary alluvial fan, improve riparian and alluvial fan habitat that will provide shade, cover, and food sources for fish. Spawning habitat will be improved by delivering gravel and cobble to the lower portions of the tributaries and side channels of the South Fork immediately upstream of Eagle Falls. Habitat access would be improved for salmonids.</td></tr>
</table>

Opportunity Name	**SFSR #27: Lower Eagle Falls**
Activity	**Feasibility analysis – fill removal**



Project sponsor	WSDOT
Target habitat	Adult and juvenile edge habitat
Current ownership	WSDOT
Hydrogeomorphic classification	Mainstem
Project size	~400 feet of mainstem riverbank
Strategy	Feasibility analysis

Existing conditions	In the middle of Eagle Falls, between the upper falls and lower falls, there are two separate armored banks that abut US 2. The lower portion consists of a nearly vertical masonry wall. The wall by its construction and wear appears to be very old (at least 50 years). The wall is undermined by quarrying of suspended gravel. For at least a length of 6 feet into the wall (and underneath US 2), there is nothing supporting the roadway. The other armored bank is standard rock revetment, which appears to be the site of regular maintenance because of the erosive conditions there.
Project description	The project would entail replacing the masonry wall and rock revetment, possibly by putting US 2 on a causeway in these areas or by relocating further northeast.
Future threats	The masonry wall will eventually fail due to undermining and will close US 2, a major access road for thousands of people. Road failure is also a risk to human life. At the rock revetment, continued dumping of rock creates disturbance to the stream. Finally, the orientation of the road in this area is dangerous, as this was a site of a fatal accident during the course of the work there.
Project rationale	The masonry wall and rock revetment will require significant maintenance in the future, which will produce impacts to wildlife. Instead of maintaining marginal structures, the area could be analyzed in detail to come up with a strategy that could both improve human/roadway safety and habitat quality.
Project benefits	Restored predevelopment geomorphic functions, improve riparian and edge habitat that will provide shade, cover, and food sources for fish.

Opportunity Name	SFSR #28: Lower Eagle Falls Tributary
Activity	Tributary alluvial fan reconnection and fill removal

Project sponsor	Snohomish County or WSDOT
Target habitat	Rearing, spawning and adult and juvenile edge habitat
Current ownership	WSDOT
Hydrogeomorphic classification	Tributary alluvial fan
Project size	~200 feet of tributary
Strategy	Fill removal, culvert replacement and/or road relocation

Existing conditions	A small unnamed tributary drains the right bank of the South Fork and drains to the tailout of Eagle Falls. The tributary is bridged at the railroad, but runs through a culvert under US 2. Both crossings are undersized, though under US 2, the situation is much worse than at the railway (see photo of railway crossing). The constriction has caused accumulation upstream of the crossing such that the flow goes underground during low periods. The crossings have starved the floodplain below them at the falls tailout of gravel that could be used for spawning.
Project description	The project would replace the culvert and/or the railway bridge, possibly in conjunction with road realignment (see SFSR #29).
Future threats	The continued deposition of sediment upstream of the crossings will continue. Eventually the sediment deposition upstream will force an avulsion, which could endanger US 2 and the BNSF railway. Sediment starvation will also continue downstream, eventually eliminating the floodplain associated with this small creek.
Project rationale	The alluvial fan is highly degraded and constricted due to past development and the placement of US 2 and the BNSF railway across its lowest reaches. Expanding the crossing will improve the connection of the tributary to the main stem and create off-channel opportunities for mainstem fish. It will also allow tributary gravel, which could be spawnable into the mainstem.
Project benefits	Restored predevelopment geomorphic functions, improve alluvial fan habitat that will improve off-channel opportunities for fish. Spawning habitat will be improved by delivering gravel and cobble to the lower portions of the tributary and floodplain of the South Fork in a more natural way.

Opportunity Name	SFSR #29: Sunset Falls Tailout
Activity	Bank armoring removal

Project sponsor	USFS
Target habitat	Adult and juvenile edge habitat
Current ownership	USFS and Private
Hydrogeomorphic classification	Mainstem riverbank
Project size	~1,000 feet of mainstem riverbank
Strategy	Armoring removal, LWD placement, revegetation, or road relocation

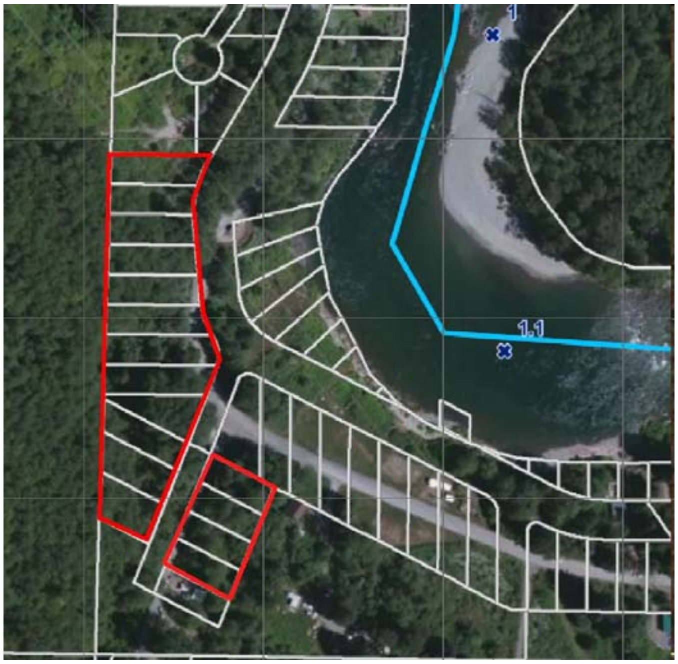
Existing conditions	At the downstream base of Sunset Falls is a large tailout from the falls. This area, like similar features at the base of Canyon and Eagle Falls is a highly dynamic environment that is exposed intermittently to a large range of energetic flows. Mt. Index River Road runs along the south side of the tailout, and is armored along its entire length.
Project description	The project would examine the need for the armoring and determine suitable alternatives including, but not limited to, moving the road to higher ground.
Future threats	The existing revetment will continue to impair the riparian and edge habitat at the tailout of the falls, where large populations of juveniles and adults congregate at the natural fish barrier and trap and haul facility. The road will always be at risk to failure given the unpredictable nature of the tailout during large floods.
Project rationale	The tailout is a risky place for both people and wildlife. The simplest and most effective means to improve safety for people and wildlife is to move the road to higher ground away from unpredictable floodwaters. If that is not possible, there may be other ways to help protect the road and improve riparian conditions through the use of engineered wood and plantings.
Project benefits	Restored predevelopment geomorphic functions, improve riparian habitat that will provide shade, cover, and food sources for fish.

Opportunity Name	SFSR #30: Mt. Index Riversites Floodplain
Activity	**Lidar acquisition**
	
Project sponsor	USFS or Snohomish County
Target habitat	Rearing, adult and juvenile edge and floodplain habitats
Current ownership	Private and USFS
Hydrogeomorphic classification	Mainstem riverbank and floodplain
Project size	~10 acres
Strategy	Lidar acquisition
Existing conditions	Near the outlet of McCall Creek and Bridal Veil Creek in the Mt. Index Riversites is a large flat area that appears to be a former channel and floodplain area. The area does not have lidar coverage and as a result is difficult to determine what the geomorphology of the site is. The area is lightly developed, but there are many abandoned structures and undeveloped lots.
Project description	The project would acquire lidar topography of the area to determine the extent of the floodplain in the area and which parcels were most at risk to flooding. It would also provide information with regards to those areas that could be most easily restored for off-channel habitat.
Future threats	Side channels and floodplain areas are extremely rare in the South Fork in this area. This floodplain area and other off-channel habitats could be developed, lowering the quality of habitat in an already degraded area. If former channels are developed, they could also be at risk to loss of property and human life during a flood.
Project rationale	The floodplain in the area is already degraded by light development and Mt. Index Road. Currently it is unknown which properties are in the floodplain and which aren't. Collection of lidar will assist in the understanding of this complicated, interrelated and potentially ecologically productive site.
Project benefits	Restored predevelopment geomorphic functions, improved riparian and alluvial fan habitat that will provide shade, cover, and food sources for fish.

Opportunity Name	SFSR #31: Mt. Index Riversites Riparian Improvement		
Activity	Revegetation and landowner education		
	**Project sponsor**	USFS or Snohomish County	
	Target habitat	Rearing, adult and juvenile edge habitat	
	Current ownership	Private	
	Hydrogeomorphic classification	Mainstem riverbank	
	Project size	~4,000 feet of mainstem riverbank	
	Strategy	Landowner education and planting assistance	
Existing conditions	Throughout the Mt. Index Riversites development below Sunset Falls, the riparian corridor on the right bank has been cleared for views, in some cases completely. This clearing has significantly reduced shade, cover and food sources for fish. It has also reduced the supply of wood to the river. The area is used extensively by juvenile salmonids.		
Project description	The project would educate landowners about the ecological value of riparian vegetation. The project may also assist in acquiring plants to revegetate riverbanks, and provide technical assistance in the installation of new riparian vegetation.		
Future threats	Without an educational program, it is likely that riparian vegetation will continue to be removed. This will further degrade edge habitat in this key reach.		
Project rationale	The riparian corridor in the area is degraded by past clearing for views. An educational assistance program will reverse the trend towards deforestation and improve riparian and edge habitat for the many juvenile that use this area.		
Project benefits	Improve riparian and edge habitat that will provide shade, cover, and food sources for fish.		

<table>
<tr><td>Opportunity Name</td><td colspan="3">SFSR #32: Mt. Index Riversites Right Bank Floodplain</td></tr>
<tr><td>Activity</td><td colspan="3">Property acquisition</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>USFS or Snohomish County</td></tr>
<tr><td>Target habitat</td><td>Rearing, adult and juvenile edge habitat</td></tr>
<tr><td>Current ownership</td><td>Private and USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Mainstem riverbank and floodplain</td></tr>
<tr><td>Project size</td><td>~0.8 acres</td></tr>
<tr><td>Strategy</td><td>Property acquisition, structure demolition, revegetation</td></tr>
<tr><td>Existing conditions</td><td colspan="3">Near the outlet of McCall Creek and Bridal Veil Creek in the Mt. Index Riversites is a large flat area that appears to be a former channel and floodplain area. Several parcels adjacent to the river have either abandoned or no development on them. These properties are likely at risk of flooding and could be deconstructed and revegetated to improve edge habitat conditions.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would acquire properties at most risk of flooding and those properties that could provide the best habitat for fish. The project would be most effective if it were done in conjunction with Opportunity #32 to better assess risks and opportunities.</td></tr>
<tr><td>Future threats</td><td colspan="3">Side channels and floodplain areas are extremely rare in this area. This floodplain area and other off-channel habitats could be developed lowering the habitat of an already degraded site, and placing that development and people in it at severe risk. Abandoned development is an attractive nuisance and precludes habitat in its footprint.</td></tr>
<tr><td>Project rationale</td><td colspan="3">The floodplain in the area is already somewhat degraded from low-density abandoned development. These abandoned properties in addition to several undeveloped properties could be acquired, restored, and placed in conservation to expand the intact riparian corridor that extends well downstream.</td></tr>
<tr><td>Project benefits</td><td colspan="3">Restored predevelopment geomorphic functions, improved riparian habitat that will provide shade, cover, and food sources for fish.</td></tr>
</table>

Opportunity Name	**SFSR #33: McCall Creek Alluvial Fan**
Activity	**Future development in floodplain**



Project sponsor	USFS or Snohomish County
Target habitat	Rearing, spawning, adult and juvenile edge habitat
Current ownership	Private
Hydrogeomorphic classification	Tributary alluvial fan
Project size	~10 acres
Strategy	Property acquisition

Existing conditions	Near the outlet of McCall Creek in the Mt. Index Riversites development, there are numerous undeveloped parcels on the McCall Creek Alluvial Fan (see red outline in aerial). These parcels are susceptible to flooding and possible debris flows. If developed, they could significantly affect habitat through clearing, grading and armoring.
Project description	The project would acquire these parcels and place them into conservation.
Future threats	Tributary alluvial fans are key areas of habitat complexity particularly in this area where juvenile use is intense. Alluvial fans are also dangerous to human life and property in that they are sites of heightened geomorphic activity.
Project rationale	The alluvial fan is somewhat degraded by the presence of Mt. Index Road and culvert there, but otherwise there are intact areas that are undeveloped. It is likely that these undeveloped parcels are prone to geomorphic activity, which if developed, would represent a risk to human life and property. Development of these areas would further impair habitat in the vicinity.
Project benefits	Conserve predevelopment geomorphic function, conserve riparian and alluvial fan habitat that provides shade, cover, and food sources for fish.

Opportunity Name	**SFSR #34: McCall Creek Culvert**
Activity	**Fish barrier and floodplain disconnection**

Project sponsor	USFS or Snohomish County
Target habitat	Rearing, adult and juvenile edge habitat
Current ownership	Private and USFS
Hydrogeomorphic classification	Tributary confluence floodplain
Project size	50 feet of tributary
Strategy	Culvert replacement and fill removal

Existing conditions	Mt. Index Road crosses McCall Creek in the Mt. Index Riversides development. McCall Creek is carried by a four- to five-foot corrugated metal pipe, which is perched several feet on the downstream side. It is choked with debris and sediment on the upstream side, with considerable above the culvert. There is also a large amount of fill in the area that also disrupts geomorphic function.
Project description	The project would replace the culvert with a bridge and remove fill where possible in order to reconnect the large amount of floodplain upstream from the existing culvert.
Future threats	The existing culvert prevents fish access and will increasingly continue to do over time as the downstream scours further. The crossing is severely undersized and could fail during a flood, initiating emergency actions to ensure access that could have negative impacts to wildlife.
Project rationale	The floodplain in the area is degraded, constricted and disconnected due to the presence of the culvert. Opening up the crossing and allowing full passage of fish, water and sediment will allow high quality intact floodplain areas further upstream on McCall Creek to be accessed by fish. Restoring sediment transport across the road will improve geomorphic function and deliver spawning gravels and hydraulic complexity to the floodplain of the South Fork.
Project benefits	Restored predevelopment geomorphic functions, improve riparian and alluvial fan habitat that will provide shade, cover, and food sources for fish. Fish passage and spawning habitat will be improved by delivering gravel and cobble to the lower portions of the tributaries and side channels of the South Fork in a more natural way.

Opportunity Name	**SFSR #35: Bridal Veil Creek**		
Activity	**Undersized bridge and fill**		
		**Project sponsor**	USFS
		Target habitat	Adult and juvenile edge habitat
		Current ownership	USFS
		Hydrogeomorphic classification	Tributary alluvial fan
		Project size	~100 feet of tributary alluvial fan
		Strategy	Bridge replacement and fill removal
Existing conditions	Mt. Index Road crosses Bridal Veil Creek in the middle of the Mt. Index Riversites development. At the point where the road crosses the creek, the road is owned and operated by USFS. The bridge over the creek shows of undermining on both abutments. Fill has been placed on either side of both abutments, which constricts the creek. The area around the mouth of the creek is used extensively by juvenile salmonids and the bridge significantly restricts flow of water and sediment.		
Project description	The project would replace the bridge with one with a much greater span and remove fill from the road prism where possible.		
Future threats	Side channels and floodplain areas are extremely rare in the South Fork in this area and Bridal Veil Creek represents one of the few opportunities to expand habitat in an area that has been degraded. The bridge is also not in good condition and could fail, making emergency actions to ensure access likely detrimental to wildlife.		
Project rationale	The lower reaches of Bridal Veil Creek above the bridge likely provided high quality habitat to anadromous fish prior to installation of the bridge. The bridge now limits access to areas above the bridge and it negatively impacts sediment transport across it. Improving the crossing would improve access to juveniles to areas further upstream and restore predevelopment geomorphic function to the entire alluvial fan.		
Project benefits	Restored predevelopment geomorphic functions, improved riparian and fan alluvial habitat that will provide shade, cover, and food sources for fish. Spawning habitat will be improved by delivering gravel and cobble to the lower portions of the tributaries and side channels of the South Fork in a more natural way.		

Opportunity Name	SFSR #36: Paytan Creek
Activity	Undersized bridge and fill

Project sponsor	Snohomish County
Target habitat	Adult and juvenile edge habitat
Current ownership	Private
Hydrogeomorphic classification	Tributary alluvial fan
Project size	~50 feet of tributary
Strategy	Bridge replacement and fill removal

Existing conditions	In the Mt. Index Riversites development, Paytan Creek Road crosses Paytan Creek, a small tributary. The bridge is in disrepair and could easily fail given a reasonable-sized flood. The bridge pinches the creek and carries utilities infrastructure, which could pollute depending on the mode of failure. Geomorphic conditions near the bridge are severely impaired.
Project description	The project would replace the bridge and remove the fill on both abutments.
Future threats	Side channels and floodplain areas are extremely rare in the South Fork in this area and Paytan Creek represents one of the few opportunities to expand habitat in an area that has been degraded. The bridge is also not in good condition and could fail, making emergency actions to ensure access likely detrimental to wildlife.
Project rationale	The floodplain in the area is degraded and constricted due to past development and the placement of US 2 across its lowest reaches. A feasibility analysis will develop a plan of action to improve habitat conditions while protecting vital infrastructure and improving flooding conditions at this complicated, interrelated and potentially ecologically productive site.
Project benefits	Restored predevelopment geomorphic functions, improved riparian and alluvial fan habitat that will provide shade, cover, and food sources for fish. Spawning habitat will be improved by delivering gravel and cobble to the lower portions of the tributaries and side channels of the South Fork in a more natural way.

Opportunity Name	**SFSR #37: Mt. Index Road**
Activity	**Bank armoring, fill removal and revegetation**

Project sponsor	USFS or Snohomish County
Target habitat	Adult and juvenile edge habitat
Current ownership	USFS and Private
Hydrogeomorphic classification	Mainstem riverbank and floodplain
Project size	~100 feet of mainstem riverbank
Strategy	Rock and fill removal and reforestation

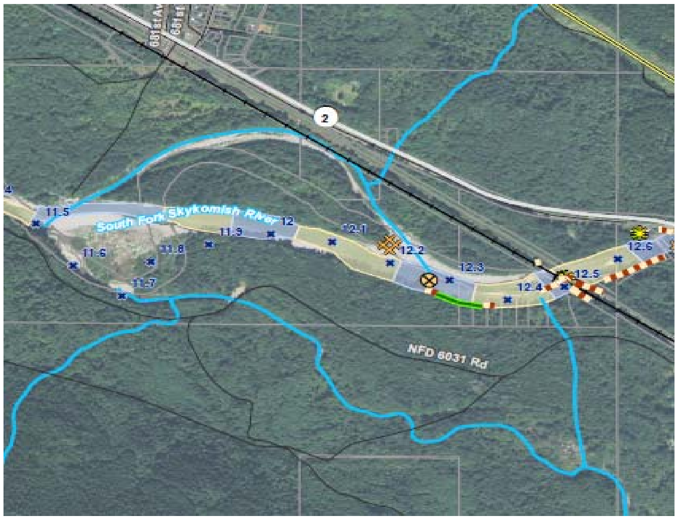
Existing conditions	Near the entrance to the Mt. Index Riversites development, Mt. Index Road has a rock revetment associated with it. Though the revetment does not extend down to the wetted edge of the river, the entire bank has been cleared. The land between the road and the river is in private ownership, but it is not developed. Further downstream the riparian habitat is good condition and owned by USFS. This area is also used extensively by salmonids.
Project description	The project would reforest the slope and remove rock and fill where possible. The project may also acquire the private property to build on the high quality habitat conditions downstream.
Future threats	The unvegetated slope is comprised primarily of alluvium and lacustrine deposits that are prone to failure. Loss of the road to failure would likely trigger emergency actions that could endanger wildlife.
Project rationale	The project would improve riparian conditions while lessening the risk of road closure from slope failure. It would improve conditions in an area highly utilized by salmonids.
Project benefits	Improved riparian habitat that will provide shade, cover, and food sources for fish.

Potential Opportunity	**SFSR #38: RM 0.3**
Location	**Debris removal**

Project sponsor	USFS
Target habitat	Spawning, adult and juvenile side channel and edge habitat
Current ownership	USFS
Hydrogeomorphic classification	Side channel
Project size	~200 feet of side channel
Strategy	Debris removal

Existing conditions	Upstream of the US 2 bridge, there is a mid-channel island that separates the thalweg on the right bank from a major side channel on the left bank. The side channel contains a large amount of deleterious debris, including the remnants of at least one corrugated metal pipe culvert (see photo) that covers potential spawning gravels. The USFS owns the entire left bank in the area. The site is accessible from the power line crossing just downstream of where the debris is located.
Project description	The project would remove the debris that covers spawning gravels in the side channel.
Future threats	Considering the volume and size of the debris, it will likely continue to persist in the stream in this portion of the river heavily utilized by salmonids. Over time, it will continue to impair water quality, and degrade spawnable substrate.
Project rationale	The reach immediately below is used extensively by juvenile salmonids and spawning adults. In particular, side channels are extensively used. The debris in the channel would be straightforward to remove owing to the reasonably good access via the power line crossing just downstream of the site. The removal of the debris would have immediate and lasting habitat benefits.
Project benefits	Predevelopment geomorphic functions, improved water quality, and allow for spawning where it cannot occur now.

Opportunity Name	**SFSR #39: RM 12.0 – 12.4 Left Bank**
Location	**Property acquisition**



Project sponsor	King County
Target habitat	Chinook, steelhead, and bull trout spawning/ rearing (side channel)
Current ownership	Private
Hydrogeomorphic classification	Mainstem South Fork Skykomish
Project size	~ 9.6 acres of combined floodplain/riparian area
Strategy	Property acquisition

Existing conditions	The BNSF railroad crosses the South Fork Skykomish River at approximately RM 12.4. An unnamed stream joins the river on the left bank just downstream of the railroad crossing. The Money Creek Alluvial Fan spans from RM 12.4 to RM 11.6 on the left bank. USFS Road 6031 cuts through the floodplain on the left bank near Money Creek crossing over the unnamed tributary. The road provides access to private residences in this area. A large and active side channel cuts through the floodplain on the right bank from RM 12.2 to RM 11.5. This side channel is fed by a tributary that crosses under US 2. The floodplain on both sides of the river downstream of the bridge is relatively intact, forested, and in good condition. However, anchored logs have been used to armor the left bank at RM 12.3 and debris is in the channel at this location.
Project description	The project would entail purchasing the private parcels on the left bank from RM 12.0 to RM 12.4 and the private parcel on the right bank at RM 12.1 that extends to the railroad. Armoring on the left bank would be removed to allow the floodplain to be reactivated.
Future threats	The right and left banks in these areas are privately owned and could become more developed over time, further impairing predevelopment floodplain processes. Bank armoring has already occurred on the left bank and more armoring could occur to protect existing and future developments, further impairing river edge habitat for fish. Development along the right bank could disconnect or impair the functioning of the side channel on that side of the river.
Project rationale	Since the right and left banks in these areas are privately owned, this area could become more developed over time. Roads and residences already exist within the floodplain and more development would continue to impair predevelopment floodplain processes. This area is particularly valuable Chinook salmon and steelhead and bull trout spawning and rearing because of the Money Creek Fan, tributary streams, and mainstem side channel.
Functions restored/improved	Restoration and preservation of predevelopment floodplain processes and side channel; preservation and improvement of Chinook, steelhead, and bull trout spawning and rearing; and restoration of river edge habitat.

Opportunity Name	SFSR #40: RM 13.8 – 14.0 Right Bank
Location	Property acquisition

Project sponsor	King County
Target habitat	Chinook, steelhead, and bull trout rearing, refugia (side channel)
Current ownership	Private
Hydrogeomorphic classification	Mainstem South Fork Skykomish
Project size	~13.7 acres of combined floodplain/riparian area
Strategy	Property acquisition

Existing conditions	The Miller River crossed under the railroad and discharges to the South Fork Skykomish River at approximately RM 13.9 on the left bank. The railroad abuts the river on the left bank where riprap was placed to secure the bank where it bends sharply to the north. On the opposite side of the river, a side channel passes through the forested floodplain between RM 13.6 and RM 14.0. The right bank from the river to US 2 (see photo) is privately owned and a residence is located near the entrance of the side channel at RM 14.0. The Miller River Alluvial Fan has been highly disturbed and a storm in 2009 blew out the Old Cascade Highway. A full accounting of the conditions of the Miller River Alluvial Fan is summarized in Herrera (2012).
Project description	The project would entail purchasing the private parcel on the right bank of the river between RM 13.8 and RM 14.0 to preserve and protect the entry to the side channel in that area. The residence would be removed.
Future threats	The right bank in this area already contains a residence and more residences could be developed, further impairing predevelopment floodplain processes. The side channel could be blocked due to development or armoring in the future. Due to the railroad, the left bank has been armored and if this bank fails, more rock may be placed in the stream disrupting edge habitat.
Project rationale	Since the right bank in this area is privately owned, this area could become more developed over time, potentially blocking or impairing the functions of the side channel. Alluvial fans are particularly important areas to protect for salmonids as they provide water, gravel, nutrients and food to the mainstem of the South Fork Skykomish River at these locations. In addition, side channel habitat is limited along the mainstem of the river.
Functions restored/improved	Restoration and preservation of predevelopment floodplain processes and side channel; preservation and improvement of Chinook, steelhead, and bull trout spawning and rearing due to removal of the residence.

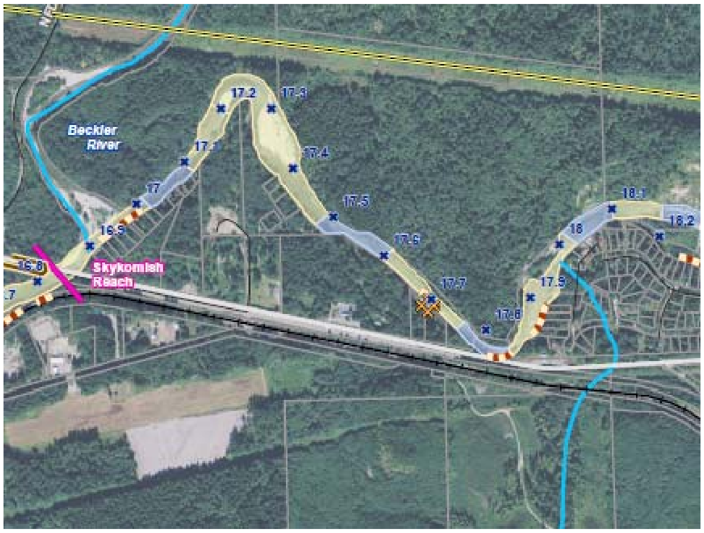
<table>
<tr><td>Opportunity Name</td><td colspan="2">SFSR #41: RM 16.0 Right Bank</td></tr>
<tr><td>Location</td><td colspan="2">Property acquisition</td></tr>
<tr><td colspan="2" rowspan="6">
</td><td>Project sponsor</td><td>King County</td></tr>
<tr><td>Target habitat</td><td>Chinook, steelhead, and bull trout rearing, refugia (side channel)</td></tr>
<tr><td>Current ownership</td><td>Private</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Mainstem South Fork Skykomish</td></tr>
<tr><td>Project size</td><td>~13.7 acres of combined floodplain/ riparian area</td></tr>
<tr><td>Strategy</td><td>Property acquisition</td></tr>
<tr><td>Existing conditions</td><td colspan="3">The City of Skykomish fronts the South Fork Skykomish River from RM 15.5 to RM 16.3 on the left bank. Across the river from the City on the right bank, is an undeveloped parcel that contains a side channel between RM 15.9 to RM 16.1. The undeveloped parcel is bounded on the north by US 2. The side channel is the only refugia within this straightened and highly developed reach of the river. This area also appears to contain wetlands, but a field investigation would be needed to make a final determination of this.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would entail purchasing the private parcel on the right bank of the river between RM 15.9 to RM 16.1 to preserve and protect the side channel.</td></tr>
<tr><td>Future threats</td><td colspan="3">This reach of the river is highly developed and confined by the City of Skykomish and the BNSF railroad on the left bank and US 2 on the right bank. Undeveloped parcels along the waterfront are prime real estate and development of the parcel at RM 16.0 could become developed, impairing or filling in the side channel. Or, riprap armoring may be placed along the right bank at this location, cutting off the side channel.</td></tr>
<tr><td>Project rationale</td><td colspan="3">Since the right bank in this area is privately owned, this area could become more developed over time, potentially blocking or impairing the functions of the side channel. Since side channel habitat is limited in the South Fork Skykomish River overall and particularly in this reach of the river, preserving this area is important for preserving refugia, rearing, and possibly spawning habitat for fish.</td></tr>
<tr><td>Functions restored/improved</td><td colspan="3">Improvement and preservation of predevelopment floodplain processes and side channel habitat; preservation and improvement of Chinook, steelhead, and bull trout rearing and refugia, and possibly spawning habitat.</td></tr>
</table>

Opportunity Name	**SFSR #42: RM 16.9 Right Bank**
Location	**Property acquisition**

Project sponsor	King County
Target habitat	Chinook, steelhead, and bull trout spawning, rearing, refugia (side channel)
Current ownership	Private
Hydrogeomorphic classification	Beckler river confluence, side channel
Project size	~11 acres of combined floodplain/riparian area
Strategy	Property acquisition

Existing conditions	The Beckler River confluence with the South Fork Skykomish River is located at approximately RM 16.9 on the right bank. The river cross under US 2 downstream of the Beckler River confluence at RM 16.8. A side channel cuts through the Beckler River Alluvial Fan floodplain on the left bank of the Beckler River where it bends sharply southeast towards the South Fork Skykomish River. This area is the site of an historic landslide from Beckler Peak that pushed the Beckler River to the west. The floodplain in this area is intact and forested. The right bank of the Beckler River in this area is in private ownership.
Project description	The project would entail purchasing the private parcel on the right bank of the South Fork Skykomish River between RM 16.9 and RM 17.1 and the Beckler River. The purpose would be to preserve and protect the floodplain in this area.
Future threats	The proposed acquisition area contains intact floodplain and riparian habitat within the Beckler River Alluvial fan. This area could be developed which would impair the predevelopment floodplain processes and side channel functions. The Beckler Road already confines the Beckler River at this location and development would cause further impairment of floodplain processes.
Project rationale	Since the right bank is privately owned between the two rivers at this location, it could become more developed over time, potentially blocking or impairing the functions of the side channel and the floodplain processes. Alluvial fan areas are particularly important areas for salmonids as they provide water, gravel, nutrients and food to the mainstem of the South Fork Skykomish River at these locations.
Functions restored/improved	Restoration and preservation of predevelopment floodplain processes and side channel; preservation and improvement of Chinook, steelhead, and bull trout spawning and rearing habitat.

Opportunity Name	**SFSR #43: RM 17.4 – 18.0 Right Bank**
Location	**Property acquisition**



Project sponsor	King County
Target habitat	Chinook, steelhead, and bull trout rearing, refugia (side channel)
Current ownership	Private
Hydrogeomorphic classification	Mainstem South Fork Skykomish; side channel
Project size	~66 acres of combined floodplain/riparian area
Strategy	Property acquisition
Existing conditions	Anthracite Creek empties into the South Fork Skykomish River at RM 17.9 on the left bank. Across the river on the right bank between RM 17.4 and 18.0, two side channels cut through an undeveloped forested floodplain and riparian area. The side channel area is privately owned and is bounded to the north by the BPA power line corridor. There are developed parcels on the left bank of the river at this location.
Project description	The project would entail purchasing the private parcel on the right bank of the river between RM 17.4 to RM 18.0 to preserve and protect the side channel and the floodplain.
Future threats	There is development along the left bank of the river at this proposed project location. This development pressure could extend to the other side and the floodplain/riparian area could become developed. Development on the right bank at this location could fill in the side channel and impair its functions. Additionally or alternatively, riprap armoring may be placed along the right bank at this location, cutting off the side channel.
Project rationale	Since the right bank in this area is privately owned, this area could become more developed over time, potentially blocking or impairing the functions of the side channel. Since side channel habitat is limited in the South Fork Skykomish River overall, preserving this area is important for preserving refugia, rearing, and possibly spawning habitat for fish.
Functions restored/improved	Improvement and preservation of predevelopment floodplain processes and side channel habitat; preservation and improvement of Chinook, steelhead, and bull trout rearing and refugia, and possibly spawning habitat.

Opportunity Name	**TR #1: Foss River Alluvial Fan**
Activity	**Property acquisition, road relocation, culvert placement**

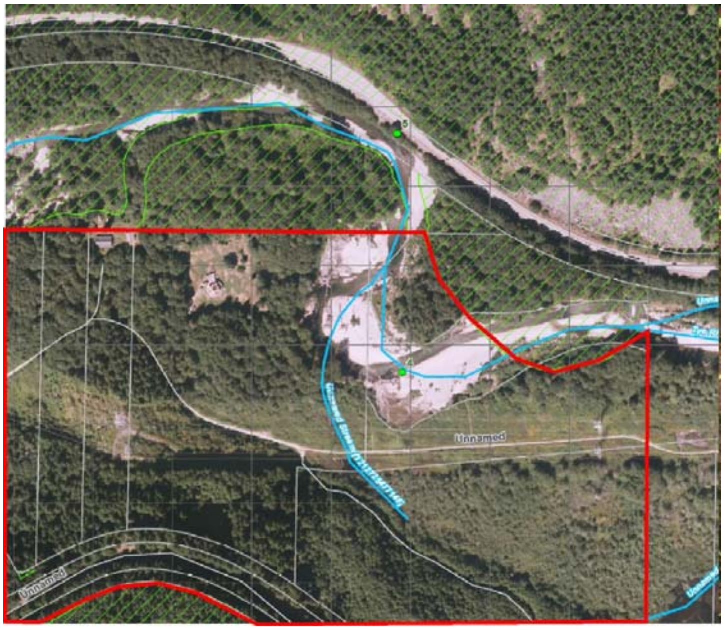
Project sponsor	King County
Target habitat	Chinook and steelhead spawning, juvenile salmonid rearing
Current ownership	King County and Private
Hydrogeomorphic classification	Alluvial fan
Project size	22 acres
Strategy	Property acquisition, road relocation

Existing conditions	Foss River Road bisects the Foss River Alluvial Fan just upstream from the confluence of the Foss River and Tye River. The alluvial fan is incised and naturally constrained. However, the road and the fill associated with it unnaturally directs the flow to two locations: the current main channel and a low spot near the junction of Foss River Road and FS Road 6810 (see picture). The low spot is not culverted, and all of the flow currently overtops the road. Though an avulsion is not imminent at this time, it is likely that as the alluvial fan aggrades more flow will be directed to the road junction. Continued overtopping will act to scour the road prism as seen in the picture above.
Project description	The project would acquire properties on the alluvial fan and relocate the road such that it does not cross an active portion of the alluvial fan, or if it does, it is bridged over appropriate side channels.
Future threats	The Foss River has been constrained by the construction of the Foss River Road. With time, aggradation in the active portion of the channel will direct more flow over the Foss River Road and FS Road 6810 road junction. With time, an avulsion similar to what occurred on the Miller River at the Old Cascade Highway could occur here. The difference being primarily that the Foss River Road is the only road access for several private landowners.
Project rationale	The Foss River Alluvial Fan is important habitat for three listed species. The rationale is to reengage the Foss River Alluvial Fan and the rearing habitat it potentially possesses and to prevent future access disruptions and environmental impacts from flooding. Improvement of the road configuration may increase channel length and alluvial fan activity also expanding spawning habitat area.
Functions restored	Restored and increased rearing for a variety of juvenile salmonids, possibly increased spawning habitat for Chinook, steelhead and bull trout, and partially restored predevelopment geomorphic processes, or completely restored geomorphic processes if combined with other opportunities that occur in the vicinity of the alluvial fan.

Opportunity Name	**TR #2: RM 1.2 Tributary**
Activity	**Culvert replacement, road relocation or removal**

Project sponsor	USFS
Target habitat	Juvenile salmonid rearing
Current ownership	USFS
Hydrogeomorphic classification	Tributary alluvial fan
Project size	200 feet of tributary
Strategy	Culvert replacement, road relocation or removal

Existing conditions	A small unnamed tributary enters the Tye River at RM 1.2, just after crossing through a collapsed culvert under FS Road 6810. The tributary possesses a low-gradient alluvial fan upstream from the road, which now consists primarily of an intact, but impounded (by the road), forested wetland. The downstream end of the culvert is perched several feet above existing grade.
Project description	The project would replace the culvert either with a much larger box culvert or bridge. If performed in conjunction with Opportunity #3, the road could be removed altogether.
Future threats	The small tributary alluvial fan will continue to be cut off by FS Road 6810 and preclude juvenile salmonids present in the Tye River from accessing the high quality off-channel alluvial fan complex. The culvert is collapsed and may need to be replaced soon to ensure the viability of the road.
Project rationale	The high quality habitat upstream of the road is currently inaccessible during most if not all flow conditions. Replacing and expanding the culvert would reengage the aluvial fan and floodplain upstream of the road, expanding high quality rearing habitat.
Functions restored	Restored juvenile salmonid passage, increased access to intact off-channel habitat, and restored predevelopment geomorphic processes.

<table>
<tr><td>Opportunity Name</td><td colspan="3">TR #3: Upstream Beckler Peak Rock Avalanche</td></tr>
<tr><td>Activity</td><td colspan="3">Property acquisition and road removal</td></tr>
<tr><td colspan="2" rowspan="6">
</td><td>Project sponsor</td><td>USFS</td></tr>
<tr><td>Target habitat</td><td>Chinook and steelhead spawning and rearing</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Floodplain and side channels</td></tr>
<tr><td>Project size</td><td>74 acres</td></tr>
<tr><td>Strategy</td><td>Property acquisition, road removal</td></tr>
<tr><td>Existing conditions</td><td colspan="3">Several private properties exist at the end of FS Road 6810 (outlined in red). These properties occupy a particularly active reach of the Tye River immediately upstream of (and historically impounded by) the Beckler Peak Avalanche. There are several structures in former river channels and in the floodplain at large. The areas around these structures have been cleared.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would be to acquire the properties at the end of FS Road 6810 and remove all structures from the floodplain, including the end of FS Road 6810. Cleared areas would be replanted.</td></tr>
<tr><td>Future threats</td><td colspan="3">Although access was not obtained to the properties, it is evident from lidar that the structures on these properties are in the floodplain of the Tye River. Therefore it is possible, even likely, that flood protection structures will be constructed to protect these homes in the future. These structures will disrupt geomorphic processes and endanger and preclude juveniles from rearing in the area.</td></tr>
<tr><td>Project rationale</td><td colspan="3">The structures and deforestation in the Tye River floodplain impact a critical reach of the river upstream of the Beckler Peak Rock Avalanche. The stream is particularly dynamic in this reach and, besides the development in the floodplain, surrounding conditions are relatively good. Acquiring the properties would enable reconnection and reforestation of the floodplain, as well as being able to remove the end of FS Road 6810, which is also in the floodplain.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Improved floodplain connectivity and riparian vegetation, increased and improved juvenile salmonid rearing habitat, and restored predevelopment geomorphic processes.</td></tr>
</table>

Opportunity Name	**TR #4: RM 1.9**
Activity	**LWD placement**

Project sponsor	WSDOT or USFS
Target habitat	Chinook and steelhead rearing habitat
Current ownership	WSDOT and USFS
Hydrogeomorphic classification	Riverbank
Project size	350 feet of riverbank
Strategy	LWD placement

Existing conditions	The Tye River upstream of the Beckler Peak Rock Avalanche is highly meandered due to the kink in the profile induced by the avalanche. In fact, it is one of the most dynamic areas in the entire South Fork Skykomish basin. At RM 2.0, the stream is now pinned against US 2, which is similarly pinned against the Beckler Peak slope. A large floodplain, with a relatively large amount of LWD exists on the other side of the valley. The area is developed by a few private landowners (see Opportunity #3). Despite the high potential for floodplain engagement and channel migration, the thalweg of the Tye River is trapped next to the road, as often occurs where deforested banks are placed with riprap.
Project description	The project would be to supplement the bank with LWD to increase hydraulic complexity and cover. Without implementing Opportunity #3 concurrently, a significant landowner outreach strategy would also be required.
Future threats	Without intervention, it is likely that the river will remain entrained against the rock bank of US 2. It is likely that the rock will gradually be removed and require maintenance over time, further impacting habitat in this critical reach.
Project rationale	The reach immediately above the Beckler Peak Rock Avalanche is a key rearing and spawning area for Chinook, coho and steelhead. The project would increase engagement of the floodplain, increase hydraulic complexity of the thalweg, and improve in the rearing and edge habitats adjacent to the road.
Functions restored	Improved edge habitat for migrating salmonids, restored floodplain and side channel connection (particularly if combined with TR #3).

Opportunity Name	TR #5: RM 2.4
Activity	**LWD placement, road relocation**

Project sponsor	WSDOT or USFS
Target habitat	Chinook and steelhead spawning and rearing
Current ownership	WSDOT and USFS
Hydrogeomorphic classification	Riverbank
Project size	350 feet of riverbank
Strategy	LWD placement, road relocation

Existing conditions	The Tye River upstream of the Beckler Peak Rock Avalanche is highly meandered due to the kink in the profile induced by the avalanche. In fact, it is one of the most dynamic areas in the entire South Fork Skykomish basin. At RM 2.7, the stream is now pinned against US 2 on the right bank. The road is primarily on fill and could be relocated further upslope. There is a large undeveloped floodplain on t he left bank. The floodplain is undeveloped, though in private hands.
Project description	The project would be to place LWD to roughen the right bank and push the river towards the intact left bank floodplain. These actions would increase hydraulic complexity and cover on the right bank. Road relocation should also be investigated.
Future threats	Without intervention, it is likely that the river will remain entrained against the rock bank of US 2. It is likely that the rock will gradually be removed and require maintenance over time, further impacting habitat in this critical reach.
Project rationale	The project would increase the engagement of the left bank floodplain and left bank side channels, expanding rearing habitat for all juvenile salmonids. If side channels are completely reengaged, it could expand spawning habitat as well. Finally the project would also generate large amounts of wood that could serve to supplement the relatively poor supply of wood the lower South Fork. Relocating the road would further expand floodplain habitat.
Functions restored	Partial restoration of predevelopment geomorphic processes, improved cover and hydraulic complexity, increased wood supply.

Opportunity Name	**TR #6: RM 4.1 Tributary Colluvial Fan**
Activity	**Culvert removal, bridge placement**

Project sponsor	WSDOT or USFS
Target habitat	Chinook and steelhead spawning
Current ownership	WSDOT and USFS
Hydrogeomorphic classification	Tributary colluvial fan
Project size	~5 acres
Strategy	Hazard analysis

Existing conditions	An colluvial fan exists on the north side of US 2 near RM 4.5. Several channels cross the road. The largest channel is spanned with a 10-foot bottomless box culvert, even though the active stream width at this location appears to be about 20 feet. Two side channels are even more undersized, generally spanned with culverts only 1 foot in diameter for >5 foot active channels. Sediment in all of the channels is generally sized cobble and larger (i.e., larger than the smaller culverts), though no perennial flow was found on the summertime visit. Sedimentological evidence, and the placement of a Jersey barrier in the configuration shown in the picture above indicate that overtopping of the road is common.
Project description	The project would analyze the geomorphic character of the colluvial fan and propose a general road crossing strategy for the highway. The road crossings would be capable of conveying all runoff and sediment without causing overtopping or clogging of the crossings.
Future threats	The potential for an avulsion of the main channel is significant, which could cause the road to fail and create an emergency repair that would have detrimental impacts to Chinook and steelhead habitat. Even regular overtopping inputs hydrocarbons and other roadway pollution directly into what would otherwise be a pristine mountain stream.
Project rationale	The project would evaluate the hazards of the colluvial fan and propose a road-crossing strategy that would eliminate highway overtopping and crossing clogging.
Functions restored	Partial restoration of predevelopment geomorphic conditions, reduced embedment to Chinook and steelhead spawning areas, improved water quality.

Opportunity Name	**TR #7: Deception Falls Side Channel**
Activity	**Hazard analysis**

Project sponsor	USFS
Target habitat	Resident trout
Current ownership	USFS
Hydrogeomorphic classification	Tributary alluvial fan
Project size	1300 feet of side channel
Strategy	Hazard analysis

Existing conditions	The Deception Falls rest area has a network of trails throughout the Deception Creek Alluvial Fan. Currently a side channel exists that transits the entire area over about 1300 feet. It appears that flows in the side channel are beginning increase, making an avulsion possible, if not imminent. The trail network crosses the side channel in several locations and has already shown signs of damage and disturbance to the bed of the side channel from hikers.
Project description	The project would examine the risks of an avulsion of the Tye River at Deception Falls and environmentally sound means of either preventing it or ameliorating the impacts from it.
Future threats	The primary threat is a wholesale avulsion of the Tye River through the side channel. This would likely destroy several bridges in the site and either extremely limit access to the area or necessitate emergency in-water construction that would have impacts to resident trout. Even increased or perennial flow to the side channel could increase disturbance to both the water column and the bed from hikers.
Project rationale	Deception Falls is a popular summertime rest area, where the public gets a chance to enjoy the beauty of the central Cascades. However, were the Tye River to avulse or simply split flow more equally between side channel and the existing main channel (as seems to be happening), access would be severely compromised and could only be regained by a large amount of trail construction, which would have impacts to resident trout.
Functions restored	Reduced physical disturbance to resident trout habitat from hikers and tourists.

Opportunity Name	TR #8: Deception Falls Pedestrian Bridge
Activity	Bridge replacement

Project sponsor	USFS
Target habitat	Resident trout habitat
Current ownership	USFS
Hydrogeomorphic classification	Tributary stream bank
Project size	~100 feet
Strategy	Bridge replacement

Existing conditions	A structural footbridge constricts Deception Creek and sends high waters over the rock and concrete access trail and through informal drain tiles shown in the picture above. Otherwise the site is in nearly pristine condition.
Project description	The project would entail expanding the bridge so that it does not constrict the flow and route it to undesirable areas (i.e., the trail).
Future threats	The stream will continue overtop the trail and may avulse, compromising access to the well-used Deception Creek Trail and likely necessitating in-water emergency work that would have detrimental environmental impacts.
Project rationale	The current crossing over Deception Creek is constricted and sends floodwaters down the trail, introducing fine sediment and potentially human litter to the stream. Improving the crossing will eliminate this introduction, and improve edge habitat.
Functions restored	Improved edge and riparian habitat for resident trout, lessened disturbance of left bank floodplain at high flows.

Opportunity Name	TR #9: RM 6.6 Tributary		
Activity	**LWD placement, road relocation**		
		**Project sponsor**	WSDOT or USFS
		Target habitat	Resident trout
		Current ownership	WSDOT and USFS
		Hydrogeomorphic classification	Riverbank
		Project size	100 feet of river bank
		Strategy	LWD placement, road relocation
Existing conditions	At RM 7.3, the Tye River is sandwiched between US 2 and Old Cascade Highway. Neither bank has fully intact riparian corridor. Both banks have some degree of rock armoring.		
Project description	The project would supplement one or both of the existing rock revetments with LWD. The placement of the LWD would need to be coordinated between the USFS and WSDOT. Relocating the road to higher ground should also be investigated.		
Future threats	This reach is highly impaired, and lacks riparian cover and hydraulic complexity. The reach currently effectively acts like a drainage ditch and will continue to do so in the future without intervention.		
Project rationale	While the reach in question only possesses resident trout, this reach is probably important for these species, and the impairments to the stream are severe. LWD would add complexity and cover to this highly constrained reach.		
Functions restored	Improved complexity and cover for resident trout.		

<table>
<tr><td>Opportunity Name</td><td colspan="3">TR #10: RM 7.1 Tributary</td></tr>
<tr><td>Activity</td><td colspan="3">Armoring removal, crossing replacement or removal</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>King County or WSDOT</td></tr>
<tr><td>Target habitat</td><td>Resident trout</td></tr>
<tr><td>Current ownership</td><td>Private and WSDOT</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Tributary</td></tr>
<tr><td>Project size</td><td>200 feet of tributary</td></tr>
<tr><td>Strategy</td><td>Armoring removal, crossing replacement or removal</td></tr>
<tr><td>Existing conditions</td><td colspan="3">A small unnamed tributary drains the ridge that separates Deception Creek from Surprise Creek on the south side of US 2. As it nears US 2 it is spanned by an informal plank bridge mantled with placed riprap. The crossing is severely undersized and sends excess floodwater down the slope directly onto and over US 2. A channel is beginning to form through the road grade on the other (north) side.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would either remove the crossing and rock entirely or reconstruct the crossing such that it does not cause floodwater to pour over the roadway.</td></tr>
<tr><td>Future threats</td><td colspan="3">If the crossing becomes further clogged, a full avulsion of the stream over and through the roadway could occur. This would necessitate an emergency action that would have an array of detrimental environmental impacts.</td></tr>
<tr><td>Project rationale</td><td colspan="3">The project would be small and simple (possibly handled by King Conservation District) and have benefits to the private landowner (improved access), to WSDOT and the driving public (reduced risk to US 2), and to the environment (by reducing overflow of water over the highway and fine sediment to the Tye River).</td></tr>
<tr><td>Functions restored</td><td colspan="3">Reduction in fine sediment from trail and road overtopping, some restoration of predevelopment conditions, improved water quality and processing of flood flows.</td></tr>
</table>

Opportunity Name	TR #11: Surprise Creek Railroad Culvert
Activity	Armoring removal
	
Project sponsor	BNSF
Target habitat	Resident trout
Current ownership	BNSF
Hydrogeomorphic classification	Alluvial fan
Project size	About 1 acre
Strategy	Culvert replacement and fill removal, railroad relocation
Existing conditions	The BNSF railway exists on a large fill prism in the vicinity of its crossing of Surprise Creek. The road prism is particularly large here to accommodate the grade necessary to cross Stevens Pass. The fill cuts off a large amount of floodplain (about 15 acres). In this fill, the railway crosses Surprise Creek with two tall, but narrow box culverts, each about 20 feet in width. This is a constriction to Surprise Creek, which has an active channel width of at least 80 feet at high water at this location. The culvert has impounded sediment above it, complicating Surprise Creek Trailhead access road bridge upstream from it (see Opportunity #12).
Project description	The project would replace the culvert over Surprise Creek with a larger bridge. Railroad relocation should be investigated, but will likely be prohibitively expensive because of the proximity and approach to the opening of the Cascade Tunnel.
Future threats	Eventually the Surprise Creek crossing will aggrade to the point where Surprise Creek will avulse to the next stream system down the valley (about 3000 feet downstream). If this were to occur, Surprise Creek would run parallel along the fill, greatly simplifying the channel, reducing riparian cover, and exposing the creek to railway detritus for a great length.
Project rationale	Although there are only resident trout in Surprise Creek, the impact from the railway at this location is large. The small crossing, though not a risk to the railway in general, complicates ecological management of Surprise Creek, and access to the Surprise Creek Trailhead. The fill cuts off a large amount of intact forested floodplain.
Functions restored	Some restoration of predevelopment geomorphic functions, improved capacity for flood and debris flows.

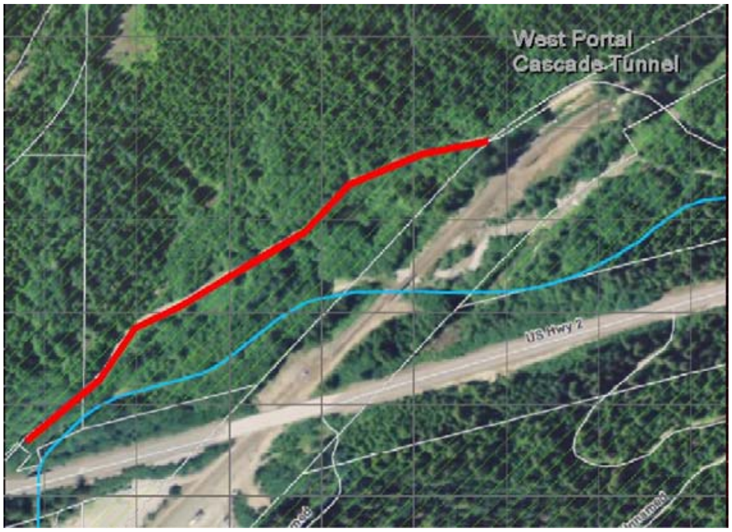
Opportunity Name	**TR #12: Surprise Creek FS Road Bridge**
Activity	**Bridge replacement, road relocation or removal**

Project sponsor	USFS
Target habitat	Resident trout
Current ownership	USFS
Hydrogeomorphic classification	Alluvial fan
Project size	About 1 acre
Strategy	Bridge replacement, road relocation or removal

Existing conditions	A 60-foot bridge on the Surprise Creek Trailhead access road spans Surprise Creek upstream of its confluence with the Tye River. The road appears to be only used for access to the Surprise Creek trailhead and the BPA corridor. As the road is a through-road, the BPA corridor can also be accessed from the west. The bridge is undersized as can be seen in the large amount of deposition upstream from the bridge, and signs of overtopping of the road on its flanks, though some of this may be due to the even small constriction at the railroad (see Opportunity #12). There is also some amount of fill in the floodplain associated with the abutments.
Project description	The project would either replace the bridge with a larger and higher bridge or it would remove the road in this section and relocate the trailhead to the east side of the creek. The creek could then be crossed via a much lower impact (and less expensive) footbridge.
Future threats	Given that the bridge already exhibits signs of overtopping and is accumulating a large sediment load upstream, it is expected that the creek will more frequently overtop the road causing fine sediment and auto pollution to contaminate what is otherwise a pristine mountain stream. Overtopping the roadway may also cause complete loss of the road, impairing access and possibly necessitating environmentally harmful emergency actions.
Project rationale	Replacing the bridge or removing the crossing entirely would expand floodplain connection of Surprise Creek Alluvial Fan. Though it would only benefit resident, this is a key habitat feature on the upper Tye River, and one that would be easily achievable (i.e., cheap), particularly if the trailhead is relocated and the road is removed entirely.
Functions restored	Predevelopment conditions (some, if bridge replaced; complete, if road removed), improved water quality and capacity for flood and debris flows.

Opportunity Name	TR #13: BNSF Staging Area		
Activity	**Fill, armoring and debris removal, reforestation**		
		**Project sponsor**	USFS or BNSF
		Target habitat	Resident trout
		Current ownership	USFS and BNSF
		Hydrogeomorphic classification	Floodplain
		Project size	5 acres of floodplain
		Strategy	Fill, armoring, and debris removal, reforestation
Existing conditions	The Surprise Creek Trailhead access road crosses the Tye River immediately downstream of the uppermost US 2 crossing of the Tye River. The US 2 does not impinge significantly on the river, but the FS Road contains a significant amount of fill, some of which appears to contain construction and other plastic waste. The 60-foot-long Surprise Creek Trailhead access road bridge is serious risk of failure, with both abutments being undermined and layered with several generations of riprap and construction debris. In addition, much of the riparian vegetation has been removed to accommodate a large gravel staging lot.		
Project description	The project would install a new larger bridge over the Tye River that would span much if not all of the floodplain. In installing the bridge, the waste that has been dumped on both of sides of the river would be removed and replanted, including at least a 50-foot buffer in the staging lot.		
Future threats	The existing bridge is severely undersized and will likely fail in the future causing an emergency action to preserve access to the staging lot and trailhead. These actions would further impair habitat in this reach.		
Project rationale	The Surprise Creek Trailhead access road bridge, and the waste that surrounds it, contributes fine material, possibly deleterious in nature, to the river. Though impacts would only be to resident trout (i.e., not salmonids), they are likely severe. They can also be prevented by simple waste removal and the construction of standard 110-foot bridge.		
Functions restored	Improved resident trout habitat, some restoration of predevelopment conditions, improved water quality and capacity for flood and debris flows.		

Opportunity Name	TR #14: FS Road 6099
Activity	Fill and/or road relocation or removal



Project sponsor	USFS
Target habitat	Resident trout
Current ownership	USFS
Hydrogeomorphic classification	Floodplain
Project size	3,000 feet of floodplain edge
Strategy	Fill and/or road relocation or removal

Existing conditions	FS Road 6099 skirts the right bank floodplain of the Tye River upstream of the highest crossing of the river by US 2. FS Road 6099 currently occupies the edge of the Tye River floodplain immediately north of its junction with US 2 to the west portal of the BNSF Cascade Tunnel. It is located on fill for much of this length (see red line on picture for extent of fill). Though the area is extremely mountainous, the slopes in the immediate vicinity of the road are not particularly steep and it is possible to relocate the roadway such that it does not occupy the floodplain.
Project description	The project would relocate FS Road 6099 further west outside of the Tye River floodplain and remove the fill currently in the floodplain.
Future threats	None.
Project rationale	Nearly the entire length of the road is on fill. Removing the fill and relocating the road outside of the floodplain would expand rearing habitat for resident trout.
Functions restored	Partially restored predevelopment geomorphic conditions, and expanded rearing habitat for resident trout.

Opportunity Name	**TR #15: Tunnel Tributary**
Activity	**Pipe, barrier and road removal**
	
Project sponsor	BNSF or USFS
Target habitat	Adult and juvenile salmonid rearing and refugia
Current ownership	BNSF and USFS
Hydrogeomorphic classification	Tributary
Project size	1,000 feet of tributary
Strategy	Pipe, barrier, and road removal
Existing conditions	A small tributary to the Tye River at the west entrance to the BNSF Cascade Tunnel has been placed in a half-pipe for more than 500 feet above the tunnel entrance (see photo at left above). The tributary then flows through a culvert underneath the FS Road 6099, which dead-ends less than a mile north. The channel proceeds downslope to a gate attached to the side of the Cascade Tunnel entrance. The gate (shown at right above) appears to be largely fish impassable. The surrounding landscape is largely undeveloped and pristine.
Project description	The project would reroute the stream away from the tunnel entrance through the pristine forest owned by the USFS to the Tye River upstream of the tunnel, circumventing the existing pipe and gate. The project would also consider the further removal of FS Road 6099.
Future threats	The gate at the tunnel prevents resident fish from using one of the largest unnamed tributaries to the upper Tye River, which is surrounded by intact forest. Above the gate and the Old Cascade Highway the stream is literally disconnected from the landscape, impairing any natural ecological function of the stream. This not only prevents a range of aquatic wildlife from using what would otherwise be a pristine mountain stream, it also disrupts the hydrologic interaction with the hillside. This disconnection likely affects all upland wildlife on this slope.
Project rationale	The unnamed tributary is severely and unnecessarily altered. And while the benefit would only be to non-listed species, the impacts are locally extreme. Further existing infrastructure is unlikely to survive large flood events, and will likely necessitate emergency actions. These actions would disrupt all wildlife nearby and potentially discharge large quantities of fine sediment to the stream.
Functions restored	Restored fish access to one of the largest unnamed tributaries on the upper Tye River, and restoration of predevelopment geomorphic functions.

APPENDIX B

South Fork Skykomish River Salmon Habitat Information Review and Future Studies Scoping Summary Report

SOUTH FORK SKYKOMISH RIVER SALMON HABITAT INFORMATION REVIEW AND FUTURE STUDIES SCOPING SUMMARY REPORT

KING COUNTY, WASHINGTON

Prepared for
King County Department of Natural Resources and Parks
Water and Land Resources Division
and
USDA Forest Service
Mt. Baker-Snoqualmie National Forest

Prepared by
Herrera Environmental Consultants, Inc.

HERRERA

SOUTH FORK SKYKOMISH BASIN SALMON HABITAT INFORMATION REVIEW AND FUTURE STUDIES SCOPING SUMMARY REPORT

KING COUNTY, WASHINGTON

Prepared for
King County Department of Natural Resources and Parks
Water and Land Resources Division
201 S. Jackson Street, Suite 600
Seattle, Washington 98104

and
USDA Forest Service
Mt. Baker-Snoqualmie National Forest

Prepared by
Herrera Environmental Consultants, Inc.
2200 Sixth Avenue, Suite 1100
Seattle, Washington 98121
Telephone: 206/441-9080

April 30, 2013

CONTENTS

TABLES

FIGURES

PROJECT OBJECTIVES AND SCOPE

King County, in partnership with USFS, is leading a salmon habitat restoration feasibility study in the South Fork Skykomish River basin. The feasibility study is supported by mitigation funds from a Natural Resource Damage Assessment (NRDA) in accordance with the Washington State Model Toxics Control Act resulting from decades of oil contamination in the Town of Skykomish. Because the desired habitat restoration is mitigation under NRDA program, the study is to be performed in collaboration with the Washington State Department of Ecology (Ecology) and the USFS. This feasibility study aims to generate a prioritized list of river restoration projects and conceptual designs within the South Fork Skykomish River basin in the MBSNF.

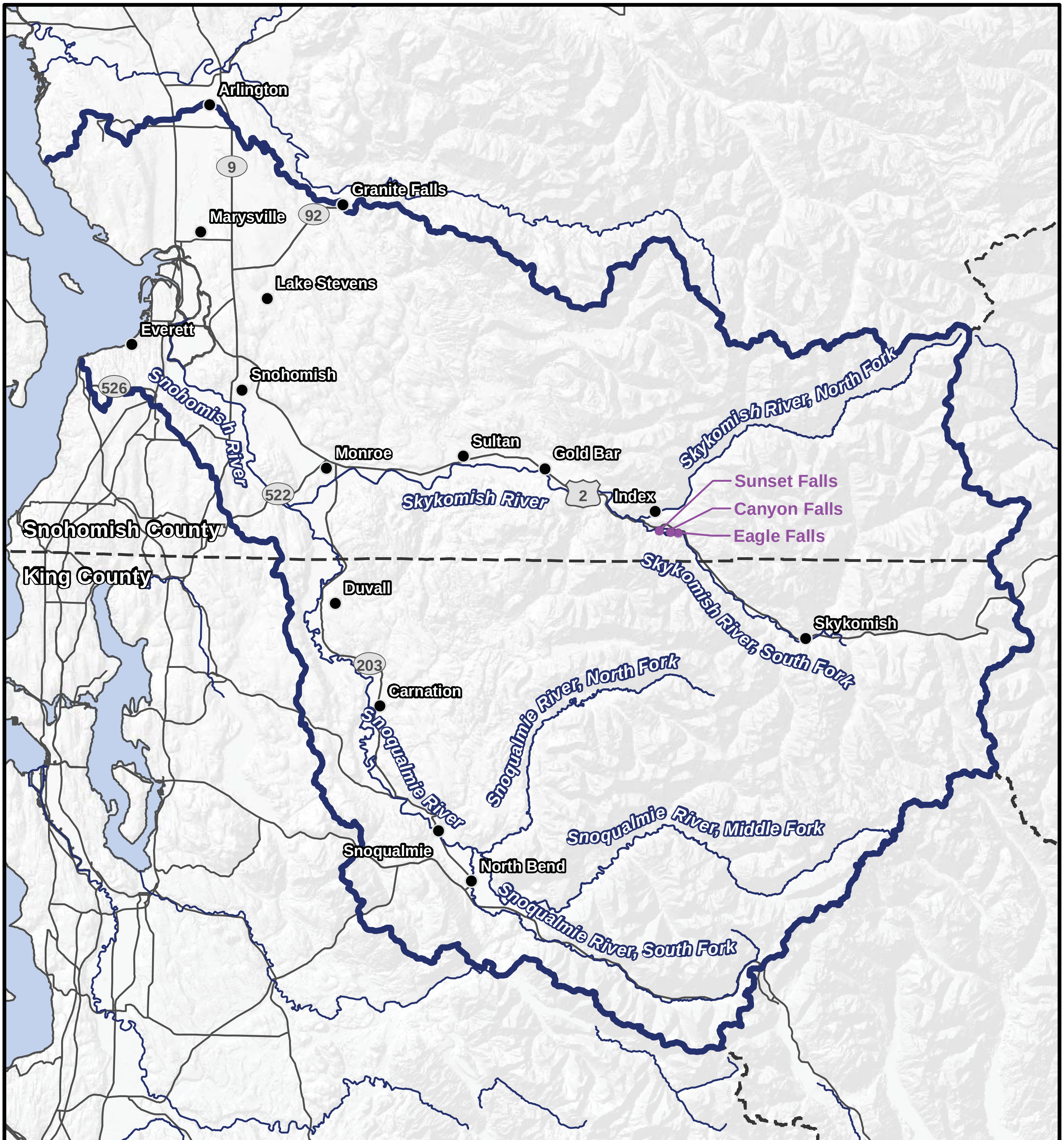
Prior to implementing the full feasibility study, King County contracted with Herrera to provide: (1) a summary of existing data and information resources, and data gaps, and (2) a preliminary estimate of costs for a list of possible studies that will fill the data gaps and set the foundation for the feasibility study. This document summarizes both Herrera efforts.

Project setting information on the South Fork Skykomish watershed is presented first, followed by the methods and results of this existing information summary study. Following that introductory material, each major type of data required to evaluate restoration feasibility is described. For each type of data, the existing data is described and data gaps are summarized. Preliminary costs to perform additional studies to fill the data gaps are described. This data and preliminary cost estimates will be used by King County to prioritize data collection efforts under the larger feasibility project.

Project Setting

The Snohomish River drains into Puget Sound near Everett, Washington. The Snohomish Basin is Water Resource Inventory Area (WRIA) 7 and is 1,856 square miles in area; it is the second largest basin draining into Puget Sound after the Skagit basin (Figure 1). The North Fork Skykomish (HUC 1711000904) and South Fork Skykomish (HUC 1711000903) Watersheds lie within the Skykomish sub-basin of the Snohomish basin. These two watersheds combined are typically referred to as the Skykomish Forks. The Skykomish Forks is one of the Focused Watersheds on the Mt. Baker-Snoqualmie National Forest (MBSNF) that is managed by the United States Forest Service (USFS) (USFS 2009b). Within the Skykomish Forks, the Upper South Fork Skykomish subwatershed became a priority watershed in 2011 under a recent national process known as Watershed Condition Framework.

The South Fork Skykomish watershed spans 77,030 acres, with about 85 percent under management by the MBSNF (USFS 1995b). The Beckler, Foss, and Tye rivers flow into the South Fork Skykomish near the Town of Skykomish, Washington. The Tye River is an extension of the South Fork Skykomish upstream of its confluence with the Foss River. The Miller River drains to the South Fork Skykomish west of the Town of Skykomish. Most of the private and



Legend

- City
- River
- Highway
- County
- Basin boundary

Figure 1. Snohomish River Basin South Fork Skykomish Feasibility Project, King County, Washington

N

0 8.5 17

Miles

HERRERA

K:\Projects\10-04766-008\Project\snohomish_basin.mxd (6/4/2012) state lands in this watershed occur in the lowermost portions of the river systems, with some relatively small private in-holdings (e.g., patented mine sites) distributed farther upstream.

According to USFS (2009b), no anadromous fish species historically utilized habitat in the South Fork Skykomish River above Sunset, Canyon, and Eagle Falls, natural migration barriers located about 2 river miles above the confluence of the North and South Forks of the Skykomish River (Figure 1). In 1958, the Washington State Department of Fisheries (WDF – now the Washington Department of Fish and Wildlife [WDFW]) began a trap-and-haul facility, which currently operates July through December. It releases all the fish it traps to locations upstream of Sunset, Canyon, and Eagle Falls. Escapement records have been kept for the fish hauled around the falls since 1958. The trap-and-haul operation has allowed establishment of several anadromous species including Chinook salmon, coho salmon, pink salmon, chum salmon, steelhead, bull trout, and Dolly Varden. Sockeye salmon are also trucked around the falls, but they are likely straying from populations in neighboring river basins (i.e., Skagit and Lake Washington stocks) (USFS 1995b). All of these anadromous species, with the exception of steelhead, are derived from naturally-reproducing populations. The (summer) steelhead are out-plants from the WDFW fish hatchery on the Wallace River near Gold Bar, Washington.

The long-term annual average of returns for fish at the trap-and-haul facility ranges from approximately 20,000 for coho to 7,000 for pink (odd number years only), 600 to 800 for Chinook and for steelhead, and about 60 or less for chum, native charr, and some stray sockeye (USFS 2009b; WDFW 2002). Annual returns for coho and pink salmon (odd number years only) have increased substantially over the last decade compared to these long-term averages, averaging about 30,000 and 15,000 fish, respectively.

All of the lands in the National Forest system in the Skykomish Basin, including those drained by the Miller, South Fork Skykomish, and North Fork Skykomish River systems, have been designated Tier 1 Key Watershed in the Northwest Forest Plan (USDA FS and USDI BLM 1994), which serves as crucial refugia for maintaining and recovering the at-risk stocks of Chinook, bull trout, and steelhead in the Skykomish system. Widespread impacts to estuarine habitats, as well as instream, riparian, and upland areas (especially downstream of the Forest boundary), have resulted in large reductions in the quantity and quality of spawning and rearing habitats of resident and anadromous fish stocks within the North and South Fork Skykomish watersheds, as well as elsewhere within the Snohomish Basin (Snohomish Basin Salmonid Recovery Technical Committee 1999, 2002; Snohomish Basin Salmonid Recovery Technical Committee and NMFS 2005; Snohomish Basin Salmon Recovery Forum 2005; USFS 1994, 1995a, 1995b, 2009b). Therefore, restoration projects are being and will be implemented to restore this crucial habitat within these areas in the Skykomish Basin.

Geographic Scope of the Project

The geographic scope of this information summary report (referred to as study area)includes the following stream segments (Figure 2):

- The entire main stem of the South Fork Skykomish River between its confluence with the North Fork Skykomish River and the Tye River
- The entire Beckler River, including the lower 3 miles of Rapid River

- The entire Tye River, including the lowest mile of Surprise and Deception creeks
- The lower Foss River up to the FS 68 Bridge on the East Fork and up to Trout Lake on the West Fork
- The lower Miller River up to FS 6412 Bridge on the East Fork and up to the confluence of Coney Creek on the West Fork

Methods for Data Review

Herrera collected and reviewed information regarding salmon habitat conditions, watershed conditions, and restoration for the South Fork Skykomish River basin from King County and from other organizations. Data gaps that require further study were identified as part of this review. The findings of this review are summarized in the *Data and Information Review Results* section of this report.

Herrera contacted 11 organizations selected in cooperation with King County to determine if they had additional information and data regarding salmon and salmon habitat in the South Fork Skykomish River basin. These organizations included:

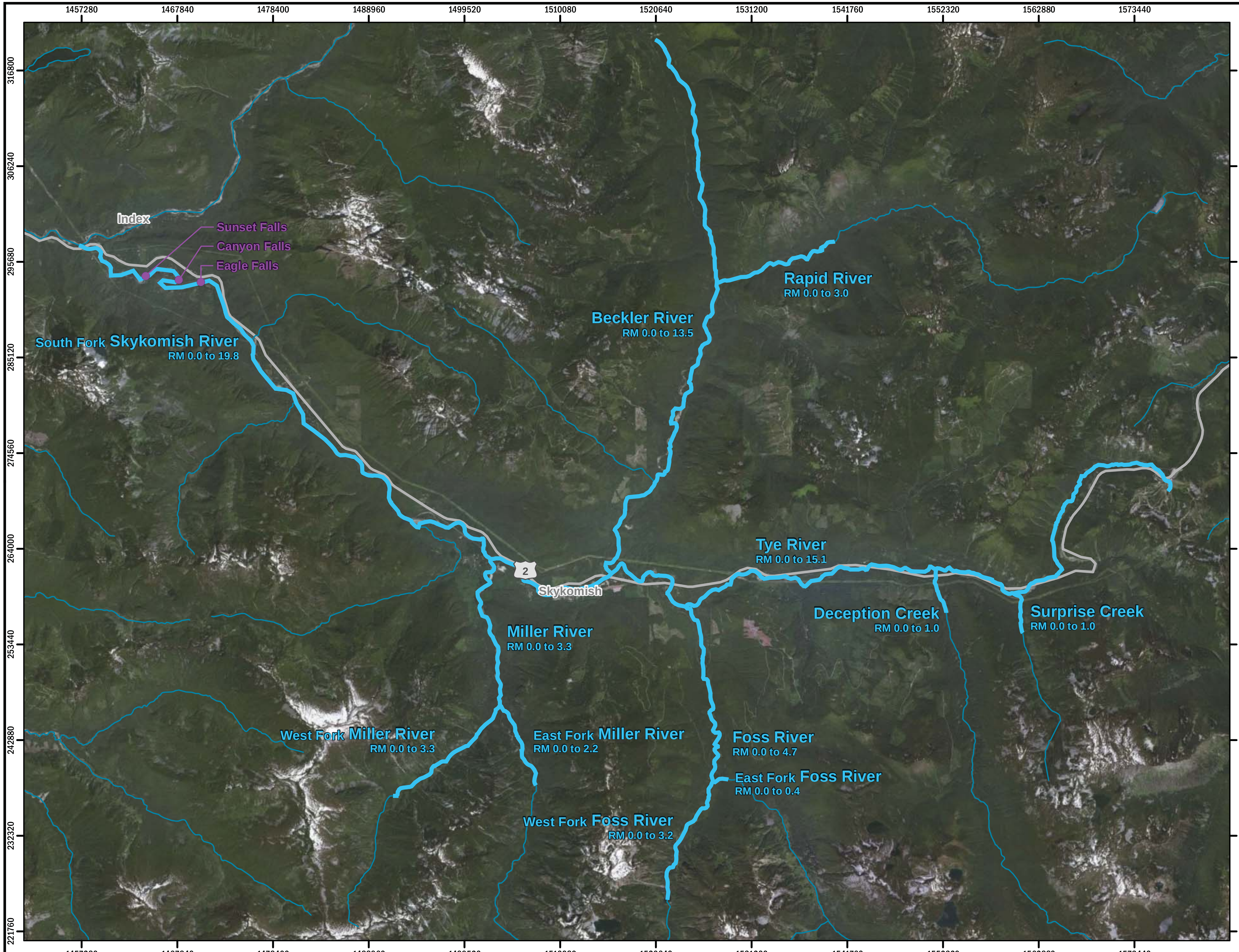
- National Marine Fisheries Service
- The Tulalip Tribes
- Washington Departments of Transportation
- Washington Department of Fish and Wildlife
- Washington Department of Ecology
- Snohomish County
- Wild Fish Conservancy
- Trout Unlimited
- Burlington Northern Santa Fe Railroad
- Cascade Land Conservancy
- ForterraUSFS

Information collected from these organizations and the status of the contact is summarized in the *Information Request Contacts and Status* section.

Preliminary cost estimates for a list of possible future studies was completed. King County had provided the following original list of potential future studies:

- Sediment trends analysis and sediment budget
- Hydrologic analysis

Figure 2.
Study Area
South Fork Skykomish
Feasibility Project
King County, Washington



Legend

- Reach of interest
- River
- Highway

N

0 1 2 4
Miles

HERRERA

Coordinates: NAD83 Washington State Plane North (feet)

Produced By: GIS
Project: K:\Projects\10-04766-008\Project\Area_of_Interest.mxd (6/4/2012)

- Channel Migration Zone (CMZ) delineation
- Shoreline armoring assessment
- Off-channel habitat connectivity survey
- Large wood analysis
- Aquatic habitat assessment
- Substrate characterization
- Riparian habitat assessment
- Invasive vegetation inventory
- Reach Assessment

After the existing information review was completed, Herrera evaluated this original list of potential future studies to determine if these studies were still needed or if other studies would need to be added to this list. Preliminary cost estimates for a modified list of potential future studies is provided under the *Preliminary Cost Estimates of Potential Future Studies* section.

Data and Information Review Results

The following two sections of this report include a summary of the information collected from the list of organizations provided in the *Methods* section. The status of data collection from these organizations is also provided. The *Review of Existing Studies and Data* section contains a brief summary of the existing information and data that were reviewed followed by a list of data gaps that were identified through this review.

Information Request Contacts and Status

The 11 organizations listed above were contacted by Herrera to determine if additional natural resource studies had been completed for the South Fork Skykomish River study area defined above. The findings and status of these inquiries are provided in Table 1. Only the USFS, Wild Fish Conservancy, and Snohomish County had some additional data available beyond existing studies that King County had already provided for this summary report (these studies are summarized later in this report). The Wild Fish Conservancy has conducted the most recent priority salmonid (Chinook, steelhead trout, and coho) spawner surveys within the study area streams and provided these data to WDFW to include in their Salmonscape database of fish distribution within Washington streams. There are still pending responses from Burlington Northern Santa Fe (BNSF) and Andy Haas (a former Snohomish County employee).

Review of Existing Studies and Data

This section provides a brief summary of existing studies and plans that address salmon habitat conditions and/or restoration planning within the South Fork Skykomish River basin including the study area for this report. Table 2 summarizes the content of these studies in regards to watershed, stream, and salmon habitat conditions, data gaps, and existing or proposed restoration projects. A list of data gaps identified from the review of existing information is provided under the *Data Gaps* section.

A Snohomish Basin Salmon Habitat Plan was completed in 1999 by the Snohomish Basin Salmonid Recovery Technical Committee. This study identified the major limiting factors to salmonid production with the Snohomish Basin (including the South Fork Skykomish River basin): habitat degradation, potential weakening of natural salmonid stocks due to intermixing and competition of hatchery stock, fisheries harvesting, habitat access limited by hydropower dams and man-made barriers, and reduced marine survival. The study laid out next steps for salmonid habitat improvement and Chinook salmon population recovery within the basin.

A follow-up study was conducted in 2002 by the Snohomish Basin Salmonid Recovery Technical Committee that examined the salmon habitat conditions in the Snohomish River Basin. This study provided a detailed evaluation of existing conditions (fish habitat barriers, sediment, hydrologic, water quality, riparian, and shoreline armoring and floodplain connectivity) within the sub-basins of the Snohomish River Basin including the South Fork Skykomish sub-basin.

Table 1. Organizations Contacted and Information Collected.			
Organization Name	**Contact Name**	**Information Obtained**	**Contact Status**
Snohomish County	Tim Walls	Study on Climate Change in the Pacific Northwest	Completed
	Mike Rustay	Snohomish Basin Plan EDT Detailed Analysis Results	Completed
	Bob Aldrich	None at this time	Response pending
Snohomish County/Seattle City Light	Andy Haas	None at this time	Response pending
Tulalip Tribes	Kit Rawson, Kurt Nelson	No additional data	Complete
Abby Hook (formerly Tulalip Tribes)	Abby Hook	Hook's Thesis: Geomorphological study of North Fork Skykomish River	Complete
WDFW	Doug Hennick	None at this time	No response
	Tom Cox	No additional data	Complete
NMFS	Krista Bartz	No additional data	Complete
Brian Collins	Brian Collins	No historical studies completed for study area	Complete
Trout Unlimited	Alan Moore	No additional data	Complete
Wild Fish Conservancy	Jamie Glasgow	Fish spawning surveys provided to WDFW	Complete
BNSF	Mike Shawver	No additional data	Suggested contacting Bruce Shepard
	Bruce Shepard	None at this time	Pending response
Forterra (formerly Cascade Land Conservancy)	Charlie Raines	No additional data	Complete
USFS		Watershed and salmon restoration studies for South Fork Skykomish, Beckler, Miller, Foss, and Tye rivers	Complete
Washington Department of Transportation	Jim Parks	WSDOT has no restoration projects in the South Fork Skykomish Basin	Complete
King County Noxious Weed Group	Frances Lucero	Noxious weed GIS files and management information for King County	Complete

This study also identified data gaps where information was insufficient to make a determination of the conditions within a stream or sub-basin.

In 2004 and 2005, the Snohomish Basin Salmon Recovery Forum and NMFS completed the Snohomish River Basin Salmon Conservation Plan, which included an Ecosystem Diagnosis and Treatment (EDT) analysis to determine primary and secondary conservation strategies for each sub-basin within the Snohomish Basin. The EDT analysis results are presented in the Snohomish River Basin Ecological Analysis for Salmon Conservation report (Snohomish Basin Salmonid Recovery Technical Committee and NMFS 2005). The EDT analysis identified the following recommended restoration actions for the Upper South Fork Skykomish River (from confluence of the Foss River to Sunset Falls): preservation of intact habitat, rearing habitat improvement, off-channel habitat improvement, setting back or removing shoreline armoring,

Table 2. Summary of Reviewed Historical Studies and Information Pertaining to Salmon and Salmonid Habitat Conditions in the South Fork Skykomish River Basin.

Study Title	Author	Date	Stream Name	Existing Data/Information Provided In Each Study: Shoreline Armoring Survey	Off-channel Connectivity Survey	Habitat Assessment	Riparian Vegetation Assessment	Large Wood Analysis	Hydrologic Analysis	Channel Migration Zone Analysis	Reach Classification	Sediment Trends Analysis and Sediment Budget	Invasive Vegetation Inventory	Data Gaps Identified	Restoration Project Recommendations
Initial Snohomish River Basin Chinook Salmon Conservation/Recovery Technical Work Plan	Snohomish Basin Salmonid Recovery Technical Committee	1999	Snohomish Basin, "Skykomish Forks"	N	N	Y	Y	N	Y	N	N	N	N	Y	Y
Snohomish River Basin Salmonid Habitat Conditions Review	Snohomish Basin Salmonid Recovery Technical Committee	2002	Snohomish Basin, "Skykomish Forks"	Y	Y	Y	Y	y	Y	N	N	Y	N	Y	Y
Snohomish River Basin Ecological Analysis for Salmonid Conservation	Snohomish Basin Salmonid Recovery Technical Committee and NMFS	2004 / Updated 2005	Snohomish Basin, "Skykomish Forks"	N	N	Y	Y	N	Y	N	N	N	N	Y	Y
Snohomish River Basing Conditions and Issues Report	Pentec and NW GIS	1999	Snohomish Basin including South Fork Skykomish	N	N	Y	Y	N	Y no modeling	N	N	N	N	Y	Y
Miller-Foss Watershed Analysis, Mt. Baker-Snoqualmie National Forest	USFS	2009	Miller-Foss Watershed	N	N	Y	Y	Y	Y no modeling	N	N	N	N	Y	N
Watershed Action Plan for the National Forest System Lands of the North and South Fork Skykomish 5th-Field Focused Watersheds, A Framework for Prioritizing Restoration, MBSNF	USFS	2009	North & South Fork Skykomish Watersheds	N	N	N	N	N	N	N	N	N	N	Y	Y
Skykomish Forks Watershed Analysis, Mt. Baker-Snoqualmie National Forest	USFS	1995	North & South Fork Skykomish Watersheds	N	N	Y	Y	Y	Y no modeling	N	N	Y	Y	N	Y

Table 2 (continued). Summary of Reviewed Historical Studies and Information Pertaining to Salmon and Salmonid Habitat Conditions in the South Fork Skykomish River Basin.

Study Title	Author	Date	Stream Name	Existing Data/Information Provided In Each Study										Data Gaps Identified	Restoration Project Recommendations
				Shoreline Armoring Survey	Off-channel Connectivity Survey	Habitat Assessment	Riparian Vegetation Assessment	Large Wood Analysis	Hydrologic Analysis	Channel Migration Zone Analysis	Reach Classification	Sediment Trends Analysis and Sediment Budget	Invasive Vegetation Inventory		
Beckler River Watershed Analysis, Mt. Baker-Snoqualmie National Forest	USFS	1995	Beckler River Watershed	N	N	Y	Y	Y	Y no modeling	N	N	Y	Y	N	Y
Tye River Watershed Analysis, Mt. Baker-Snoqualmie National Forest, Skykomish Ranger District	USFS	1994	Tye River Watershed	N	N	Y	Y	Y	Y no modeling	N	N	Y	Y	N	Y
Fisheries Analysis on the Beckler River	Cyr, LeRoy (USFS)	1992	Beckler River	N	Y	Y	Y limited	Y limited	N	N	Y	N	N	N	N
Snoqualmie/Skykomish Early Action Habitat Projects in King County	King County	2001	Snoqualmie and Skykomish rivers	N	N	Y limited	N	N	N	N	N	N	N	N	Y
South Fork Skykomish Historic Channel Mapping, Flood Control Assistance Account Program, Final Summary Report.	King County	2005	South Fork Skykomish	N	N	N	N	N	N	Y	N	Y	N	N	N
Geomorphic Assessment: Miller River Fan	Herrera	2009	Miller River	N	N	N	N	N	N	Y	N	Y	N	N	N
Distribution of fish and stream habitats and influences of watershed conditions, Beckler River.	Wissmar, R.C. and W.N. Beer	1994	Beckler River	N	N	Y	Y limited	N	N	N	N	N	N	N	N
Snohomish River Watershed WRIA 7 Salmonid Habitat Limiting Factors Report	Washington State Conservation Commission	2002	Snohomish Basin	N	Y	Y	Y	Y	N	N	N	N	N	Y	Y

Y= Yes, N=No

removal of barriers to habitat access, restoring normative sediment transport processes, and where needed, riparian revegetation. For the Lower South Fork Skykomish River, the following restoration actions were identified: high quality habitat protection, removal of barriers to habitat access, riparian forest restoration, and reestablishing floodplain connectivity. Similar restoration actions were identified for the major tributaries of the South Fork Skykomish River.

In parallel to the Snohomish Basin Plan studies, the USFS conducted watershed analyses of the South Fork Skykomish and its tributaries (Skykomish Forks [USFS 1995b]; Millerand Foss rivers [USFS 2009a]; Tye River [USFS 1994]; Beckler River [USFS 1995a]); and a watershed restoration project action plan (USFS 2009b). These watershed analyses provide historic and existing (at the time of each study) habitat condition information for these streams at a stream watershed level. As part of these studies a detailed analysis of road crossings, culverts, and fish passage barriers was also conducted for each of the stream watersheds. These USFS studies also identify future data needs (data gaps) and suggested restoration projects for each watershed. The watershed action plan (USFS 2009b) describes previously completed or on-going restoration projects in the South Fork Skykomish River basin as road drainage, erosion control, and fish passage improvements, pointing to the need for more in-stream restoration activities.

The USFS has designated the Skykomish Forks watershed as a “Focused Watershed,” and the Upper South Fork Skykomish subwatershed as a “priority watershed,” where additional stream restoration actions are in the process of being identified and moving towards implementation by the USFS in partnership with other organizations. The South Fork Skykomish River salmon habitat restoration feasibility project is one of the projects being implemented under this program (USFS 2009b).

Herrera (2009) also produced a geomorphic assessment for the County as part of its program to better study the Old Cascade Highway crossing of the Miller River. The study was targeted on threats to the roadway and focused only on the lower mile of the river. Future work is anticipated in this area, but it is within a small fraction of Miller River reach described here and will therefore have no bearing on the cost estimates provided later in this document.

Finally, a cursory review of the peer-reviewed scientific literature generated several studies of peripheral relevance to the identification and characterization of restoration projects in the basin (Steel et al. 1999; Hren et al. 2007; Pelto 2011). First, Steel et al. (1999) report a study of the associations of birds and small mammals at numerous locations on North Fork Skykomish River. While not specifically in the South Fork Skykomish sub-basin, the extreme proximity of this work to the South Fork does provide a basis for the types of ecological communities that can be found in the basin. Next, Hren et al. (2007) reported chemical weathering and erosion rates from the greater Skykomish Basin (including from the Sultan and Wallace tributary basins). While only a few of the samples were obtained from the South Fork basin, the erosion data would be useful for sediment production estimates in any kind of sediment transport analysis. Finally Pelto (2011) reports on the hydrologic changes associated with modern glacial retreat, both from field observations and a historical analysis of USGS gage records obtained at Gold Bar. The hydrologic analysis lumps the effects of the forks, making it only marginally relevant to hydrology of the South Fork (or its tributaries) itself, but the field observations of glacial retreat would be useful as the basis for any sediment transport analysis in the basin.

In addition to the studies mentioned above the following data products are available for potential use in future analyses: 2002 LIDAR images and 2010 aerial ortho-photographs of the entire study area, 2006 and 2011 LIDAR images and 2011 aerial photographs for the South Fork Skykomish River and only the lower reaches of the tributaries identified in the study area. Evaluation of the quality and resolution of the 2006 and 2011 LIDAR images indicates that they would be insufficient for building detailed topographic surfaces from these images; however, they can be used for coarse level analyses. A HEC-RAS hydraulic model was completed in 1997 for the South Fork Skykomish sub-basin that used US Geological Survey gage data. While this model may be useful to provide historical hydraulic context for the South Fork basin, it would not provide useful data for future hydrologic or hydraulic analyses.

Data Gaps

The following data gaps were identified through the review of the existing studies listed in Table 2 and discussion with contacts listed in Table 1.

- Sediment transport processes analysis in South Fork Skykomish sub-basin and in particular the South Fork Skykomish, Miller, and Beckler rivers; including, but not limited to, sediment budgets, sediment trends analyses, and sediment transport modeling
- Historic and present day geomorphic analysis of the entire South Fork Skykomish sub-basin
- Channel migration zone analysis of the floodplains of the streams in the study area
- Hydrologic analysis in the entire South Fork Skykomish sub-basin
- Hydraulic analysis in South Fork Skykomish sub-basin (a HEC-RAS model of the South Fork Skykomish River was completed in 1997, but only used existing USGS gage data and is outdated)
- Stream reach-level instream habitat conditions survey for identification of restoration opportunities within the South Fork Skykomish River study area
- Stream reach-level riparian habitat conditions survey that is specifically relevant to salmonid habitat conditions within the South Fork Skykomish River study area
- Detailed quantification of shoreline armoring and floodplain disconnection studies of the entire basin
- Reach level off-channel habitat assessment within the South Fork Skykomish River study area
- Comprehensive large woody debris study of the South Fork Skykomish River sub-basin including the relevant portions of the major tributaries
- Stream reach-level study of invasive vegetation species for the entire study area

PRELIMINARY DESCRIPTIONS AND COST ESTIMATES OF POTENTIAL FUTURE STUDIES

Based on the existing information and data review, Herrera determined which ones of the following potential future studies identified by King County (see *Methods* section) would potentially be needed to fill data gaps and added additional studies that would also be appropriate. The following is the revised list of proposed potential future studies:

- Sediment trends analysis and sediment budget
- Hydrologic analysis
- Channel Migration Zone (CMZ) delineation
- Geomorphic assessment (includes Shoreline armoring assessment)
- Off-channel habitat connectivity survey
- Large wood analysis
- Aquatic habitat assessment and substrate characterization
- Riparian habitat assessment
- Invasive vegetation inventory

Appendix 1 provides a brief description of the potential future studies that may be needed to fill data gaps and determine potential salmon habitat restoration projects within the study area. A preliminary cost estimate is provided for each proposed study by stream within the study area, where appropriate, and for all streams combined. Costs could be reduced by combining the field investigations and reporting for some of these studies. For example, the invasive vegetation inventory could be combined with the riparian habitat assessment, or the riparian habitat assessment could be completed at the same time as the aquatic habitat assessment is completed (see Appendix 1).

REFERENCES

Cyr, LeRoy. 1992. Fisheries Analysis on the Beckler River. Mt. Baker-Snoqualmie National Forest, Skykomish Ranger District, Washington.

Herrera. 2007. Cedar River 2007 Wood Inventory Memorandum. Prepared for Seattle Public Utilities by Herrera Environmental Consultants, Inc., Seattle, Washington.

Herrera. 2009. Geomorphic Assessment: Miller River Fan. Prepared for King County Department of Natural Resources and Parks, Water and Land Resources Division, by Herrera Environmental Consultants, Inc., Seattle, Washington. December 2009.

Herrera. 2010. Summary of Sediment Trends: Lower White River: RM 4.44 to RM 10.60. Prepared for King County Department of Natural Resources and Parks, Water and Land Resources Division, River and Floodplain Management Section, by Herrera Environmental Consultants, Inc., Seattle, Washington. February 2010.

Hren, M.T., G.E. Hilley, and C.P. Chamberlin. 2007. The relationship between tectonic uplift and chemical weathering rates in the Washington Cascades: Field measurements and model predictions. *American Journal of Science* 307:1041-1063.

Kassler. T.W., D.K. Hawkins, and J.M. Tipping. 2008. Summer-Run Hatchery Steelhead have naturalized in the South Fork Skykomish River, Washington. *Transactions of the American Fisheries Society* 137:763–771.

King County. 2001. Snoqualmie/Skykomish Early Action Habitat Projects in King County. Preliminary Priorities 2000-2001.

King County. 2005. South Fork Skykomish Historic Channel Mapping, Flood Control Assistance Account Program, Final Summary Report. Prepared for: Washington State Department of Ecology, Shorelands & Environment Assistance Program. Prepared by King County Department of Natural Resources and Parks, Flood Hazard Reduction Section.

Lestelle, L.C., W.E. McConnaha, G. Blair, and B. Watson. 2005. Chinook salmon use of floodplain, secondary channel, and non-natal tributary habitats in rivers of western North America. Report prepared for the Mid-Willamette Valley Council of Governments, US Army Corps of Engineers, and Oregon Department of Fish and Wildlife by Mobrand-Jones and Stokes, Vashon, Washington, and Portland, Oregon.

Pelto, M.S. 2011. Skykomish River, Washington: Impact of ongoing glacier retreat on streamflow. *Hydrological Processes* 25:3356-3363.

Pentec and NW GIS. 1999. Snohomish River Basing Conditions and Issues Report. Report No. 293-001, Revised Final Report. Prepared for The Snohomish River Basin Work Group. December 17, 1999.

Rapp, C.F. and T.B. Abbe. 2003. A framework for delineating Channel Migration Zones. Washington State Department of Ecology. Final Draft Publication #03-06-027.

Snohomish Basin Salmon Recovery Forum. 2005. Snohomish River Basin Salmon Conservation Plan. Snohomish County Department of Public Works,Surface Water Management Division, Everett, Washington. June 2005.

Snohomish Basin Salmonid Recovery Technical Committee and National Marine Fisheries Service. 2005. Snohomish River Basin Ecological Analysis for Salmon Conservation. May 2004, Updated June 2005.

Snohomish Basin Salmonid Recovery Technical Committee. 1999. Initial Snohomish River Basin Chinook Salmon Conservation/Recovery Technical Work Plan. October 6, 1999.

Snohomish Basin Salmonid Recovery Technical Committee. 2002. Snohomish River Basin Salmonid Habitat Conditions Review. September 2002.

Snohomish County Public Works. 2008. Snohomish County Wadeable Stream Habitat Survey Protocol for Status and Trend Monitoring. Snohomish County Public Works Surface Water Management Division.

Steel, E.A., R.J. Naiman, and S.D. West. 1999. Use of woody debris piles by birds and small mammals in a riparian corridor. *Northwest Science* 73(1):19-26.

Syvitski, J.P.M., S.D. Peckham, R. Hilberman, and T. Mulder. 2003. Predicting the Terrestrial Flux of Sediment to the Global Ocean: A Planetary Perspective. *Sedimentary Geology* 162(1-2):5-24.

USFS. 1994. Tye River Watershed Analysis, Mt. Baker-Snoqualmie National Forest, Skykomish Ranger District.

USFS. 1995a. Watershed Analysis - Beckler River, Skykomish Ranger District.

USFS. 1995b. Skykomish Forks Watershed Analysis, Mt. Baker-Snoqualmie National Forest.

USFS. 2009a. Miller-Foss Watershed Analysis, Mt. Baker-Snoqualmie National Forest.

USFS. 2009b. Watershed Action Plan for the National Forest System Lands of the North and South Fork Skykomish 5th-Field Focused Watersheds. A Framework for Prioritizing Restoration. Skykomish Ranger District Mt. Baker – Snoqualmie National Forest. September 2009.

Washington State Conservation Commission. 2002. Snohomish River Watershed Water Resource Inventory Area 7 Salmonid Habitat Limiting Factors Report. December 2002.

WDFW. 2002. Salmonid Stock Inventory (SaSI) reports, WRIA 7 Snohomish Basin. Obtained from website on May 24, 2012: http://wdfw.wa.gov/conservation/fisheries/sasi/search.php?searchby=WRIA&search=07&orderby=Species%20ASC,%20StockName%20ASC.

Wissmar, R.C. and W.N. Beer. 1994. Distribution of fish and stream habitats and influences of watershed conditions, Beckler River, Washington. Fisheries Research Institute Technical Report FRI-UW-9417. University of Washington, School of Fisheries WH4O, Seattle, Washington. 54 p.

APPENDIX 1

Preliminary Descriptions and Cost Estimates of Potential Future Studies

APPENDIX 1: PRELIMINARY DESCRIPTIONS AND COST ESTIMATES OF POTENTIAL FUTURE STUDIES

Sediment Trends Analysis and Sediment Budget

Description of Study

This sediment trends effort will be similar to the work that was done on the lower White River in support of the White River Countyline project (Herrera 2010). The area covered is much larger, but it is expected that the level of detail would be much less, breaking the quantitative estimates to basin-scale, not reach scale.

A key parameter in any sediment trends analysis is the determination of the sediment influx from surrounding hillslopes. The Syvitski et al. (2003) model (Syvitski model) can estimate sediment output in each of the major basins in the study area. This model requires delineation of the entire basin, along with basic basin geometry (area, relief, etc.). The Syvitski model results will be validated and assessed in three different ways. First, debris flows evident in aerial photographs in the entire basin will be cataloged. A limited number of these will be visited to determine the amount eroded from them since placement, their current size and their potential for erosion in the future. Second, there are several slide-dammed lakes in the basin (e.g., Trout Lake on the West Fork Foss River), which can be used to document the sediment accumulation rates behind them. Third, existing County documents and documents from other stakeholders will be searched to identify engineering design and maintenance activities that have occurred in the past to impound sediment, and the volumes of sediment stored from these actions. Finally the results of the analysis will be summarized in a memorandum.

Extent of Study

This study will be completed for the entire study area as shown in Figure 1 and defined here in the introduction of this document. It is necessary to do this since sediment contribution from the upper basins will necessarily have to be determined to estimate the sediment flux through the South Fork, the main target of restoration activities.

Description of Previous Studies

There have been no previous studies like this in the basin. However, there are resources available (e.g., Hren 2007; Pelto 2011) that will be used to guide the analysis that will be conducted.

Estimated Budget

Total for all streams: $90,500

Hydrologic Analysis

Description of Study

A hydrologic analysis on the upper South Fork Skykomish River Basin may be completed with the existing peak data available from historic USGS and Snohomish County stream gages, and a flood frequency relationship established. While USGS gages in the upper South Fork Skykomish sub-basin were discontinued in the 1950s and 1980s, and those records that are available are from the early part of the 20th century, there is good concurrence amongst the data sets: Tye River near Skykomish (1929–1946), South Fork Skykomish River near Skykomish (1929–1950), Beckler River near Skykomish (1929-1949), Miller River at Miller River (1911-1946), and South Fork Skykomish River near Index (1902-1982).

Hydrologic modeling may help gain greater resolution, and confidence in sub-basin level flood frequency, especially where data gaps exist for the sub-basins, and to determine fish passable low flows. One such model is the U.S. Army Corps of Engineers Hydrologic Engineering Center’s Hydrologic Modeling System (HEC-HMS). HEC-HMS inputs would come from local climate gages, and a combination of LIDAR and, where needed, USGS 10-meter grid data. Individual 24-hour hydrographs may be generated from the model and calibrated against gaged data. The methods and results of this analysis will be provided in a technical report.

Extent of Study

A hydrologic analysis creates a calibrated HEC-HMS model of the South Fork Skykomish River basin, in order to establish a flood frequency for the entire basin. The estimated budget below reflects the effort to conduct such a hydrologic analysis on the upper South Fork Skykomish River basin, above the confluence with the North Fork Skykomish River.

Description of Previous Studies

A flood frequency analysis was performed for the mainstem South Fork Skykomish at Index (Skykomish Forks Watershed Assessment, 1995). Flood frequency analyses were not conducted on the sub-basins, as there were insufficient data (Beckler River Watershed Assessment [USFS 1995a], Tye Watershed Assessment [USFS 1994]), or only average annual, and monthly average data available (Miller-Foss Watershed Assessment [USFS 2009a]). Historic hydrologic analysis has also been performed on the USGS record at Gold Bar (Pelto 2011), but this study aggregates the effects of both forks and is not sufficiently resolved for South Fork restoration projects. The Town of Skykomish has cross-section data of the South Fork Skykomish River for the reach that passes through the town. This information will be incorporated into this study, if it is appropriate.

Estimated Budget

Total for all streams: $40,000

Channel Migration Zone (CMZ) Delineation

Description of Study

The historical (channel) migration zone (HMZ) will be delineated for each river in a manner similar to the South Fork Skykomish River study already conducted (King County 2005). The budget below also includes the option of a delineation of the avulsion hazard zone (AHZ), erosion hazard area (EHA) and disconnected migration area (DMA), as described by Rapp and Abbe (2003) as a complete CMZ delineation. Delineating these wider areas provides information particularly relevant to the restoration and protection of the study area. The wider delineations assume that lidar would be available and require field work to establish their precise limits. The HMZ-only delineations would not require field work. The HMZ and CMZ delineations will be provided on maps that will be included in a report. The methods and findings will be provided in a technical report.

Extent of Study

This study can be completed piecemeal and the budgets for each of these individual studies are indicated parenthetically below, although the methodology will remain the same (as stated above) for each area. Also note that there could be some cost savings if the County were to implement all of these studies simultaneously.

Description of Previous Studies

There have been no previous studies like this in the basin.

Estimated Budget

HMZ Only

$12,000 (remainder of South Fork Skykomish River, north of county line)

$17,000 (Miller River)

$17,000 (Foss River)

$17,000 (Tye River, including lower Surprise and Deception creeks)

$17,000 (Beckler River, including the lower Rapid River)

Total for all streams: $75,000

Full CMZ Delineation

$45,000 (South Fork Skykomish River, including HMZ extension to county line)

$50,000 (Miller River)

$50,000 (Foss River)

$50,000 (Tye River, including lower Surprise and Deception creeks)

$50,000 (Beckler River, including the lower Rapid River)

Total for all streams: $250,000

Geomorphic Assessment

Description of Study

Herrera will conduct a geomorphic assessment for the entire South Fork Skykomish River study area. A review of existing information and field verification will also be conducted. Herrera will review existing data including technical reports (including USFS [1994, 1995a, 1995b, 2009a] watershed studies), peer-reviewed publications, geologic maps, LIDAR data, historic aerial photographs, and General Land Office (GLO) surveys for the identification and description of the geologic, geomorphic, and sediment processes that formed and are active within the South Fork Skykomish study area. This will entail examining the evolution, morphology, and influence of the upper watersheds of the study area streams within the basin. Additionally, Herrera will examine the study area channel dynamics and stability through historic and existing maps, LIDAR images, photographs, and data. The type and extent of shoreline armoring that are constraints to geomorphic processes will be assessed during the field investigation. According to the Snohomish River Basin Salmonid Habitat Conditions Review (Snohomish Basin Salmonid Recovery Technical Committee 2002), the South Fork Skykomish and possibly the Tye River are degraded due to shoreline armoring.

Based on this analysis, Herrera will divide the study area streams into reaches based on dominant geomorphic processes. Herrera will identify channel type and the unique channel morphology of each reach based upon channel planform patterns, gradient, width, depth, sinuosity, grain size, and sediment supply. This information will be used to describe the physical regime of each channel type. This information will then be used to identify the salmonid habitat physical components that can be expected to develop and be sustained within each channel type and therefore reach. Maps will be developed to show the findings of the analysis including but not limited to: key basin geologic features and material types, comparison of historic and current river corridor and channel cross sections, a delineation of shoreline armoring, and geomorphic reaches (to illustrated important geomorphic features or conditions along the river corridor). A technical report of the study findings will be prepared.

Extent of Study

The geomorphic assessment will include all streams within the study area, but could be done piecemeal according to the budgets below.

Description of Previous Studies

The USFS (1994, 1995a, 1995b, 2009a) watershed studies contain information regarding geomorphic features and stability and geology within the each of the stream watersheds, but they are targeted towards restoration actions. The Snohomish River Basin Salmonid Habitat Conditions Review (Snohomish Basin Salmonid Recovery Technical Committee 2002) provides information on shoreline armoring for the South Fork Skykomish and the tributaries that are included in the study area.

Estimated Budget

$40,000 (South Fork Skykomish River)

$30,000 (Miller River)

$30,000 (Foss River)

$40,000 (Tye River, including lower Surprise and Deception creeks)

$40,000 (Beckler River, including the lower Rapid River)

Total for all streams: $180,000

Off-channel Habitat Connectivity Assessment

Description of Study

An off-channel habitat connectivity assessment will be completed in areas identified in the geomorphic assessment and shoreline armoring study described above. This study will entail three main elements: background information analysis, field assessment, and mapping and report preparation. It is assumed that the Geomorphic Assessment would be completed before this study is performed. Also, included in the cost estimate is a hydrologic analysis that would be conducted prior to the off-channel habitat analysis. The hydrologic analysis is described under that *Hydrologic Analysis* section and would be used to estimate the extent of potential floodplain habitats and when they would be available for use by fish. As described under the *Geomorphic Assessment* section, the Snohomish River Basin Salmonid Habitat Conditions Review (Snohomish Basin Salmonid Recovery Technical Committee 2002) indicates that the South Fork Skykomish is degraded due to shoreline armoring and the Tye River may be as well. Aerial photographs, King County's GIS information, and other existing information will be used to identify areas where off-channel habitats may be disconnected from the mainstem channel. Results from the geomorphic assessment may also be used to identify potential off-channel habitats that have been disconnected from the mainstem of the streams. A field assessment will be conducted to collect information regarding the quality of the off-channel habitats. A technical memorandum will be prepared and will include maps of the off-channel habitats, a description and rating of the off-channel habitats, and restoration recommendations.

Extent of Study

The off-channel habitat assessment will focus on the South Fork Skykomish and Tye rivers because they have been identified to have shoreline armoring. Spot locations on other tributaries will also be included in the study if existing information and analysis determine other locations where disconnected off-channel habitat occurs.

Description of Previous Studies

The Snohomish River Basin Salmonid Habitat Conditions Review (Snohomish Basin Salmonid Recovery Technical Committee 2002) provides information on shoreline armoring for the

South Fork Skykomish and the tributaries that are included in the study area. The USFS (1994, 1995a, 1995b, 2009a) watershed studies also include limited information on off-channel habitat and wetland and riparian conditions and will be evaluated during the background analysis of this study.

Estimated Budget

$88,000 (South Fork Skykomish River and Tye River and other potential spot locations)

Note this cost estimate includes the cost for a hydrologic analysis of the South Fork Skykomish sub-basin.

Large Wood Analysis

Description of Study

This Large Wood Analysis will be similar to the work that was done on the Cedar River for Seattle Public Utilities (SPU) in 2007 (Herrera 2007). The area covered in this analysis is much larger (~70 RM) than that of the Cedar River (~12.5 RM), but it is expected that the analysis will have a much narrower focus on wood presence and function in supporting fish habitat.

A LWD inventory of the Skykomish River would help establish baseline information on wood loading, wood distribution, wood associated fish habitat, and the geomorphic function of large wood on the South Fork Skykomish and its tributaries. A systematic field survey would catalog wood presence and function throughout the reach. For maximum efficiency, data could be collected using GPS units and stored in a GIS-based data dictionary specially developed for the inventory. Such a data dictionary may be used to easily display spatial wood densities, generate spatial statistics, and could be the basis of comparison with similar studies in the future. A technical memorandum will be prepared and will include a description of LWD characteristics within each stream by reach, wood distribution, wood recruitment, effects of LWD conditions on fish habitat, and identification of restoration projects where LWD is lacking.

Extent of Study

This study can be completed piecemeal, and the budget for each of these individual studies is indicated below, although the methodology will remain the same (as stated above) for each stream. Also, note that there could be some cost savings if the County were to implement this study for all streams simultaneously.

Description of Previous Studies

While several of the USFS (1994, 1995a, 1995b, 2009a) watershed analyses of the South Fork Skykomish and its tributaries contain information regarding large wood loading, distribution, and geomorphic and habitat function, the data contained in those reports are piecemeal, stretches across two decades, and is impractical for use in assessing potential areas targeted for restoration efforts. Steel et al. (1999) observed significant use of LWD piles by birds, small mammals, and insects in the North Fork Skykomish River. Limited wildlife information could also be collected during the LWD inventory to use as a habitat quality indicator of the river ecosystem.

Estimated Budget

$86,000 (South Fork Skykomish River)

$86,000 (Tye River, including lower Surprise and Deception creeks

$86,000 (Beckler River, including the lower Rapid River)

$55,000 (Foss River)

$55,000 (Miller River)

Total if all streams were studied together: $298,000

Aquatic Habitat Assessment

Description of Study

An aquatic (instream) habitat analysis will be completed using a similar methodology employed for the King County Tolt River flood damage and habitat restoration project. It is assumed that geomorphic and hydrologic assessments will be conducted prior to conducting this aquatic habitat assessment. We assume the geomorphic assessment on at least the mainstem South Fork will be conducted. However, we cannot assume the hydrologic assessment will be conducted and therefore we have included the cost of the hydrologic assessment (as described under the *Hydrologic Assessment* section) in this study. This study also includes a substrate analysis. The focus will primarily be to support determination of salmonid habitat restoration projects and not on flood damage, although this study will include an assessment of where flood damage affects salmonid habitat. The study will follow the process-based principles identified by Beechie et al. (2010). These process-based restoration principles are intended to reestablish physical, chemical, and biological processes that create and sustain river and floodplain ecosystems. This assessment only includes instream habitat (including substrate characterization); riparian habitat assessment is described under the *Riparian Habitat Assessment* section. However, cost savings would be realized if this study was combined with the riparian habitat assessment.

This analysis will involve four elements: existing information analysis, aerial photographic and LIDAR analysis, field studies, and mapping and reporting. The study will focus on quantifying the current habitat diversity for salmonids (i.e., spawning and rearing habitat, high flow refugia, pool-riffle habitat, substrate characterization, etc.) and identifying opportunities for improving aquatic habitat. Stream habitat types will be defined and mapped on the basis of channel type and geomorphic units according to the classification approach discussed in Lestelle et al. (2005) and applied in Snohomish Basin Salmonid Recovery Technical Committee and National Marine Fisheries Service (2005). This classification approach is used in Ecosystem Diagnosis and Treatment (EDT) and includes the following channel types: main channel, side channel, braided channel, overflow channel, groundwater channel, pond, and seasonally flooded wetland habitat type. In order to minimize cost and for the purpose of this study, some of the geomorphic units discussed in Lestelle et al. (2005) will be grouped into the pools or riffles categories as applicable. The final mapping protocol will be reviewed and approved by King County before implementation. Field studies will be limited only to areas where habitat conditions need to be verified and assessed on the ground.

Additionally, information from the Sediment Trends Analysis and Sediment Budget (see above) will be used to assess water quality (sediment loading) and substrate embeddedness for this study.

A technical memorandum will be prepared and will include at minimum descriptions of current conditions of the instream habitat and potential restoration projects.

Extent of Study

The aquatic habitat assessment will focus on the study section of the South Fork Skykomish River (as defined for this report) and will also include relevant portions the Tye, Miller, Beckler, and Foss rivers and possibly Surprise and Deception creeks.

Description of Previous Studies

The Snohomish Basin Salmon Habitat Plans and habitat conditions report (Snohomish Basin Salmonid Recovery Technical Committee 1999, 2002, 2005, and Pentec and NW GIS 1999) and the EDT analysis (Snohomish Basin Salmon Recovery Forum 2005) of the entire Snohomish Basin will be analyzed as part of the background information analysis for this assessment. The USFS Watershed Analyses of the South and North Forks of the Skykomish River (USFS 1995b), Miller and Foss rivers (USFS 2009a), the Beckler River (USFS 1995a), and the Tye River (USFS 1994) contain information regarding geomorphic and habitat functions in these streams, although the primary focus of the studies is in regards to riparian functions. Relevant information from these USFS studies will be used for the existing information analysis for the aquatic habitat assessment. A fish habitat survey review of the Beckler River (Cyr 1992) provides reach level information on instream habitat conditions and could be used as baseline information for that river, although these data are relatively old. Kassler et. al. (2008) also provides information regarding habitat conditions in the South Fork and North Fork Skykomish rivers particular to steelhead trout that will be reviewed as part of the existing information analysis.

Estimated Budget

This budget includes a combination of this hydrologic assessment as described in the *Hydrologic Assessment* section and this study’s cost estimate

$120,000 (South Fork Skykomish River study segment)

$115,000 (Tye River, including lower Surprise and Deception creeks)

$115,000 (Beckler River, including the lower Rapid River)

$98,000 (Miller River)

$98,000 (Foss River)

Total if all streams were studied together: $195,000

Riparian Habitat Assessment

Description of Study

A riparian habitat analysis will be completed using a similar methodology (as applicable) employed for the King County Tolt River flood damage and habitat restoration project. The study will also follow the process-based principles identified by Beechie et al. (2010). This assessment only includes riparian habitat; aquatic instream habitat assessment is described under the *Aquatic Habitat Assessment* section. The study will focus on quantifying the historical and present-day riparian habitat conditions. It is assumed that the information from the Geomorphic Assessment described above will be completed prior to this study.

This analysis will involve four elements: existing information analysis (including results from the geomorphic assessment, aerial photographic and LIDAR analysis and review of previous studies), field studies, and mapping and reporting. The approach to assessing riparian conditions will entail an assessment of previous information, maps, and results from the geomorphic assessment. The approach will be loosely based on methods utilized by Collins and Sheikh (2002) where historical information from GLO surveys and notes; historic aerial photographs, and LIDAR imagery is available for the Geomorphic Assessment. Existing information will be synthesized in order to map the channel, floodplain wetlands, riparian vegetation communities, and ponds. Current and, where possible historic, riparian habitats that affect salmonid habitat will be defined and mapped. Field studies will be limited only to areas where habitat conditions need to be verified and assessed on the ground. A technical memorandum discussing the current conditions of the riparian habitat and potential areas for restoration will be prepared.

Extent of Study

The riparian habitat assessment will focus on the study section of the South Fork Skykomish River (as defined above) and will also include relevant portions the Tye, Miller, Beckler, and Foss rivers and possibly Surprise and Deception creeks.

Description of Previous Studies

The Snohomish Basin Plans (Snohomish Basin Salmonid Recovery Technical Committee 1999, 2002, 2005, and Pentec and NW GIS 1999) provide an overview of the riparian habitat conditions of the South Fork Skykomish, Beckler, Tye, Foss, and Miller rivers. Information from the EDT analysis of the South Fork Skykomish sub-basin (Snohomish Basin Salmon Recovery Forum 2005) will be used for background information where relevant. The USFS watershed analyses of the South and North Forks of the Skykomish River (USFS 1995b), Miller and Foss rivers (USFS 2009a), Tye River (USFS 1994), and Beckler River (USFS 1995a) contain maps and riparian habitat conditions information that will be used as existing information to build on.

Estimated Budget

$75,000 (South Fork Skykomish River study segment)

$73,000 (Tye River, including lower Surprise and Deception creeks)

$73,000 (Beckler River, including the lower Rapid River)

$49,000 (Foss River)

$49,000 (Miller River)

Total if all streams were studied together: $100,000

Invasive Species Inventory

Description of Study

An invasive species assessment will be completed for the South Fork Skykomish River and the mouths of the tributaries identified in the study area and where roads cross or are within 50 feet of the tributaries. The rationale for not surveying the upper reaches of the tributaries and only where they are crossed or near roads is because most non-native riparian species will be within these more disturbed areas. This analysis will involve three elements: existing information analysis, field studies, and mapping and reporting. Existing information analysis will include a review of the King County noxious weed list and identifying a list of other problematic invasive species as identified in the USFS watershed studies. A review of the USFS (1994, 1995a, 1995b, 2009a) watershed study invasive species maps and information will be used for preliminary mapping of invasive species and to determine a plan for spot surveys of invasive species within the South Fork Skykomish and the disturbed portions of the tributaries. Invasive species will be mapped within the study area and a technical memorandum will be prepared describing the invasive species, locations, effects on salmonid habitat, and management recommendations both already proposed by USFS and King County, and that are determined to improve salmonid habitat within the entire study area.

Extent of Study

The invasive species assessment will collect existing information for the entire study area and the field studies will focus South Fork Skykomish River and disturbed areas of the Tye, Beckler, and Foss rivers. The Miller River invasive species assessment will be conducted separately.

Description of Previous Studies

The USFS Watershed Analyses of the South and North Forks of the Skykomish River (USFS 1995b), Tye River (USFS 1994), Miller and Foss rivers (USFS 2009a), and Beckler River (USFS 1995a) contain invasive species information at the stream watershed level that will be used as existing information to build on.

Estimated Budget

Total for all streams: $50,000

APPENDIX C

South Fork Skykomish River Geomorphic Assessment

GEOMORPHIC ASSESSMENT

SOUTH FORK SKYKOMISH RIVER

Prepared for
King County
Department of Natural Resources and Parks
River and Floodplain Management Section

Prepared by
Herrera Environmental Consultants, Inc.

HERRERA

GEOMORPHIC ASSESSMENT

SOUTH FORK SKYKOMISH RIVER

Prepared for
King County
Department of Natural Resources and Parks
River and Floodplain Management Section
201 S. Jackson Street, Suite 600
Seattle, Washington 98104

Prepared by
Herrera Environmental Consultants, Inc.
2200 Sixth Avenue, Suite 1100
Seattle, Washington 98121
Telephone: 206/441-9080

December 19, 2012

CONTENTS

TABLES

FIGURES

INTRODUCTION

This technical memorandum outlines the approach, analytical methods, and results of a geomorphic assessment that includes identification of restoration opportunities on the entire South Fork Skykomish River (the South Fork), from its headwaters at the confluence of the Tye and Foss rivers to its terminus at the confluence with the North Fork Skykomish River (the North Fork) near the Town of Index (Figure 1).

This technical memorandum is part of a larger feasibility study of salmonid habitat restoration projects within the South Fork basin conducted by King County (the County). This larger feasibility study includes work and project identification on major South Fork tributaries, and a site-specific analysis of the lower Miller River Fan. The feasibility study is intended to be the first step in a process to improve habitat conditions and reduce flood and erosion risks in the South Fork.

This geomorphic assessment describes the physical and ecological basis for restoration of predevelopment geomorphic conditions and improvement of in-stream habitat in the South Fork. The focus of the assessment is on habitat for anadromous fish, including Chinook, coho, steelhead and bull trout. The assessment is then the basis for the development of specific restoration opportunities, identified during the field work conducted as a part of the assessment. The assessment follows a physical-process-based approach, which has been suggested by many researchers for assessments of this kind (Kondolf et al. 2006; Beechie et al. 2010). The purpose of the identifying projects in this assessment is not to evaluate these projects, but merely to identify potential actions that could restore habitat conditions and predevelopment geomorphic functions. Details regarding the design and implementation of restoration actions are beyond the scope of this document.

This assessment explicitly does not include a formal analysis of the hydrology of the basin, hydraulic modeling, a detailed analysis of the fish utilization of the area, or a delineation of large woody debris (LWD). Because a formal survey of all in-channel LWD has not been made, it was not possible to recommend LWD placement locations. Nonetheless, LWD could be added anywhere within the study area and would improve habitat quality, provided that care is taken to ensure that the added wood does not affect flood protection or cause other off-site impacts.

Assessment Area Limits

The assessment area for this portion of the feasibility study extends between the confluence of the Tye and Foss Rivers to the confluence of the South Fork and the North Fork near the town of Index, Washington. It includes the mainstem of the South Fork, its side channels, and the tributary junctions of its major tributaries, which include the Foss River, Beckler River, Anthracite Creek, Maloney Creek, Miller River, Money Creek, Barclay Creek, Index Creek, Bridal Veil Creek and Philadelphia Creek. The assessment area covers nearly 20 miles of river, which were observed over the course of 4 days, 3 of which were by boat. As a result of the speed of the field reconnaissance, exhaustive, detailed observations of geomorphic features (such as bar sizes) were not possible. The primary intent of the field reconnaissance was to identify possible restoration projects, and to describe how science informed the prioritization of those projects.

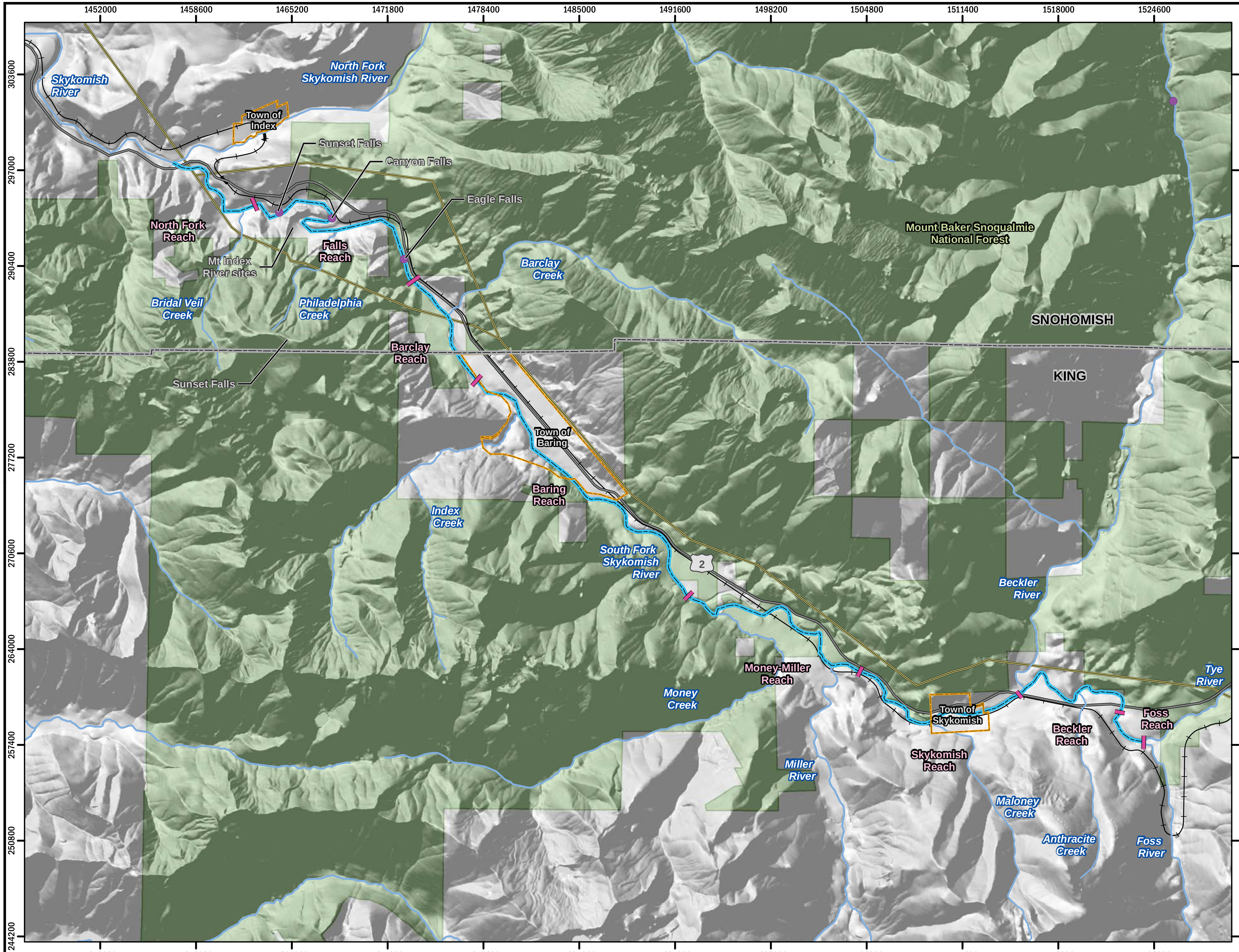


Figure 1.
South Fork Skykomish River assessment area, King County, Washington.

Legend

- South Fork Skykomish River
- Reach break
- River or creek
- Highway
- Railroad
- BPA powerlines
- Community boundary
- County boundary
- Mount Baker Snoqualmie NF

N

0 0.625 1.25 2.5 mi

HERRERA

Coordinates: NAD83 Washington State Plane North (feet)
Aerial: USDA (2012)

Produced By: GIS
Project: K:\Projects\10-04766-019\Project\Report_Maps\Area_of_Interest_2.mxd (12/14/2012)

METHODOLOGY

A process-based approach was used in the identification of restoration opportunities and assessment of existing geomorphic conditions (Kondolf et al. 2006; Beechie et al. 2010). That is, the emphasis of identification of restoration opportunities is on those actions that restore habitat-forming and predevelopment geomorphic processes. In addition, consideration was given to the watershed conditions (opportunities and constraints) to ensure a holistic approach to restoration of the entire assessment area. In particular, the assessment used existing information and field reconnaissance from a 3-day float trip and a 1-day walking reconnaissance of all but 2 miles of the study area to locate and identify the existing geomorphic conditions and impairments, to determine opportunities for restoration of habitat-forming and predevelopment geomorphic processes. River miles used in the reconnaissance and in the reporting of that information in this document were generated using GeoWizards Version 10.2 software and therefore may deviate from King County flood hazard maps by as much as 0.1 mile.

Existing Information

Physical Setting

Geologic Context

The geologic context for the geomorphic assessment was primarily provided by Tabor et al. (1993). This map and associated text provides information regarding the recent geologic past that serves as a template for the analysis performed herein. Because geologic history has influenced both predevelopment conditions in and near the river as well as human development patterns in the Skykomish Valley, a description of this history is important for ascertaining the potential geomorphic ramifications and habitat benefits of restoration actions. Also included in the assessment were photographic observations of Eagle Falls taken by Herrera staff that date back to 2002.

The stream profile was developed using the United States Geological Survey (USGS) 10-meter digital elevation model (DEM) and the King County stream layer to sample elevations at regularly spaced intervals down the channel centerline. The 10-meter USGS DEM is not intended to represent bed elevation, so the longitudinal profile sampled in this way probably represents average banktop elevation. However, given the elevation change in the assessment area (well over 500 feet), the profile provided reasonable qualitative information. In two locations, the stream layer deviated significantly from the valley centerline provided by the County and the known path of the river. In these locations, the stream layer was corrected using recent aerial photography and lidar to more accurately reflect the path of the valley and the river.

Predevelopment Geomorphic Processes

Several historical references were examined, including a recent book that describes the early development of the assessment area (Carlson 2009), and annotated photo archives available from the University of Washington (UW 2012). General Land Office (GLO) surveys and survey notes were also examined (GLO 1895a and b, 1899), as well as other peer-reviewed publications of similar settings (e.g., Collins et al. 2002; Collins and Montgomery 2011). Professional experience and reconnaissance, by boat, foot, and car, were used to field verify the information provided in these resources.

Reach-specific Geomorphic Conditions

For the purpose of the geomorphic assessment, reaches were delineated using a method similar to that proposed by Washington State Department of Ecology (Ecology) for characterizing shorelines to update shoreline master plans (Ecology 2010).

The method delineates reaches based upon a mix of geomorphic and land use characteristics. First, large-scale geologic breaks in the shoreline landscape are noted based upon existing information. Refinements to these larger geologic breaks are then made based on specific shoreline land uses. In the assessment area, reach breaks were quite easy to identify because the large scale geological changes in the assessment area often dictate land use changes, so the differences between the reaches are quite stark. Conditions (e.g., substrate, riparian vegetation, presence of habitat features, LWD, side channels, etc.) within the reaches were derived primarily from direct observations made on the site visit, complemented by existing information (e.g., lidar, floodplain delineation, etc.) where present. Finally these observations are placed within the context of the general background information described above.

Field Studies

A Herrera geomorphologist and an ecologist, accompanied by King County staff, conducted a four-day field reconnaissance of the assessment area in August and September of 2012. The purpose of the field reconnaissance was to observe and document existing conditions and field verify the validity of the literature and other resources. The field reconnaissance occurred via raft over the first three days (August 21 through 23, 2012), covering the area between the Foss River Road Bridge over the Foss River, and Eagle Falls. Flow rates during this period were approximately 1,000 cfs at the Gold Bar gage on the Skykomish River. Because this gage is below the confluence with the North Fork, this is approximately 50 percent greater than the discharge in the lower reaches of the assessment area. The first day of the field reconnaissance (August 21) proceeded from the Foss River Road Bridge to the Fifth Street Bridge in the Town of Skykomish. The second day of the field reconnaissance (August 22) proceeded from the Fifth Street Bridge to the Index Creek Road Bridge. The third day of the field reconnaissance (August 23) proceeded from the Index Creek Road Bridge to Eagle Falls.

In addition to the rafting, 1 day of reconnaissance by car and on foot occurred on September 7, 2012. The reconnaissance thoroughly explored on foot all of the South Fork downstream of Sunset Falls at about river mile (RM) 2. Public roads were also used to access the Mt. Index Riversites development on the alluvial fans and floodplains associated with Bridal Veil and McCall Creeks.

Habitat Impairments

Natural Habitat Limitations

Natural constraints on habitat are described within the context of the physical setting of each reach in the following sections. Once the primary natural constraints on habitat are characterized, the extent of any additional impairment caused by human modifications is assessed.

Human Modifications

Existing human modifications were surveyed and mapped during the field reconnaissance on maps that included aerial photographic coverage for all the reaches, and lidar coverage for all reaches within King County. All manner of human modifications were noted and georeferenced where possible including but not limited to rock armoring, culverts, bridge, fill, and other roadway and railway infrastructure. These marked-up maps were then digitized and imported into a GIS map project.

Observed Habitat Features

Habitat features of the South Fork Skykomish and lower Foss River were observed and marked on aerial orthophotographs during the field reconnaissance. Lidar imagery was initially used to identify habitats, particularly off-channel habitat features (as defined below) and these were confirmed in the field where possible. The observed habitat features were then digitized in GIS and mapped for this technical memorandum. Typically, only the first 20 to 40 feet of the side channels and other off-channel habitats were observed from the boat, unless a clear feature was identified previously in the lidar. Lack of access to private property typically limited further investigation. Aquatic habitat types that were mapped in the field were based on the classification approach used in Ecosystem Diagnosis and Treatment (EDT) as described in Lestelle et al. (2005); channel types and geomorphic units followed the system defined by Montgomery and Buffington (1997); and stream habitats were based on Bisson et al. (1982). Channel types (e.g., braided channel) represent broad patterns of flow that are controlled by bed morphology and flow characteristics. Geomorphic units and stream habitats (e.g., pools and riffles), are distinct physical features of the channel that have relatively homogenous depth, velocity, and substrate characteristics.

Aquatic habitat types are distinguished by whether they occur in-channel (i.e., on the main river) or off-channel (i.e., off main river). The aquatic habitat types identified within the South Fork Skykomish River assessment area are presented in Table 1 and are defined further in the following sections.

Table 1. Aquatic Habitat Types Identified Within the South Fork Skykomish River Corridor.

In-Channel Aquatic Habitats	Off-Channel Aquatic Habitats
Riffle	Overflow channel
Glide/pool	Groundwater channel
Side channel	Tributary
Bedrock	Tributary fan

In-Channel Aquatic Habitats

Riffle

Riffle habitats are characterized by shallow reaches with moderate current velocity and moderate turbulence. Substrate is usually composed of gravel and cobble. The upper gradient limit for this habitat is approximately 4 percent.

Glide/Pool

Glide habitats are characterized by moderately shallow water with an even flow that lacks pronounced turbulence. Glides are most frequently located at the transition between a pool and the head of a riffle, where flow velocity is typically accelerating in the downstream direction. The typical substrate is gravel and cobble.

Pool habitats are topographic depressions within the channel that may include a wide range of flow conditions and can be formed by a variety of different processes. Within the main channel of the river, pools are typically part of a pool-riffle sequence and are maintained by convergence of flow at the lower end of the upper riffle and by the backwater created by sediment accumulation at the head of the lower riffle. The pool-riffle sequence is often associated with bars whose position is frequently set by channel bends and obstructions (e.g., large woody debris). Bars were not mapped as a part of this assessment. Pools can also occur in the absence of obvious bars near major obstructions to flow (e.g., adjacent to bedrock outcrops). Pool types affected by obstructions include backwater pools, trench pools, and lateral scour pools. Substrate size in pools varies from sand to boulder, but typically is gravel and cobble sized in pool-riffle channels.

For purposes of this assessment, glide and pool habitats are classified as a single habitat based on their typically close proximity to each other. In-depth surveying that is beyond the scope of this assessment would be necessary to identify individual pools.

Side Channel

Side channels contain a portion of the streamflow from the main stream channel at flows less than bankfull and are partially or entirely surrounded by vegetated or stable island(s). The side channel may remain connected at its upper end through all flows less than bankfull, or it may become disconnected at some point as flows decline. When flowing, the channel is connected to the main channel at its upper and lower ends. Side channels can contain a variety of subhabitats including riffles, pools, glides, and bars. These subhabitats are generally seasonally variable depending on the hydroperiod of the area. Vegetative and geomorphic (substrate) clues were used determined whether a channel was wetted regularly (less than a 2-year event) and therefore not an overflow channel.

Bedrock

Bedrock is common in the assessment area. While the habitat quality provided by these areas is often marginal, particularly for anadromous fish that require sediment in which to spawn, the extensive presence of bedrock does represent an important habitat type in the assessment area because local bedrock outcrops can drive habitat-forming process and occasionally lead to a diverse range of nearby habitats.

Off-Channel Aquatic Habitat Types

Overflow Channel

Overflow channels represent flood swales, and are often relict mainstem or side channels that carry surface water when high discharges connect their upper end to the main river. Like side channels, they are bordered partly or entirely by vegetated areas. The distinction is that they flow only when flows exceed bankfull stage (i.e., approximately the 2-year event) and therefore do not have water in them most of the time. They may even be vegetated. For purposes of this assessment, overflow channels are characterized as those channels that were observed to have no flow during the site investigation and no obvious flow in the recent past. It is likely that some overflow channels were not mapped because proper delineation of them would require hydrologic and hydraulic information that was not available.

Tributary

Tributaries encompass stream channels that flow into the main river channel, and included Foss River, Beckler River, Anthracite Creek, Maloney Creek, Miller River, Money Creek, Barclay Creek, Index Creek, Bridal Veil Creek, and Philadelphia Creek. Also all tributaries previously mapped by USGS in the assessment area were identified and searched for their current connection to the river. Other smaller tributaries were mapped where found (e.g., McCall Creek in the Mt. Index Riversites development). However, given the channel width and density of vegetation, some smaller tributaries not identified by the USGS were probably missed, especially since the site visit occurred after nearly 2 months of no precipitation. Likely, there are many more ephemeral tributaries that are only active in the wet season.

Tributary Fan

Tributary fans include areas of alluvial deposition at the confluence of the tributary stream with the main river channel. They are generally very productive areas for anadromous fish because they create a wide variety of interrelated habitat types. Previous work in the area has documented extensive use of the alluvial fans in the reach by anadromous fish because of the diversity and quality of the habitat they provide (Herrera 2009). Finally, alluvial fans are common in the assessment area and can produce other habitat types (e.g., groundwater channels).

The extents of tributary fans were mapped based on field observations and the existing topographic data set for the larger named streams mentioned above. It is likely that smaller tributary fans do occur on some of the smaller unnamed tributaries; however, time constraints and access limited a full mapping of these features.

In addition to habitat features, other physical process features were identified. Primarily this included slumps and slides. Though these features were relatively rare, they do provide some context for geophysical hazards, which was a secondary motivation for the assessment.

Observed Restoration Opportunities

Possible restoration opportunities were drawn from the human modifications and their impairments to habitat detailed above. The opportunities also focused on edge and off-channel (side channel and floodplain) habitat improvements, which have been identified by previous studies as the key limiting factors in the assessment area (Snohomish Basin Salmonid Recovery Technical Committee and National Marine Fisheries Service 2005). The focus of restoration activities is exactly what the name implies: restoration of predevelopment conditions. Because recent geological history has resulted in limitations on habitat, there is also potential for habitat creation and augmentation that would result in habitat conditions that are somewhat different from those likely present before major human development (i.e., the construction of the railway, Highway US-2 (US-2), and the residences built along portions of their alignments). These projects were generally not detailed because of their large number and the availability of many other restoration projects that directly mitigate past human impacts.

RESULTS

This section presents the results of the geomorphic analyses and project identification activities described above. It begins with a description of the physical processes responsible for aquatic habitat formation, followed by observations of human modifications and habitat conditions made on-site in the late summer of 2012.The section concludes with the identification of restoration projects identified in the course of the analysis.

Existing Information

Physical Setting

Geologic Context

The assessment area is entirely within the core of the Cascade Range (the Cascades) in central Washington. The Cascades are oriented along a north-south axis that roughly corresponds to the compression of the North American Plate by the Juan de Fuca and Pacific Plate. The Cascades are bisected by a large fault complex, typically called the Straight Creek Fault, which separates younger deep crustal, oceanic-derived rocks in the west from older, heavily metamorphosed continental rocks in the east. The Straight Creek Fault is not exposed as well here as it is elsewhere in the region, but it is expressed in a series of parallel, related (en echelon) faults (e.g., the Evergreen Fault) that define the upstream extent of the assessment area near the confluence with the Beckler, Foss, and Tye rivers. These faults present rocks of varying materials and ages that define the valleys of the Beckler and Foss Rivers (Tabor et al. 1993).

In the Cascades, primarily west of the Straight Creek Fault, the geology is dominated by several large batholiths. Batholiths are large masses of igneous intrusive rock (typically granite or related rocks) that form from cooled magma deep in the Earth's crust. These rocks are resistant to erosion and therefore can support near vertical slopes. The Index and Grotto batholiths cross the assessment area, while the Stuart and Snoqualmie batholiths border the eastern and southern ends of the basin respectively (Tabor et al. 1993).

The Index and Grotto batholiths confine the assessment area into a steep-walled gorge downstream of the Straight Creek Fault. At the downstream end of the assessment area, immediately upstream from the confluence with the North Fork, the Index batholith is exposed in the channel itself, forming a series of bedrock waterfalls that include Eagle Falls, Canyon Falls and Sunset Falls. These falls serve as the long-term geologic (structural) control on the channel profile, as can be seen in the convexity of the profile near RM 2 (Figure 2). Even outside the falls in this area, the banks show exposures of the batholiths, which occasionally dominate local channel morphology and migration.

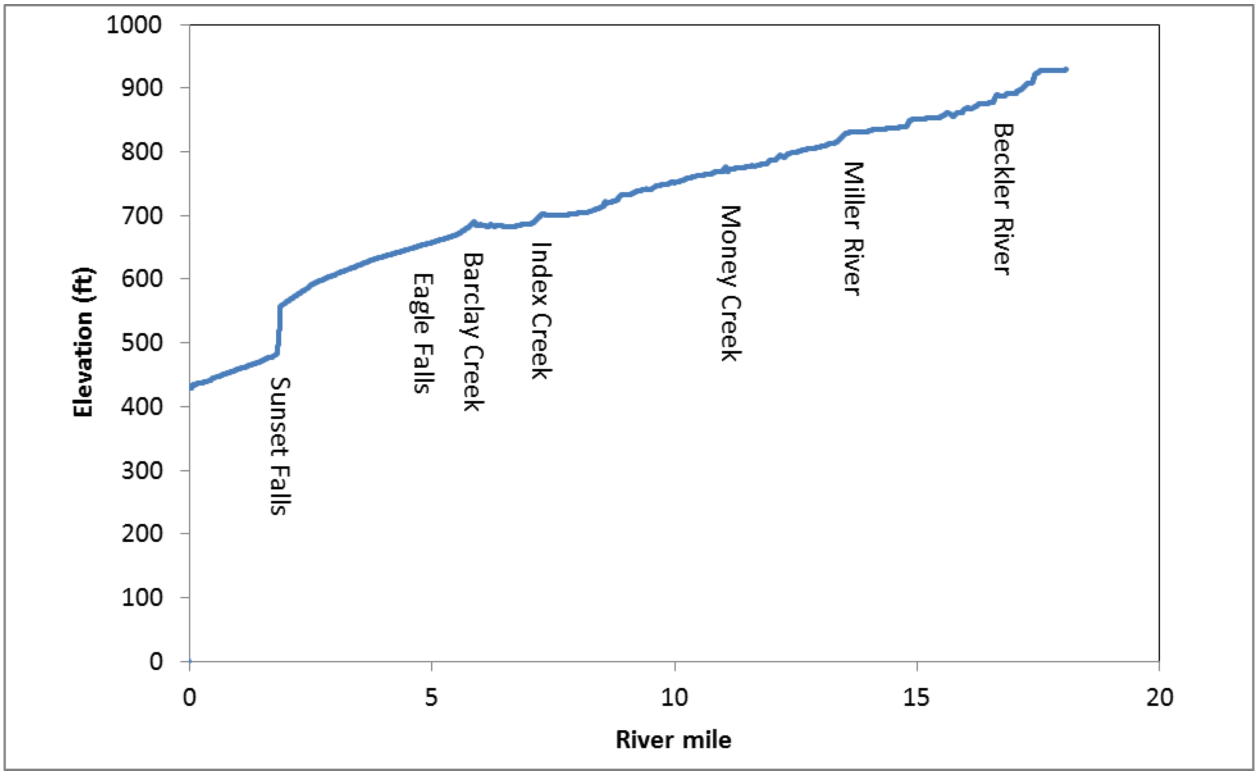


Figure 2. South Fork Skykomish River Longitudinal Profile.

Overprinted on these larger structural features are a series of sedimentary deposits from recent glaciation. Key to the geomorphology of the assessment area, and ultimately the physical controls on the habitat are a series of events that occurred at the end of the last ice age. There were two ice sheets of interest in the assessment area; alpine glaciers that originated in the high Cascades, and the Puget Lobe, a part of the continental-scale Cordilleran ice sheet. The maximum extent of alpine glaciation occurred several thousand years prior to the arrival of the Puget Lobe in western Washington approximately 17,000 years ago (Tabor et al. 1993). Therefore alpine glacial deposits are generally buried by the deposits of the Puget Lobe, and those of later periods (e.g., modern alluvium). As such, the extent of recent alpine glaciation is somewhat unclear, though alpine glacial deposits are observed within the valley such as on the north end of Maloney Ridge above the Town of Skykomish (Tabor et al. 1993).

Once the Puget Lobe reached the area 17,000 years ago, it dammed the Skykomish River below the existing forks, near the east end of Gold Bar (Tabor et al. 1993). The dam diverted the flow of the Skykomish River over a low pass between Mount Persis and Haystack Mountain, and into the Tolt River drainage. The pass has a modern elevation of approximately 1,500 feet. The diversion of drainage water into the Tolt formed a large glacial lake called Lake Skykomish. Due to glacial overpressure, which locally compressed the Earth’s crust, the lake outlet elevation at the pass to the Tolt was suppressed at that time (probably about 1,000 feet) and has since rebounded. This means that the current elevation of the outlet (about 1,500 feet) is higher than the deltaic deposits at the upstream end of the lake, which at the east end are about 1,000 feet in elevation. At elevations below a line connecting these points, lacustrine clays from this lake are found throughout the assessment area. For further details about the extent, timing, and collapse of Lake Skykomish, see Tabor et al. (1993).

Once the Puget Lobe collapsed approximately 12,000 years ago, the Skykomish River once again flowed out through its current path to the Snohomish, and incised through the lacustrine clays of Lake Skykomish until it reached bedrock at Sunset, Canyon, and Eagle falls (Tabor et al. 1993). Erosion into the clays led to the river being incised and having a limited number of side channels and other off-channel areas. If there were juvenile anadromous fish in the system historically, rearing opportunities would be limited. Incision continues today, though it occurs extremely slowly; at most about 1 millimeter per year (Parsons et al. 2002). The incision also led to the formation of valley bottom wetlands that are not connected to or associated with the modern river. The most conspicuous of these is a large wetland complex immediately northwest of the town of Grotto along the north side of US-2. Aside from conventional alluvial processes and the tributary fan processes, the most significant post-glacial process was the Beckler Peak rock avalanche. This 50-million-cubic-yard rock avalanche occurred sometime between 3,400 and 450 years ago, and moved the confluence of the Tye and Foss rivers 2,000 feet to the south (Tabor et al. 1993). The deposit continues to dominate the Foss reach, as described in detail below.

Predevelopment Geomorphic Processes

The post-glacial incision of the Skykomish River into formerly lacustrine deposits in a setting that has undergone alpine glaciation has led to the somewhat unusual geomorphology of the Skykomish Valley. The Skykomish Valley, defined as the broad flat area between bedrock escarpments of the Cascades, is characterized by a series of relatively flat terraces. The highest terraces, which are most prominent at the downstream end of the assessment area above the falls, are primarily lacustrine in origin, with little to no alluvial character. Lower alluvial terraces and off-channel areas are most common between the towns of Skykomish and Baring (Figure 3). The degree to which the river is inset into these terraces increases (roughly) from the Town of Skykomish to Eagle Falls. The lone exception to that trend is near the headwaters at the Foss and Tye river confluence, where the river is incised into the Beckler Peak rock avalanche and the glaciolacustrine deposits near the confluence with the Beckler River.

Prior to the arrival of European settlers, the assessment area was covered in a dense old-growth rain forest (Carlson 2009). The trees in this forest likely contributed to large logjams throughout the assessment area, as has been discussed extensively in the literature (Collins and Montgomery 2011). However, there are some unusual aspects of the assessment area as compared to other Puget Sound rivers that likely altered the typical distribution of large wood. The incised nature of the reach and the ubiquitous presence of lacustrine clay and bedrock meant that there were relatively few opportunities for large wood to become buried in alluvium prior to development. Despite the relative lack of wood storage, instream wood removal was common until recently (up until the 1990s), which is typical for the region (Collins et al. 2002). Rock blasting and logjam removal occurred in the main stem channel near Eagle Falls (Parsons et al. 2002), which also limited wood retention and storage, and channel migration. Although predevelopment wood volumes may have been smaller than elsewhere in the region, the volume of wood found in the river, and its ability to store and deliver wood downstream in the present has been compromised compared to predevelopment conditions as a result of these actions.

Another key aspect to the assessment area is the tributary stream confluences. The tributaries are quite diverse. With the exception of the confluence of the Foss and Tye rivers, all of the largest tributary streams (Beckler River, Miller River, Money Creek, Maloney Creek, Barclay Creek, and Index Creek) have some form of alluvial fan associated with them at the confluence. The Money-Miller Fan is by far the largest and most complex (Herrera 2009). This is most likely a result of its location in the river profile. These are the only large streams that flow across what was once the bed of Lake Skykomish. This means that they enter the South Fork at a relatively flat portion of its profile, heightening bedload deposition, and local storage of tributary sediment. The Beckler River is confined within glaciodeltaic deposits of Lake Skykomish, and the Foss River confluence is dominated and confined by the Beckler Peak rock avalanche. The other large creeks have smaller alluvial fans because they are derived from smaller basins, but they do exert a strong influence on sediment supply, riparian conditions and overall habitat diversity at their confluence points.

Historic channel geometry and migration through time is well summarized by King County (2005). The conclusion of this work is that the river is actually quite locked in place, which is consistent with the overall incisive nature of the system. The areas with the most pronounced channel positions over time are on the Money-Miller Fan, again consistent with the explanation of these features provided in the previous paragraph.

Reach-specific Geomorphic Conditions

The reaches are shown in Figure 1. The natural and anthropogenic geomorphic conditions are highly variable throughout the assessment area. Because of this, the assessment area was divided into eight discrete reaches, each of which is discussed below.

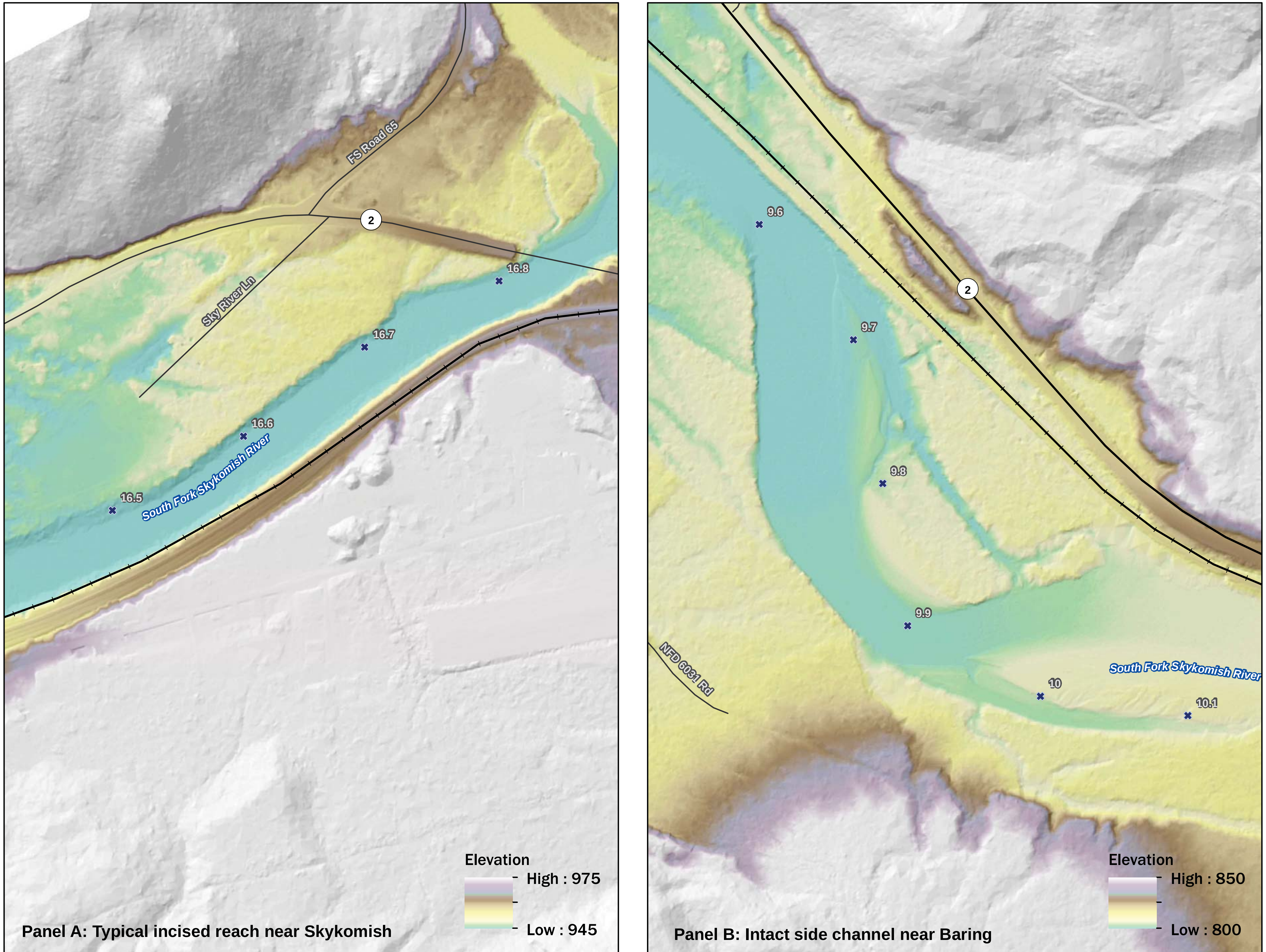
Foss Reach

The confluence with the Foss River, formerly called Coal Creek (UW 2012), has been strongly influenced by the Beckler Peak rock avalanche. This reach is dominated by slide debris that typically has a diameter of approximately 5 meters (or 15 feet: Tabor et al. 1993). The channel itself is incised into this material, making it difficult to navigate at low flow, though there is a small alluvial fan associated with the Foss River, where there are opportunities to remove fill and improve floodplain connectivity. There is development along the banks throughout the reach; however, because of the large size of the rock within the rock avalanche and the degree of incision of the river, there is little need for bank armoring and other human modifications. Erosion is ongoing as the river continues to incise through the rock avalanche deposit, but it is relatively slow and can prevented with soft armoring techniques. As such, the reach does not significantly deviate from predevelopment conditions and is at limited risk to future bank protection actions.

Beckler Reach

The Beckler reach includes the South Fork from the downstream extent of the Beckler Peak rock avalanche to the US-2 Bridge at RM 16.8. This reach is in the part of the valley

Figure 3.
Illustration of a typical incised reach near Skykomish and a more unusual example of an intact side channel near the town of Baring.



Legend

- River mile
- Railroad
- Road

N

0 175 350 700
Feet

HERRERA

LiDAR: King County (2011)

Produced By: GIS
Project: K:\Projects\10-04766-019\Project\Report_Maps\Incised_Reaches.mxd (12/6/2012)

dominated by the large deltas that formed at the upstream end of glacial Lake Skykomish. The banks of the river consist of poorly consolidated deltaic sediments, ranging from cobble-size to poorly consolidated clay. Due to temporal variations in sediment supply to the former lake, there are many unstable horizons or layers in the sediments. Banks are often unraveling rapidly, and many slides were observed. The interbeddedness of the deposits also makes them prone to sliding. There are numerous slides on the right bank, particularly across the river from the developed left bank (Timber Lane Village). Unfortunately, these slides are coincident with both the Anthracite Creek and Beckler River fans. In places, these slides have created side channels with reasonably intact riparian conditions. However, in several areas, the dynamic nature of the slides forces the river against armored shorelines immediately adjacent to private homes in the Timber Lane Village development.

Skykomish Reach

This reach is the most altered by human activities of all reaches in the assessment (Table 2). Revetments in the King County facility inventory are located on both sides of the river within the Town of Skykomish. The primary crossing in town is located on an ideal geomorphic location for a crossing, evident by the bedrock outcrop on the north (right bank) side and the high floodplain terrace to the south (on the left bank). Extensive side channel networks likely existed through most of the town on the far south edge of the floodplain prior to development, as evidenced by the abandoned outlets upstream of town (on the left bank) and the extensive flooding observed shortly after the construction of the town (i.e., in 1932: UW 2012). These side channels have largely been obliterated by development.

Table 2. Summary of Armoring Length and Percentage by Reach.

Reach	Total Armoring Length (ft)	% of Total Shoreline
North Fork Reach (River Mile 0.0 to 1.5)	696.94	0.37%
Falls Reach (River Mile 1.5 to 5.3) [a]	1,970.15	1.04%
Barclay Reach (River Mile 5.3 to 6.9)	1,300.33	0.69%
Baring Reach (River Mile 6.9 to 11.2)	8,076.95	4.26%
Money-Miller Reach (River Mile 11.2 to 14.3)	4,942.59	2.60%
Skykomish Reach (River Mile 14.3 to 16.8)	6,892.90	3.63%
Beckler Reach (River Mile 16.8 to 18.85)	2,233.76	1.18%
Foss Reach (River Mile 18.85 to 19.4)	252.95	0.13%

[a] Approximately 3 miles of shoreline between Sunset and Eagle Falls was not surveyed.

Money-Miller Reach

The Money-Miller Fan is a large, complex alluvial fan that spans nearly three river miles along the South Fork. Here, the South Fork is forced up against US-2 and the BNSF railway by the sediment supply from the Milller River and Money Creek. The South Fork often abuts bedrock on the north side of the valley, including at a bedrock outcrop, where a short, well-known tunnel is built in US-2. As a result, there are large stretches of river that have rock revetments on them (likely built to protect infrastructure), particularly near the Money Creek

Campground, where the river is pinched on both sides by the Old Cascade Highway and US-2. The grain size is also the most variable of any reach because of the variability in sediment supply from the two sedimentologically active tributaries. All of the channels in these areas (i.e., the South Fork, Miller River, and Money Creek) are much more dynamic than in the other reaches (Herrera 2009) because these two large streams discharge into what was a former flat glacial lake bottom. Therefore the channel profile of the Miller River and Money Creek change significantly near their confluences with the South Fork, allowing for much more deposition to occur than occurs elsewhere on the South Fork. The Money-Miller Reach is a highly ecologically productive reach because nearly the entire reach is a tributary fan, despite significant abandoned human modifications. As such ecological lift from restoration activities could be significant. Therefore the most heavily modified portion of the reach (i.e., the Miller River Fan) is the subject of a more detailed analysis (Herrera 2012).

Baring Reach

After the Skykomish reach, this is the second most modified reach (Table 2). However, outside the developed corridors in the vicinity and the Index Creek Bridge, pre-development conditions are relatively intact (i.e., unmodified). Several active side channels occur in the reach, some of which also have several logjams and scattered LWD throughout. The location of side channels is set by the overall profile of the reach and its position in the landscape (i.e., it is upstream from the bedrock constriction, facilitating sediment deposition and a relatively active channel migration zone, but not too deeply incised into the clay deposits), making it an excellent place to expand or restore side channel habitat.

Barclay Reach

The Barclay reach is deeply incised (up to 40 feet) into Lake Skykomish clay deposits. As such the clay riverbanks within this reach are eroded by the river (as compared to bedrock, though not as much as loose alluvium), and actively eroding (unarmored) banks are more common in this reach than in any other. In several locations, erosion has placed several private residences at risk, particularly near the Barclay Creek Fan.

Falls Reach

The Falls reach is dominated by three sets of bedrock waterfalls: Eagle Falls, Canyon Falls, and Sunset Falls. The river drops nearly 200 vertical feet in this 5-mile section of river. All of the exposed bedrock is part of the Index Batholith (primarily granodiorite and tonalite), though lacustrine clay can be found in more quiescent backwaters. The elevation drops at all three falls are complete upstream fish barriers. Because bedrock is common, flow energy is extreme and, historically, anadromous fish were precluded from the reach. The reach is developed, and although deforestation of the riparian areas is common, the presence of bedrock means that very little bank armoring occurs here. Detailed information is not available for this reach since it was not directly observed. This was because the area was inaccessible due to being completely in private ownership and unfloatable.

North Fork Reach

Approximately the lowest 1.5 miles of the South Fork are distinct from the Falls reach, though this portion is also controlled by bedrock outcrops. For the lowest mile it is essentially undeveloped, with only a few cabins on the right bank. As such, stream conditions are intact in this area, although they are slightly naturally constrained by the near-surface bedrock. The upper reaches extend into the Mt. Index Riversites development. The Mt. Index Riversites development has a large floodplain that is developed. Infrastructure and residential development has added fill in several locations. Several of the homes that are in the floodplain are in extreme disrepair and would likely make good acquisition targets. Though the US-2 Bridge is quite old, it is in a suitable place from a geomorphic perspective and does not constrict the channel or floodplain in a significant way.

Field Studies

As stated earlier in this document, the field reconnaissance began on August 21, 2012, at the Foss River Road Bridge immediately upstream from the upstream end of the assessment area. The river was floated down to the Fifth Street Bridge in the Town of Skykomish. Initial progress was slowed by having to navigate the large rocks in the middle of the channel that originated from the Beckler Peak rock avalanche. Because of intact riparian conditions in this area, very few restoration opportunities were noted on this day.

On the second day (August 22), the reach between the Fifth Street Bridge in the Town of Skykomish and the Index Creek Bridge was observed. This day included an examination of several bars near US-2 and a large side channel complex immediately upstream from the developed area near the town of Baring at approximately RM 7.4.

On the third day of the raft trip, the reach between the Index Creek Road Bridge and Eagle Falls was examined. This included detailed examination of several side channels with varying degrees of modification and a complete reconnaissance of Eagle Falls and its vicinity, where several restoration projects were identified.

On the fourth day of reconnaissance (September 7), which was done by car and on foot, the main stem of the river was walked below the ordinary high water mark between the US-2 Bridge over the South Fork and Sunset Falls. Juvenile fish were abundant in nearly all of the pools observed. One redd was identified near adult coho fish at the downstream end of the Mt. Index Riversites neighborhood. Due to constraints imposed by a vehicle accident and road closure on US-2, only the Mt. Index Riversites neighborhood was visited by car. Several floodplain creek crossings were identified and documented. Improvement of several of these crossings represents an excellent restoration opportunity.

Habitat Impairments

Natural Limitations

It is important to place the habitat observed in context with the predevelopment conditions described above. The South Fork Skykomish River did not have anadromous fish prior to the trap and haul operations at Sunset Falls, which began in 1958. Therefore, historically interactions between anadromous fish and the riparian ecosystem have not occurred, although resident fish were historically present and are currently present. In addition, there are several other limitations to salmon habitat that have always existed. Probably the most significant is in the Falls reach that is mostly comprised of bedrock, limiting substrate suitable for spawning. Lacustrine clay also regularly outcrops in the assessment area (Figure 4).

Figure 4. Lacustrine Clay Exposed Along the Banks of the South Fork Skykomish River.

Landslides, another common natural limitation, which results in the filling of pools and production of anomalous amounts of fine sediment which can embed spawning gravel, also occur in the assessment area (in and around the mainstem) but are relatively rare (Washington DNR 2012). They do occur extensively in the Beckler reach due to the presence of unraveling glaciodeltaic deposits, rich in fine sediment. Riparian conditions in this area are compromised, primarily due to the anomalous supply of fine-grained material. Bank erosion also occurs elsewhere within the assessment area, but at a generally low density and in isolated patches and should not be considered a habitat limitation.

Human Modifications

The primary human modification throughout the assessment area is the placement of fill and protective armor along the prism of US-2 and the BNSF rail line (Figure 5). While the active

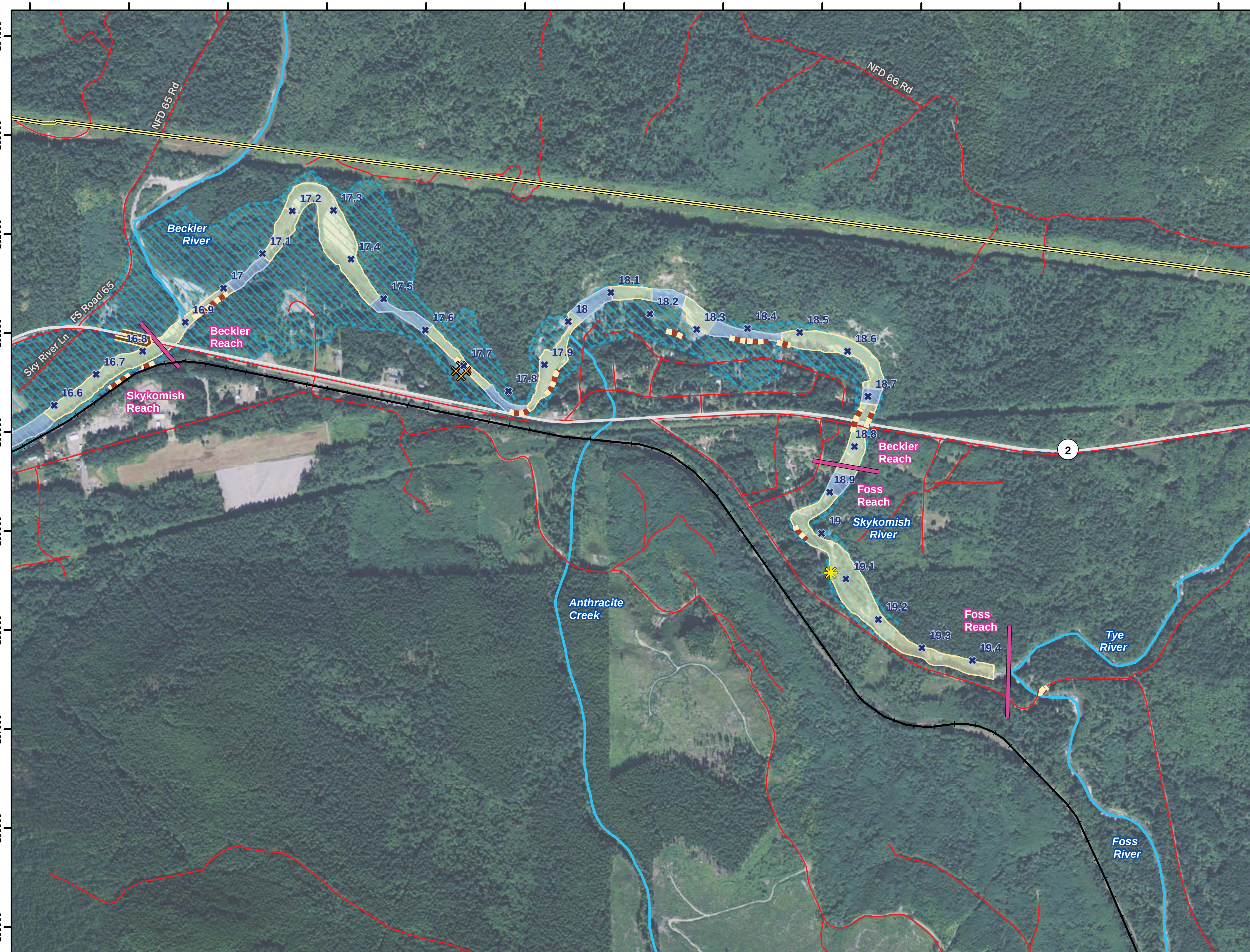
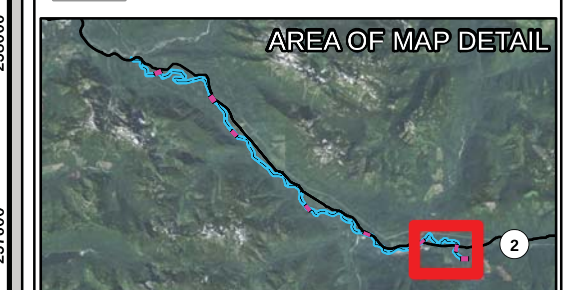


Figure 5.
Observed human modifications on the South Fork Skykomish River, Washington.
(Sheet 1 of 7)

Legend

- River mile
- Floodplain
- Facility observed
- LWD
- Reach break
- Anchored LWD
- Structure
- Rock/riprap
- Culvert
- Trash
- Fill
- Pool
- Riffle
- BPA powerlines
- Road
- Railroad
- Parcel



N

0 500 1,000 2,000
Feet

HERRERA

Aerial: USDA (2011)

Produced By: GIS
Project: K:\Projects\10-04766-019\Project\Report_Maps\Human_Mods.mxd (12/13/2012)

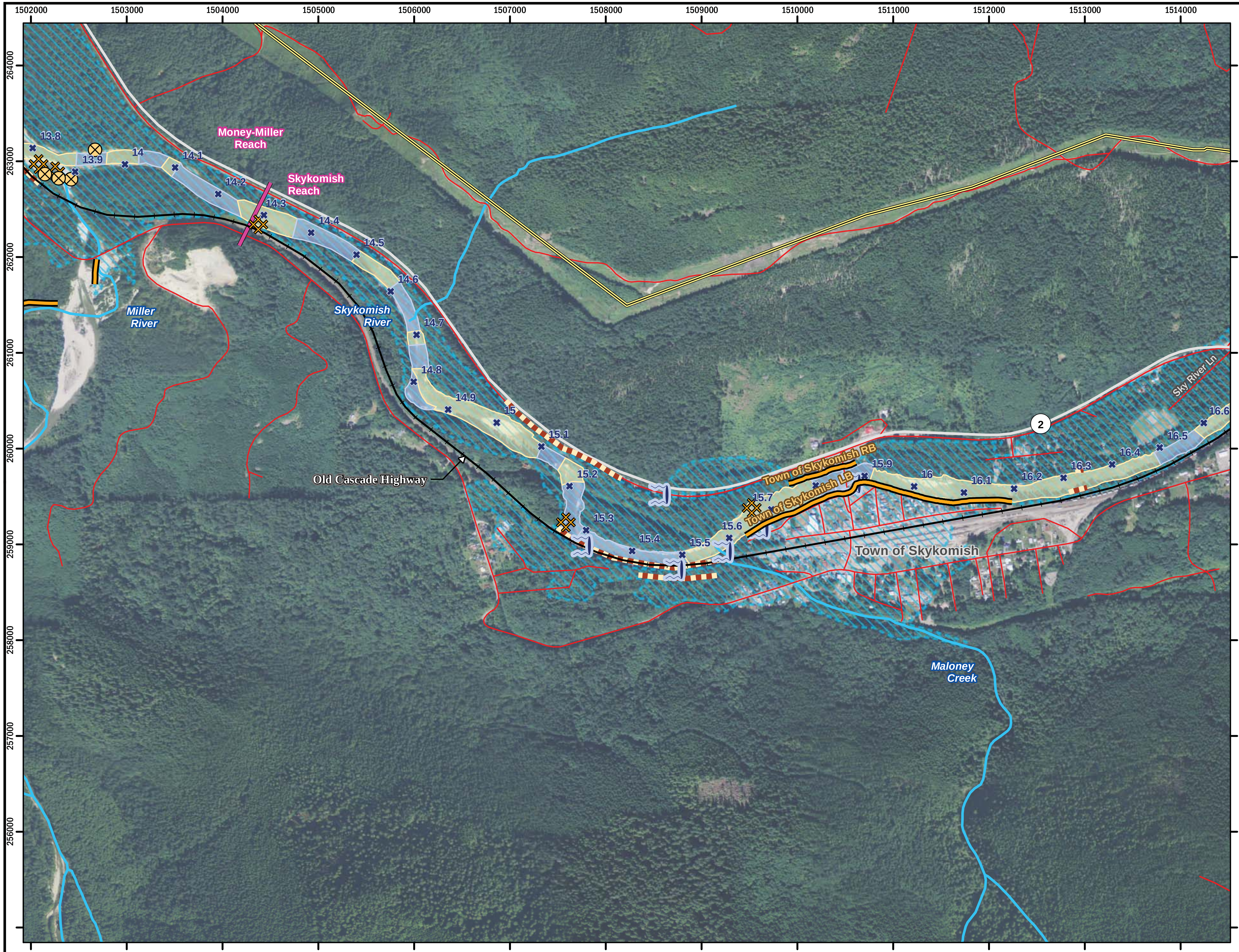
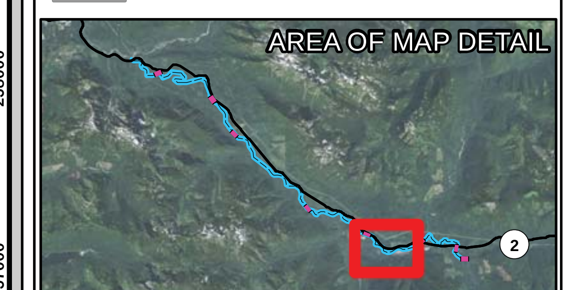


Figure 5.
Observed human modifications on the South Fork Skykomish River, Washington.
(Sheet 2 of 7)

Legend

- River mile
- Floodplain
- Facility observed
- LWD
- Reach break
- Anchored LWD
- Structure
- Rock/riprap
- Culvert
- Trash
- Fill
- Pool
- Riffle
- BPA powerlines
- Road
- Railroad
- Parcel



N

0 500 1,000 2,000
Feet

HERRERA

Aerial: USDA (2011)

Produced By: GIS
Project: K:\Projects\10-04766-019\Project\Report_Maps\Human_Mods.mxd (12/13/2012)

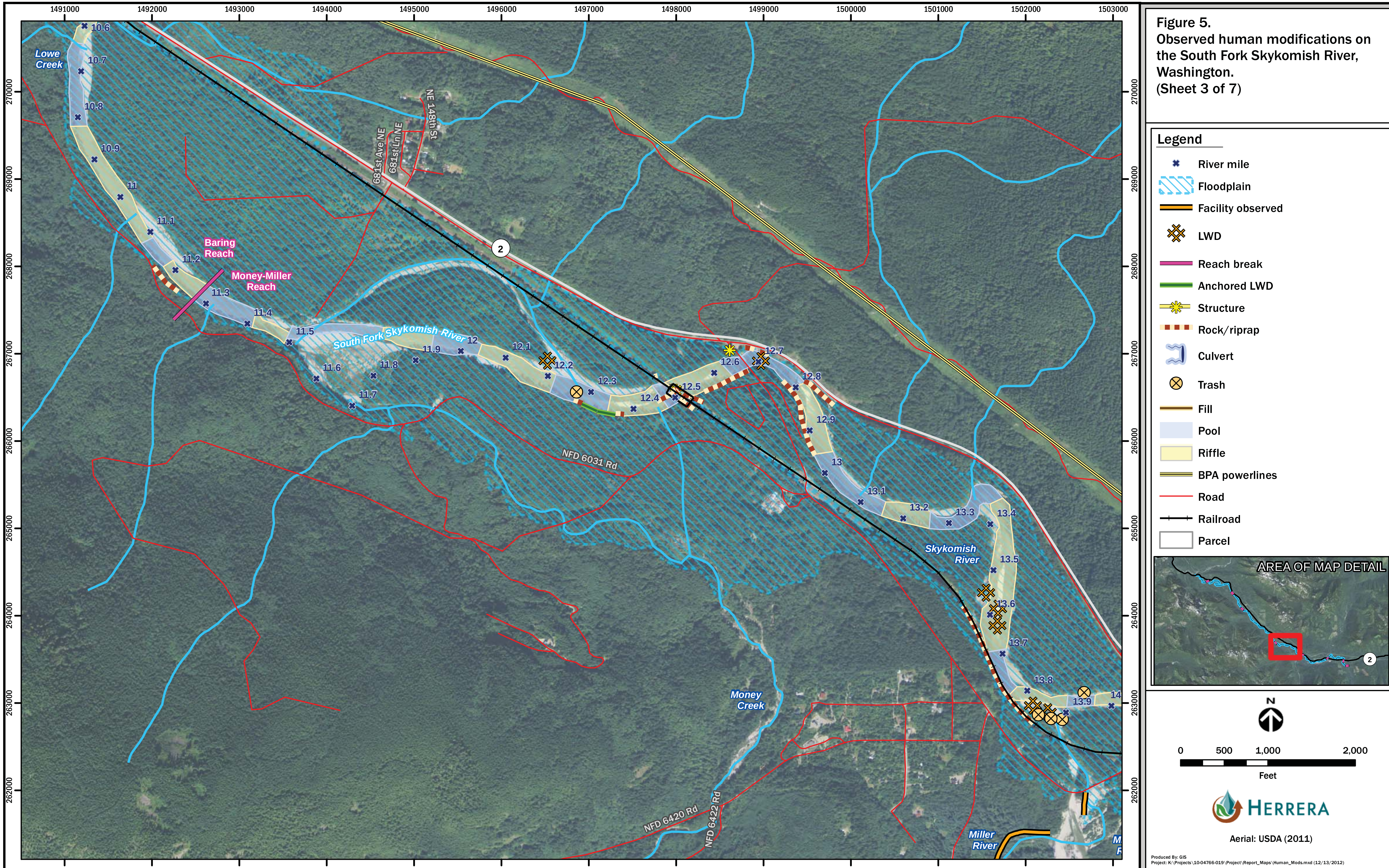
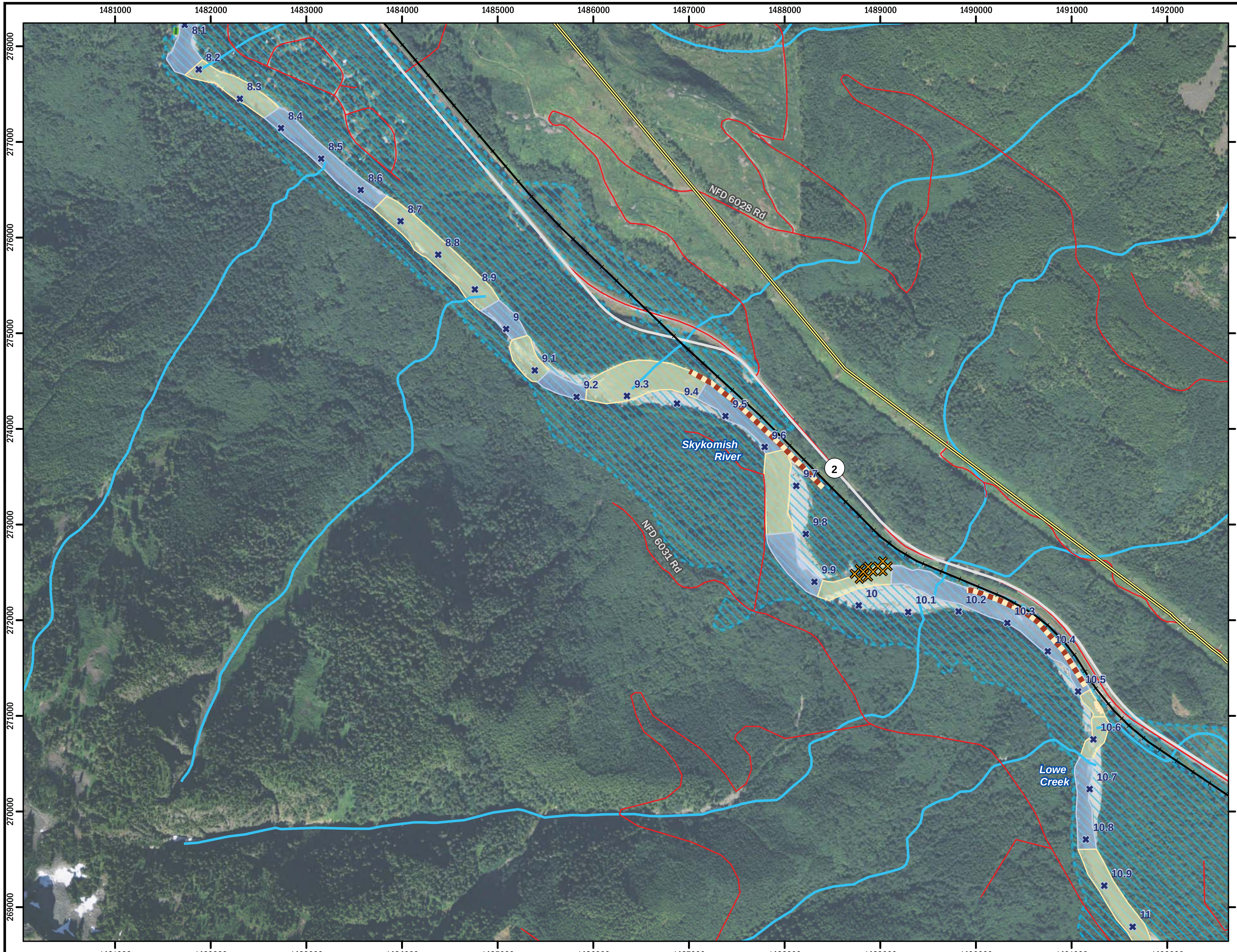


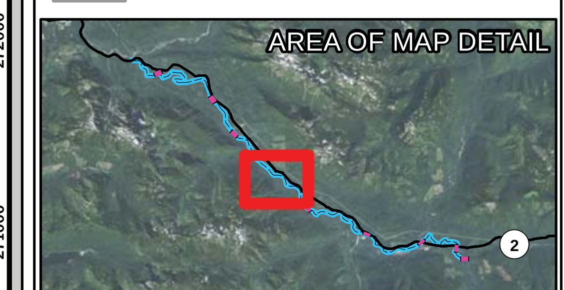
Figure 5.
Observed human modifications on the South Fork Skykomish River, Washington.
(Sheet 3 of 7)

Figure 5.
Observed human modifications on the South Fork Skykomish River, Washington.
(Sheet 4 of 7)



Legend

- River mile
- Floodplain
- Facility observed
- LWD
- Reach break
- Anchored LWD
- Structure
- Rock/riprap
- Culvert
- Trash
- Fill
- Pool
- Riffle
- BPA powerlines
- Road
- Railroad
- Parcel



N

0 500 1,000 2,000

Feet

HERRERA

Aerial: USDA (2011)

Produced By: GIS
Project: K:\Projects\10-04766-019\Project\Report_Maps\Human_Mods.mxd (12/13/2012)

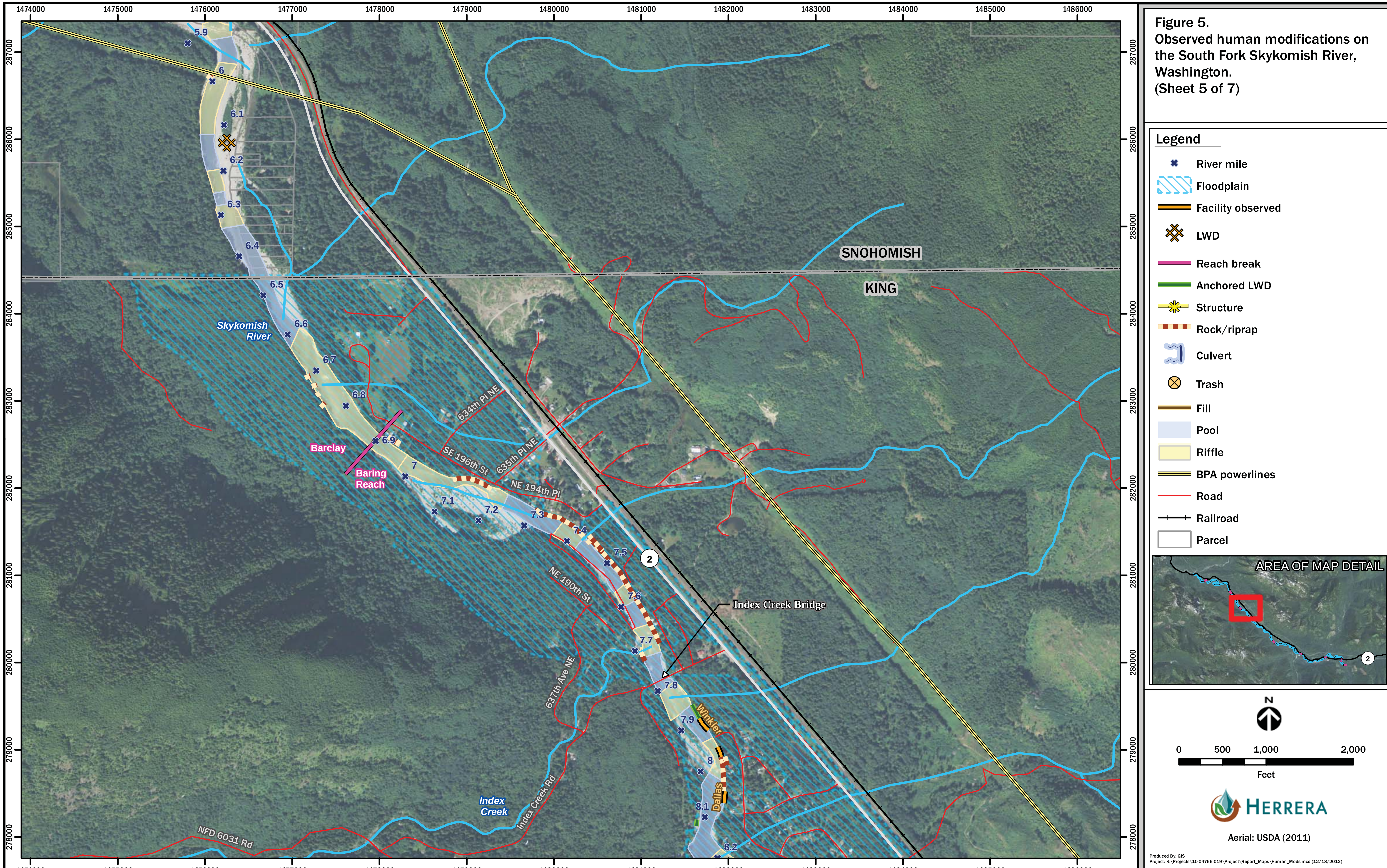


Figure 5.
Observed human modifications on the South Fork Skykomish River, Washington.
(Sheet 5 of 7)

HERRERA

Aerial: USDA (2011)

Produced By: GIS
Project: K:\Projects\10-04766-019\Project\Report_Maps\Human_Mods.mxd (12/13/2012)

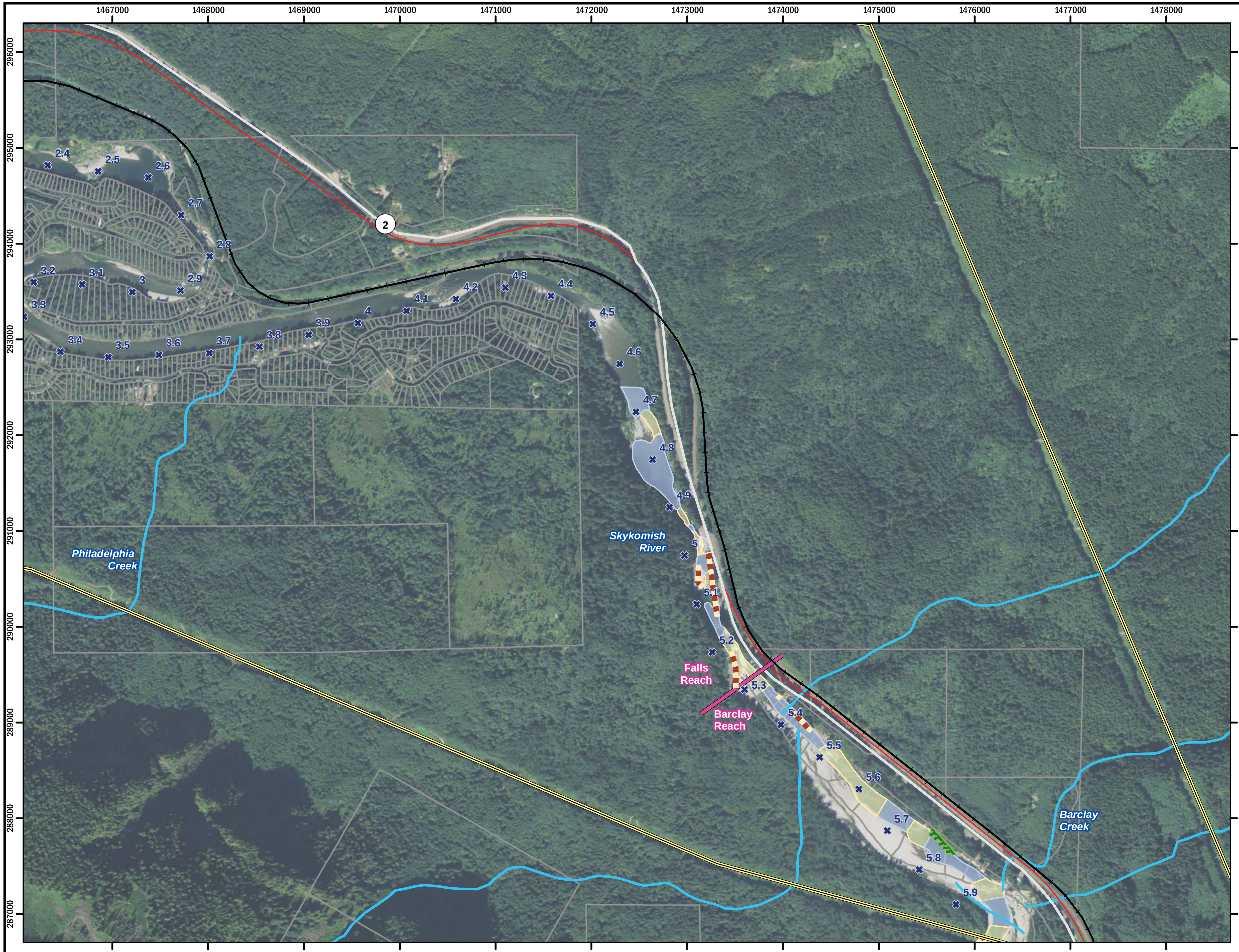


Figure 5.
Observed human modifications on the South Fork Skykomish River, Washington.
(Sheet 6 of 7)

Legend

- River mile
- Floodplain
- Facility observed
- LWD
- Reach break
- Anchored LWD
- Structure
- Rock/riprap
- Culvert
- Trash
- Fill
- Pool
- Riffle
- BPA powerlines
- Road
- Railroad
- Parcel

N

0 500 1,000 2,000
Feet

HERRERA

Aerial: USDA (2011)

Produced By: GIS
Project: K:\Projects\10-04766-019\Project\Report_Maps\Human_Mods.mxd (12/13/2012)

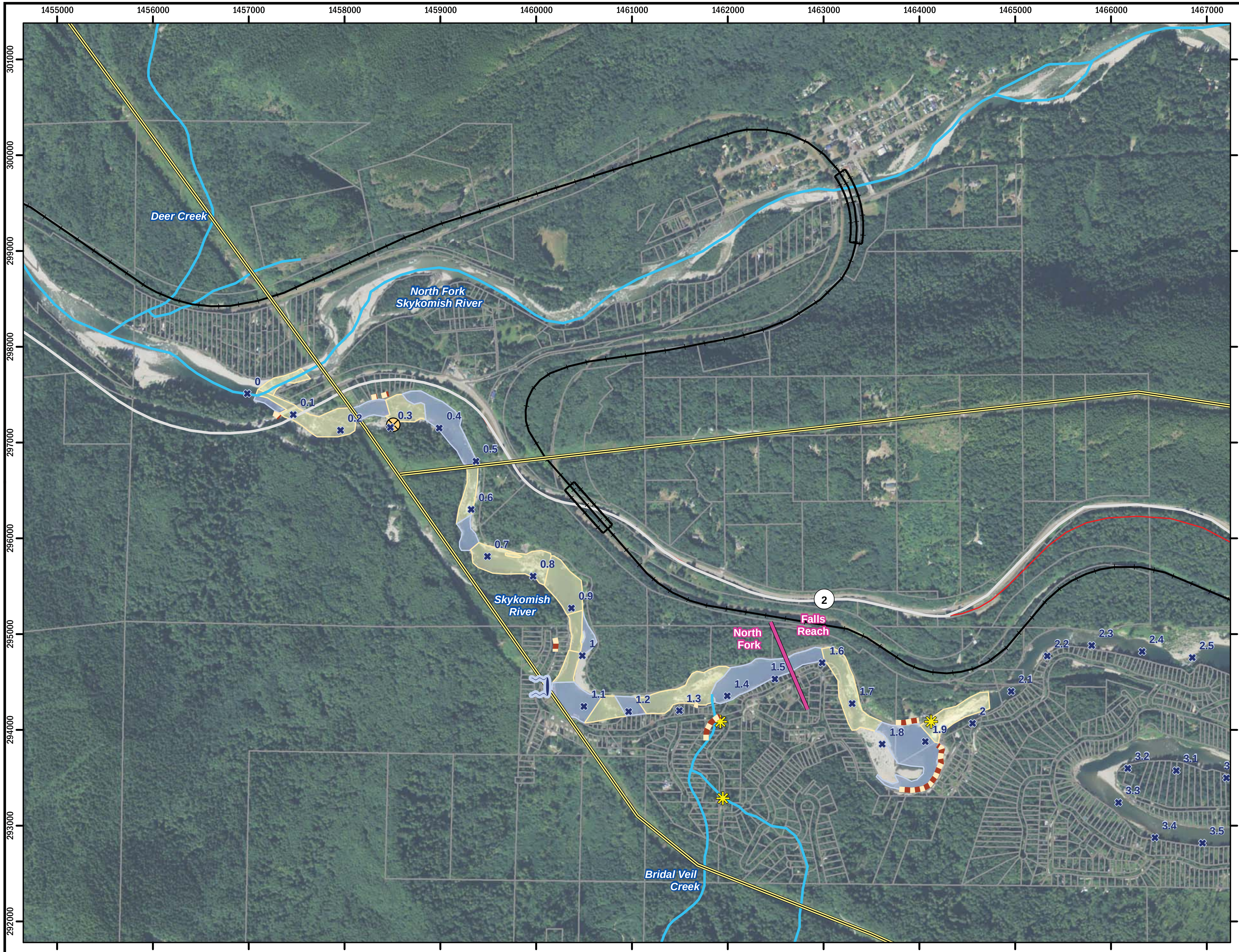


Figure 5.
Observed human modifications on the South Fork Skykomish River, Washington.
(Sheet 7 of 7)

Legend

- River mile
- Floodplain
- Facility observed
- LWD
- Reach break
- Anchored LWD
- Structure
- Rock/riprap
- Culvert
- Trash
- Fill
- Pool
- Riffle
- BPA powerlines
- Road
- Railroad
- Parcel

AREA OF MAP DETAIL

N

0 500 1,000 2,000
Feet

HERRERA

Aerial: USDA (2011)

Produced By: GIS
Project: K:\Projects\10-04766-019\Project\Report_Maps\Human_Mods.mxd (12/13/2012)

channel complex remains somewhat naturally confined by the incision of the Skykomish River into glaciolacustrine deposits of former glacial Lake Skykomish, the road and the rail line pinch the river further, similar to what occurs on the east side of Stevens Pass on Nason Creek (BOR 2008). Because of the natural confinement (unlike on Nason Creek), it is less clear what role and to what extent natural incision has played in the disconnection of off-channel areas.

Outside of these developed areas and away from the road and rail line, human modifications are relatively modest and isolated and have very little impact on predevelopment geomorphic conditions. As expected, most of the private (i.e., not associated with US-2 or the BNSF rail line) human modifications (primarily bank armoring) occur in association with the two largest towns in the assessment area, which are Skykomish and Baring. Though some of these modifications are owned and maintained by the County, there are significant lengths that are in purely private ownership.

Another assessment area-wide modification is logging. Much of the private land in upland areas is actively managed for timber production. Logging has also occurred within the National Forest lands, previously in valley bottoms, and more recently on steep slopes. In general, logging is usually associated with an increase in sediment yield, particularly when done in areas with high relief (Croke and Hairsine 2006), which is where it now predominantly occurs. Logging can also increase the incidence of debris flows (Wemple et al. 2001). Both forest roads and logged areas produce large amounts of fine grain material, which can cause redds to embed, reduce the viability of salmonid embryos, and thus reduce egg-to-embryo survival (Chapman 1988). Logging also has changed the supply of woody debris to the channel. Smaller wood is more common and in this high-gradient, high-energy system, this impact could also reduce the retention of LWD.

Human modifications have had the most pronounced influence on habitat conditions on the tributary fans. The two largest of these alluvial fans, the Beckler Fan and the Money-Miller Fan, have human modifications and existing infrastructure, which heavily constrain the dynamic nature of these features. In addition to the habitat implications, the presence of infrastructure and development on these alluvial fans represents a potential hazard to human life, and makes it particularly difficult to manage the existing infrastructure and preserve habitat functions.

Observed Habitat Features

The following section describes the observed habitat features within the South Fork Skykomish River assessment area.

In-Channel

The main channel of the South Fork Skykomish is dominated by a regular sequence of interchanging glide/pool and riffle habitats (Figure 6). A coarse assessment of pool frequency per stream mile was performed. Results show pool density to be very low, at only 3.5 pools per stream mile, although this is likely underestimated due to the coarse and rapid nature of the field reconnaissance. Also, pool frequency is likely to be lower than other streams due to natural incision through the lakebed clays. Although a different protocol than what was used in the field reconnaissance, National Oceanic and Atmospheric Administration (NOAA)

Fisheries (1996) indicates a properly functioning river that is between 75 and 100 feet wide should have a pool frequency ranging from 18 to 23 pools per mile. Even if the field estimate is low, it is not likely to be as high as the NOAA Fisheries (1996) indicator because of the geomorphic constraints discussed above. However, pools were high quality, as they tended to be at least three feet deep or deeper, meeting the NOAA Fisheries (1996) indicator for properly functioning pool quality. These pools were mostly formed by underlying changes in the substrate and bedrock, though modifications, such as revetments, commonly reinforce these patterns.

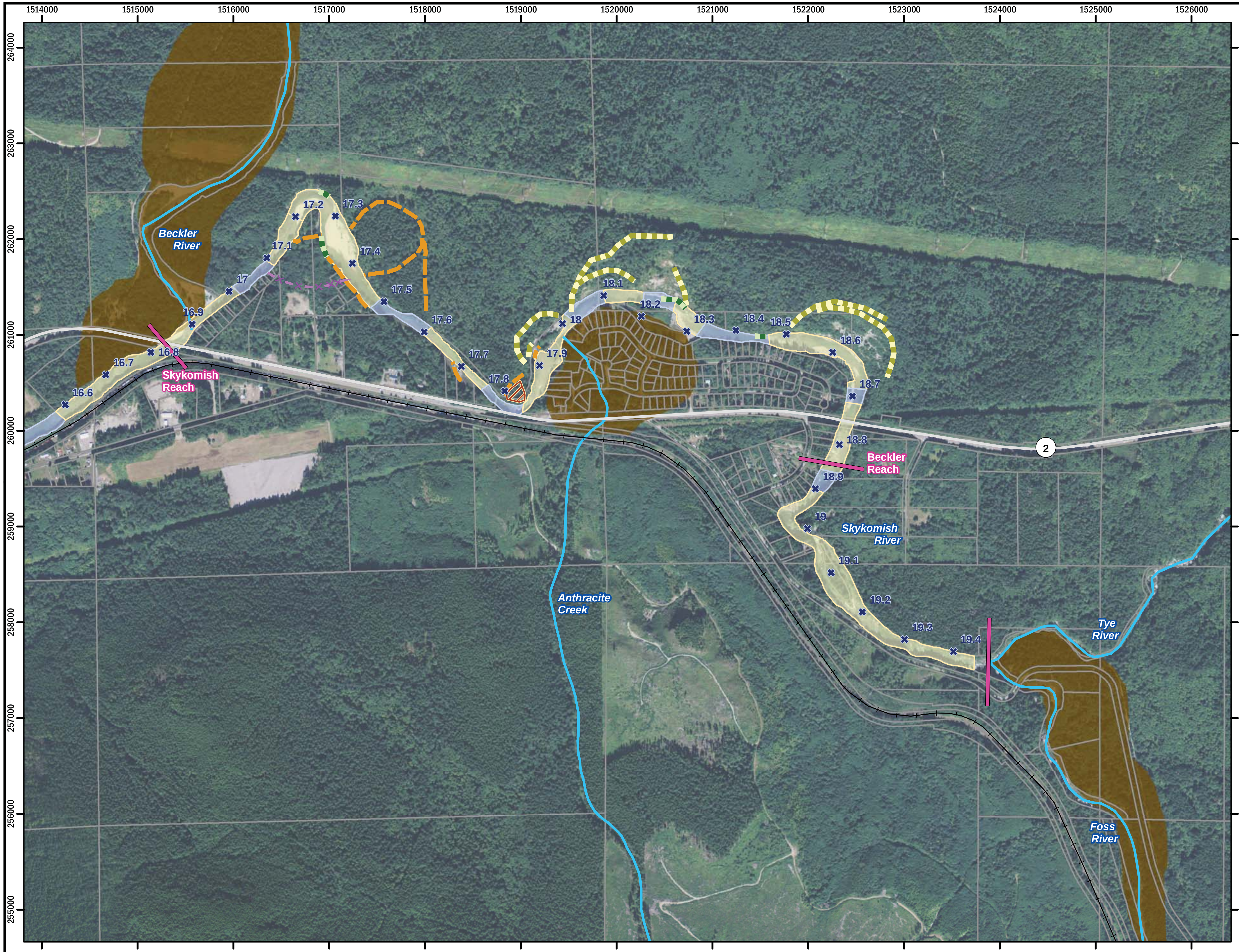
Bars comprised of a range of materials from large boulders (mean diameter in excess of 2 to 3 feet) to gravel were located throughout the study area, though the mechanisms that formed them vary widely. In-channel bars that are unvegetated are typically dynamic and a diversity of habitats form in and around them, such as quiescent pools, tailouts for spawning, and seasonal shallow channels during high water. Bar habitat is limited in areas where development, the BNSF rail line, or US-2 confine the channel from the confluence with the Foss River downstream to approximately RM 14.3, at the upper end of the Money-Miller reach. Bars are also limited starting in the Falls reach to the confluence with the North Fork because the channel is constricted by bedrock outcrops (discussed above). Bars are more expansive in the reach between Miller Creek confluence and Eagle Falls due to this area being near a local minimum of post-glacial incision.

Active side channels (including backwater channels) are also more extensive in the reach between the Miller River confluence and Eagle Falls than in any other reaches of the South Fork Skykomish River. Juvenile fish were observed in two side channels in these reaches, where pools were available for rearing. Where the channel was confined by bedrock or rock avalanche deposits, side channels were generally not present. Side channels in the more developed reaches at Skykomish and Baring were constricted or partially blocked by development, roads, and in some places, by bank armoring.

The presence of LWD was extremely limited within the assessment area, relative to other western Washington rivers. This is due to numerous factors, including deforestation for timber harvesting and stream cleaning that occurred most extensively in the 1970s through early 1990s (Snohomish Basin Salmonid Recovery Technical Committee and National Marine Fisheries Service 2005; USFS 1995). There may be other natural factors that contribute to the lack of the wood in the stream, primarily related to the river being simplified and incised. As expected, an infrequent number of large log jams were observed primarily in the reaches below Skykomish until the Falls Reach. Two log jams were also observed along the right bank where landslides had occurred across from housing developments on the upstream outskirts of Skykomish between RM 18.6 and RM 18.1 in the Beckler Reach. Two single logs that were cabled into the bank were observed along the eroding banks at Money Creek Campground, but these examples are an incredibly small amount given the length of river examined (nearly 20 miles).

Edge habitat is another key habitat type that has been identified as needing improvement in the assessment area (Snohomish Basin Salmonid Recovery Technical Committee and National Marine Fisheries Service 2005). Riprap and rock have been placed along approximately 5 miles (26,000 feet) of shoreline in the South Fork assessment area (see Table 2). Placement of

Figure 6.
Observed geomorphic and habitat features on the South Fork Skykomish River, Washington.
(Sheet 1 of 7)



Legend
- River mile
- Reach break
- Clay
- Redd
- Bedrock
- LWD
- Erosion
- Slide
- Side channel
- Overflow channel
- Tributary
- Tributary alluvial fan
- Railroad
- Pool
- Riffle
- Parcel
- County boundary

AREA OF MAP DETAIL

N

0 500 1,000 2,000
Feet

HERRERA

Aerial: USDA (2012)

Produced By: GIS
Project: K:\Projects\10-04766-019\Project\Report_Maps\Geomorph_and_Habitat_v2.mxd (12/18/2012)

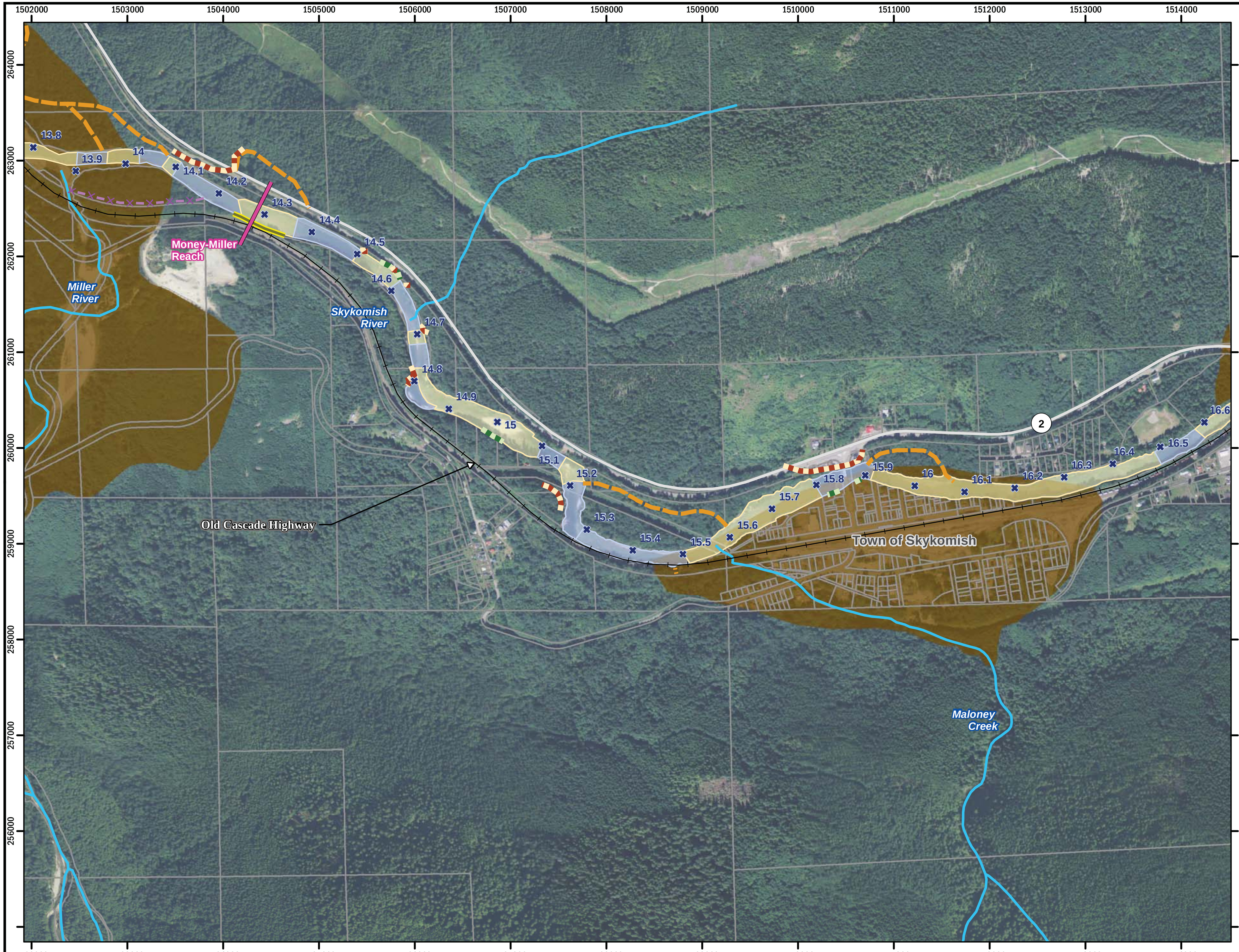
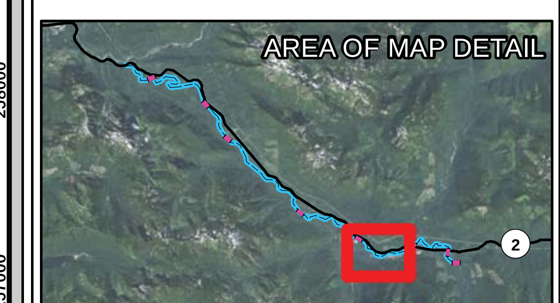


Figure 6.
Observed geomorphic and habitat features on the South Fork Skykomish River, Washington.
(Sheet 2 of 7)

Legend

- River mile
- Reach break
- Clay
- Redd
- Bedrock
- LWD
- Erosion
- Slide
- Side channel
- Overflow channel
- Tributary
- Tributary alluvial fan
- Railroad
- Pool
- Riffle
- Parcel
- County boundary



N

0 500 1,000 2,000
Feet

HERRERA

Aerial: USDA (2012)

Produced By: GIS
Project: K:\Projects\10-04766-019\Project\Report_Maps\Geomorph_and_Habitat_v2.mxd (12/18/2012)

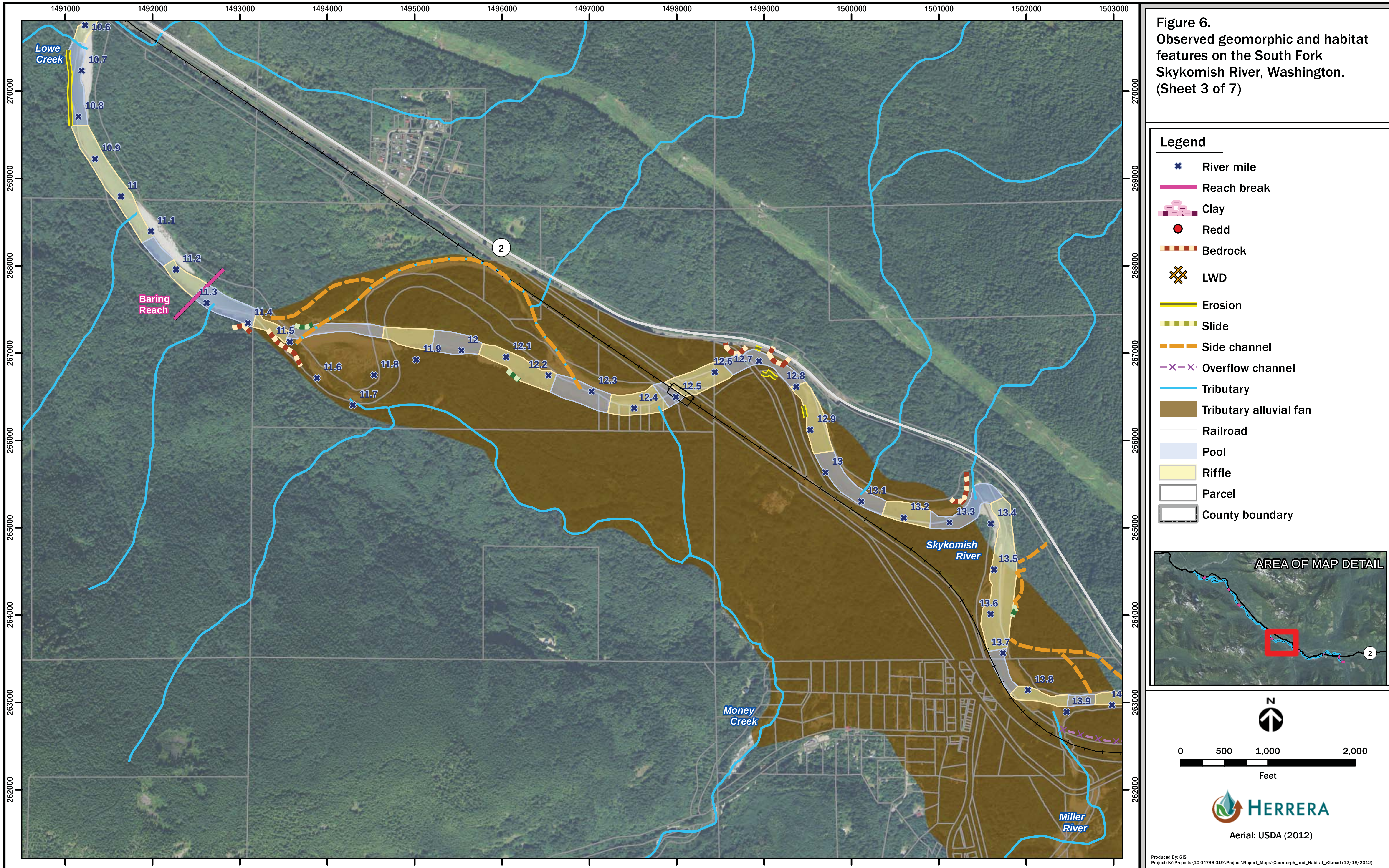


Figure 6.
Observed geomorphic and habitat features on the South Fork Skykomish River, Washington.
(Sheet 3 of 7)

Aerial: USDA (2012)

Produced By: GIS
Project: K:\Projects\10-04766-019\Project\Report_Maps\Geomorph_and_Habitat_v2.mxd (12/18/2012)

Figure 6.
Observed geomorphic and habitat features on the South Fork Skykomish River, Washington.
(Sheet 4 of 7)

Figure 6.
Observed geomorphic and habitat features on the South Fork Skykomish River, Washington. (Sheet 5 of 7)

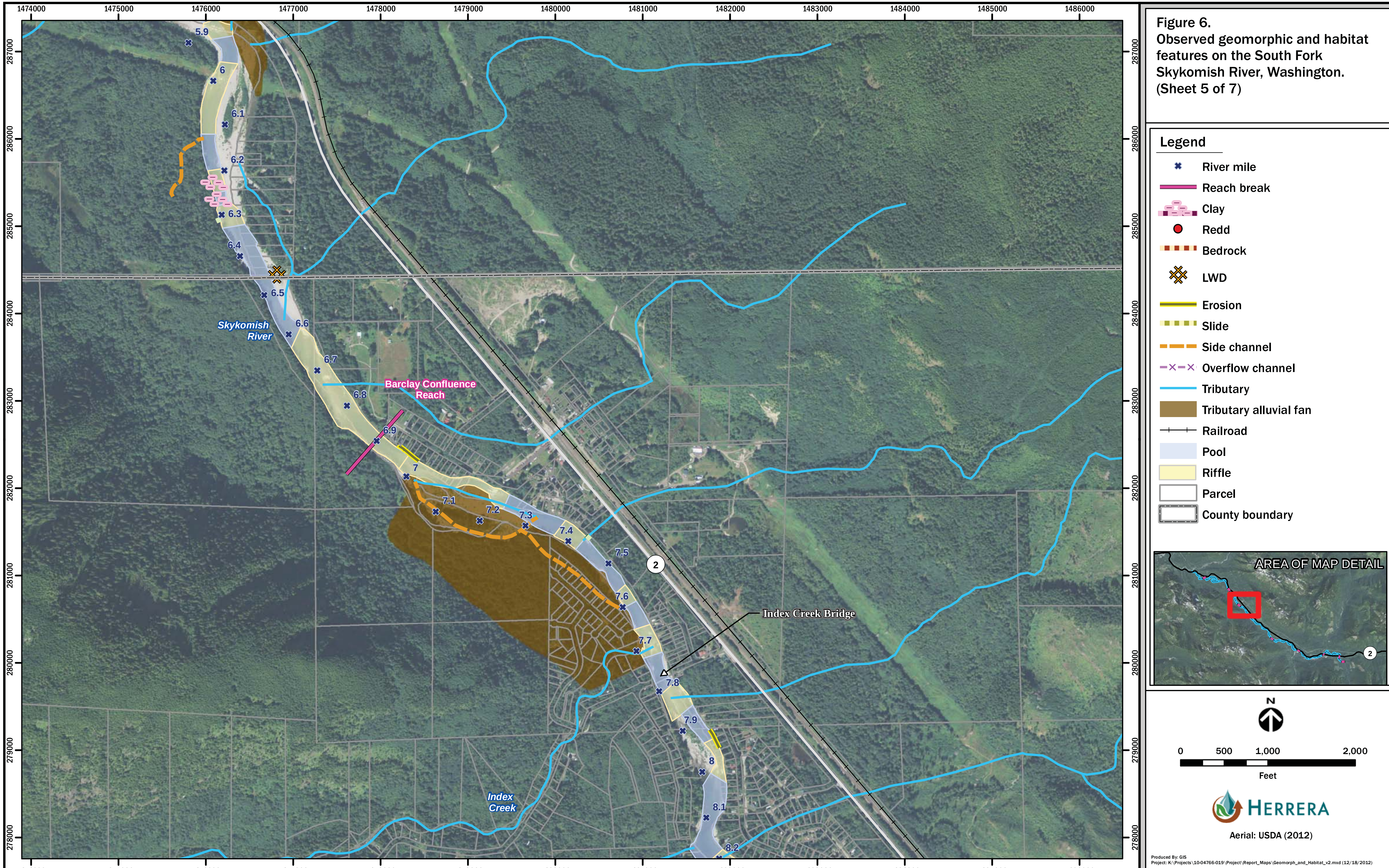


Figure 6.
Observed geomorphic and habitat features on the South Fork Skykomish River, Washington.
(Sheet 6 of 7)

Legend

- River mile
- Reach break
- Clay
- Redd
- Bedrock
- LWD
- Erosion
- Slide
- Side channel
- Overflow channel
- Tributary
- Tributary alluvial fan
- Railroad
- Pool
- Riffle
- Parcel
- County boundary

N

0 500 1,000 2,000
Feet

HERRERA

Aerial: USDA (2012)

Produced By: GIS
Project: K:\Projects\10-04766-019\Project\Report_Maps\Geomorph_and_Habitat_v2.mxd (12/18/2012)

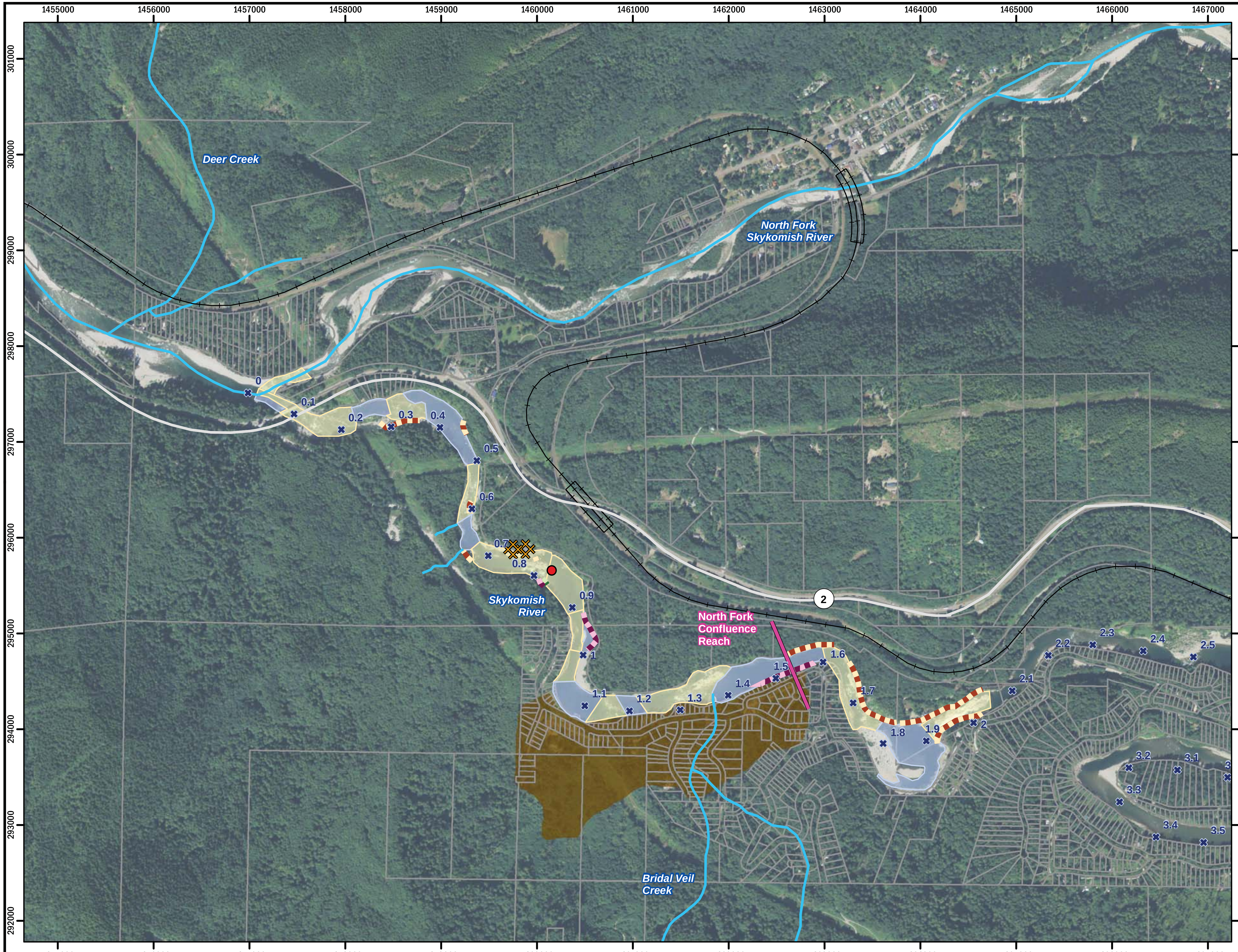


Figure 6.
Observed geomorphic and habitat features on the South Fork Skykomish River, Washington.
(Sheet 7 of 7)

Legend

- River mile
- Reach break
- Clay
- Redd
- Bedrock
- LWD
- Erosion
- Slide
- Side channel
- Overflow channel
- Tributary
- Tributary alluvial fan
- Railroad
- Pool
- Riffle
- Parcel
- County boundary

AREA OF MAP DETAIL

N

0 500 1,000 2,000
Feet

HERRERA

Aerial: USDA (2012)

Produced By: GIS
Project: K:\Projects\10-04766-019\Project\Report_Maps\Geomorph_and_Habitat_v2.mxd (12/18/2012)

riprap along channel banks simplifies the channel geometry, reduces total length of edge habitat, and increases the bank slope. Riprap also has a tendency to alter geomorphic functions by attracting the thalweg to long, straight, unvegetated areas. This often pulls the channel away from undeveloped, forested areas and towards development and the riprap itself, further exacerbating impaired conditions.

Bedrock edge habitat is discussed in the geologic context section of this report.

Off-Channel

As described in the *Physical Setting* section, the South Fork Skykomish River is confined by bedrock and lacustrine clay in several reaches. It does not migrate through a wide floodplain like many other large rivers in the region. However, the reaches where incision is less pronounced (in the Skykomish to Baring area and near tributary fans) do have intact active side channel networks. Due to limited surveys of the riparian area and the geomorphic features of the river basin, only a few off-channel habitats were observed during the field investigation, which means that some side channels were likely missed. An overflow channel or relict channel was observed on the lidar and during the field investigation between RM 17.2 and 17.5. This area is relatively disturbed with the Bonneville Power Administration (BPA) power line corridor to the north and US-2 and the railroad to the south on the left bank of the river. Insufficient information due to limited surveys is available to determine the type of habitat within this relict channel. At RM 14.2, the lidar imagery showed a relict channel to the north of US-2. This channel is now presumably blocked by the highway. A wide channel migration zone was observed on the lidar imagery on the left bank of the river from RM 7.3 to RM 6.8 and on both sides of the river from RM 6.5 to RM 6.2. These areas likely contain former channels, or groundwater channels that no longer have a surface connection to the river. Finally, the Money-Miller Fan (RM 11.5 to 14.1) contains numerous side and groundwater channels, some of which were identified in work related to the feasibility analysis (that includes the tributaries and more site-specific work on the lower Miller River). These areas are included in Figure 6 for completeness.

Observed Restoration Opportunities

Thirty-eight site-specific restoration opportunities were identified in the assessment area for projects that either restore predevelopment conditions, improve existing habitat attributes that are currently compromised by human actions or prevent future impacts by proactively initiating channel migration away from critical infrastructure (Figure 7). Table 2 summarizes these restoration opportunities and Figure 7 shows their locations. Each of the projects has an information sheet explaining the project details.

In addition there are several study-area-wise, programmatic recommendations that should be considered when prioritizing work in the basin. They include:

- Since side channel habitat is limited within the South Fork Skykomish River due to natural geomorphic elements such as bedrock outcrops, it is recommended to preserve (or restore) them where they exist (or existed),even beyond the site-specific restoration projects shown in Figure 7.

- Wood is also limited in the system because of numerous interrelated factors described above. Therefore wood placement/input projects should always be considered, even beyond the site-specific restoration projects shown in Figure 7. In order to better facilitate these projects and identify new projects not included in Figure 7 in the future, it is recommended to conduct a basin-wide survey of LWD and riparian condition to determine key input locations for LWD.

- Encourage BNSF to implement best management practices used to maintain their rail line. Observations made on the site visit indicate a number of their maintenance activities may lead to pollution of river water either directly (through herbicide application to wetted areas) or indirectly (through poor stormwater management practices).

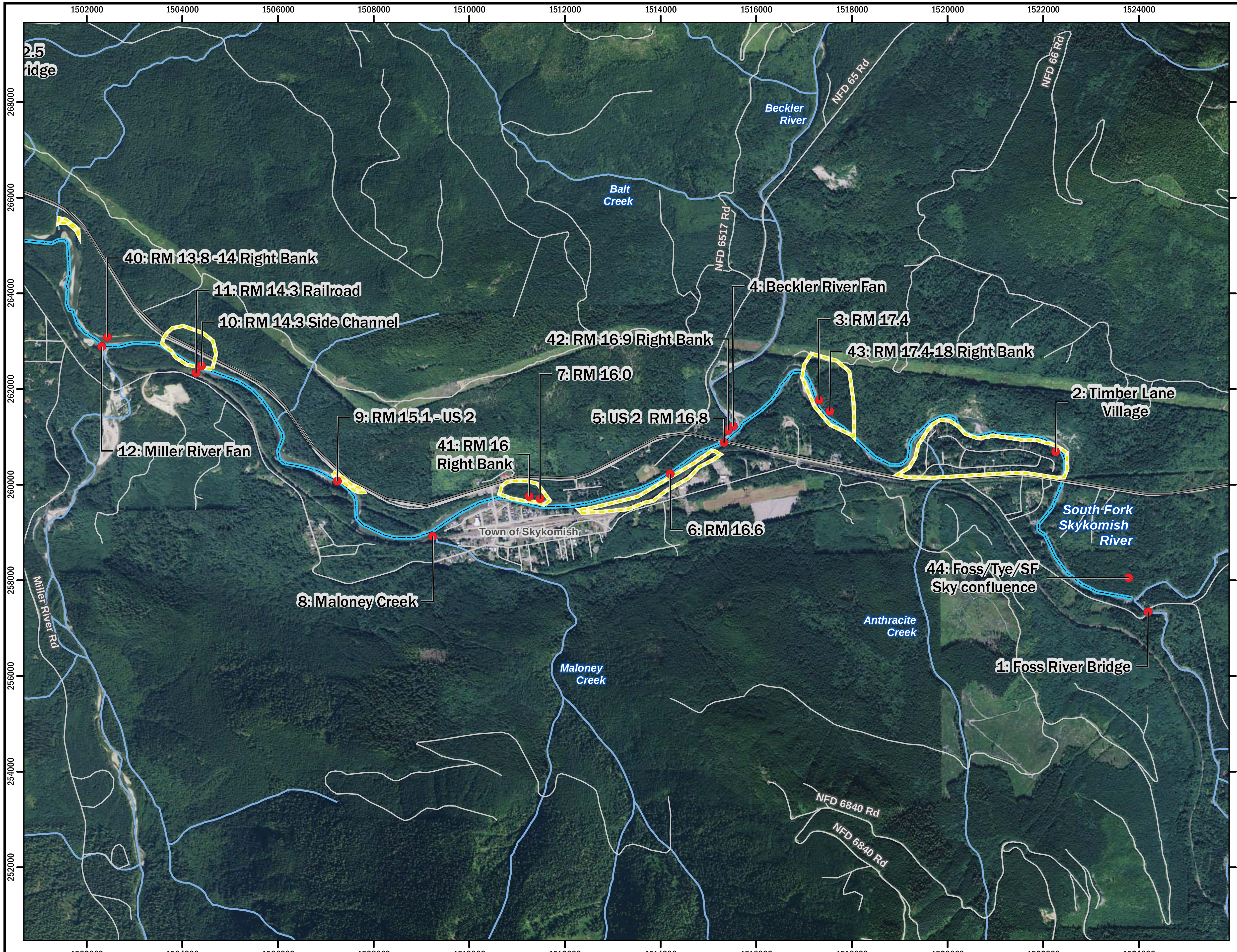


Figure 7.
Potential restoration project map, South Fork Skykomish Basin, Washington.
(Sheet 1 of 3)

Legend

- Potential project location
- Potential project area
- South Fork Skykomish River
- River or creek
- Highway
- Road

N

0 1,000 2,000 4,000

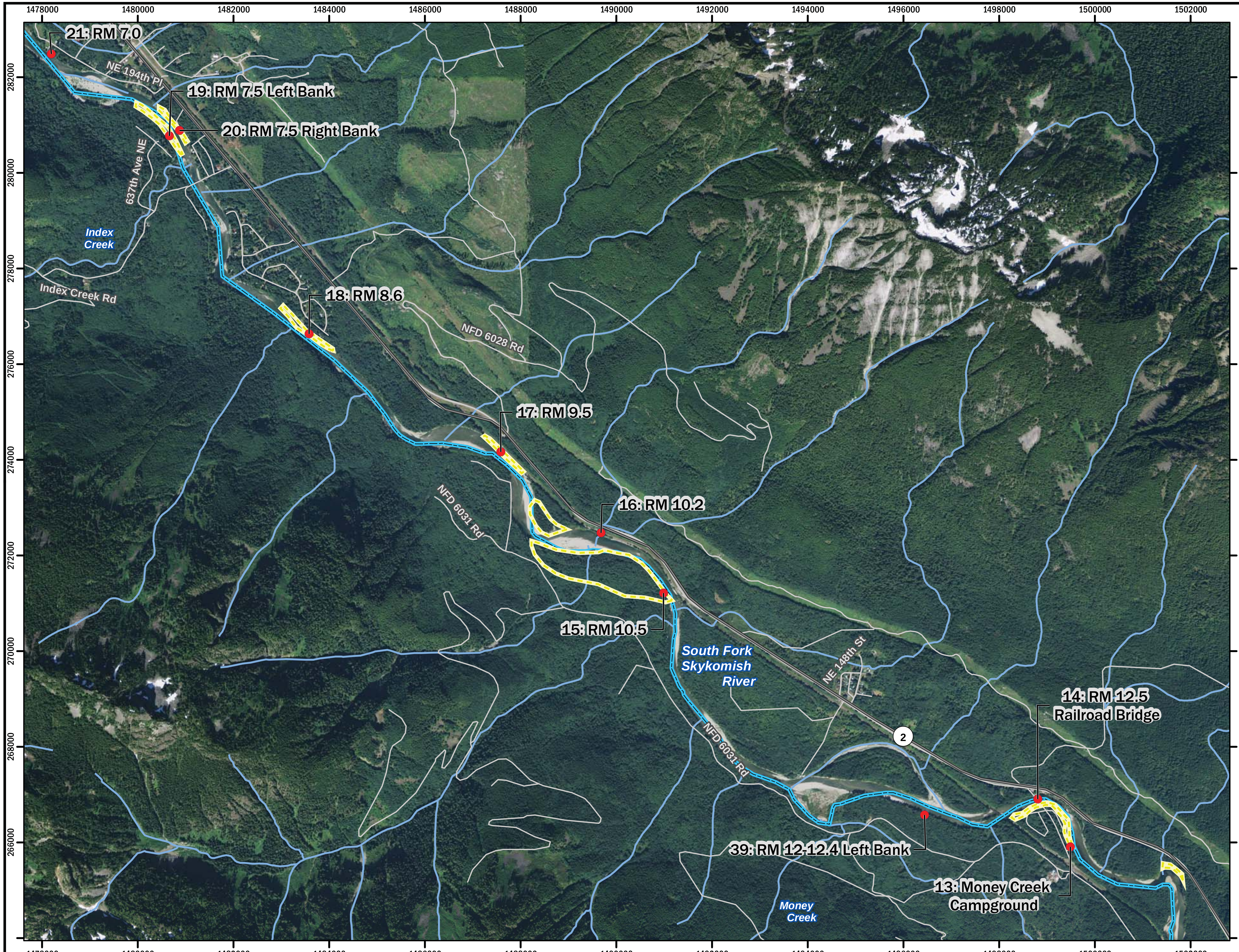
Feet

HERRERA

Aerial: USDA (2009)
Coordinates: NAD 1983 Washington State Plane North (ft)

Produced By: GIS
Project: K:\Projects\10-04766-019\Project\Report_Maps\Pot_Restoration_Proj.mxd (12/19/2012)

Figure 7.
Potential restoration project map, South Fork Skykomish Basin, Washington.
(Sheet 2 of 3)



Legend

- Potential project location
- Potential project area
- South Fork Skykomish River
- River or creek
- Highway
- Road

N

0 1,000 2,000 4,000
Feet

HERRERA

Aerial: USDA (2009)
Coordinates: NAD 1983 Washington State Plane North (ft)

Produced By: GIS
Project: K:\Projects\10-04766-019\Project\Report_Maps\Pot_Restoration_Proj.mxd (12/19/2012)

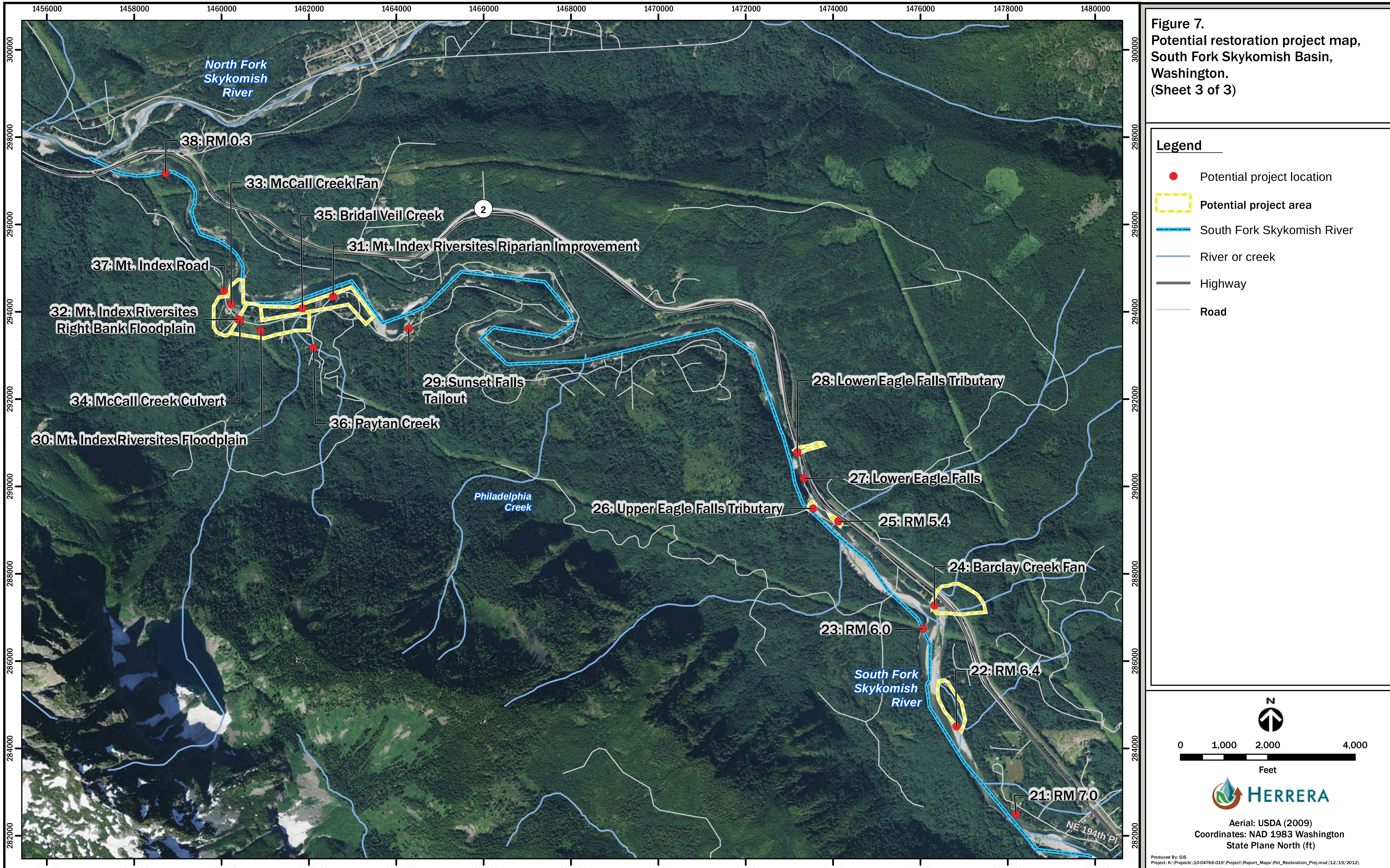


Figure 7.
Potential restoration project map, South Fork Skykomish Basin, Washington.
(Sheet 3 of 3)

HERRERA

Aerial: USDA (2009)
Coordinates: NAD 1983 Washington State Plane North (ft)

Produced By: GIS
Project: K:\Projects\10-04766-019\Project\Report_Maps\Pot_Restoration_Proj.mxd (12/19/2012)

Table 3. Summary of Potential Restoration Projects Identified During This Assessment.

Site No.	Site Name	Impairment	Potential Opportunity
1	Foss River Bridge	Floodplain disconnection, bank armoring and fill	Bridge replacement, fill removal
2	Timber Lane Village	Bank armoring	Feasibility analysis
3	RM 17.4	Side channel disconnection	LWD placement and side channel reconnection
4	Beckler River Fan	Bank armoring (riprap), channel simplification	LWD placement, riprap removal
5	US 2 RM 16.8	Channel constriction, bank armoring and fill	Bridge replacement, fill removal
6	RM 16.6	Bank armoring	LWD placement, rail line relocation
7	RM 16.0	Side channel disconnection	LWD placement
8	Maloney Creek	Side channel disconnection, bank armoring	LWD placement, riprap removal, rail line relocation
9	RM 15.1 - US 2	Bank armoring (riprap)	LWD placement, riprap removal
10	RM 14.3 Side Channel	Side channel disconnection	Bridge placement, side channel reconnection
11	RM 14.3 Railroad	Bank erosion	LWD placement, proactive bank stabilization, rail line relocation
12	Miller River Fan	Deleterious debris in river, side channel disconnection	Debris removal, LWD placement
13	RM 13.4	Bank erosion	Proactive bank stabilization
14	Money Creek Campground	Channel constriction, side channel disconnection, bank armoring and erosion	Feasibility analysis
15	RM 12.5 Railroad Bridge	Channel constriction, bank armoring and fill	Bridge replacement, fill removal
16	RM 10.5	Side channel constriction, bank armoring and fill	LWD placement, side channel reconnection, proactive bank stabilization
17	RM 10.2	Floodplain disconnection	Bridge placement, tributary reconnection
18	RM 9.9	Future development in floodplain	Property acquisition
19	RM 9.5	Side channel disconnection, bank erosion and armoring	LWD placement, road and railroad relocation
20	RM 8.6	Future side channel disconnection and bank armoring	Property acquisition
21	RM 7.5 Left Bank	Future side channel disconnection and bank armoring	Property acquisition
22	RM 7.5 Right Bank	Bank armoring (riprap)	LWD placement, riprap removal, property acquisition

Table 3 (continued). Summary of Potential Restoration Projects Identified During This Assessment.

Site No.	Site name	Impairment	Potential opportunity
23	RM 7.0	Bank erosion	Proactive bank stabilization
24	RM 6.4	Future side channel disconnection and bank armoring	Proactive bank stabilization
25	RM 6.0	Bank armoring	Riprap removal
26	Barclay Creek Fan	Floodplain disconnection, bank armoring and erosion	Feasibility analysis
27	RM 5.4	Bank armoring	Riprap removal and LWD placement
28	Upper Eagle Falls Tributary	Blast rock debris in channel, tributary disconnection	Debris removal, tributary reconnection
29	Lower Eagle Falls	Bank armoring and erosion	Debris removal, road and rail road relocation
30	Lower Eagle Falls Tributary	Floodplain disconnection, fill	Bridge(s) replacement
31	Sunset Falls Tailout	Bank armoring (riprap)	LWD placement, riprap removal, road relocation, riparian planting
32	Mt. Index Riversites Floodplain	Unknown topography and floodplain disconnection	LIDAR acquisition
33	Mt. Index Riversites Riparian Improvement	Riparian degradation	Riparian planting
34	Mt. Index Riversites Right Bank	Future development in floodplain	Property acquisition or conservation easement
35	McCall Creek Fan	Future development in floodplain	Property acquisition, structure removal
36	McCall Creek Culvert	Fish barrier and floodplain disconnection	Culvert removal, bridge placement
37	Bridal Veil Creek	Undersized bridge and fill	Bridge replacement and fill removal
38	Paytan Creek	Undersized bridge and fill	Bridge replacement and fill removal
39	Mt. Index Road	Bank armoring and fill	Riprap removal, property acquisition, road relocation
40	RM 0.3	Deleterious debris in river	Debris removal

Notes:

Feasibility analyses are called for as opportunities when there are complex interrelated impairments that could not be reconciled without further analysis.

Bank armoring and erosion are typically associated with the road and rail line and where relocation is possible it is identified.

Proactive bank stabilization is identified in areas where bank erosion threatens critical infrastructure. It is anticipated that proactive bank stabilization will be comprised mostly if not entirely of wood and/or plantings and be a habitat improvement over existing conditions.

Based on field investigations performed on August 21-23, 2012, and on-site reconnaissance on September 7, 2012.

SUMMARY OF FINDINGS

The following statements can be made based upon the results of the analysis discussed herein:

- The South Fork Skykomish floodplain occupies only a fraction of the apparent base of the Skykomish valley due to post-glacial incision.
- There are many of the off-channel wetlands that can be seen from US-2. However, these wetlands are not directly related or could be easily reconnected to the river. Rather they are local impoundments on lacustrine clays. Hence, they do not and cannot provide off-channel fish habitat.
- Habitat conditions are relatively good for a developed river valley, though the entire South Fork Skykomish contains less LWD and pools than predevelopment conditions, and results in highly simplified channel geometry in most locations. It is unclear the degree to which the system is impaired because of the uncertainty of the amount of wood and channel complexity present prior to development.
- The most widespread human modification in the assessment area is the prism and armoring associated with US-2 and the BNSF railway.
- The uppermost 0.6 miles of the South Fork Skykomish River (i.e., the Foss Reach) is incised to a large rock avalanche originating on Beckler Peak, and therefore has few restoration opportunities outside of the immediate Foss River confluence.
- The channel profile is convex in the Falls Reach indicating that the falls are an important control on the overall incision of the river valley.
- The most intact side channels that were found, and most that could be restored or protected, are present in the Baring Reach, in the area around the towns of Baring and Grotto. A more detailed study is necessary to identify all of the side channels in the floodplain.The Money-Miller Fan (i.e., the Money-Miller Reach) also has great off-channel opportunities, but they are generally associated with the two tributaries on the fan that have been highly compromised by past development associated with roads, levees, and the railroad.

REFERENCES

Beechie, T.J., D.A. Sear, J.D. Olden, G.R. Pess, J.M. Buffington, H. Moir, P. Roni, and M.M. Pollock. 2010. Process-based Principles for Restoring River Ecosystems. *BioScience* 60(3):209–222.

Bisson, P.A., J.L. Nielsen, R.A. Palmason, and L.E. Grove. 1982. A system of naming habitat types in small streams, with examples of habitat utilization by salmonids during low streamflow. Pages 62-73 in N.B. Armantrout, editor. Acquisition and utilization of aquatic habitat inventory information. Proceedings of a symposium held 28-30 October, 1981, Portland, Oregon. Western Division, American Fisheries Society.

Bureau of Reclamation (BOR). 2008. Nason Creek tributary assessment, Chelan County, Washington. Technical Service Center, Bureau of Reclamation, Denver, Colorado.

Carlson, W. and the Skykomish Historical Society. 2009. *Images of America: Upper Skykomish Valley*. Arcadia Publishing, San Francisco.

Chapman, D.W. 1988. Critical review of variables used to define effects of fines in redds of large salmonids. *Transactions of the American Fisheries Society* 117:1-21.

Collins, B.D. and D.R. Montgomery. 2011. The legacy of Pleistocene glaciation and the organization of lowland alluvial process domains in the Puget Sound region. *Geomorphology* 126:174-185.

Collins, B.D., D.R. Montgomery, and A.D. Haas. 2002. Historical changes in the distribution and functions of large wood in Puget Lowland rivers. *Canadian Journal of Aquatic and Fishery Sciences* 59:66-76.

Croke, J.C. and P.B. Hairsine. 2006. Sediment delivery in managed forests: a review. *Environmental Reviews* 14:59-87.

Ecology. 2010. SMP Handbook Chapter 7: Shoreline Inventory and Characterization. Available at: http://www.ecy.wa.gov/programs/sea/shorelines/smp/handbook/Chapter7.pdf.

General Land Office (GLO). 1895a. Township No. 26 North Range No. 10 East Willamette Meridian, Washington. Olympia, Washington, US Surveyor General's Office.

General Land Office (GLO). 1895b. Township No. 26 North Range No. 11 East Willamette Meridian, Washington. Olympia, Washington, US Surveyor General's Office.

General Land Office (GLO). 1899. Township No. 27 North Range No. 10 East Willamette Meridian, Washington. Olympia, Washington, US Surveyor General's Office.

Herrera. 2009. Miller River Fan Geomorphic Assessment. Prepared for King County Department of Natural Resources and Parks, Water and Land Resources Division, River and Floodplain Management Section, by Herrera Environmental Consultants, Inc., Seattle, Washington. December 2009.

Herrera. 2012. Draft Restoration Feasibility Report: Lower Miller River. Prepared for King County Department of Natural Resources and Parks, Water and Land Resources Division, River and Floodplain Management Section, by Herrera Environmental Consultants, Inc., Seattle, Washington. November 8, 2012.

King County. 2005. Flood Control Assistance Account Program Final Summary Report. Prepared for: Washington State Department of Ecology. Prepared by King County Department of Natural Resources and Parks Flood Hazard Reduction Section. June 30, 2005.

Kondolf, G.M. and 13 others. 2006. Process-based ecological river restoration: Visualizing three-dimensional connectivity and dynamic vectors to recover lost linkages. *Ecology and Society* 11(2):5.

Lestelle, L.C., W.E. McConnaha, G. Blair, and B. Watson. 2005. Chinook Salmon Use of Floodplain, Secondary Channel, and Non-Natal Tributary Habitats in Rivers of Western North America: Application to the Willamette River (Oregon) and Formulation of Species-Habitat Rules for EDT Analysis. Mobrand-Jones and Stokes, Vashon, Washington and Portland, Oregon. September 28, 2005.

Montgomery, D.R. and J.M. Buffington. 1997. Channel-reach morphology in mountain drainage basins. *Geological Society of America Bulletin* 109: 596-611.

NOAA Fisheries. 1996. Making Endangered Species Act Determinations of Effect for Individual or Grouped Actions at the Watershed Scale. Environmental and Technical Services Division, Habitat Conservation Branch. August 1996.

Parsons, J.D., D. Finlayson, and N.P. Finnegan. 2002. Eagle Falls in the North Cascades: A test bed for the Himalaya. 2002 AGU Winter Meeting, San Francisco.

Snohomish Basin Salmonid Recovery Technical Committee and National Marine Fisheries Service. 2005. Snohomish River Basin Ecological Analysis for Salmon Conservation. May 2004, Updated June 2005.

Tabor, R.W., V.A. Frizzell, Jr., D.B. Booth, R.B. Waitt, J.T. Whetten, and R.E. Zartman. 1993. Geologic map of the Skykomish River 30- by 60-minute quadrangle. US Geologic Survey, Map I-1963.

USFS. 1995. Skykomish Forks Watershed Analysis, Mt. Baker-Snoqualmie National Forest.

UW. 2012. University of Washington Libraries Digital Collections. Available at: http://content.lib.washington.edu/.

Washington Department of Natural Resources (DNR). 2012. DNR Landslide website. Available at: https://fortress.wa.gov/dnr/geology/?Site=landslides.

Wemple, B.C., F.J. Swanson, and Julia A. Jones. 2001. Forest roads and geomorphic process interactions, Cascade Range, Oregon. *Earth Surface Processes and Landforms* 26(2):194-204.

APPENDIX 1

Information Sheets

The contents of this attachment are provided in Appendix A of the Restoration Opportunity Report.

APPENDIX D

Beckler and Rapid Rivers Habitat Restoration Opportunities Identification Study

HABITAT RESTORATION OPPORTUNITIES IDENTIFICATION STUDY

BECKLER AND RAPID RIVERS

Prepared for
King County
Department of Natural Resources
and Parks

Prepared by
Herrera Environmental Consultants, Inc.

HERRERA

HABITAT RESTORATION OPPORTUNITIES IDENTIFICATION STUDY

BECKLER AND RAPID RIVERS

Prepared for
King County
Department of Natural Resources and Parks
River and Floodplain Management Section

Prepared by
Herrera Environmental Consultants, Inc.
2200 Sixth Avenue, Suite 1100
Seattle, Washington 98121
Telephone: 206/441-9080

April 30, 2013

CONTENTS

TABLES

FIGURES

INTRODUCTION

This technical memorandum is part of a larger feasibility study of salmonid habitat restoration projects within the South Fork Skykomish River Basin. The larger feasibility study covers an area of 70 miles of streams within the basin and includes the South Fork Skykomish River and its major tributaries: Tye, Foss, Miller, and Beckler rivers, and Deception, Surprise, and Money creeks (Figure 1). These tributaries comprise the project study area for the larger feasibility study; however, this technical memorandum only includes identification of restoration opportunities within the Beckler and Rapid rivers. The Rapid River is a major tributary to the Beckler River. This study was completed for King County and USFS technical review team, which have been involved in the oversight and review of this project.

The feasibility study is being implemented in two phases. The first phase includes completion of three studies/reports that will feed into a final feasibility report. These reports include:

- **Summary Report**: a review of existing literature and data available for the South Fork Skykomish Basin, data gaps, and potential studies that could be completed to fill those gaps. A draft report was completed by Herrera in June 2012.
- **Geomorphic Analysis Report**: a geomorphic assessment of the South Fork Skykomish Basin and identification of potential restoration opportunities along the South Fork Skykomish River mainstem. A draft report was completed by Herrera in October 2012.
- **Beckler and Rapid Rivers Restoration Opportunities Identification Study (this technical memorandum)**: an identification of potential restoration opportunities along the Beckler and Rapid Rivers based on a 1-day rapid field reconnaissance and review of existing literature/information about these rivers.

The second phase entails synthesizing into one consolidated list, information collected from these studies regarding potential restoration opportunities. These potential restoration opportunities will then be evaluated to determine the top priority restoration projects that would potentially be implemented by King County in the future. The findings from this synthesis and prioritization will be described in a final feasibility report.

Purpose of the Study

The purpose of this study is to conduct a rapid reconnaissance to identify, potential salmon habitat restoration opportunities along the Beckler and Rapid rivers (Figure 1). This is a pilot study that was completed to inform similar reconnaissance-level investigations of the other major tributaries to the South Fork Skykomish River, including the Tye, Foss, and Miller rivers, and Deception, Surprise, and Money creeks (Figure 1). Results of the investigations of these additional tributaries will be described in the final feasibility report.

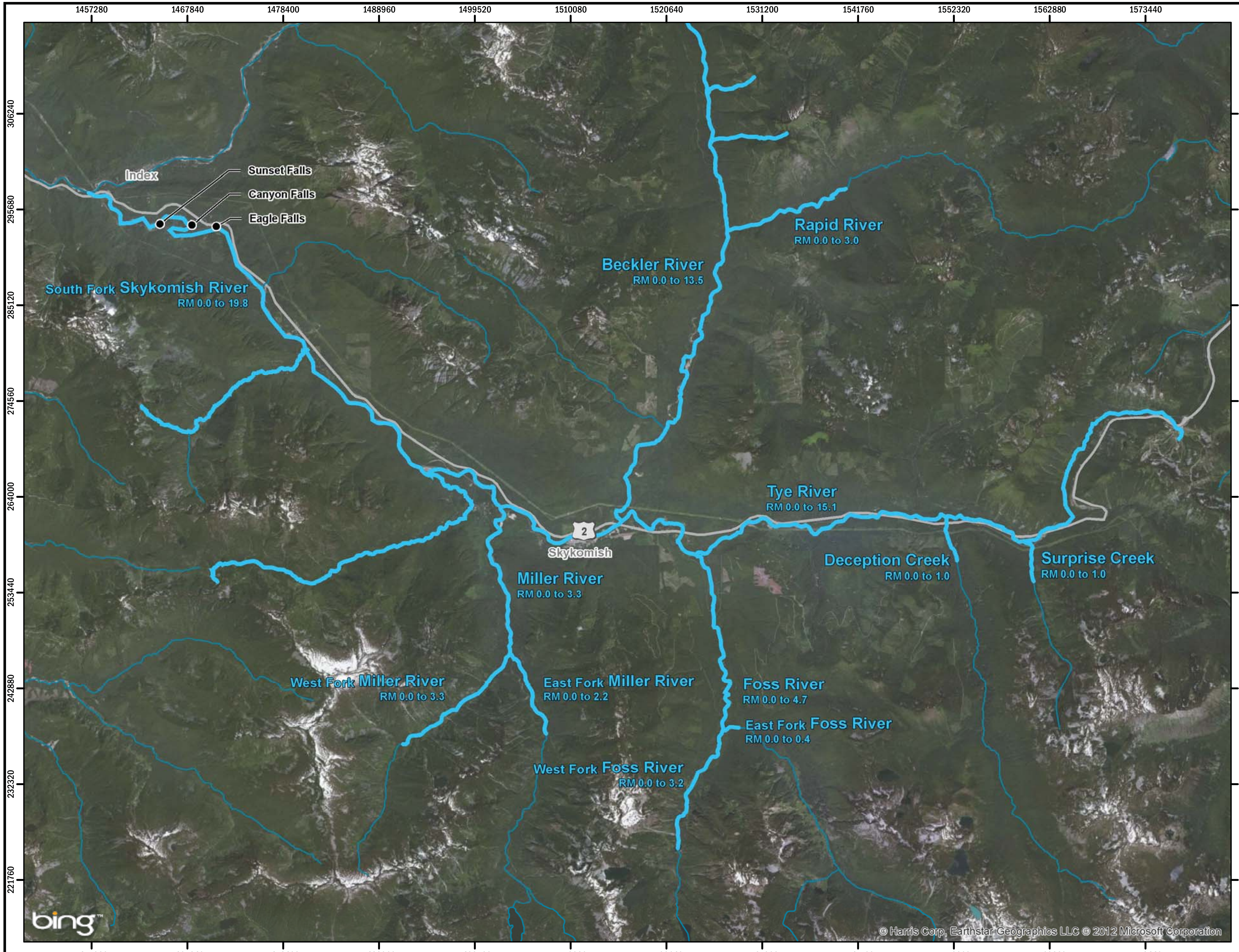


Figure 1.
Study Area
South Fork Skykomish
Feasibility Project
King County, Washington

Legend

- Reach of interest
- River
- Highway

N

0 1 2 4

Miles

HERRERA

Coordinates: NAD83 Washington State Plane North (feet)

Produced By: GIS
Project: K:\Projects\10-04766-008\Project\Area_of_Interest2.mxd (11/8/2012)

METHODOLOGY

The study followed the process-based principles identified by Beechie et al. (2010). Process-based restoration principles are intended to reestablish physical, chemical, and biological processes that create and sustain river and floodplain ecosystems. The approach involved review and analysis of available information.

Two types of information about existing salmon habitat conditions, geomorphic setting, and potential salmon habitat restoration opportunities were collected for this study of the Beckler and Rapid rivers: existing literature and maps, and observations from a rapid 1-day field reconnaissance.

In general, the criteria used to select potential salmon habitat restoration projects considered that functional flow dynamics are important as they, for example, include floodplain channel flushing flows, channel maintenance flows, and channel forming flows (Wald 2009). Functional flows contribute to watershed processes, natural variability, and ecological connectivity that support the resilience of salmonid species to natural and anthropogenic disturbances (Bisson et al. 2009). So, an attempt was made to identify restoration opportunities that take full advantage of longitudinal, lateral, and vertical hydrologic connectivity in an effort to maximize flow dynamics and thus habitat in the study area.

Specifically, the ccriteria used to select potential salmon habitat restoration projects included: 1) projects that would restore predevelopment processes to the river system, 2) projects that would result in restoring or reconnecting fish habitat directly (such as removal of a road within a floodplain), and 3) projects that would benefit fish and also prevent future emergency actions to protect human infrastructure (e.g., LWD placement within a riprapped stream bank along a road, where the road was at significant risk of being damaged within the next few years). More details about the methods used to collect information for this study are provided below.

Existing Information

Physical Setting

The physical setting for the Beckler and Rapid rivers is primarily provided by a watershed analysis of the greater Beckler River basin (USFS 1995), and a geologic map of the area (Tabor et al. 1993). The geologic map and associated text provides information on the recent geologic past that serves as a template for the analysis performed herein. The watershed analysis provides basic physical variables, such as rainfall, and past human activities in the basin. When placed in context with observed human modifications, and hypothesized predevelopment conditions, the geomorphic ramifications and habitat benefits of restoration actions can be ascertained.

Habitat Conditions

Herrera reviewed United States Forest Service (USFS) historic (mid 1990s) reach and watershed assessments of the Beckler and Rapid rivers. Where relevant for the Beckler and Rapid rivers, historic habitat conditions were obtained from these studies and from aerial photographs.

Habitat Impairments

Predevelopment Habitat Constraints

Predevelopment constraints on habitat include natural features within the river system (such as fish passage barriers or landslide debris) that existed prior to development of the sub-basin and had a potential effect to fish populations and/or fish habitat (this effect could be beneficial or temporarily negative). Information on these constraints were obtained from the USFS historic (mid 1990s) reports for the Beckler River, if it was available. Predevelopment constraints on habitat were considered within context of the physical setting described below. Once the primary predevelopment constraints on habitat were understood they were placed within the context of observed human modifications, which are described in the next subsection.

Human Modifications

Existing human modifications were identified using Google Earth and aerial photographs provided by the County. Additional information on human modifications and their locations was obtained from a Level II Stream Survey of the Beckler River and some of its tributaries that was completed for the USFS by Cascades Environmental Services, Inc. in 1997 (Cascade Environmental Services, Inc. 1997). A map of the potential human modifications to the Beckler and Rapid rivers was developed as a guide for field verification.

Previously Proposed Restoration Opportunities

Information on historic restoration projects that occurred during the years of 1998 through 2007 was obtained from the Interagency Restoration Database (IRDA) GIS files that are maintained by the USFS as well as from USFS hard copy records of restoration projects.

USFS switched to using the WIT database to store information about the restoration projects that occurred after 2007. This data were not available for this memorandum, but will be added to the final feasibility report.

Field Investigation

Habitat Impairments

A Herrera geomorphologist and an ecologist, accompanied by King County and USFS staff, conducted a 1-day field reconnaissance of the Beckler and Rapid rivers on August 16, 2012. The purpose of the field reconnaissance was to observe and document existing conditions, habitat impairments, and identify potential salmonid habitat restoration opportunities in the

Beckler and Rapid rivers. The field reconnaissance occurred in vehicles and on foot along the Beckler River from river mile (RM) 0.0 to approximately RM 10.0, and along the Rapid River from its mouth to RM 3.5. The Beckler River was accessed by vehicle along the Beckler River Road (also known as Forest Service [FS] Road 65), and by FS Road 6550; the Rapid River was accessed by FS Road 6530 (Figure 2). Only areas that could be reached by vehicle and a short walk from the road were investigated. Access to private property was not granted and therefore no habitat areas within private properties were investigated unless viewed from the road.

Predevelopment Habitat Constraints

During the field reconnaissance, constraints to habitat such as landslides or other natural modifications that would have occurred prior to development were observed if possible. These observations were noted, but not mapped during the field reconnaissance. A brief description of these constraints is provided in this report. Predevelopment constraints on habitat were considered within context of the physical setting. Once the primary predevelopment constraints on habitat were understood through the field investigation, they were placed within the context of observed human modifications, which are described in the next subsection.

Human Modifications

A field map of potential human modifications to the Beckler and Rapid rivers that had been identified from existing information was used as a guide to target the field reconnaissance. Human modifications including but not limited to rock armoring, culverts, bridge, fill, and roadway infrastructure were observed and mapped in the field. Notes and photographs of human modifications were noted and georeferenced in the field and compiled.

Observed Habitat Features

Where access was possible during the 1-day field reconnaissance of the Beckler and Rapid rivers, general habitat features such as amount of large woody debris, instream fish habitat diversity, and riparian condition were noted, but not mapped. Descriptions of these general field observations are provided in the Results section of this technical memorandum.

Observed Restoration Opportunities

Salmonid habitat restoration opportunities were identified and mapped during the 1-day field reconnaissance of the Beckler and Rapid rivers. As previously stated, restoration opportunities identification was based on restoring predevelopment geomorphological processes to the river and watershed. The criteria for selecting restoration opportunities were described in the introduction of this Methodology section. During the limited field reconnaissance, restoration opportunities were primarily identified where human modifications and their impairments on fish habitat were observed. A list and map of the potential restoration opportunities were developed.

Legend

- Potential project location
- Stream
- Road
- Potential project area
- Countyline

Figure 2. Beckler and Rapid River Salmon Restoration Project Opportunties, South Fork Skykomish Basin, Washington

N

0 2,250 4,500 9,000 Feet

HERRERA

Aerial: USDA (2009)

K:\Support\Templates\Beckler_river_restoration_opt2.mxd (11/16/2012)

RESULTS

This section presents the results of the restoration opportunities identification. It begins with information about the physical setting and the existing and observed habitat in the Beckler and Rapid rivers and then describes the potential restoration opportunities that were observed during the site visit.

Existing Information

Physical Setting

The physical setting of the study area is described by USFS (1995), a watershed analysis of the basin, and the geologic map of the Skykomish Quadrangle (Tabor et al. 1993). The basin as a whole is highly concave with the lowermost stretches of the two primary rivers (Beckler and Rapid) having slopes on the order of a few percent, with extremely steep side slopes on most of the valley walls, typically exceeding 100 percent. The lowermost reaches are the focus of the work described here. The main stem of the Beckler River is completely controlled by and confined within the Straight Creek fault zone, which in most areas of Washington State separates marine intrusive rock to the west from older continental metamorphic rock to the east. The Rapid River is perpendicular to the Straight Creek fault, and dissects predominantly metamorphic rocks of the Cascade Mountains central core. Both the Beckler and Rapid river valleys contained alpine glaciers, which melted back before the Puget Lobe continental glacier advanced and dammed the lower reaches of the Skykomish River. The dammed waters, called glacial Lake Skykomish, only influenced the lowest few miles of the Beckler River, but there remain large volumes of unconsolidated sediment in this area on and near the riverbanks. Glacial sediment coats the remainder of the lower reaches of channels that are a focus of this restoration opportunity identification study. Other more specific historical changes are discussed later in this document in terms of the restoration opportunities.

Like the rest of the Skykomish River basin, the hydrology of the Beckler River is dominated by intense rain and rain-on-snow events (USFS 1995); however, there has been no work to determine flood frequency curves for the basin as a whole or any of the subbasins (e.g., the Rapid River). The Rapid River has a lower elevation (around 4,000 feet in three places) connected across to the eastern slope of the Cascades than other subbasins in the Skykomish River and may be much more of an eastern-slope snowmelt basin. There are significant data gaps in the basin concerning quantitative physical variables (topography, hydrology, and geomorphology) that would enhance restoration activities with further study.

Habitat Conditions

The Beckler/Rapid watershed riparian habitat contains a patchwork of different aged forest stands that range from 15 years to 400 years old with a few small patches of very old growth stands (900 to 1,000 years in age) (USFS 1995). As expected in a disturbed system, the forest stands that are closest to the rivers range in age from 20 to 75 years and are referred to as mid-seral stands. Timber harvesting, fires, and other human activities are attributed to the disturbance of the riparian areas. Timber harvesting has been active within the Beckler/Rapid River watershed since the turn of the 20th century. Timber operations were expanded briefly in the 1970s and 1980s. In 1987, the Timber and Fish Act was established to provide protection of streams and wetlands by prohibiting harvesting in core riparian zones within 50 feet from the river (Washington Administrative Code Riparian Management Zones Section 222-30-021 and defined in Section 222-16-010). Also, roughly half of the basin is now permanently protected from logging by the creation of the Wild Sky Wilderness in 2008. Active timber harvest is still ongoing within the Beckler River watershed outside riparian areas and in a few cases within riparian areas that are privately owned. Sedimentation of spawning gravels is exacerbated by timber harvesting and roads that dissect the watershed, particularly in its lower portion (USFS 1995, 2010; Cascade Environmental Services, Inc. 1997).

Instream habitat quality is relatively good although both the numbers of pools and pool diversity were rated moderate to low in a stream survey performed in 1997 (Cascades Environmental Services, Inc. 1997). Cascade Environmental Services (1997) observed 2.6 pools per mile in the lower reach of the Beckler to RM 8.5 and 6.7 pools per mile from RM 8.5 to RM 13. 2. The study indicates that the higher pool frequency in the upper reaches is due to both a steeper gradient and greater amounts of LWD. Spawning gravel was found to be abundant and of good quality during the 1997 stream survey. Stream temperatures were in the optimum range for salmonids when surveyed in 1997 (55 to 65 degrees Fahrenheit) (Cascades Environmental Services, Inc. 1997). While this information is outdated, more recent information is not available.

Predevelopment Habitat Impairments

The South Fork Skykomish River did not have anadromous fish prior to the trap and haul operations at Sunset Falls that started in 1958, although resident fish did exist within the subbasin (WDFW 1998). The Beckler River also has a predevelopment fish barrier to anadromous fish. At RM 11.8, just below the confluence of Elbow Creek (see Figure 2), a 12-foot waterfall presents an impassable barrier to upstream migration of fish (USFS 1995).

Landslides and avalanches cause vegetation removal within unstable chutes that reach the edge of the mainstem Beckler and Rapid rivers in many places. Mass erosion from these areas can either contribute fine sediment to the system which can cause embeddedness of spawning gravels (impairment of fish habitat) or alternatively can provide additional gravel to the system (i.e., beneficial to fish), depending on the soils associated with the chutes.

Fires within the Beckler/Rapid River watershed have also affected the forest age, species composition, and species diversity (USFS 1995). The most recent large fire event was the Evergreen fire in 1967 that burned many thousands of acres around Evergreen Mountain and Evergreen Creek near the confluence of the Beckler and Rapid rivers (USFS 1995).

Human Modifications

Human modifications within the Beckler/Rapid River watersheds include timber harvest, road fill, bridges or culverts at road crossings, bank armoring, recreational facilities (such as campgrounds and dispersed campsite), and stormwater runoff with pollutant from vehicles. Timber harvesting and roads (and associated infrastructure and fill) are the two modifications that have created the largest amount of disturbance within the watershed.

Field Investigation

Habitat Impairments

Predevelopment Impairments

The primary rivers that contain the species of interest are generally all fault-confined mountain rivers. Landslides and mass wasting (natural geophysical events) are common in these environments. As such, periodic natural disturbance is expected. Wildlife species are generally adapted to these processes, although they may temporarily be negatively impacted from these geophysical events, but generally they provide beneficial inputs of sediment and gravel into the system. Human disturbance such as timber harvesting within the watershed exacerbates these natural landslides, causing much more debris (usually fine sediment) to discharge into rivers and ultimately overwhelming the system and negatively affecting fish habitat. The Beckler River system has been disturbed by timber harvesting over several decades.

Human Modifications

The primary human modifications observed throughout the Beckler River and Rapid River study reaches are the placement of fill and protective armor along the prisms of FS Road 65, FS Road 6550, and FS Road 6530 (FS Road 6530 is along the Rapid River), and along bridge abutments. FS Road 65 crosses the Beckler River at RM 1.0 just after crossing over Bolt Creek. The road then runs along the east side of the river and crosses seven tributaries to the Beckler River (including the Rapid River) between RM 2.9 and RM 10.0. The FS Road 6550 roadbed is direct fill within the floodplain of the Beckler River. Because the road sits low within the floodplain, it was washed out at the confluence of Bullbucker Creek (RM 9.6; see Figure 2), and was blocked off and abandoned at that point. Several dispersed campsites are also located along this floodplain road, which add to riparian disturbance.

Similar human modifications as those on the Beckler River were found on the Rapid River. FS Road 6530 crosses the Rapid River three times within the first river mile, and FS Road 65 crosses the mouth of the Rapid River. While there was less armoring of the Rapid River compared to the Beckler River, the amount of armoring and fill per mile of stream was still at a relatively high level compared to streams in less disturbed watersheds.

Observed Habitat Features

Field investigations confirmed similar conditions to those described in the Level II Stream Survey of the Beckler River and some of its tributaries (Cascades Environmental Services, Inc.

1997). Generally, riparian habitat along the Beckler River from RM 0.0 to RM 10.0 consists of intact forest along the river embankments, except where roads and road crossings occur. Most of the riparian area consists of second growth mixed coniferous/deciduous forest canopy that had good potential to provide large woody debris (LWD) recruitment in the future if not harvested.

Field observations indicated a relatively low amount of LWD in areas where observations were made. The lack of LWD within the Beckler River was also reported earlier in the USFS report (Cascades Environmental Services 1997). Observations in the field where LWD was lacking indicated that instream habitat diversity was likely reduced from predevelopment conditions, particularly in the lower reaches of the Beckler River, where LWD was virtually absent. The upper reaches of the Beckler River have a slightly steeper gradient and the channel is more confined. Pools and riffles were present but most pools were in-channel pools, and there were few pools along the edges of the channel where they would be formed in conjunction with LWD and shading from riparian vegetation (based on a 1-day reconnaissance from the road). LWD that is present in the river provides cover for juvenile salmonids. Because of the importance of LWD, a programmatic restoration activity could be to survey LWD throughout the lower reaches of the river and introduce wood on those reaches with low density. This should include locations where wood is likely to help increase the habitat area (pool and off-channel habitat formation) as well as increase existing habitat complexity and partitioning (see discussion below).

Recommended Programmatic Activities and Restoration Opportunities

Potential restoration opportunities were identified based on field investigation and available existing information. A total of 17 site-specific potential restoration opportunities were observed during the field investigation on August 16, 2012. Thirteen of the restoration opportunities are along the Beckler River and the remaining four are along the Rapid River. Table 1 presents a summary of the results of the potential restoration project identification study, and Figure 2 shows the location of the opportunities.

Recommended programmatic restoration activities as well as a detailed description of each potential restoration opportunity are described below. Each potential restoration opportunity is described in a summary table format (Table 1) that includes: potential opportunity number and name (related to Figure 2), approximate location, project sponsor, target type of fish or riparian habitat, current land ownership, hydrogeomorphic classification or position within the landscape (e.g., tributary fan), project size or size of area (or lineal feet) to be restored, and project type. The project description sheets also include a brief description of the existing habitat conditions at each site. Potential future threats to fish and fish habitat and risks to human infrastructure are also described based on the limited information obtained from field observations and literature of effects of human modifications on impairing processes and fish habitat. The rationale for the opportunity is briefly discussed. Finally, the habitat functions and processes that may be potentially restored if the project is implemented are listed based on past experience of similar projects implemented in similar river systems.

Table 1. Observed Potential Site-Specific Restoration Opportunities, Beckler and Rapid Rivers.

Site Number	Site Name	Impairment	Potential Opportunity
1	RM 0.1 Beckler River	Bank armoring failure	Proactive* bank stabilization
2	Power line - Beckler River	Bank erosion	Proactive bank stabilization
3	Bolt Creek	Bank armoring, channel confinement	Proactive bank stabilization
4	Beckler River Campground	Bank erosion, side channel disconnection	Proactive bank stabilization, campsite relocation
5	RM 1.9 Upland	Future bank armoring risk	Upland property acquisition
6	RM 2.9 Unnamed stream	Undersized culvert	Culvert replacement
7	RM 3.5 to RM 4.8	LWD deficiency	LWD placement at strategic locations
8	Johnson Creek bridge	Undersized bridge and fill, channel confinement	Bridge replacement and fill removal
9	RM 7.4 to 7.6	Bank armoring, channel confinement	LWD placement and/or road relocation
10	RM 7.6 Dispersed campsite	Bank erosion, riparian disturbance	Dispersed campsite decommission
11	FS Road 65 at Rapid River	Undersized bridge and fill, channel confinement	Bridge replacement and fill removal
12	Fourth of July Creek	Undersized bridge and fill	Bridge replacement and fill removal
13	FS Road 6550	Floodplain disconnection, fill, bank armoring, riparian disturbance	Road and fill removal feasibility analysis
14	RM 0.8 Rapid River	Bank armoring and fill, channel confinement	Armoring and fill removal
15	Evergreen mountain side channel	Channel constriction and fill	Feasibility analysis
16	RM 1.8 Tributary	Undersized culvert	Replace culvert with bridge
17	RM 3.2 Alluvial fan	Undersized culvert, floodplain disconnection, fill, ford	Ford and fill removal, bridge entire fan with one bridge

Note:

* For the purpose of this document, a proactive bank stabilization is the placement of secured large woody debris that would have both restorative and bank stabilizing benefits. This proactive action would be performed before the site becomes an emergency. Part of the restorative benefits of the project would be to prevent implementing emergency actions for which impact avoidance may not be possible and thus are likely to harm fish and wildlife.

Restoration Opportunities

<table>
<tr><td>Potential Opportunity</td><td colspan="3">1. Proactive Bank Stabilization</td></tr>
<tr><td>Location</td><td colspan="3">RM 0.1 Beckler River</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>USFS/King County</td></tr>
<tr><td>Target habitat</td><td>Adult and juvenile salmonid migration and rearing</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Mainstem riverbank</td></tr>
<tr><td>Project size</td><td>~100 feet of riverbank</td></tr>
<tr><td>Type of Project</td><td>Proactive bank stabilization</td></tr>
<tr><td>Existing conditions</td><td colspan="3">Beckler Road runs along the right bank (west side) of the Beckler River at this site location. The road serves as the primary connector route from US Route 2 to the North Fork of the Skykomish and to recreational sites and timber production lands. At RM 0.1, the river makes a sharp turn to the southeast due to a bedrock outcrop. The river has scoured out the road embankment just upstream of the bedrock and is starting to undermine the road (see photo). Riprap was placed in this area, but has failed and has been mostly carried downstream during large storm events. While some large woody debris has collected where the bedrock is located, the bank is still unstable.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would entail proactive banks stabilization and placement of LWD and vegetation to both secure the bank and to provide fish habitat complexity. Another option would be to move the road to the west, away from the river and then add LWD and vegetation on the bank to prevent further erosion, break up river flows, and provide refugia and cover for fish.</td></tr>
<tr><td>Future threats</td><td colspan="3">Further erosion of the channel, undermining the road, and potential road collapse into the channel necessitating a less habitat friendly fix. This would result in loss and damage of fish habitat and fish habitat diversity in this reach, and likely cause debris to enter the channel.</td></tr>
<tr><td>Project rationale</td><td colspan="3">The road fill impairs this reach of the river, where it would typically overtop the banks into the floodplain. If LWD were placed within the erosion area and the bank was revegetated, it would break up the flow, provide habitat diversity, and prevent the road debris from entering the channel. Setting back the road, removing the fill, placing LWD, and revegetating the bank would also restore floodplain functions, habitat diversity, and vegetative cover to this reach of the river.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Floodplain connection, greater juvenile salmonid habitat diversity, refugia and cover, and some additional shading of the shoreline. Additionally, localized water quality improvement would be provided by the project implementation.</td></tr>
</table>

Return to Figure 2

Potential Opportunity	**2. Proactive Bank Stabilization**
Location	**Power line - Beckler River**

Project sponsor	USFS/King County
Target habitat	Adult and juvenile salmonid rearing and refugia
Current ownership	USFS
Hydrogeomorphic classification	Mainstem riverbank
Project size	~200 feet of riverbank
Type of Project	Proactive bank stabilization

Existing conditions	Bonneville Power Administration (BPA) power lines cross perpendicularly over the Beckler River at approximately RM 0.5. To maintain the utility alignment, the vegetation is periodically cut down within a 100 foot swath below the power lines. Due to the loss of forested riparian habitat and the erosive force of the river, the steep left bank of the river is eroding under the power lines (see photo). Bank armoring at this location was not observed during the field investigation and erosion is likely to continue to occur over time.
Project description	The project would entail proactive bank stabilization and placement of LWD and vegetation to both secure the bank and to provide localized fish habitat complexity.
Future threats	Entrainment of the stream along the bank and armoring with rock or other means by BPA. Further erosion of the embankment would cause more slumping of the bank into the river and may cause a perception of risk to the power line poles. Since no LWD is present at this location, erosion will continue to occur, potentially causing embeddedness within spawning gravels, loss of fish habitat diversity, and loss of riparian vegetation and cover. Rock armor would further degrade stream conditions.
Project rationale	The loss of riparian vegetation along the power line corridor has resulted in erosion and instability of the bank. Placing LWD and revegetating the eroding bank would break up the flow, increase habitat diversity, and restore riparian cover, which provide critical functions to maintaining good salmonid habitat.
Functions restored	Greater salmonid habitat diversity, refugia and cover, moderating the delivery of sediment to the channel, and providing some additional shading of the shoreline. Additionally, localized water quality improvement would be provided by the project implementation.

Return to Figure 2

<table>
<tr><td>Potential Opportunity</td><td colspan="3">3. Proactive Bank Stabilization</td></tr>
<tr><td>Location</td><td colspan="3">Bolt Creek</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>USFS/King County</td></tr>
<tr><td>Target habitat</td><td>Adult and juvenile salmonid rearing and refugia</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Tributary streambank</td></tr>
<tr><td>Project size</td><td>~75 feet of riverbank</td></tr>
<tr><td>Type of Project</td><td>Proactive bank stabilization</td></tr>
<tr><td>Existing conditions</td><td colspan="3">FS Road 65 crosses over Bolt Creek, a tributary to the Beckler River, via a bridge. The bridge abutments adequately span the channel so that no scouring appears to be occurring. As part of the bridge installation, riprap armoring was placed along the right bank of the stream. The riprap extends approximately 75 feet downstream of the bridge. The riprap appeared to have been at this location for long enough to allow vegetation to grow over the riprap.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would entail removal of fill and riprap and replacement with LWD and vegetation to both secure the bank and to provide fish habitat complexity.</td></tr>
<tr><td>Future threats</td><td colspan="3">Entrainment of the river against the armored bank due to the lack of roughness. Potential future bank failure and then localized erosion of the embankment. Additional threats include erosion and sedimentation causing embeddedness within spawning gravels, greater loss of fish habitat diversity, and loss of riparian vegetation and cover.</td></tr>
<tr><td>Project rationale</td><td colspan="3">Hard armored embankments typically entrain the river against the bank, which results in erosion and eventually bank failure. Placing LWD and revegetating the eroding bank would restore critical functions to maintaining good salmonid habitat.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Greater salmonid habitat diversity, refugia and cover, stabilizing the bank, and providing some additional shading of the shoreline. Additionally, localized water quality improvement would be provided by the project implementation.</td></tr>
</table>

Return to Figure 2

<table>
<tr><td>Potential Opportunity</td><td colspan="3">4. Proactive Bank Stabilization, Campsite Relocation</td></tr>
<tr><td>Location</td><td colspan="3">Beckler River Campground</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>USFS/King County</td></tr>
<tr><td>Target habitat</td><td>Adult spawning and juvenile salmonid edge habitat; side channel habitat</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Mainstem riverbank and side channel</td></tr>
<tr><td>Project size</td><td>~300 feet of riverbank</td></tr>
<tr><td>Type of Project</td><td>Proactive bank stabilization, campsite relocation</td></tr>
<tr><td>Existing conditions</td><td colspan="3">The USFS Beckler River Campground is set on the banks of the Beckler River at about RM 1.5. The car-based campground contains 27 campsites, of which approximately five are located at the water's edge. Two of the five campsites located at the river's edge, have been nearly cleared of vegetation and are eroding into the river (see photo). Some log armoring has been placed along the riverbank at the campsite closest to the entrance of the campground and the other campsite contains more vegetation. Also, a high-flow side channel exists at the north end (upstream end) of the campground.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would entail placement of stable LWD, and planting of vegetation to both secure the bank and to provide fish habitat complexity, or alternatively relocating the campsites to a location that is farther from the water's edge. If feasible, an existing partially connected side channel could be better reconnected with the river as part of the project.</td></tr>
<tr><td>Future threats</td><td colspan="3">The campsites are in the process of eroding away, and they may be eroded into the river at some time. Bank failure would cause more localized sedimentation of the river and eventually result in loss of riparian habitat. Since no LWD or riparian vegetation exists in this area, erosion will continue to occur, potentially causing embeddedness of spawning gravels. The bank may be riprapped to prevent erosion and this would result in, loss of fish habitat diversity on the edge of the channel. The side channel may be abandoned, if campgrounds are being threatened with flooding and armoring measures are taken.</td></tr>
<tr><td>Project rationale</td><td colspan="3">The campground is in danger of being flooded and the campsites eroded away. The embankments could be stabilized through a combination of relocating campsites and then adding LWD and vegetation to the riverbank. This would also prevent fish habitat disturbance and improve edge habitat diversity. If campsites are relocated, then the side channel could be reconnected, improving rearing and refugia habitat.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Greater salmonid habitat diversity, refugia and cover, slowing the delivery of fine sediment to the channel, and providing some additional shading of the shoreline. Additionally, localized water quality improvement (temperature and turbidity) would be provided by the project implementation.</td></tr>
</table>

Return to Figure 2

<table>
<tr><td>Potential Opportunity</td><td colspan="3">5. Upland Property Acquisition</td></tr>
<tr><td>Location</td><td colspan="3">RM 1.9 Upland</td></tr>
<tr><td colspan="2" rowspan="6">
</td><td>Project sponsor</td><td>USFS/King County</td></tr>
<tr><td>Target habitat</td><td>Adult spawning and juvenile salmonid rearing</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Mainstem riverbank</td></tr>
<tr><td>Project size</td><td>~90 acres</td></tr>
<tr><td>Type of Project</td><td>Property acquisition</td></tr>
<tr><td>Existing conditions</td><td colspan="3">FS Road 6510 extends north and west from the FS Road 65 (Beckler Road) and provides access to private timber harvest properties and recreation. Active timber harvest activities were observed along this road during the field investigation. A large clear-cut was observed approximately 1 mile north of FS Road 65 and can be seen in the aerial above. From the aerial photograph, the area is estimated to be approximately 90 acres in size and within 150 feet of the active channel. This area consists of a patchwork of USFS and private land. The 90-acre clear-cut area is surrounded by USFS land.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would entail property acquisition of the timber harvest area (approximately 90 acres) or possibly a larger area.</td></tr>
<tr><td>Future threats</td><td colspan="3">More timber harvesting and road building could occur within this area, causing potential debris flows and sedimentation in the river (and thus embeddedness of spawning gravels) and loss of intact forest habitat within the watershed. Additional timber harvesting reduces the amount of LWD that is available for possible recruitment within the stream.</td></tr>
<tr><td>Project rationale</td><td colspan="3">The forests in the lower Beckler River watershed continue to be actively harvested on private lands. Acquiring this property would prevent further clear-cutting, and forest practices could be applied to move the forest towards old growth succession characteristics with the target of restoring the watershed.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Riparian vegetation functions including improving water quality, dampening peak flood flows, and providing LWD for recruitment into the river.</td></tr>
</table>

Return to Figure 2

Potential Opportunity	**6. Culvert Replacement**
Location	**RM 2.9 Unnamed stream**

Project sponsor	USFS/King County
Target habitat	Adult spawning
Current ownership	USFS
Hydrogeomorphic classification	Tributary fan
Project size	~50 lineal feet of tributary stream
Type of Project	Culvert replacement

Existing conditions	FS Road 65 crosses an Unnamed Creek that flows through an undersized culvert at RM 2.9. A large debris flow of large boulders was observed on the upstream side of the culvert. The stream was also observed to be intermittent as it was dry at the time of the field investigation. These boulders were not able to pass through the culvert due to the size (36 inches). Anadromous fish are not likely present in this small tributary. The culvert is currently a hanging culvert and would be a fish barrier because it is hanging above the streambed on the downstream side of the culvert, although the steepness of the stream would also be a barrier to fish passage.
Project description	The project would entail a culvert replacement with a properly sized bottomless culvert.
Future threats	Additional debris flows could cause blockage of the existing culvert and cause flooding of FS Road 65, and also additional sedimentation of the stream and the Beckler River. Boulders and LWD would not be able to pass through the culvert to the Beckler River during a large storm event.
Project rationale	Predevelopment debris flows like the one observed at RM 2.9 are blocked from reaching their final destination – the Beckler River. Also, the culvert could become plugged resulting in a washout of the culvert, damage to the road, and sedimentation of the Beckler River, initiating emergency actions that may endanger wildlife. Restoring predevelopment geomorphic processes would improve habitat within the tributary and the Beckler River.
Functions restored	Restoration of predevelopment geomorphic processes. It would improve downstream transport of spawning-size gravel.

Return to Figure 2

<table>
<tr><td>Potential Opportunity</td><td colspan="3">8. Bridge Replacement and Fill Removal</td></tr>
<tr><td>Location</td><td colspan="3">Johnson Creek bridge</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>USFS/King County</td></tr>
<tr><td>Target habitat</td><td>Adult spawning and juvenile salmonid rearing</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Tributary fan</td></tr>
<tr><td>Project size</td><td>~75 foot bridge span</td></tr>
<tr><td>Type of Project</td><td>Bridge replacement</td></tr>
<tr><td>Existing conditions</td><td colspan="3">FS Road 65 crosses Johnson Creek that flows into the Beckler from the east at RM 6.9. The bridge is undersized for the volume of flows that pass under the bridge. Scouring of the bridge abutments and adjacent riverbank was observed indicating the bridge is undersized. Also a pressure crack was observed at each end of the bridge indicating instability of the bridge (see photo). Fill has been placed within the stream in order to accommodate construction of the bridge. The bridge is a pinch point in the stream that will continue to erode over time.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would entail determining the appropriate size bridge to construct at the site, replacing the bridge with a properly sized bridge, and removing fill from the old bridge and reengaging lost floodplain. Also, the stream bank will be treated with LWD and vegetated with native vegetation to both stabilize the bank and provide improved fish habitat.</td></tr>
<tr><td>Future threats</td><td colspan="3">The river will continue to entrain against the left bank of the bridge. Over time the bridge abutment will scour, which could cause the bridge to fail, and the bank will continue to erode behind the abutments. This will require more riprap fill to be placed on the bank and within the stream to protect the bank and bridge, and may initiate emergency actions that could further endanger wildlife. Fish habitat diversity in this area will continue to decrease and would continue to allow the potential of predation (due to the lack of LWD for cover). Scouring of the streambank both up and downstream of the bridge may also occur. Sedimentation of downstream spawning gravel may occur due to the erosion.</td></tr>
<tr><td>Project rationale</td><td colspan="3">The bridge is undersized and at some point in the future could fail. Currently, the bridge is having a negative effect on fish habitat within this reach. A bridge replacement would be proactive before failure happens, and would restore properly functioning fish habitat.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Improved fish habitat diversity, restored predevelopment flow regime, stabilized banks, and reduced potential sedimentation of spawning gravels.</td></tr>
</table>

Return to Figure 2

<table>
<tr><td>Potential Opportunity</td><td colspan="3">9. LWD Placement and/or Road Relocation</td></tr>
<tr><td>Location</td><td colspan="3">RM 7.4 to 7.6</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>USFS/King County</td></tr>
<tr><td>Target habitat</td><td>Adult and juvenile salmonid habitat complexity and access to off-channel habitats</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Mainstem riverbank</td></tr>
<tr><td>Project size</td><td>~2,000 feet of streambank</td></tr>
<tr><td>Type of Project</td><td>LWD placement and/or road relocation</td></tr>
<tr><td>Existing conditions</td><td colspan="3">FS Road 65 is close to the Beckler River between RM 7.4 and 7.6, just downstream of its confluence with the Rapid River. Upstream of RM 7.6, the river bends east towards the road, and then bends south along the road. Since the river flows towards the road at this location, riprap has been placed on the riverbank to protect it from erosion. The road and riprap bank confine and straighten the stream at this location. Alders that were 10 to 20 years old were observed growing out of the riprap, indicating the bank armoring has been present and stable for that period.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would entail two potential options: 1) remove some or all of the riprap, incorporate LWD into the bank, and plant native vegetation, or 2) relocate the road to the east (connecting it to FS Road 6520), remove the riprap, and then incorporate LWD and vegetation along the riverbank.</td></tr>
<tr><td>Future threats</td><td colspan="3">The river will continue to entrain against the left bank along the road due to the riprap. Over time, the riprap is likely to fail and the bank will scour, or more riprap will be placed along the river. As a result, the fish habitat within this reach will continue to degrade. Riprap banks would continue to allow the potential of predation (due to the lack of LWD for cover)Erosion of the bank would cause sedimentation of downstream spawning gravel.</td></tr>
<tr><td>Project rationale</td><td colspan="3">Riprap armoring results in the threats that are listed under the Future Threats section above, as well as maintains poor riparian conditions. Fish habitat is continuing to degrade under current conditions. The incorporation of LWD and vegetation within this reach will improve habitat functions. If the road was relocated away from the river, this would provide habitat benefits, and allow the river to move freely within its floodplain within this reach.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Improved fish habitat diversity, increased food sources for fish, additional riparian cover provided, restored predevelopment flow regime, reconnected floodplain with the stream, and reduced potential sedimentation of spawning gravels.</td></tr>
</table>

Return to Figure 2

<table>
<tr><th>Potential Opportunity</th><th colspan="3">10. Dispersed Campsite Decommission</th></tr>
<tr><td>Location</td><td colspan="3">RM 7.6 Dispersed campsite</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>USFS/King County</td></tr>
<tr><td>Target habitat</td><td>Adult spawning and juvenile salmonid edge habitat</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Rapid River fan</td></tr>
<tr><td>Project size</td><td>0.3 acres</td></tr>
<tr><td>Type of Project</td><td>Dispersed campsite decommission</td></tr>
<tr><td>Existing conditions</td><td colspan="3">A small spur road off of FS Road 65 heads toward the Beckler River to a dispersed campsite at RM 7.6. The river bends south along the FS Road 65 just downstream of this location (see opportunity # 9 for more details). An approximate 15,000 square foot area is cleared of vegetation to allow cars and camping. The vegetation on the riverbank and has been cleared and trampled at the campsite.</td></tr>
<tr><td>Project description</td><td colspan="3">The spur road and campsite area would be blocked off, and revegetated with native shrubs and trees.</td></tr>
<tr><td>Future threats</td><td colspan="3">Use of the campsite would continue to result in trampling and clearing of riparian vegetation. Due to the loss of vegetation, erosion would occur that could result in sedimentation of downstream spawning gravels. Also, bank failure may occur, and the river may avulse through the campsite. The loss of vegetation also results in the loss of shade, cover, and food sources for fish. Riprap may be placed at this location to stop bank erosion. Pollutant contamination of the stream from vehicular traffic at the river's edge may occur.</td></tr>
<tr><td>Project rationale</td><td colspan="3">Dispersed camping at the river's edge at this location adversely affects fish habitat as described in the Future Threats section. This potential project opportunity would complement opportunity #9 and would restore this reach to predevelopment conditions.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Improved fish habitat diversity, restoration of the riparian cover would increase food sources and cover for fish, and shade for the stream, reduced potential sedimentation of spawning gravels, and improved water quality.</td></tr>
</table>

Return to Figure 2

Potential Opportunity	**11. Bridge Replacement and Fill Removal**
Location	**USFS Road 65 at Rapid River**

Project sponsor	USFS/King County
Target habitat	Juvenile salmonid edge habitat and habitat complexity
Current ownership	USFS
Hydrogeomorphic classification	Rapid River fan
Project size	~100 foot bridge span
Type of Project	Bridge replacement

Existing conditions	FS Road 65 crosses the Rapid River approximately 300 feet upstream of its confluence with the Beckler River. Scouring along the banks and bridge abutments was observed indicating the bridge is undersized. Fill has been placed within the river in order to accommodate construction of the bridge, causing disconnection of the river with the rest of its fan. The bridge is a pinch point in the stream that will continue to erode over time.
Project description	The project would entail determining the appropriate size bridge to construct at the site, replacing the bridge with a properly sized bridge, and removing fill from the old bridge. In addition, LWD and native vegetation will be incorporated into the riverbanks for stabilization, and to provide improved fish habitat.
Future threats	The river will continue to scour the banks and bridge abutments, potentially causing bridge and bank failure. Over time, this will require more fill to be placed on the bank and within the stream to protect the bank and bridge, and may initiate emergency actions that endanger wildlife habitat. Fish habitat diversity in this area will continue to degrade, and would continue to allow the potential of predation (due to the lack of LWD for cover). Scouring of the stream bank both up and downstream of the bridge will continue to occur. Sedimentation of downstream spawning gravels may occur due to the erosion.
Project rationale	The bridge is undersized and at some point in the future could fail. Currently, the bridge and fill within the stream is having a negative effect on fish habitat within this reach. Bridge replacement that removes the abutments and fill from the stream before failure would restore the predevelopment processes to the stream, prevent more damage to fish habitat in the future, and prevent complete bridge failure. The remainder of the fan may be reconnected.
Functions restored	Improved fish habitat complexity, restored predevelopment geomorphic conditions, stabilized banks and reduced potential sedimentation of spawning gravels, restored riparian vegetation resulting in improved shade, cover, and increased food sources for fish.

Return to Figure 2

<table>
<tr><td>Potential Opportunity</td><td colspan="3">12. Bridge replacement and fill removal</td></tr>
<tr><td>Location</td><td colspan="3">Fourth of July Creek</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>USFS/King County</td></tr>
<tr><td>Target habitat</td><td>Adult spawning and juvenile salmonid edge habitat and habitat complexity</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Tributary fan</td></tr>
<tr><td>Project size</td><td>~75 foot bridge span</td></tr>
<tr><td>Type of Project</td><td>Bridge replacement</td></tr>
<tr><td>Existing conditions</td><td colspan="3">FS Road 65 crosses Fourth of July Creek at RM 8.3 of the Beckler River. The bridge is undersized for the volume of flows that pass under the bridge. Scouring along the banks and bridge abutments was observed indicating the bridge is undersized. Also, a stress crack (see photo) between the bridge and the road connector was observed. Fill has been placed within the stream in order to accommodate construction of the bridge. The bridge is a pinch point in the stream that will continue to erode over timed and continue to disconnect the creek from its fan.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would entail determining the appropriate size bridge to construct at the site, replacing the bridge with a properly sized bridge, and removing fill from the old bridge. Also, LWD and native vegetation will be incorporated into the riverbanks for stabilization and to provide improved fish habitat.</td></tr>
<tr><td>Future threats</td><td colspan="3">The river will continue to scour the banks and bridge abutments, potentially causing bridge and bank failure. Over time, this will require more fill to be placed on the bank and within the stream to protect the bank and bridged and may initiate emergency actions that endanger wildlife Fish habitat diversity in this area will continue to degrade and would continue to allow the potential of predation (due to the lack of LWD for cover). Scouring of the stream bank both up and downstream of the bridge will continue to occur. Sedimentation of downstream spawning gravels may occur due to the erosion.</td></tr>
<tr><td>Project rationale</td><td colspan="3">The bridge is undersized and at some point in the future is likely to fail. Currently, the bridge and fill within the stream is having a negative effect on fish habitat within this reach by disconnecting the creek from its fan and floodplain. Bridge replacement that removes the abutments and fill from the stream before failure would restore the predevelopment processes to the stream, prevent more damage to fish habitat in the future, and prevent complete bridge failure.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Improved fish habitat diversity, restored predevelopment geomorphic conditions, stabilized banks and reduced potential sedimentation of spawning gravels, restored riparian vegetation resulting in improved shade, cover, and increased food sources for fish.</td></tr>
</table>

Return to Figure 2

<table>
<tr><td colspan="2">Potential Opportunity</td><td colspan="2">13. Road and Fill Removal Feasibility Analysis</td></tr>
<tr><td colspan="2">Location</td><td colspan="2">USFS Road 6550</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>USFS/King County</td></tr>
<tr><td>Target habitat</td><td>Adult and juvenile salmonid habitat complexity and access to off-channel habitats</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Mainstem floodplain</td></tr>
<tr><td>Project size</td><td>~1.3 miles of stream and 15 acres of floodplain</td></tr>
<tr><td>Type of Project</td><td>Road and fill removal feasibility analysis</td></tr>
<tr><td>Existing conditions</td><td colspan="3">FS Road 6550 extends east from FS Road 65 just after its crossing of Fourth of July Creek. As observed in the field and shown on the USFS road map, FS Road 6550 dead ends at Bullbucker Creek (Beckler River RM 9.6). Originally the road continued to the north to connect with FS Road 65 and FS Road 63 that runs along the North Fork Skykomish River. The abandoned roadbed north of Bullbucker Creek has been reclaimed by vegetation and wetland seeps, but is still elevated above the floodplain. Several dispersed campsites are located along the 1.3 mile maintained existing road spur. A low bridge over the Beckler River at RM 8.8 is undersized and appears to be in danger of being washed out in the next flood. The river is confined by the road fill along this spur road that starts on the west side of the river, and then crosses to the east side. The roadbed cuts the river off from its floodplain.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would entail abandonment of 1.3 miles of FS Road 6550, removal of the road fill from the floodplain, and removal of the bridge at RM 8.8. Additional roadbed that was previously abandoned could also be removed. Due to the large size of this project, a feasibility study of this large floodplain reconnection and fill removal project would need to be completed in order to determine its elements.</td></tr>
<tr><td>Future threats</td><td colspan="3">The river will continue to be cut off from its floodplain on both sides of the river where the road is located. The road fill confines the channel, causing downcutting and straightening of the channel, and eliminating off-channel refugia. This results in degradation of the fish habitat and disruption of predevelopment geomorphic processes within the floodplain. The bridge at RM 8.8 further restricts the channel at that location.</td></tr>
<tr><td>Project rationale</td><td colspan="3">Since FS Road 6550 is within the floodplain of the Beckler River, it has the largest impact on fish and riparian habitat of any of the other human modifications that were observed within the study reach (with the possible exception of Beckler Road on the lower river). Removal of the road fill and bridge could restore predevelopment floodplain functions within a 10- to 15-acre area.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Improved fish access to off-channel habitats, habitat diversity, additional riparian cover provided that would result in increased shade for the stream, and cover, and food sources for fish, restored predevelopment flow regimes, reconnected floodplain and stream, increased off-channel refugia and reduced potential sedimentation of spawning gravels.</td></tr>
</table>

Return to Figure 2

<table>
<tr><td>Potential Opportunity</td><td colspan="3">14. Bank Armoring and Fill Removal</td></tr>
<tr><td>Location</td><td colspan="3">RM 0.8 Rapid River</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>USFS/King County</td></tr>
<tr><td>Target habitat</td><td>Adult and juvenile salmonid edge habitat</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Mainstem riverbank</td></tr>
<tr><td>Project size</td><td>~75 feet of streambank</td></tr>
<tr><td>Type of Project</td><td>Bank armoring and fill removal</td></tr>
<tr><td>Existing conditions</td><td colspan="3">FS Road 6530 crosses the Rapid River via a bridge at RM 0.8. The bridge completely spans the river and floodplain at this location and does not warrant replacement. However, bank armoring and fill along the right bank are present.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would entail removing the bank armoring and incorporating LWD into the bank. The bank would also be vegetated with native vegetation. LWD and native vegetation would be incorporated into the riverbanks for stabilization, and to provide improved fish habitat.</td></tr>
<tr><td>Future threats</td><td colspan="3">The river will continue to scour the banks and be entrained along the riprap, potentially causing bank failure. Over time, this will require more fill to be placed on the bank and within the stream to protect the bank and bridge, and may initiate emergency actions that endanger wildlife. Fish habitat diversity in this area will continue to degrade and would continue to allow the potential of predation (due to the lack of LWD for cover). Scouring of the stream bank both up and downstream of the bridge will continue to occur. Sedimentation of downstream spawning gravels may occur due to the erosion.</td></tr>
<tr><td>Project rationale</td><td colspan="3">Currently, the armored banks are having a negative effect on fish habitat within this reach. Replacement of the riprap with LWD, and adding native vegetation to the banks will restore predevelopment processes to the stream, prevent more damage to fish habitat in the future, and prevent potential slope failure.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Improved fish habitat diversity, restored predevelopment flow regime, stabilized banks and reduced potential sedimentation of spawning gravels, restored riparian vegetation resulting in improved shade, cover, and increased food sources for fish.</td></tr>
</table>

[Return to Figure 2]

<table>
<tr><td>Potential Opportunity</td><td colspan="3">15. Feasibility Analysis</td></tr>
<tr><td>Location</td><td colspan="3">Evergreen mountain side channel</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>USFS/King County</td></tr>
<tr><td>Target habitat</td><td>Adult/ juvenile off-channel habitat access and complexity</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Mainstem riverbank and floodplain</td></tr>
<tr><td>Project size</td><td>~1.3 miles of stream</td></tr>
<tr><td>Type of Project</td><td>Bridge, road, and fill removal feasibility analysis</td></tr>
<tr><td>Existing conditions</td><td colspan="3">FS Road 6530 crosses the Rapid River via bridges at RM 1.0 and then again at RM 1.3. An unnamed tributary joins the river from the west at RM 1.2. Another tributary joins the river from the east just upstream of RM 1.3. At RM 1.3, the Rapid River curves sharply to the west and under the bridge and then winds back around to the southeast until it passes back under the bridge at RM 1.0. Riprap armoring and fill is present along the left bank of the curve at RM 1.3 (see photo). Field observations revealed FS Road 6530 was constructed within a side channel of the Rapid River between the two bridges, and the bank armoring and fill at RM 1.3 prevents the river from avulsing through the bank to the old side channel where FS 6530 is now present. The bridges are both slightly undersized at each location.</td></tr>
<tr><td>Project description</td><td colspan="3">A feasibility study would need to be completed to understand the complexities of the potential road relocation and removal of one or both bridges and alternative road options. It is possible that the road could be relocated to higher ground and reconnected upstream of the RM 1.3 bridge. The side channel could then be restored by removing the armoring at RM 1.3, the roadbed within the channel, and stabilizing and vegetating the banks.</td></tr>
<tr><td>Future threats</td><td colspan="3">The river may avulse through the bank armoring at RM 1.3 and damage FS Road 6530, potentially causing one of the bridges to fail, and initiate emergency actions that endanger wildlife. This would damage fish habitat by adding debris and sediment to the channel. The side channel will continue to be cut off, reducing the rearing habitat, and potentially spawning and refugia habitat that could be available for fish. Bridge crossing and road confinement of the Rapid River will continue to disrupt the predevelopment hydraulic and geomorphic processes within the floodplain.</td></tr>
<tr><td>Project rationale</td><td colspan="3">Since FS Road 6530 is within the floodplain of the Rapid River, it has the largest impact on fish and riparian habitat of any of the other human modifications that were observed on the Rapid River. Restoration of the side channel would provide 0.3 miles of potential rearing, spawning, and refugia habitat to this segment of the river.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Increased available stream habitat, improved fish habitat diversity, reconnected side channel and floodplain with the river, increased off-channel and side-channel refugia, additional riparian cover provided, which would result in increased shade for the stream, cover and food sources for fish, restored predevelopment flow regimes, and reduced potential sedimentation of downstream spawning gravels.</td></tr>
</table>

Return to Figure 2

<table>
<tr><td>Potential Opportunity</td><td colspan="3">16. Culvert Replacement</td></tr>
<tr><td>Location</td><td colspan="3">RM 1.8 Tributary</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>USFS/King County</td></tr>
<tr><td>Target habitat</td><td>Adult and juvenile salmonid passage</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Tributary fan</td></tr>
<tr><td>Project size</td><td>~100 lineal feet of stream</td></tr>
<tr><td>Type of Project</td><td>Culvert replacement</td></tr>
<tr><td>Existing conditions</td><td colspan="3">FS Road 6530 crosses an unnamed creek that flows from the north through an undersized culvert at RM 1.8 of the Rapid River. The tributary flows down the steep slopes to the north of the Rapid River valley, where debris flows are frequent. The culvert is not sized large enough to pass large boulders and wood carried by the stream to the Rapid River, and the culvert has effectively disconnected the stream from its fan.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would entail a culvert replacement with a properly sized culvert.</td></tr>
<tr><td>Future threats</td><td colspan="3">Additional debris flows could cause blockage of the existing culvert, cause flooding or damage of FS Road 6530, and initiate emergency actions that could endanger wildlife. The undersized culvert will continue to disrupt the predevelopment hydraulic and geomorphic processes of sediment and debris flows into the Rapid River and continue to disconnect the stream from its fan.</td></tr>
<tr><td>Project rationale</td><td colspan="3">Predevelopment debris flows like the one observed at RM 1.8 are blocked from reaching their final destination – the Rapid River. Also, there is potential that the roadbed and culvert could end up in the Rapid River during a large storm event. Allowing the predevelopment hydraulic and geomorphic processes to be restored will improve conditions for fish on the tributary fan.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Fish passage and movement and predevelopment hydraulic and geomorphic processes, stabilized streambank, additional riparian habitat provided that would result in improved cover, shade, and food sources for fish.</td></tr>
</table>

Return to Figure 2

<table>
<tr><td>Potential Opportunity</td><td colspan="3">17. Culvert Replacement</td></tr>
<tr><td>Location</td><td colspan="3">RM 3.2 Alluvial fan</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Project sponsor</td><td>USFS/King County</td></tr>
<tr><td>Target habitat</td><td>Adult and juvenile salmonid passage and juvenile off-channel refugia.</td></tr>
<tr><td>Current ownership</td><td>USFS</td></tr>
<tr><td>Hydrogeomorphic classification</td><td>Tributary fan</td></tr>
<tr><td>Project size</td><td>~1 acre of fan</td></tr>
<tr><td>Type of Project</td><td>Culvert replacement</td></tr>
<tr><td>Existing conditions</td><td colspan="3">Forest Road 6530 crosses two unnamed creeks that flow from the north through an undersized culvert and a ford at RM 3.2 of the Rapid River. The two tributaries to the Rapid River combine to form an alluvial fan as they flatten out at the base of the slope along the road. Alluvial fans typically provide sediment and gravel to the stream in the floodplain valleys below the slopes. The culvert is not sized large enough to pass the potentially large amount of sediment and debris and the ford exposing the stream of vehicular pollution. Culverts at the base of the slopes of alluvial fans often fill up with sediment if they are undersized.</td></tr>
<tr><td>Project description</td><td colspan="3">The project would entail a culvert replacement with a properly sized set of culverts or bridges that can accommodate the sediment flows of the alluvial fan.</td></tr>
<tr><td>Future threats</td><td colspan="3">Over time the undersized culvert could become blocked with sediment and other debris. Once blocked, the stream may start undermining the area around the culvert and could result in culvert failure. Culvert failure may initiate emergency actions that could endanger wildlife. The undersized culvert will continue to disrupt predevelopment geomorphic processes. The ford exposes the stream to vehicular pollution.</td></tr>
<tr><td>Project rationale</td><td colspan="3">Fish will continue to be adversely affected by the undersized culvert. The culvert could be blown out in a storm and end up in the Rapid River during a large storm event. Allowing the predevelopment hydraulic and geomorphic processes to be restored will improve conditions for fish in both the tributary and the Rapid River, and expand off-channel refugia.</td></tr>
<tr><td>Functions restored</td><td colspan="3">Restored predevelopment geomorphic processes, stabilized streambank, additional riparian habitat provided that would result in improved cover, expanded off-channel refugia, shade, and food sources for fish.</td></tr>
</table>

Return to Figure 2

Recommended Programmatic Activities

LWD Survey

The Beckler River basin lacks LWD from past logging, bank armoring and LWD removal, particularly in its lowermost reaches below RM 8.5 (Cascades Environmental Services 1997 and limited field observations). A survey could lead to the identification of key places where LWD placement would be most beneficial.

Geomorphic Assessment

The Beckler and Rapid Rivers are fault-controlled rivers, but the ramifications of that on the geomorphology and its impact on habitat is unknown. A geomorphic assessment could allow more sophisticated prioritization of the projects in those rivers, as well as providing a resource for future infrastructure and educational projects.

Hydrologic Analysis

The frequency and size of floods in the Beckler River basin are largely unknown. Conducting a hydrologic analysis of the basin, similar to what is being done on the Miller River, would allow sizing future road crossing structures in the basin in a more thoughtful way. The hydrologic analysis would also inform future habitat restoration and flood management projects that may occur in this watershed.

SUMMARY OF FINDINGS

The following is a summary of the observations of this study:

- The Beckler River lacks LWD; however, insufficient information is available to determine all the reasons why this is the case.
- Bank armoring, bridge crossing, road confinement, and fill placement are the primary human impairments within the study reaches of the Beckler and Rapid Rivers.
- Instream habitat is relatively functional, but human modifications and lack of LWD have reduced habitat diversity and complexity. In particular, pools per river mile are at moderate numbers, and pool complexity is also moderate.
- FS Road 6550 is within the floodplain of the Beckler River and has one of the largest impacts on fish habitat of all the human modifications identified in this report, despite its limited use.
- FS Road 6530 is within a side channel of the Rapid River and has had a large impact on fish habitat in the localized reach at that location.
- The Rapid River also lacks LWD in its lower reach below RM 1.5.

REFERENCES

Beechie, T.J., D.A. Sear, J.D. Olden, G.R. Pess, J.M. Buffington, H. Moir, P. Roni, and M.M. Pollock. 2010. Process-based Principles for Restoring River Ecosystems. *BioScience* 60(3):209-222.

Bisson, P., J. Dunham, and G. Reeves. 2009. Freshwater ecosystems and resilience of Pacific salmon: habitat management based on natural variability. *Ecology and Society* 14.

Cascades Environmental Services, Inc. 1997. Beckler River Stream Survey Level II, Version 9.6 for Region 6, Final Report. Prepared for US Forest Service, Skykomish Ranger District, Skykomish, Washington. November 12, 1997.

Tabor, R.W., V.A. Frizzell, Jr., D.B. Booth, R.B. Waitt, J.T. Whetten, and R.E. Zartman. 1993. Geologic map of the Skykomish River 30- by 60-minute quadrangle, Washington. US Geological Survey Map I-1963.

USFS. 1995. Watershed Analysis – Beckler River, Skykomish Ranger District. US Forest Service. September 1995.

USFS. 2010. Map of Skykomish Ranger District. Wild Sky Wilderness and Henry M. Jackson Wilderness, Mount Baker – Snoqualmie National Forest. US Forest Service.

Wald, A.R. 2009. High Flows for Fish and Wildlife in Washington: Report of Investigations in Instream Flow. Washington Department of Fish and Wildlife, Olympia, Washington.

APPENDIX E

Lower Miller River Restoration Feasibility Report

RESTORATION FEASIBILITY REPORT

LOWER MILLER RIVER

Prepared for
King County
Department of Natural Resources
and Parks
Water and Land Resources Division

Prepared by
Herrera Environmental Consultants, Inc.

RESTORATION FEASIBILITY REPORT

LOWER MILLER RIVER

Prepared for
King County
Department of Natural Resources and Parks
Water and Land Resources Division
River and Floodplain Management Section
201 S. Jackson Street
Seattle, Washington 98104-3855

Prepared by
Herrera Environmental Consultants, Inc.
2200 Sixth Avenue, Suite 1100
Seattle, Washington 98121
Telephone: 206/441-9080

April 17, 2013

CONTENTS

TABLES

FIGURES

INTRODUCTION

In January 2011, the Miller River avulsed through the Old Cascade Highway near the left bank abutment of an existing bridge over the river approximately 2 miles west of Skykomish, Washington, just upstream from its confluence with the South Fork Skykomish River (South Fork). The avulsion was largely complete immediately following the event. Because the highway crosses what is an extraordinarily active alluvial fan and replacement of the road washout area had many complicated factors including funding the recommended solution, the decision was ultimately made to close the road indefinitely. In addition to the highway closure, King County acquired a former monastery property on the northwest edge of the alluvial fan to avoid or minimize maintenance costs associated with flood control/damage, allow natural physical river processes, and restore or enhance habitat in the area. In addition support for this study was provided in part by the Natural Resources Damages (NRD) settlement made between Burlington Northern Santa Fe (BNSF) and the Washington State Department of Ecology (Ecology).King County retained Herrera Environmental Consultants (Herrera) to study the feasibility of designing and implementing a project to restore physical processes and habitat in the area, as part of the larger restoration feasibility analysis performed on the South Fork basin. The work was performed under Contract #E00201E10, Work Order E00201T.

This technical memorandum presents the feasibility study. It outlines the approach, analytical methods, results, as well as the identification of specific restoration actions (project alternatives) that could be implemented to improve aquatic habitat on the Miller River fan in rural eastern King County, Washington.

Study Area Limits

The study area is the lowermost 2 miles of the Miller River (Figure 1), including all of the areas on its alluvial fan that have been or might have been active in the recent geologic past (the last 150 years). Most of the emphasis of the analysis performed as part of the study (hydraulic analysis, thorough on-the-ground survey, etc.) was on the alluvial fan itself, which is roughly the lowest 1 mile.

Goal and Objectives

The goal of this study is to assess the feasibility of restoring physical processes and habitat in the lower Miller River. To this end, the study included the following three objectives: 1) estimate the flood inundation frequency and other geomorphic hazards on the alluvial fan, 2) characterize existing aquatic habitat conditions and fish species use within the study area, and 3) identify restoration alternatives that address habitat impacts associated with the Old Cascade Highway, other County infrastructure, as well as other factors limiting aquatic habitat (and thus fish and wildlife species) in the study area.

Legend

- Stream gage
- Reach break
- River or creek
- Money-Miller fan
- Project area
- City limits
- Road

Figure 1.
Lower Miller River project area.

N

0 2,000 4,000 8,000 ft

HERRERA

Aerial: USDA (2011)

K:\Projects\10-04766-023\Project\Report_Maps\vicinity_map.mxd (1/15/2013)

METHODOLOGY

Geomorphic Assessment

Understanding the geology of a site is a critical step to provide context in support of a geomorphic assessment. The geologic context of the study area is primarily provided by Tabor et al. (1993). Tabor et al. (1993) provide information regarding the recent geologic past that serves as a template for the analysis discussed and presented in this document. A short summary is provided herein, though a more detailed is provided in Tabor et al. (1993) and in the South Fork Skykomish geomorphic assessment, which accompanies this report (Herrera 2012a).

There have already been two geomorphic assessments of the study area (Herrera 2009 and 2012a). In late 2009, Herrera examined the Miller River fan to determine risks to the roadway in the vicinity of what is now the 2011 avulsion site (Herrera 2009). Herrera (2009) was performed before the avulsion. Herrera also performed a much larger assessment that characterized the geomorphology of the South Fork Skykomish River, including the Miller River fan, and is appended to this document (Herrera 2012a). These two assessments serve as the basis for the updated geomorphic assessment described herein. In addition to the existing literature, a site visit occurred on September 14, 2012, in order to characterize the geomorphic changes on the alluvial fan since the avulsion took place in 2011. These changes are described later in the *Results* section of this document along with an updated analysis of the geomorphic risks to remaining infrastructure.

The study area was divided into two main reaches: the lower Miller River (RM 0 to RM 1) and upper Miller River (RM 1 to RM 2). These two reaches were used as a framework for the analyses and characterizations discussed in this document as well as for habitat mapping purposes. The level detail was different for each reach. The lowest 1 mile (i.e., the alluvial fan) was thoroughly examined, primarily on foot, while RM 1 to RM 2 was analyzed primarily using existing aerial photographs.

Habitat Assessment

The objective of the habitat assessment was to characterize existing aquatic habitat conditions and fish species use within the study area (and throughout the Miller River watershed). The habitat assessment will also guide the identification of habitat restoration opportunities that provide benefits to priority fish species by addressing habitat impacts and limiting factors.

This habitat assessment involved the following tasks:

1. Review of background information on existing conditions and documented fish habitat use within the study area and the watershed (including review of recovery plans and guidance documents)

2. Field reconnaissance of habitat conditions
3. Geographic Information System (GIS)-based mapping and characterization of habitat features

Background information reviewed as part of the habitat assessment included:

- Fish species distribution data (WDFW 2012a, 2012b)
- Miller River Bridge #999W West Approach Roadway Washout Type, Size, and Location (TSL) Feasibility Study Report - King County Department of Transportation (King County 2011)
- Miller River Fan Geomorphic Assessment (Herrera 2009)
- Salmon and steelhead recovery planning and watershed limiting factors analysis documents (Haring 2002; USFS 2009; Snohomish Basin Salmon Recovery Forum 2005)
- Hydrography data (WDNR 2009)
- Recent aerial photography (flown in 2009 and 2011)
- LiDAR imagery
- Hydraulic model results

Staff ecologists conducted a field reconnaissance of the Miller River and associated floodplain accessible by Miller River Road and the Old Cascade Highway on September 14, 2012. General observations of current habitat conditions were recorded on field maps and in field notes, and supported with photographs. Field notes generally included observations of channel conditions (i.e., geomorphology, sediment, wood, hydrology, and hydraulics), vegetation structure, floodplain condition, and human caused modifications. A more in-depth field reconnaissance was conducted from RM 0 to RM 1 (i.e., the alluvial fan), particularly from the apex of the alluvial fan to the vicinity of the former monastery. River mile 1.0 to RM 2.0 was of a lower priority for this assessment and much of the reconnaissance was conducted from Miller Road access points. Due to this limited access and lack of hydraulic model results for this area, mapping of habitat types was primarily limited to aerial photograph and lidar interpretation checked in limited locations by observations made in the field.

Herrera established habitat types for GIS mapping based on the classification approach used in Ecosystem Diagnosis and Treatment (EDT) as described in Lestelle et al. (2005). Habitat types are distinguished by occurring in-channel (i.e., on the main river) and off-channel (i.e., near the main river). In addition, tributary streams were identified based on hydraulic modeling and lidar data and field observations. Herrera ecologists also consulted with the geomorphologists and engineers responsible for the hydraulic modeling and geomorphic analysis in order to understand the geologic history of the modern alluvial fan and its current hydrologic characteristics.

Following field work, ArcMap (Version 10) software was used to map habitat types and geomorphic features. Data sources used included aerial photographs, LiDAR imagery, King

County levee locations, and hydraulic modeling results for the 2-year flood event (lower mile of study area only). LiDAR and aerial photography served as the primary datasets for delineation/digitizing of habitat polygons, while the hydraulic modeling results provided information on inundation frequency to assist in the attributing of different channel types.

The following sections presents descriptions of the habitat types identified within the study area. These habitat type descriptions were used during the field reconnaissance to characterize habitat conditions as well as in the office to prepare the GIS maps.

Side Channel

Side channels are in-channel habitats that contain a portion of the streamflow from the main or primary stream channel at flows less than bankfull, partially or entirely surrounded by vegetated or stable island(s). The channel may remain connected at its top end through all flows less than bankfull or it may become disconnected at some point as flows decline. Therefore, intermittently connected side channels can have seasonal patterns of connectivity associated with the hydrograph. For purposes of this study, active side channels correspond to channel features (other than the main channel) inundated to average depths of approximately 3 feet or greater during 2-year peak flow events (based on hydraulic model results). When flowing, the channel is connected to the main channel at its top and bottom ends.

Overflow Channel

Overflow channels represent off-channel flood swales, often a former mainstem or side channel, carrying surface water and directly connected to the main river at its upstream end when flows exceed bankfull. Therefore, overflow channels have seasonal variation associated with the hydrograph. For purposes of this study, overflow channels correspond to channel features inundated at the 2-year peak flow event (based on hydraulic model results) that contain average depths less than 3 feet. Like side channels, they are bordered partly or entirely by vegetated ground. Unlike side channels, overflow channels can contain vegetation within the channel.

Groundwater Channel

Groundwater channels represent off-channel habitats that are often relict river and/or flood channels fed by groundwater, though surface runoff from higher terraces can also contribute to flow. They include several subtypes of channels, including: 1) channels originating from the exfiltration of main channel surface water (i.e., very shallow groundwater associated with the main river)—sometimes called backwater channel or slough, 2) channels fed by the floodplain aquifer (hyporheic zone)—sometimes called percolation channel, and 3) channels fed by lateral groundwater supplied from adjacent terraces—sometimes called wall-base channels. Some groundwater channels can also be classified as overflow channels. For the purpose of this study, these channels are classified as groundwater channels if the dominant source of hydrology is from groundwater.

The size of groundwater channels will have some seasonal variation though tempered from the range of change associated with the hydrograph.

Seasonally Flooded Wetland

Seasonally flooded wetlands are off-channel habitats that occur on a stream's floodplain, often occurring on the remnants of ancient ponds and relict channels. Inundation of these wetlands typically occurs during fall-winter or spring, depending on the river's runoff pattern. Connection to the main river may be broad and extensive (i.e., sheet flow) or it may be more restricted through narrow swales depending on flow level. These areas may be associated with perennial ponds or they may dry entirely during low flow. Flooded wetland can have a strong seasonal variation in size associated with the hydrograph. In the study area, seasonally flooded wetland habitat includes the vegetated pond on the old monastery property and beaver ponds in the right bank floodplain near RM 0.3.

Backwater

For the purposes of this study, backwater habitats include only off channel areas near the mouth of the Miller River where, according to the hydraulic model developed for this project, inundation appears to be driven largely by high flow events on the South Fork Skykomish River.

Tributary

Tributaries include stream channels that flow into the main river channel.

Hydrologic Analysis

The hydrology of the Miller River has not been analyzed in detail before (Herrera 2009, 2012a). Anecdotal accounts of flooding indicate that the Miller River is quite different from other basins in the area because of a variety of geographic factors. These factors include:

- The Miller River basin extends further south than any other tributary to the South Fork. In doing so, it has a low elevation (3,800 feet) unnamed pass to the Snoqualmie River basin at the southwest end of the East Fork portion of the basin (i.e., in between Bear Lake and Lake Dorothy).
- In spite of the relatively low land to the south and west, a relatively high, continuous ridge (approximately 6,000 feet in elevation, consisting of Camp Robber Peak, Patina Peak, Malachite Peak, and ultimately the somewhat lower Maloney Ridge) separates the Miller River basin from the Foss River basin to the east. It is likely that this ridge, which has a north-northwest orientation perpendicular to onshore winds, captures a large amount of marine-derived moisture to the central Cascades.
- A similar, but smaller ridge exists at the northwest edge of the West Fork Miller River basin (varying between 4,500 and 5,500 feet, consisting of Morpheus, Canoe Peak, and Lennox Mountain).
- In examination of the upper forks of the Miller River for the primary Skykomish restoration feasibility analysis (Herrera 2012b), several large active debris chutes were found off of these ridges, indicating large amount of water was delivered in recent

rain-on-snow storm events. Similar features were generally not found in other South Fork tributary basins, with the possible exception of within the Money Creek basin (and on the west side of the west confining ridge).

- The large size of historical Miller-Money fan as compared to other tributary fans on the South Fork indicates that over recent geologic time sediment flux to the South Fork was likely much greater in the Miller River than in comparable tributaries.

Because of the limited existing information and the complexities of estimating runoff in a largely inaccessible, extremely steep basin in a dynamic maritime setting, a variety of approaches were employed to formulate and validate the hydrologic estimations. This included analysis of existing precipitation and snowfall data and existing measurements of stage in various streams in the greater Skykomish basin.

Precipitation data from Baring, Grotto and Skykomish were collected and examined. Data from three nearby Snotel (automated system of snowpack and related climate sensors at Alpine Meadows, Skookum Creek, and Stevens Pass) were also collected and examined. Table 1 summarizes these data sources. However, it was learned that these data were not well correlated to each other and existing streamflow data, partially because of the large distances between the sites and their wide ranging elevations. It is well known that rain-on-snow events are responsible for the largest, particularly in lower elevation, windward basins (e.g., Miller River) in the Cascades (Jones and Perkins 2010). Further it is also well known that runoff in rain-on-snow events is highly dependent on variety factors, many of which relate to elevation, that are highly variable and difficult to determine, particularly in logged remote areas (Jones and Perkins 2010). This variability may in part explain the differences between these observations. Therefore to accurately predict flow rates based upon precipitation and snowpack based upon the data summarized in Table 1, a hydrologic model would have had to be employed to extrapolate these data to the basin itself. This hydrologic model would require significant assumptions for large areas that are effectively inaccessible.

Table 1. Summary of Weather Station Data.

Weather Station	Operator	Elevation	Distance in Miles to Miller River / South Fork Confluence
Alpine Meadows	Snotel	3,500	15.1
Stevens Pass	Snotel	3,950	14.1
Skookum Creek	Snotel	3,310	10.4
Index	COOP	530	10.2
Baring	COOP	770	5.7
Grotto	COOP	850	1.8
Skykomish	COOP	930	1.7
Scenic	COOP	2,220	11.3
Stevens Pass	COOP	4,070	14.2

Notes:
Stevens Pass COOP gage was moved twice. Average values shown.
Straight line distance used in the calculation of distance to Miller River / South Fork confluence.

As a result, it was decided that streamflow measurements made by the USGS (at Gold Bar) and Snohomish County (at Skykomish and Index) were a more effective tool at predicting the hydrologic output of the Miller River basin. Because the Snohomish County gages recorded staff height only, rating curves were required to convert the approximately 10 years of staff height data to flow data. At Skykomish, the channel at the gage site (the Fifth Street Bridge) is well confined and it is known that most if not all of the flow is captured by the gage. The main channel was surveyed using standard survey methods by Herrera staff. At Index, the channel is less well confined. In developing the rating curve at Index, only the main channel was surveyed between Index-Galena Road and Avenue A. Because it is possible that there is significant flow beyond these roadways (on private property) during floods and there is no lidar available at this site, the flow estimates at Index should be considered a minimum value. Based upon the survey, Hydrologic Engineering Centers River Analysis System (HEC-RAS) models were developed. These models were then used to construct a rating curve at each gage site based upon the approximately 10 years of stage data at each gage.

Rating Curve Construction

Two separate one-dimensional hydraulic models were developed in HEC-RAS to capture the specific hydraulic characteristics at Index and Skykomish and develop individual rating curves for each of the existing conditions. These models are distinct from the hydraulic analysis of the site itself, which is much more sophisticated and tailored to assessing a fundamental different question (i.e., inundation on the alluvial fan, rather establishing a rating curve). Each rating curve represents the flow stage versus flow discharge relationship for the North Fork Skykomish River (North Fork) at Index (Fifth Street Bridge) and the South Fork at Skykomish (Fifth Street Bridge), respectively. The hydraulic analysis to develop the rating curves assumed steady flow.

In order to develop rating curves, the HEC-RAS hydraulic model requires geometric data in the form of cross-sections (transects) of the channel-floodplain domain and any instream crossings, obstructions or structures, flow data, and definition of boundary conditions to initiate step-backwater surface profile calculations. Geometric data files are combined with flow data files to produce a flow analysis. The following discussion briefly summarizes the various geometric data layouts, flow data files, flow analysis and boundary conditions for each HEC-RAS model developed.

Geometric Data

The geometric data files for the HEC-RAS model were developed using transects surveyed in September of 2012. Each of the models contained three surveyed transects, one upstream of the gage, one at the approximate location of the gage, and one downstream of the gage. Each geometric data file also considers the channel and floodplain domain hydraulic roughness characteristics. Manning's roughness coefficients (*n*-values) for modeled reaches are determined by correlating channel and floodplain surface characteristics with roughness coefficients. Under high flow conditions roughness from channel geometry is significantly reduced, therefore a roughness value of 0.02 was applied across all scenarios. This value is generally low and was selected because of the unusually (artificially) straight reaches in this area and because higher values generally yielded too little flow at Index and Skykomish as compared to the total observed at the USGS gage at Gold Bar.

Flow Data

To construct the two separate flow files were developed for the respective model. The flow data were developed using flows measured at the USGS Gold Bar Skykomish River gage (12134500) and estimated the flow split between the North Fork and South Fork Skykomish roughly using the geometry. Flows for the South Fork ranged from 2,500 cubic feet per second (cfs) up to 40,000 cfs in increments of 2,500 cfs. Flows for the North Fork ranged from 1,500 cfs to 20,000 cfs with increments of 500 cfs from 1,500 cfs to 2,500 cfs and increments of 2,500 cfs between 2,500 cfs and 20,000 cfs. The upper range was chosen through geometric analysis where the river stage was greater than the transect elevations measured.

Flow Analysis

The geometric data file was combined with the flow data file to create a flow analysis for each river flow simulation. Each flow analysis created in the HEC-RAS hydraulic model was simulated using a subcritical flow regime as was the hydraulics in the channels under high flow conditions. Model simulation results for each tributary produced a rating curve for existing conditions.

Boundary Conditions

One boundary condition was used to develop the one dimensional flow in the North Fork and South Fork. "Normal depth", which assumes uniform flow (channel bed slope equals the water surface slope) at a given location along the stream, establishes the boundary conditions at the upstream and downstream extent of the modeled reaches (Table 2). Assuming normal depth at the downstream extents is a commonly accepted hydraulic modeling procedure to approximate subcritical flow. The slopes in Table 2 were estimated from average slopes taken of the thalweg over large distances (200 to 300 feet) at each gage site.

Table 2. Boundary Conditions Used in the HEC-RAS Hydraulic Models.

River	Downstream Normal Depth Slope
North Fork	5.71×10^{-4}
South Fork	6.09×10^{-4}

Stream Flow Analysis

The aim of the hydrologic analysis was to estimate the recurrence intervals of different flow rates for the Miller River, and to develop recurrence interval storm hydrographs for hydraulic models of the Miller River fan. A time series of flow at Skykomish and Gold Bar were used to estimate a synthetic flow time series in the Miller River based upon the basin geometry (Figure 2). It was found that the Index flow data significantly underestimated the flow observed as compared to the basin-weighted flux at Skykomish. It was assumed that this was because some portion of the flow in the North Fork at Index escapes the main channel at the

Fifth Street Bridge. However, the synthetic South Fork data at Skykomish appeared to be accurate and would be consistent with the lack of significant flooding from the South Fork in the Town of Skykomish (i.e., the remainder of floodplain at the Fifth Street Bridge).

To estimate the Miller River flow time series, the newly-estimated flow of the South Fork at Skykomish was subtracted from the Skykomish River flow at Gold Bar and an equivalent amount (based on basin area) was also subtracted for the North Fork. The Miller River watershed area and mean annual precipitation were compared to the watershed above Gold Bar's mean annual precipitation and area to derive an area- and precipitation-weighted estimate of the fraction of the flow generated downstream of the town of Skykomish that is from the Miller River. Watershed mean annual precipitation rates and areas were taken from the USGS StreamStats website (USGS 2012).

Once the synthetic Miller River time series was created by this subtraction and rescaling, its water year annual peaks were determined. These annual peaks were fit with a log-Pearson type 3 distribution. Finally the recurrence interval flows derived from the log-Pearson distribution were used to develop design storm hydrographs. More specifically, the flow rates from the two largest storms in the synthetic Miller River record were determined and rescaled such that their peaks would match the 2-, 10-, and 100-year recurrence interval flow rates.

Gage Installation and Preliminary Data

In addition to the processing of existing data, a new gage was installed at the Miller Road Revetment to provide new information that will validate the hydrologic analysis. Because even the best estimates made herein are subject to many assumptions about the distribution of flow in the greater South Fork basin, direct observations of stage in the Miller River are necessary for accurate design estimates of velocity and depth in the Miller River. The gage, a pressure transducer mounted inside a 2-inch steel pipe, was rock-bolted onto the leeward side of a large blast rock at the Miller River Road Revetment. The gage will record pressure, which can be converted to water depth, every 15 minutes for up to 6 months at a time. The pressure transducer, an In Situ Rugged Troll 100, is a "vented" transducer, meaning that it requires simultaneously measurements of atmospheric pressure to accurately calculate water depth. Atmospheric pressure observations are being made by an In Situ BaroTroll, mounted in a nearby tree on the hillside of Miller River Road. Only preliminary measurements are reported herein. No attempt has been made yet to convert these stage measurements to discharge, though it is recommended that this be done in the future to verify the hydrologic estimation made herein.

Hydraulic Analysis

To simulate flow at the study area, a hydraulic model of the Miller River fan was developed with FLO-2D software. FLO-2D is a two-dimensional, finite-difference, dynamic-flood routing hydraulic model that can simulate channel flow and unconfined overland flow over complex topography with varying roughness. FLO-2D routes a flood hydrograph while predicting flood wave attenuation due to flood storage. The FLO-2D model was used to estimate flood inundation area, flow depths, velocities and backwater effects under a range of flood conditions for existing conditions (as of the LiDAR flight in the summer of 2011).

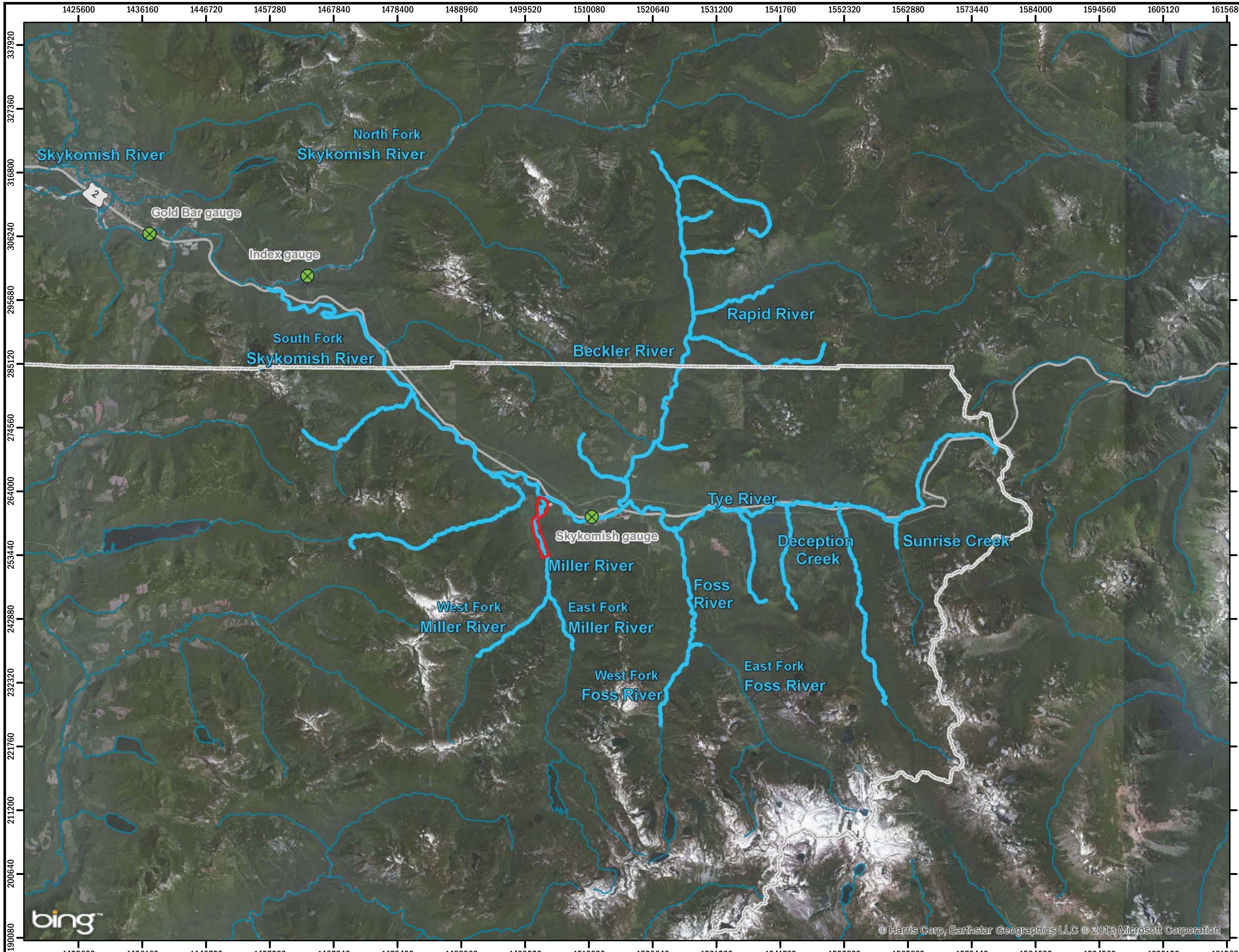


Figure 2.
Upper Skykomish River forks, tributaries, basins, and gauge locations.

Legend

- Project area
- River
- Highway
- County line
- Gauge

N

0 1.5 3 6
Miles

HERRERA

Coordinates: NAD83 Washington State Plane North (feet)

Produced By: GIS
Project: K:\Projects\10-04766-008\Project\Area_of_Interest.mxd (1/15/2013)

The model uses the full dynamic wave momentum equation and a central finite difference routing scheme with eight potential flow directions to predict the progression of a flood hydrograph and flood wave attenuation due to flood storage over a system of square grid elements. The model's highly accurate volume conservation numerical method is critical to accurate flood distribution and wetting and drying of flood marginal areas. The model computes flow exchange between the main channels and the floodplain throughout the unsteady hydrograph. Flow fields can include supercritical and subcritical regimes.

Geometric Data

The FLO-2D model for this study depicts the lower mile of Miller River as it extends from the Miller River Road, just upstream of the gage location at the fan apex, downstream to the confluence with the South Fork. 2011 LiDAR data were used to create the initial computational mesh used in the two-dimensional model of existing conditions. The only other geometric input necessary for the FLO-2D model is Manning's *n* values. FLO-2D allows for depth-varied *n*-values; however, a constant *n*-value was used for all depths. Given the extremely dynamic nature of the floodplain and lack of wood in the channel network, it was determined that a fixed value of roughness (*n* = 0.04) for most of the unvegetated main channel was most appropriate. In portions of the floodplain where side channels are present, the n-value was estimated to be 0.08 based on vegetation, the accumulation of large woody debris as determined during field visits and the size of material in these channels. Densely vegetated, mature stands of forest and areas outside of the high flow channel network were assigned a roughness value of 0.1. All of these values were derived from professional experience.

The grid element size used to represent the surface topography for the FLO-2D model was based on the detail needs to inform the alternatives analysis versus model execution times and numerical stability requirements that can significantly affect computation times and time required by the user to adjust the model parameters accordingly. It is recommended that the grid size be adjusted such that the Q/A ratio is less than 1 per the FLO-2D User's Manual (with Q = discharge into an element, and A = grid element surface area) (O'Brien 2006). Typically, Q/A ratios can be approximately 2 to 3 without significant stability issues, but a ratio exceeding 5 should be avoided to minimize model execution run times and time spent adjusting the model to correct for instabilities such as surging.

The grid element size was selected as 20 feet by 20 feet to provide a good level of detail, but coarse enough to minimize numeric instabilities and maintain reasonable execution times. Assuming a flood stage main channel flow width of approximately 300 feet, a 20-foot grid would provide 15 grid elements within the main channel. Although this resolution satisfies FLO-2D's documented requirements, it may bear evaluation of switching to a model that may better analyze deeper flows, like River FLO-2D, in future modeling efforts of the Miller River because finite-element models like RiverFLO-2D are more adept at handling deeper flows than FLO-2D, which was specifically developed for shallow flows, primarily on arid alluvial fans. It is likely that either model is capable of simulating conditions, but FLO-2D may be time-consuming to implement for design scenarios, particularly if increased grid resolution is desired. This is because FLO-2D's numerical algorithm increasingly poorly as the ratio of the depth to cross-sectional area of flow goes up.

Flow Hydrographs and Boundary Conditions

The upstream boundary condition includes the input of a flow hydrograph into an upstream flow grid element. Hydrographs developed for the 2-year, 10-year, and 100-year events as part of the hydrologic analysis were input into 33 upstream flow grid elements.

To follow the previously described recommendations for the grid size in comparison to the flow (i.e., Q/A ratio close to 1 is desired), the inflow hydrographs were divided up into individual hydrographs such that the cumulative hydrograph represented the overall total inflow hydrograph at the upstream boundary condition. With a 20-foot grid element (A=400 square feet) and a 100-year flow of approximately 28,700, divided evenly amongst the inflow grid elements, the Q/A ratio is 2.2.

Downstream boundary conditions for FLO-2D included the simple designation of outflow grid elements, which assumed a localized slope between adjacent elements and a uniform flow approximation to calculate output flow rates from the output grid element. One disadvantage of this simple type of downstream boundary condition is that when the Q/A ratio is high, the local water surface slope may not be representative of the general bed slope because of flow divergence and convergence. The resultant exit velocities can be too high and represent an artificially steep hydraulic gradient. In such instances, the *n*-values can be increased, or the bed elevation can be slightly increased at the downstream boundary grid elements to result in a more constant water surface gradient at the downstream boundary and damp any numerical instabilities. However, this was addressed in the final simulations by moving the downstream boundary conditions down into the South Fork with an assumed flow in the South Fork equal to only a roughly bankfull event (approximately 8,000 cfs). Therefore, the exit velocities were insignificant and modifications to the downstream boundary conditions were not required.

Calibration

There was no gauge data available for calibration of the FLO-2D Miller River existing conditions model described above. It is intended that the model will be refined and calibrated at a later date. The later version of the model will incorporate future in-water survey and be calibrated with gage data acquired over the upcoming months and calibrated with identified high water marks.

RESULTS

This section presents the results of the various analyses that identified habitat impairments on the alluvial fan and provides initial engineering estimates of the cost to eliminate the impairments. Also detailed are geomorphic, hydrologic, and hydraulic characteristics of the alluvial fan, which provided the physical template used in the habitat analysis.

Geomorphic Assessment

The South Fork basin is a steep, wet river basin on the west slope of the Washington Cascades primarily dominated by marine intrusive bedrock in the west and continental metamorphic rock in the east. The Miller River is a tributary to the South Fork with a confluence a few miles west of the Town of Skykomish. The alluvial fan defined by the confluence of these two rivers is particularly dynamic due to the sharp break in along-channel slope at the confluence due to the glacial history of the valley as a whole. Further details about the geomorphology of the South Fork, and the underlying reasons for the sharp slope break, can be found in an accompanying appendix (Herrera 2012a).

As described in Herrera (2009 and 2012a), the lowest 1 mile of the Miller River is the confluence alluvial fan. Prior to development, it likely merged with the Money Creek fan to the west to form a broad alluvial fan on the south side of the South Fork Skykomish River between RM 11.4 and RM 14.3. On the September 14 site visit, placed material was found that extends high ground from the junction of Miller River Road with the Old Cascade Highway to the BNSF railway prism. The Miller River Road appears to lie on top of an extension of that placed fill that acts to isolate areas all areas west of the Miller River Road from the Miller River. This fill now defines the modern Miller River fan as depicted in Figure 1.

While the course of the Miller River thalweg changes on a regular basis (after every storm event) within its active unvegetated channel complex, the most significant changes on the alluvial fan that have occurred since geomorphic conditions were assessed in 2009 (Herrera 2009) have occurred within the close proximity of the avulsion site. The avulsion occurred in January 2011 at the former location of an Old Cascade Highway culvert. The initial avulsion created a nearly straight channel that incised deeply into the alluvial fan. Eventually this channel has gradually widened as the banks began to slump into the channel. More recently, this incised channel has begun to fill with alluvium, to meander and to form a prominent bar on the right bank. However, the road prism and its protective riprap continues to confine this new channel to about 100 feet wide.

Since the avulsion, the former main channel has remained active. While there is evidence for aggradation in the former main channel, particularly on the right bank upstream from the Old Cascade Highway Bridge, wholesale filling of the channel has not occurred. From direct observations made during higher flow periods, conveyance in the new main channel at the avulsion site is still constrained by the road prism. As conveyance is expanded during floods by erosion of the road prism (e.g., erosion was observed during the course of this study in the late fall of 2012), it is expected that the former channel will increasingly fill with sediment. However, the speed at which this occurs may be quite slow in comparison to other changes on the alluvial fan.

Large wood plays an important role in regulating channel development and maintaining hydraulic complexity. Following the avulsion, a significant amount of wood was transported downstream from the left bank of the former main channel as the new main channel was formed. Some of this wood accumulated on the left bank of the new main channel, making this area much more hydraulically and topographically complex than prior to the avulsion. Necessarily some of the wood should have been transported to the South Fork, though interestingly large (new) accumulations of wood were not found in the South Fork anywhere downstream of the project site during related reconnaissance (Herrera 2012a).

In addition to the observations made near the road and railway, an island at the fan apex was also reexamined. The fan apex is critical for setting the direction of flow of water down the alluvial fan. It was also postulated in Herrera (2009) to be the site of debris flow deposit. Further examination of the banks of the island indicates some degree of matrix support in the deposits that form the island, further implying a debris flow origin. In addition to the direct observations of debris flows further upstream (Herrera 2012b), together these additional data suggest that there is a debris flow or debris flood (the collapse of debris jam further upstream) hazard on the fan itself, which could destroy the remainder of the highway prism and the railway during a single event. Now that conveyance is no longer as restricted as it once was at the Old Cascade Highway, these events could more directly affect conditions at the railway. In sum, there remain large risks to any infrastructure on the alluvial fan. The alluvial fan will continue to be a dynamic place regardless of whether any restoration actions take place. Much of the existing rock was placed for conditions that are no longer relevant to its original intended purpose. The rock could be repurposed to protect existing infrastructure from the grave hazard the river continues present. However, it is important to emphasize that even this rock does not and will not ensure safety of the railway given the magnitude of the events possible in this system.

Habitat Assessment

Background Information Review

Fish Use

Fish species documented as using the Miller River include summer/fall Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), odd-year pink salmon (*O. gorbuscha*), summer steelhead and rainbow trout (*O. mykiss*), bull trout/Dolly Varden (*Salvelinus confluentus*/*S. malma malma*), and cutthroat trout (*O. clarki clarki*) (King County 2011; WDFW 2012a, 2012b). Fall chum salmon (*O. keta*) are documented in the South Fork at its confluence with the Miller River, but not in the Miller River itself.

Chinook salmon, summer steelhead, and bull trout/Dolly Varden are listed as threatened under the Endangered Species Act (NOAA 2012; USFWS 2012). The Miller River belongs to the

Skykomish River Tier 1 Key Watershed, which serves as crucial refugia for maintaining and recovering the at-risk stocks of Chinook, bull trout, and steelhead (King County 2011; USFS 2009). Stock status for summer/fall Chinook is identified as depressed, while all other runs are identified as healthy (WDFW 2012b).

In terms of fish use in the vicinity of the study area, Chinook are documented up to RM 1.5 (above the Miller River fan), with spawning occurring primarily the South Fork (King County 2011; WDFW 2012a, 2012b). Steelhead trout are documented up to RM 6, with spawning occurring upstream of approximately RM 2. Pink salmon are documented as spawning throughout the study area, with coho also present throughout the study area. Coho spawners were observed on the alluvial fan in earlier reconnaissance. Bull trout are presumed to be present up to RM 6 (King County 2011).

Watershed Condition and Implications for Fish Use

The Miller River watershed is largely intact and in a forested condition; 77 percent of the basin is designated as Alpine Lakes Wilderness and all but 50 acres of the remainder of the National Forest is afforded protection as Late Successional Reserves (USFS 2000; King County 2011). The US Forest Service (USFS) manages 97 percent of the land in the watershed, while King County, Burlington Northern Santa Fe (BNSF) Railroad, and private landowners own the remainder. Due to the high level of watershed protection and the absence of dams in the basin, hydrology and water quality are not currently highly impacted, though most of the lower portions of the basin are still recovering from historical human activities (i.e., logging and mining in the nineteenth and twentieth centuries). Ongoing significant alterations to river geomorphology and floodplain process are occurring in the alluvial fan area, which are discussed in detail below (King County 2011; USFS 2009).

These floodplain alterations, including transportation infrastructure and flood protection facilities, have disconnected a significant amount of floodplain habitat from natural interaction with river flows. Other areas of development (e.g., old monastery) have altered floodplain habitat through addition of fill and removal of riparian vegetation.

The areas affected most by these geomorphic modifications are side channels and off-channel habitats in the lower portion of the alluvial fan, including overflow channels and wetland habitats. These habitat types are shown to be critical for various life stages and species of salmonids: juvenile fish rely on off-channel wetlands and shallow backwater areas for rearing habitat (foraging, high water refugia, and protection from predators); steelhead and coho frequently spawn in side channels and lower reaches of small tributaries; and juvenile salmonids rely on high quality edge habitat (dense vegetation and in-channel wood) for cover and protection from predators and high water velocities (King County 2011; Beamer 2010; Lestelle et al. 2005). Intact, native riparian vegetation is a critical component high quality habitat for all species of salmonids, providing essential cover, habitat for invertebrate prey, water temperature moderation, large woody debris recruitment potential, and input of allochonthus nutrients (Gregory et al. 1991).

Much of the poorly connected off-channel areas in the left bank floodplain of the lower portion of the Miller River fan overlap with the Spree Creek drainage and groundwater-fed overflow channels, amounting to approximately 1.8 acres. Areas where tributaries (particularly those fed by significant groundwater inputs) converge with river floodplains provide particularly important habitat functions for salmonids, including high flow refugia at flood flows, thermal refugia during summer months, and areas of oxygen-rich, cold water sought by spawning adults (USFWS 2008; Pratt 1992). This is particularly important for bull trout and steelhead (USFWS 2008; Pratt 1992).

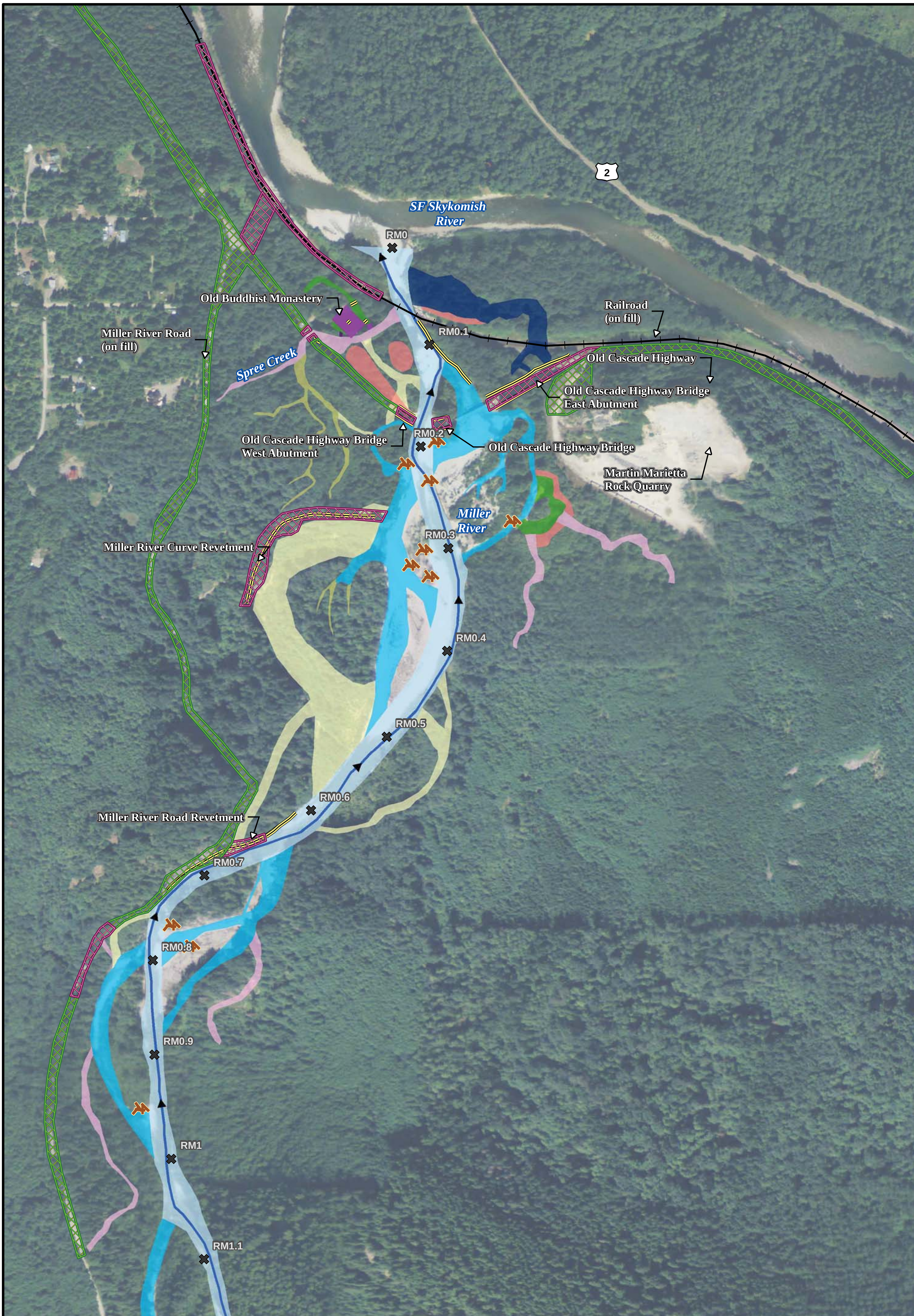
Mainstem habitats have also been affected by these geomorphic modifications (King County 2011). Approximately 7,000 feet of armoring exist on the Miller River alluvial fan, which is only a portion of the nearly 5 miles of armoring in the South Fork River at large. Constraints on movement of the river in its floodplain have reduced habitat-forming processes (e.g., recruitment of large wood and sediment), resulting in lower habitat diversity. This has impacted the quantity and quality of salmon spawning habitat in the lower river, including areas suitable for redd construction and holding habitat (e.g., pools), and rearing and foraging habitat for adult and sub-adult bull trout.

Habitat Limiting Factors and Species Recovery Planning

Reduction in quantity and quality of rearing habitat has been identified as a primary factor limiting salmon production in the Snohomish basin, which includes the South Fork and the Miller River (Haring 2002). The Miller River fan is located in a “primary restoration” subbasin as designated by the *Snohomish River Basin Salmon Conservation Plan*, which means it is one of the highest priority subbasins for restoration action (Snohomish Basin Salmon Recovery Forum 2005). These primary restoration subbasins currently have high priority habitat restoration targets for the King County portion of WRIA 7, including 80 acres of restored off-channel habitat and 5.5 miles of restored edge habitat (King County 2011). Restoration of the lower Miller River has been identified as a key element of fulfilling King County’s commitment to achieve these targets (King County 2011). In addition, the Forest Service has identified the lower reach of Miller river as an area of concern due to impairment of channel processes and has designated floodplain restoration here as a high priority within the Skykomish River Watershed (USFS 2009).

Habitat Types

The locations of the various habitat types within the Miller River study area are presented in Figure 3. The habitats are those assuming that all reasonable infrastructure was removed. It is important to mention that these are the habitat types that would exist the moment construction (i.e., demolition of existing infrastructure) was complete. On the Miller River Fan, geomorphic is rapid and would likely expand the number and size of channel features increasing habitat area further in the future. However, it is impossible to predict the rate of increase of these features in advance. It is likely that eventually side channels would eventually occupy all portions of the modern Miller River Fan, though other changes would occur in that time (i.e., deposition) to compromise what currently exists. Existing habitat areas are necessarily smaller because of the presence of significant amounts of rock on site. These maps also show the locations of existing revetments and large woody debris accumulations. A summary of the quantity of each habitat type within the lower and upper portions of the project area are provided in Table 3.



Legend

- Large wood accumulation
- Levee
- Thalweg
- Railroad
- Monastery
- Fill
- Modified

Habitat type

- Backwater
- Groundwater channel
- Main channel
- Overflow channel
- Pond inlet
- Pond outlet
- Seasonally Flooded Wetland
- Side channel
- Tributary
- Invasive species

Note:
Fill (Imported)
Modified (Landscape changed to accommodate development)

Figure 3.
Lower Miller River habitat map
(Sheet 1 of 2).

N

0 200 400 800
Feet

HERRERA

Aerial: USDA (2011)

K:\Projects\10-04766-023\Project\Report_Maps\habitat_maps.mxd (1/17/2013)

Legend

Large wood accumulation

Levee

Thalweg

Railroad

Monastery

Fill

Modified

Habitat type

Backwater

Groundwater channel

Main channel

Overflow channel

Pond inlet

Pond outlet

Seasonally Flooded Wetland

Side channel

Tributary

Invasive species

Note:
Fill (Imported)
Modified (Landscape changed to accommodate development)

Figure 3.
Lower Miller River habitat map
(Sheet 2 of 2).

N

0 200 400 800
Feet

HERRERA

Aerial: USDA (2011)

K:\Projects\10-04766-023\Project\Report_Maps\habitat_maps.mxd (1/4/2013)

Table 3. Summary of Existing and Potential Habitat Types and Associated Areas (acreages) Within the Lower (RM 0 to RM 1) and Upper (RM 1 to RM 2) Reaches of the Miller River Study Area.

	Existing	Potential
Lower Reach		
Habitat Type	Acres	Acres
Backwater	0	2.63
Groundwater channel	0.97	0.97
Main channel	14.48	14.48
Overflow channel	9.32	10.81
Seasonally Flooded Wetland	1.01	1.18
Side channel	11.79	11.79
Tributary	3.11	3.11
Upper Reach		
Habitat Type	Acres	Acres
Main channel	15.33	15.33
Overflow channel	3.07	3.07
Side channel	4.91	4.91
Tributary	8.24	8.24

Note: "Potential" acreages assume that all non-permanent infrastructure is removed. Although many habitat areas are present under existing conditions (i.e., the difference in existing and potential area quantities is low) their connectivity and function will be greatly enhanced by removal of infrastructure.

Moving downstream from the upstream boundary of the study area, the floodplain of the Miller River quickly transitions from being somewhat geologically confined to broadening into its alluvial fan. Off-channel habitats are more limited in the upstream portion of the study area, with in-channel habitats dominating the here (i.e., main channel and side channel habitats). Within the lower half of the alluvial fan, historic alignments of the main channel and side channels now function as off-channel habitats (e.g., overflow channels) and support a diverse riparian plant community including some areas of seasonally-flooded wetlands.

Stream tributaries enter the Miller River at a number of locations within the study area, and their interaction with the floodplain provides a significant contribution to off-channel habitat diversity. An example of this is the Spree Creek drainage that enters the Miller River floodplain near RM 0.1. This tributary and neighboring groundwater-fed channels provide hydrologic inputs to overflow channels and other floodplain features that may not otherwise receive flow but for flood events (e.g., 2-year flood or greater), and therefore serve as an important driver for habitat quality and quantity in these areas. Although currently somewhat disturbed by facility and road development, this stream system contributes to the diversity of aquatic features that provide off-channel rearing habitat and refuge for fish in this portion of the study area. In the right bank floodplain near RM 0.3, numerous tributaries from the hillside above contribute flow to overflow channels and beaver ponds (seasonally flooded wetlands).

A large overflow channel (historic meander) diverging from the mainstream near RM 0.6 and reconnecting near RM 0.3 is one of the most prominent features in the lower mile of the study area. It is located on the left bank of the river, with the upstream connection located just downstream of the Miller River Road Revetment. A number of side channels and overflow channels occur in the left bank floodplain downstream of this feature. The off-channel features in this portion of the study area exhibit altered geomorphology due to interrupted connectivity with the main channel by the Old Cascade Highway road prism and flood control facilities.

Vegetation Conditions

The Miller River alluvial fan is composed of upland and wetland vegetation habitats and floodplain forests. Upland vegetation habitats occurring within the study area occur within the Western hemlock (*Tsuga heterophylla*) zone of the Puget Sound area which corresponds to a climax state of conifer forest assuming natural vegetation conditions (Franklin and Dyrness 1988). However, because the lower Miller River corridor is subject to several types of stressors (e.g., prior logging, channel migration), upland vegetation habitats are typically within a state of succession composed of a variety of associated habitats and species. The forest stands observed on-site were dominated primarily by second and/or third growth forest with a mixed deciduous and coniferous species composition. It is extremely likely that the entire site was deforested initially with establishment of the (ghost) Town of Berlin on the left bank (Carlson 2009). The most recent timber harvesting activities occurred between 2003 and 2006 in the right bank floodplain (which had a riparian buffer) and just prior to 1994 in the left bank floodplain (which did not have a riparian buffer, but did leave large portions of the floodplain untouched).

Upland vegetation consists primarily of mixed forest composed of a coniferous and deciduous tree canopy and underlying shrub and herbaceous strata. Upland mixed forest typically occurs in portions of the floodplain that have not been subject to channel migration in the recent past. Common conifer trees observed includes western red cedar (*Thuja plicata*) and Douglas fir (*Pseudotsuga menziesii*) with occasional western hemlock (*Tsuga heterophylla*). Common deciduous trees observed include red alder (*Alnus rubra*), big-leaf maple (*Acer macrophyllum*), and black cottonwood (*Populus balsamifera*). Common understory shrubs, ferns, and herbs observed include vine maple (*Acer circinatum*), salmonberry (*Rubus spectabilis*), thimbleberry (*Rubus parviflorus*), willows (*Salix* spp.), Indian plum (*Oemleria cerasiformis*), sword fern (*Polystichum munitum*), and piggy-back plant (*Tolmiea menziesii*).

Early stages of upland forest succession dominated by tree saplings are common in areas that were subject to recent channel migration. For example, the historic meander along the left bank of the Miller River between RM 0.3 and RM 0.6 is dominated by dense saplings of red alder, Douglas fir, and black cottonwood. These patterns of tree age stratification, species composition, and forest structure influenced by long-term riverine disturbance regimes align with results of previous studies investigating forest succession driven by alluvial processes and river terrace development over time (Fonda 1974; Van Pelt et al. 2006).

A variety of wetland vegetation habitats are common throughout the Miller River floodplain including forested, scrub-shrub, and emergent wetlands, which have been identified as providing essential functions to support overall health and habitat value of riverine ecosystems (Hruby 2004). Forested wetland vegetation habitats are located within the floodplain typically in close association with side channels, overflow channels, tributaries, former channels, and backwater areas. A large forested wetland is located within the backwater area located along the right bank of the Miller River at the confluence with the South Fork. Common forested wetland plants include red alder, black cottonwood, western red cedar, and salmonberry. Scrub-shrub wetland vegetation habitats are common on gravel bars adjacent to the main channel and are typically dominated by willows. Emergent wetland vegetation communities are typically associated with seasonally flooded wetlands including the pond on the former monastery adjacent to the left bank and beaver ponds adjacent to the right bank near the gravel pit site. The pond on the former monastery property is dominated by spreading rush (*Juncus supiniformis*) growing throughout the shallow pond.

Invasive and exotic vegetation is generally rare throughout the study area. However a large patch of bohemian knotweed (*Polygonum x bohemicum*) was observed along the north side of the BNSF railroad just east of the railroad bridge crossing over the Miller River. Also a 1-acre patch of English ivy (*Hedera helix*) is present on the left bank of the active channel immediately upstream of the railway bridge. In addition, the edges of the beaver ponds are dominated by reed canarygrass (*Phalaris arundinacea*) and water shield (*Brasenia schreberi*) on the right bank near the gravel pit site.

In summary, riparian vegetation and wetland plant communities within the study are generally composed of native plant species and are in good condition (i.e., exhibiting low levels of human disturbance and robust growth) and providing a high level of habitat function.

Observed Restoration Opportunities

Opportunities for habitat restoration in the Miller River watershed are located primarily within the study area (lower 2 river miles), since areas upstream of RM 2 are largely intact and characterized by high functioning habitat (King County 2011). Within the study area, restoration opportunities are associated primarily with addressing the variety of floodplain modifications and subsequent impacts to geomorphic processes within the Miller River alluvial fan and along Miller River Road. Undeveloped riparian and wetland areas within the study area are largely intact and characterized primarily by native plant species, thereby exhibiting a high potential for return to a natural state if natural floodplain processes and flow regimes are restored.

As mentioned above, and identified in Herrera (2009), revetments associated with the Old Cascade Highway and Miller Road have impacted the connection of the Miller River to its floodplain in a number of locations, thereby adversely affecting the quantity and quality habitat available to fish. Juvenile salmonid rearing habitat has been affected the most by the presence of revetments and associated floodplain disconnection because these habitats tend to occur within side channels and off-channel habitats (e.g., seasonally flooded wetlands) within the floodplain where preferred lower velocity flows are more common (Lestelle et al. 2005).

Table 3 summarizes the individual restoration opportunities identified within the Miller River study area. The restoration opportunities focus on removal of revetments and human

Table 3. Individual Restoration Opportunities in the Lowest 2 Miles of the Miller River.

Site Name	Alternative Number	Location (approximate)	Action	Limiting Factors / Impacts Addressed	Targeted Benefits to Salmonids	Quantification of Habitat Lift
Old Monastery property	1 [a]	Floodplain near RM 0.3	Remove all structures/facilities on old monastery property (buildings, foundations, decks, concrete pillars, rock walls, rock outdoor fireplace, etc.); remove invasive plant species (e.g., ivy growing on trees and Japanese knotweed at confluence of side channel and Spree Creek near pond); revegetate disturbed areas and landscaped areas with native vegetation; improve monastery pond habitat (revegetation and addition of habitat structures) and hydraulic connectivity with surrounding side channel features to prevent fish stranding and improve flushing	Human modifications in floodplain	Improved quality of off-channel rearing habitat/high flow refugia; amelioration of potential fish-stranding risk and improved water quality in pond feature (higher dissolved oxygen, lower water temperature, etc.).	Restoration of approximately 2 acres of riparian and wetland habitat in floodplain
Miller River alluvial fan (left bank)	2	RM 0.1 to RM 0.2, left bank floodplain	Remove Old Cascade Highway road and underlying fill prism, Old Highway Bridge (Miller River Bridge #999W), Spree Creek Bridge (Miller River Bridge #999X), and associated bridge abutments from the west end of the right bank abutment to the driveway of the quarry; restore natural Spree Creek alignment; restore native plant communities in disturbed areas and install habitat structures where appropriate	Impaired floodplain connectivity; human modifications in floodplain; impacts to riparian vegetation	Increased access to high-flow refugia for juveniles and adults; increased access to off-channel rearing habitat for juveniles at moderate to high flows and improved in-channel habitat for juvenile rearing at low flows; increased quality of spawning habitat by restoration of habitat-forming processes and hydraulic complexity; improved quality of aquatic habitat in side channels and main channel through removal of human modifications, restoration of riparian and wetland vegetation and installation of habitat structures; increased aquatic habitat diversity and pools through restoration of habitat-forming processes and installation of habitat structures.	Reconnection of approximately 11 acres of disconnected floodplain; reconnection of approximately 1,700 linear feet of side channels; improvement of aquatic habitat complexity and quality in 200 linear feet of mainstem; and restoration of approximately 3 acres of native riparian vegetation

Table 3 (continued). Individual Restoration Opportunities in the Lowest 2 Miles of the Miller River.						
Site Name	**Alternative Number**	**Location (approximate)**	**Action**	**Limiting Factors / Impacts Addressed**	**Targeted Benefits to Salmonids**	**Quantification of Habitat Lift**
Miller River Curve Revetment	3	RM 0.3	Remove the Miller River Curve Revetment to allow reconnection of disconnected side channel (flows from Miller River Curve to Spree Creek…anticipated to facilitate connection of side channel habitat extending from Miller River Road Revetment through Miller River Curve to Spree Creek) and install habitat structures where appropriate	Impaired floodplain connectivity	Increased access to high-flow refugia for juveniles and adults; increased access to off-channel rearing habitat for juveniles at moderate to high flows; improved quality of aquatic habitat in side channel through removal of human modifications and installation of habitat structures; increased aquatic habitat diversity and pools through restoration of habitat-forming processes and installation of habitat structures.	Reconnection of approximately 5.5 acres of disconnected floodplain; reconnection of approximately 1,000 linear feet of side channels; improvement of aquatic habitat complexity and quality in 50 linear feet of mainstem; and restoration of approximately 1 acre of native riparian vegetation
Miller River Road revetment (Downstream)	4	RM 0.65	Remove the Miller River Road Revetment to facilitate reconnection of adjacent side channel (flows from Miller River main channel to Miller River Curve meander… anticipated to extend through the former Miller River mainstem south of the curve revetment) and install habitat structures where appropriate	Impaired floodplain connectivity	Increased access to high-flow refugia for juveniles and adults; increased access to off-channel rearing habitat for juveniles at moderate to high flows; improved quality of aquatic habitat in side channels and main channel through removal of human modifications and installation of habitat structures; increased aquatic habitat diversity and pools through restoration of habitat-forming processes and installation of habitat structures.	Reconnection of approximately 2.5 acres of disconnected floodplain; reconnection of approximately 800 linear feet of side channels; improvement of aquatic habitat complexity and quality in 300 linear feet of mainstem; and restoration of approximately 0.15 acres of native riparian vegetation
Miller River Road Revetment (Upstream)	4 [c]	RM 0.8 OR RM 0.7	Installation of instream ELJs to encourage flow into river-right side channel (historic mainstem) OR Replace riprap along Miller Road with bank ELJs AND/OR Replace the culvert at the upstream end of the revetment	Erosion risk to Miller River Road; riprap effects on aquatic environment	Improve mainstem and edge habitat; reduce interaction between aquatic environment and riprap bank	Improvement of aquatic edge habitat in 450 linear feet of mainstem; increase flow in 1,000 linear feet of side channel

Table 3 (continued). Individual Restoration Opportunities in the Lowest 2 Miles of the Miller River.						
Site Name	**Alternative Number**	**Location (approximate)**	**Action**	**Limiting Factors / Impacts Addressed**	**Targeted Benefits to Salmonids**	**Quantification of Habitat Lift**
Railroad causeway	N/A [b]	RM 0.05, right bank floodplain	Invasive plant species removal (i.e., Japanese knotweed north side of railroad causeway)	Invasive plant species	Improved habitat quality through removal of invasive plant species and restoration of native vegetation	Removal of approximately 0.25 acre of invasive vegetation and restoration of native vegetation

[a] It is assumed that these structures will be demolished and removed sometime in the fall of 2012.
[b] This action is not dependent on any of the others and can (and should) be implemented at any time.
[c] This action is not included in the cost estimate of this alternative.

modifications within the alluvial fan portion of the Miller River floodplain and along Miller River Road to allow for restoration of natural geomorphic, hydrologic, and hydraulic processes (i.e., habitat forming processes). This strategy coupled with revegetation of disturbed areas with native riparian and wetland plant species (which will jumpstart development of native plant communities and increase future large wood recruitment potential) will lead to both immediate aquatic habitat improvements and enhanced riparian vegetation that will support aquatic habitat function over time. The opportunities are listed in the order that they should be implemented as the benefits of the upper alluvial fan projects (at the south end of the site) would be maximized if the road (and monastery structures) were removed first. The alternative numbers correspond to alternatives listed in the Proposed Actions section.

Hydrologic Analysis

Rating Curve Construction

Results of the South Fork Skykomish HEC-RAS simulation for existing conditions show a steady increase in stage (i.e., rise in water surface elevation) between 3.1 feet and 16.4 feet. The datum for the Fifth Street Bridge gage was established using the water surface measured on the site visit and corresponding to simultaneous water surface data collected at the gage. The steady rise shows the rating curve in Table 4 can use the measured stage from the water surface elevation gage at the Fifth Street Bridge to correlate high discharge flows from the South Fork to estimate past large flow events. The size of the events observed using the rating curve are consistent with the amount of flow expected for the proportion of the basin that the South Fork at Skykomish has for observations of the entire Skykomish basin at Gold Bar.

Table 4. South Fork HEC-RAS Rating Curve.

Discharge (cfs)	Water Surface Elevation (feet)
2,500	3.1
5,000	4.6
7,500	5.9
10,000	7.0
12,500	8.0
15,000	8.9
17,500	9.8
20,000	10.6
22,500	11.4
25,000	12.2
27,500	13.0
30,000	13.7
35,000	15.1
37,500	15.8
40,000	16.4

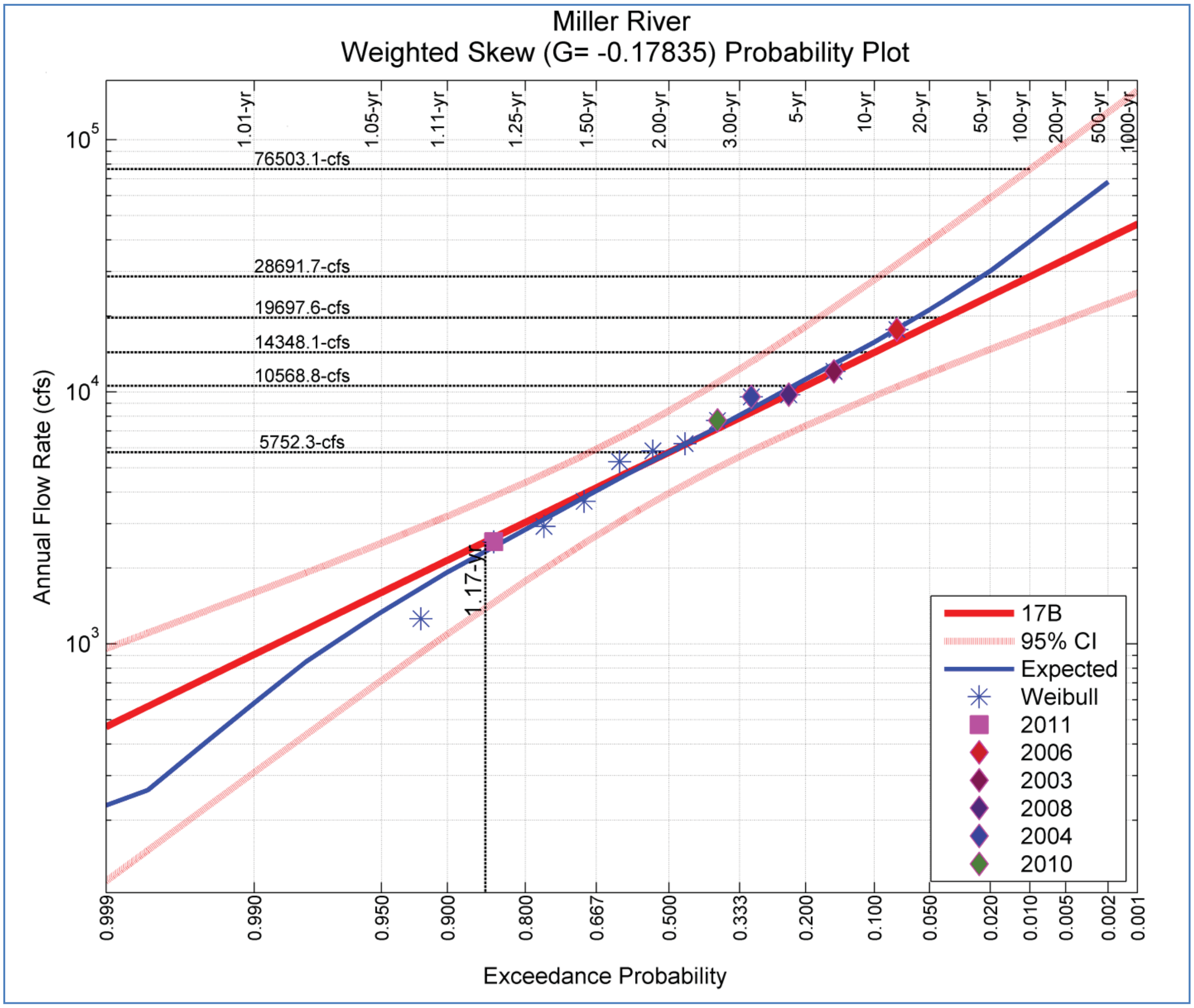
The results of the North Fork Skykomish HEC-RAS simulation for existing conditions show a steady increase in stage between 19.2 feet and 27.5 feet. Like the South Fork gage, the datum for the Fifth Street Bridge North Fork gage was established using the water surface measured on the site visit and corresponding to simultaneous water surface data collected at the gage. The rating curve appeared to generate reasonable results. However, the estimations for observations were consistently significantly less than could be expected from a reasonable relationship to South Fork flow rates. The modeled flows were approximately half the flow rates generated at the South Fork (of similar basin size) gage for comparable events. This result was found despite the fact that the basin area for each gage is about the same. Because it is known that flooding in and around Index is common, it is likely that the gage does not capture all of the flow in North Fork. As a result, it was decided that it was more appropriate to scale the North Fork (flow per basin area) to the observations made at Skykomish on the South Fork than to use the observations at Index, to predict flow rates in the Miller River, and not use the rating curve described herein.

Stream Flow Analysis

A Log Pierson Type III analysis was performed on the Miller basin contribution of the flow residual (i.e., the Gold Bar flow minus the sum of the flow at Index and Skykomish) from the calculated flow at the three gages. This analysis generated the resulting probability plot in Figure 4. From the flow residual calculations, it is found that Miller River typically contributes one-quarter of the total flow observed at Gold Bar during floods, with a greater contribution for the largest floods. Direct observations at low flow suggest that the Miller River is clearly significantly less than one-quarter of the total flow at Gold Bar during these periods, indicating that the Miller River is much flashier than other Skykomish River tributaries, with the possible exception of Money Creek. Geomorphic evidence corroborates this finding. The Money-Miller Fan and the active braid plain of both Money Creek and the Miller River are significantly larger than comparable features on the other tributaries.

Design storm peak flows were found to be 5,750 cfs for the 2-year, 14,350 cfs for the 10-year, and 28,700 cfs for the 100-year recurrence interval flows. Design storm hydrographs for the 2-, 10-, and 100-year recurrence interval flows were estimated over an 87-hour hydrographic period (Figure 5).

There is considerable uncertainty in the flood frequency curve estimate that is not necessarily reflected in the confidence interval in Figure 4. The uncertainty is primarily related to the assumption that the North Fork at Index can be related solely based upon basin area and average precipitation to the South Fork gage record. The stage data collected on the North Fork at Index imply that the North Fork produces much smaller flows at Index than the South Fork does, even if the rating curve developed herein does not encapsulate all of the flow at Index. It is highly unlikely that the rating curve misses more than half of the flow (i.e., more than half of the flow of the North Fork occurs completely outside the main channel and its nearby banks), as would need to be the case for the estimate herein to be an overprediction of Miller River flow. Therefore the Miler River estimates made herein are likely underpredicted, even though they exceed previous USFS estimates by more than a factor of two. To rectify these data and verify the hydrologic estimations made herein, a gage has been installed at the Miller Road Revetment at the apex of the Miller River fan (discussed in detail below).



17B refers to from the Log Pierson III algorithm curve fit found in Army Corps of Engineers Bulletin 17B (U. S. Army Corps of Engineers 1982).
Expected refers to the line of maximum likelihood.

Figure 4. Log-Pearson Type 3 Distribution Fitting Results for the Synthetic Miller River Flow Series (Water Years 2000 to 2011).

Finally it is important to mention that this gage will not only inform hydrologic on the Miller, but the presence of the other gages in the Skykomish basin will help piece together the relative roles of the upper South Fork, the North Fork, in their contributions to the well-known flow record at Gold Bar. In particular, these data will help describe the clearly important basin-wide trend to which distance east and elevation plays in the rain-snow dynamics in this highly complex basin.

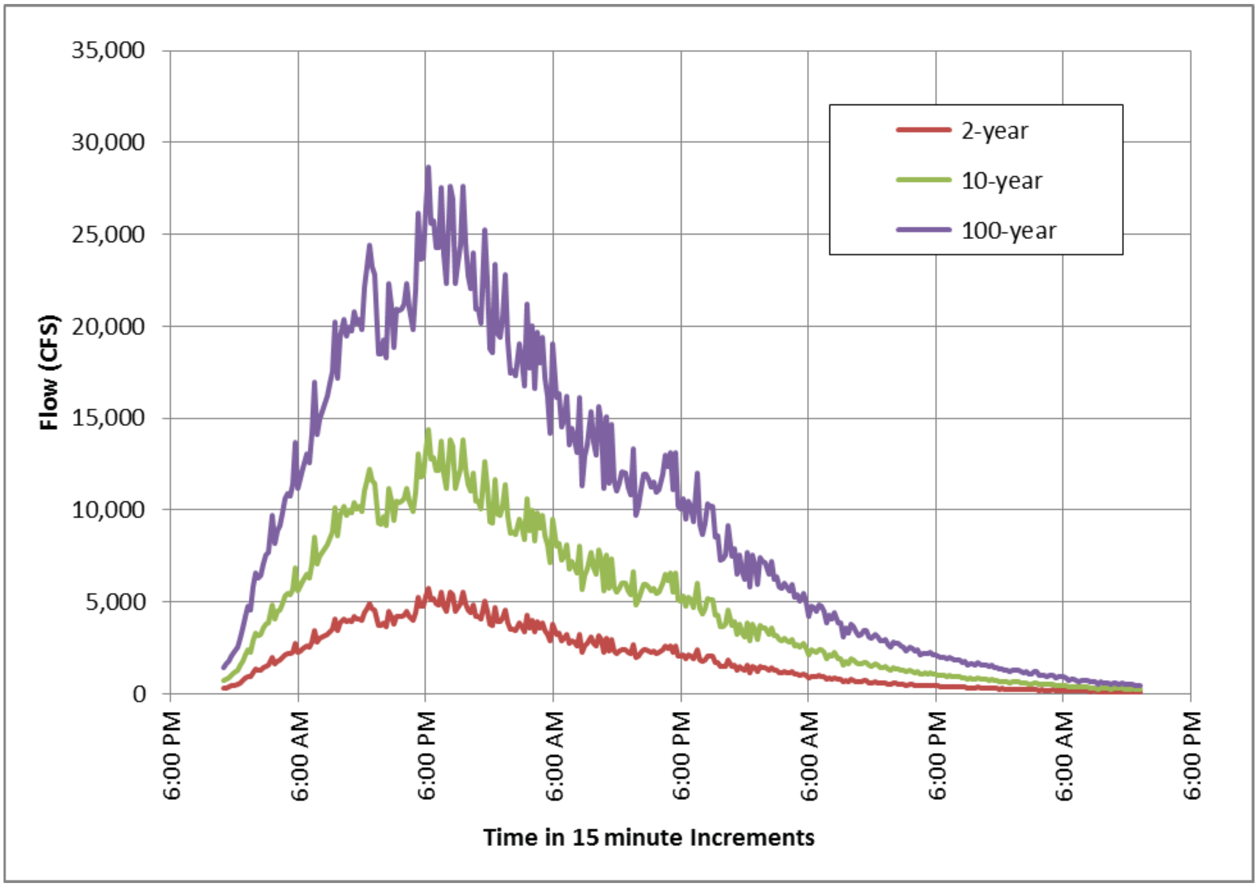


Figure 5. Miller River 2-, 10-, and 100-year Recurrence Interval Design Hydrographs.

Gage Installation and Preliminary Data

Figure 6 illustrates the stage time series on the Miller River as compared to the record on the Skykomish River at Gold Bar. As can be seen in the figure, the Miller River gage responds similarly to the gage of the Skykomish River at Gold Bar for the largest, longest duration storms. However, a closer examination of the record indicates that there are some shorter duration peaks in the Miller River data that are either subtle or not expressed in the Gold Bar record. This is to be expected because the Miller River basin is a much smaller than basin than the entire Skykomish basin. The water surface elevations observed have not yet been converted to discharge because a stage-discharge (rating) curve has not yet been developed. It is recommended that a rating curve be developed based upon survey already collected at the site. Like the South Fork gage, but unlike the North Fork gage, a survey was completed that spans the entire floodplain and should accurately capture the flow rate across. It is likely that modeling will be necessary to estimate these high-flow discharges, as the Miller River is extremely hazardous to traverse during periods of high flow. Further, it is clear from the rating curve construction discussed above on the South Fork in Skykomish and on the North Fork at Index, that the roughness characteristics of these coarse-bedded, high-gradient channels are reduced during floods.

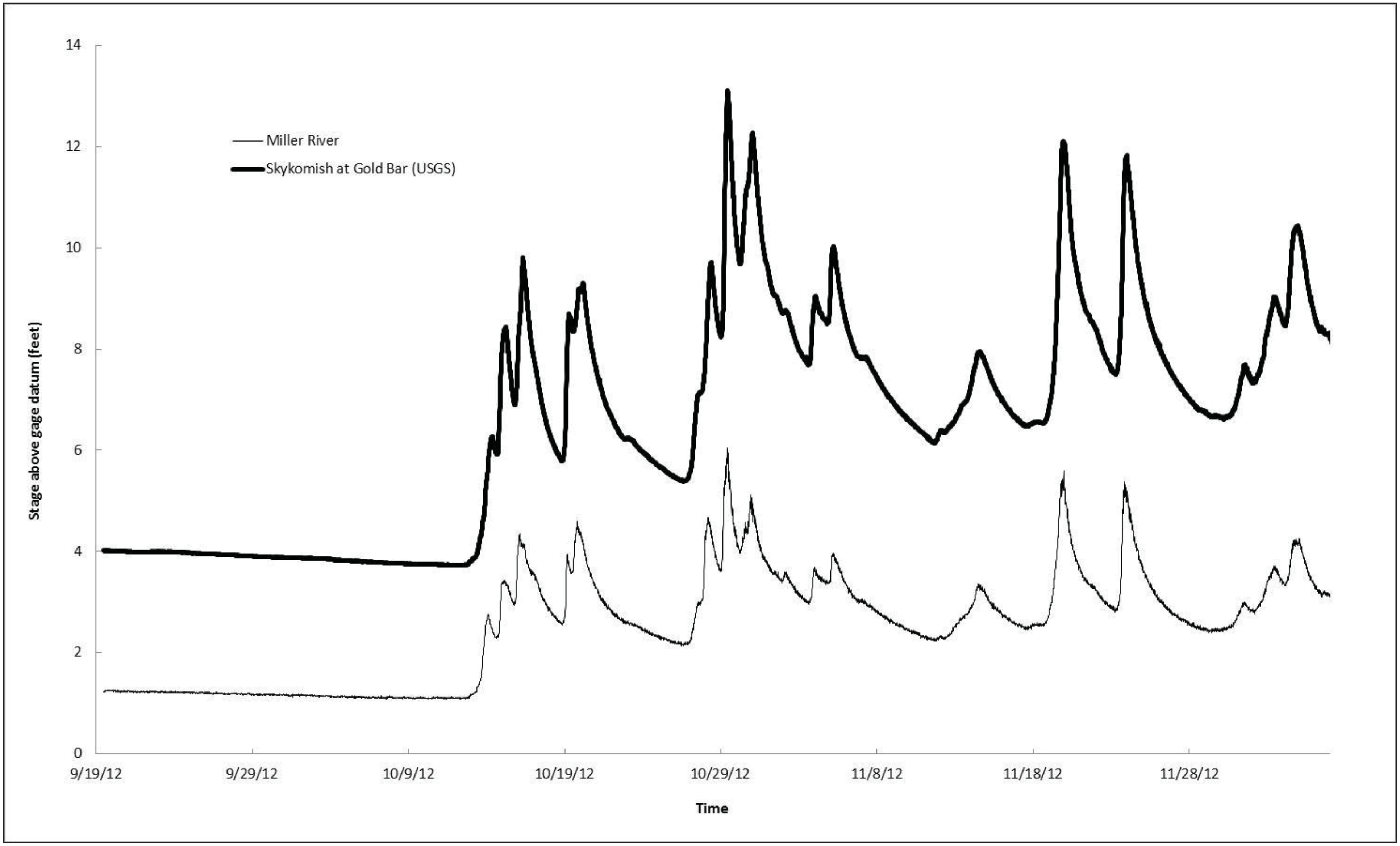


Figure 6. Stage Time Series from Gage Mounted onto Miller River Road Revetment.

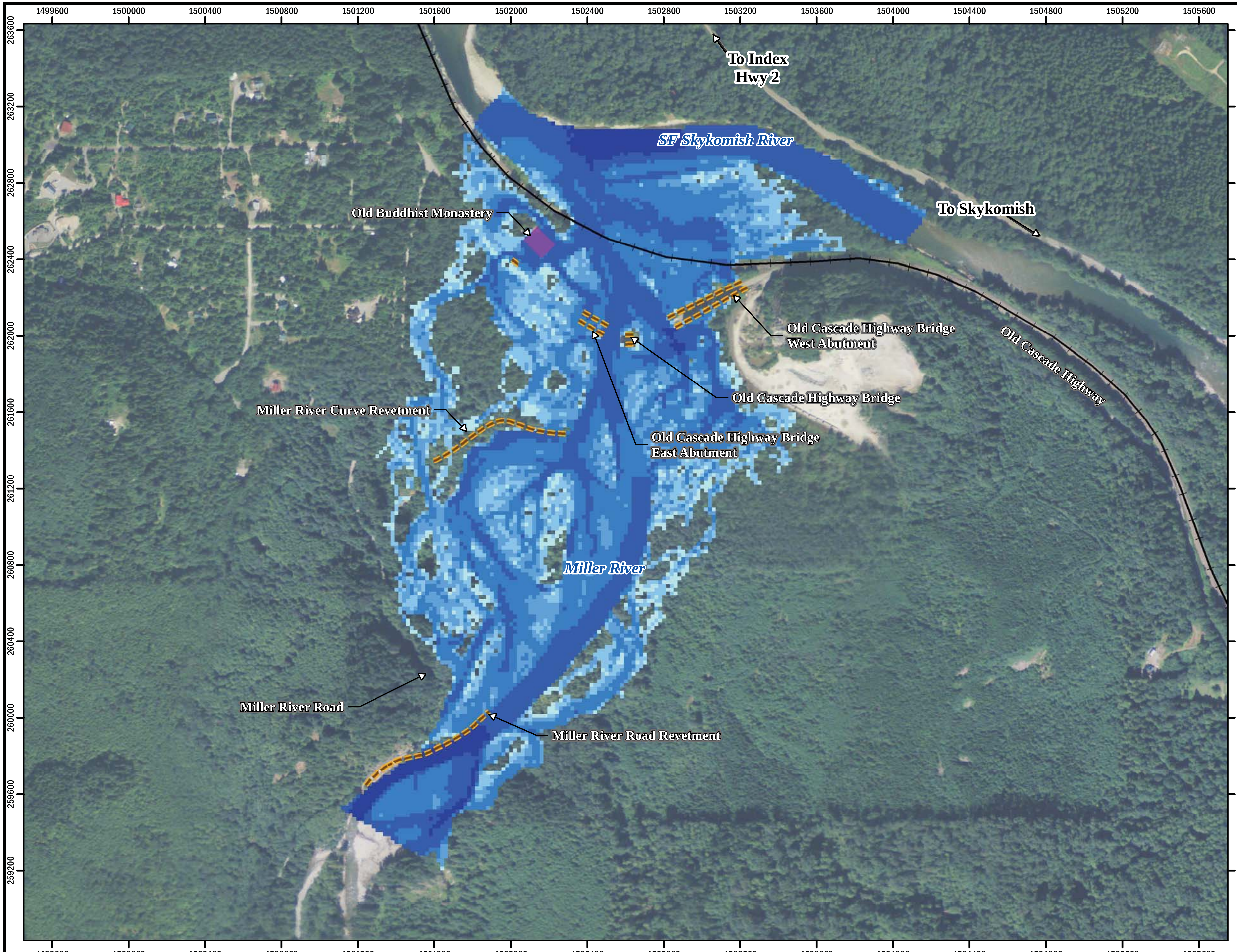
Hydraulic Analysis

The flood flow events described in the previous section were used to model the existing 2-year, 10-year, and 100-year precipitation-generated flood events. Flood depth maps show the spatial extents and depths of inundation throughout the floodplain (Figures 7 through 9), which was one of the primary purposes of the hydraulic modeling effort. With increased flow between the 2-year and the 100-year, there is correspondingly increased floodplain inundation on both the left and right overbanks. At the 2-year event, high flow channels on each of the left and right banks are activated. Between the 2-year and 100-year events, maximum flow depths range from 10 feet to 16 feet. Within the area of study, maximum depths are persistently found on the steep and confined left bank at the upstream extent of the project area, near the Miller River Road, in the vicinity of the recently eroded Old Cascade Highway and at the BNSF railroad bridge.

Between the 2-year and the 100-year events, maximum flow velocities range from 10 ft/s to 19 ft/s (Figures 10 through 12), which assess the ferocity of the flood flows, another stated objective of the hydraulic modeling. In the 2-year event, there are a greater number of high velocity areas in both the left and right bank channels as they sweep around the rocky island at the upstream end of the project area, through main channel in the center of the project area, and in the vicinity of the Old Cascade Highway left bank main channel and right bank, high flow channel. In the 100-year event, areas of greatest velocity are coalesced in the main channel of the center of the project area. This area has some of the largest conveyance capacity, with relatively little overbank flow occurring through this reach. High velocities of 10 to 15 ft/s also occur through the recently eroded left bank at the Old Cascade Highway and in the vicinity of the BNSF railroad bridge. Intense flows in this area are somewhat confirmed by the presence of enormous boulders (3 to 5 feet in diameter) that are imbricated (i.e., locked into a staked inclined position in response to shear stress from the flow), indicating that they are marginally mobile at least occasionally.

The high velocities throughout the reach verify earlier qualitative conclusions that Miller River is an extremely energetic and dynamic river (Table 5). Based upon the model results above and geomorphic observations during the course of this study, it is likely that the existing revetments and Old Cascade Highway prism will eventually be eroded away given the velocities in Table 5. The results also indicate that the BNSF railway bridge is currently at risk to damage from these energetic flows, which indicate that velocities in excess of 10 feet per second at the abutments are possible in the largest events. This is consistent with observations that both abutments have lost large riprap in the recent past. With the road prism removed, either naturally or through deliberate action, there is significant risk to the railroad prism, which is unarmored, on the left bank of the river. Both this area and the causeway on the right bank exhibit smaller velocities in the existing conditions model. The piers of the causeway are armored and are at a much smaller risk of failure. However, it is important to point out that the model results are conditions as of 2011. The proposed actions described below would need to be modeled to determine the exact nature of the impacts from road removal (or any of the other alternatives described), though general information based upon the geomorphic analysis and an extrapolation of the model results is provided below.

Figure 7.
FLO-2D results - 2-year Miller River flood flow depth under existing conditions.



Legend

Monastery
Riprap to be removed
Railroad

Flow depth (ft)

0 to 0.2
0.2 to 1
1 to 2
2 to 5
5 to 10
10 to 15
15 to 20

N

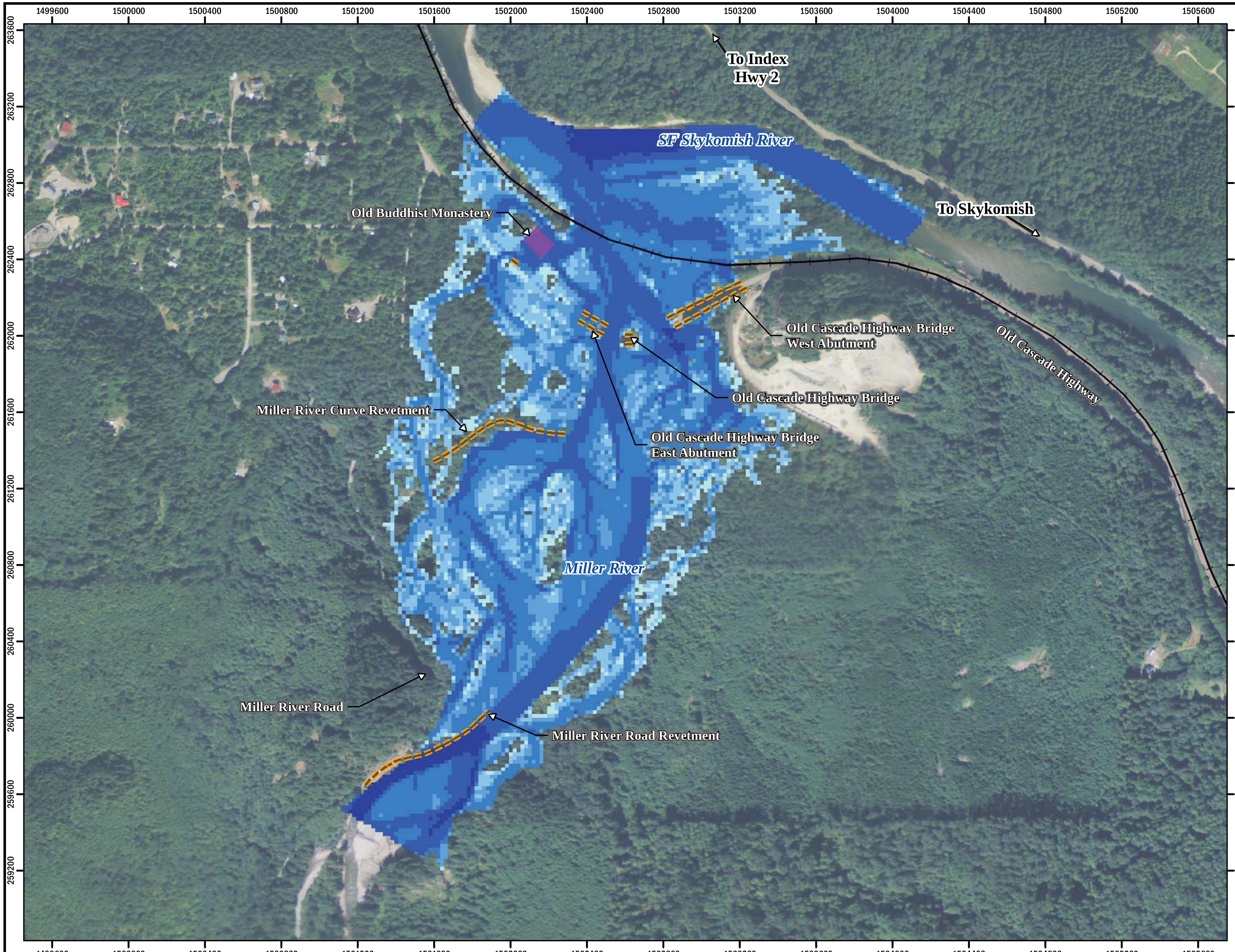
0 250 500 1,000
Feet

HERRERA

Coordinates: NAD 1983 WA State Plane North (ft)

Produced By: GIS
Project: K:\Projects\10-04766-023\Project\Miller_River_002yr_flood_flow_depth_existing.mxd (1/22/2013)

Figure 8.
FLO-2D results - 10-year Miller River flood flow depth under existing conditions.



Legend

- Monastery
- Riprap to be removed
- Railroad

Flow depth (ft)

- 0 to 0.2
- 0.2 to 1
- 1 to 2
- 2 to 5
- 5 to 10
- 10 to 15
- 15 to 20

N

0 250 500 1,000
Feet

HERRERA

Coordinates: NAD 1983 WA State Plane North (ft)

Produced By: GIS
Project: K:\Projects\10-04766-023\Project\Miller_River_010yr_flood_flow_depth_existing.mxd (1/22/2013)

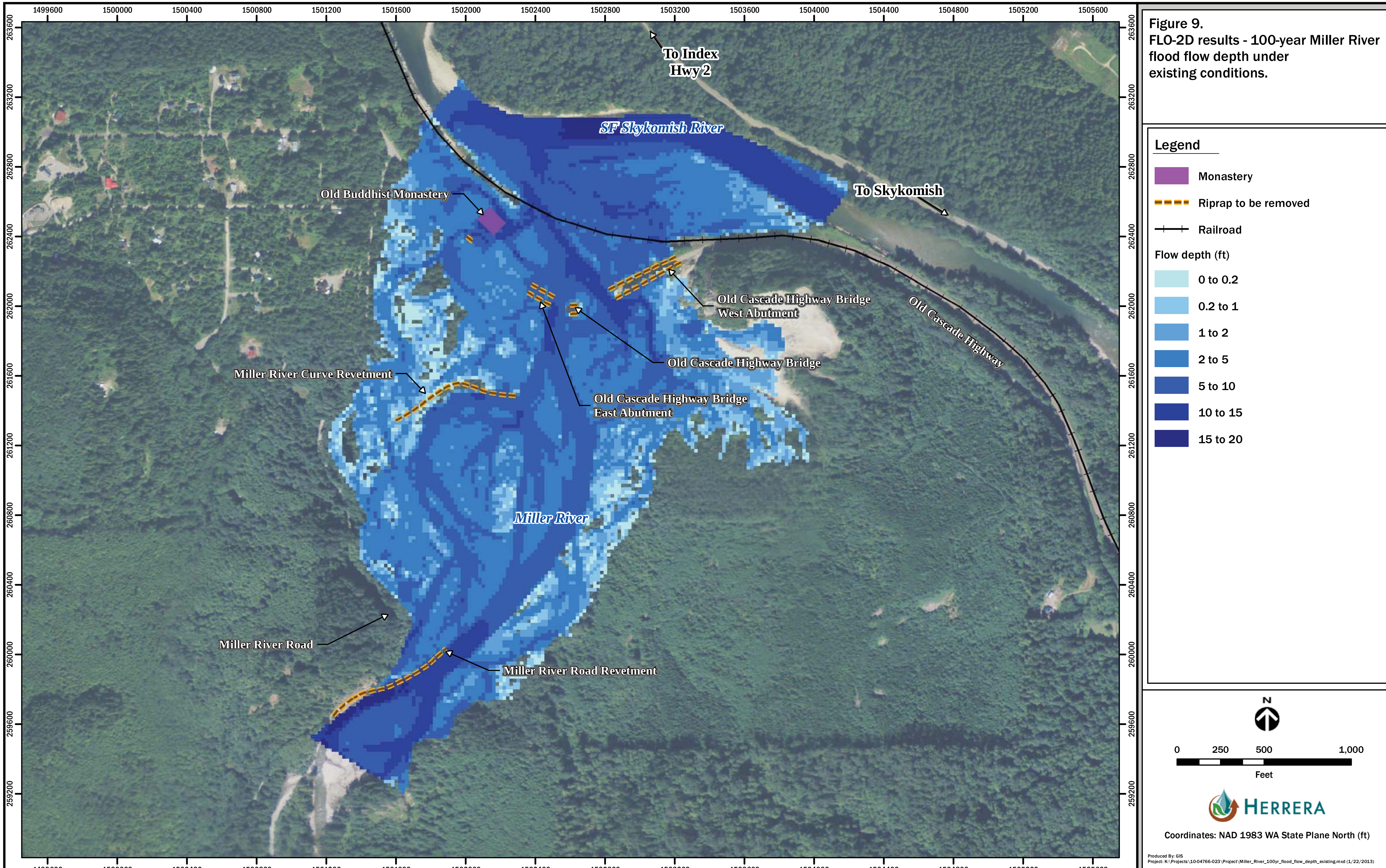


Figure 9.
FLO-2D results - 100-year Miller River flood flow depth under existing conditions.

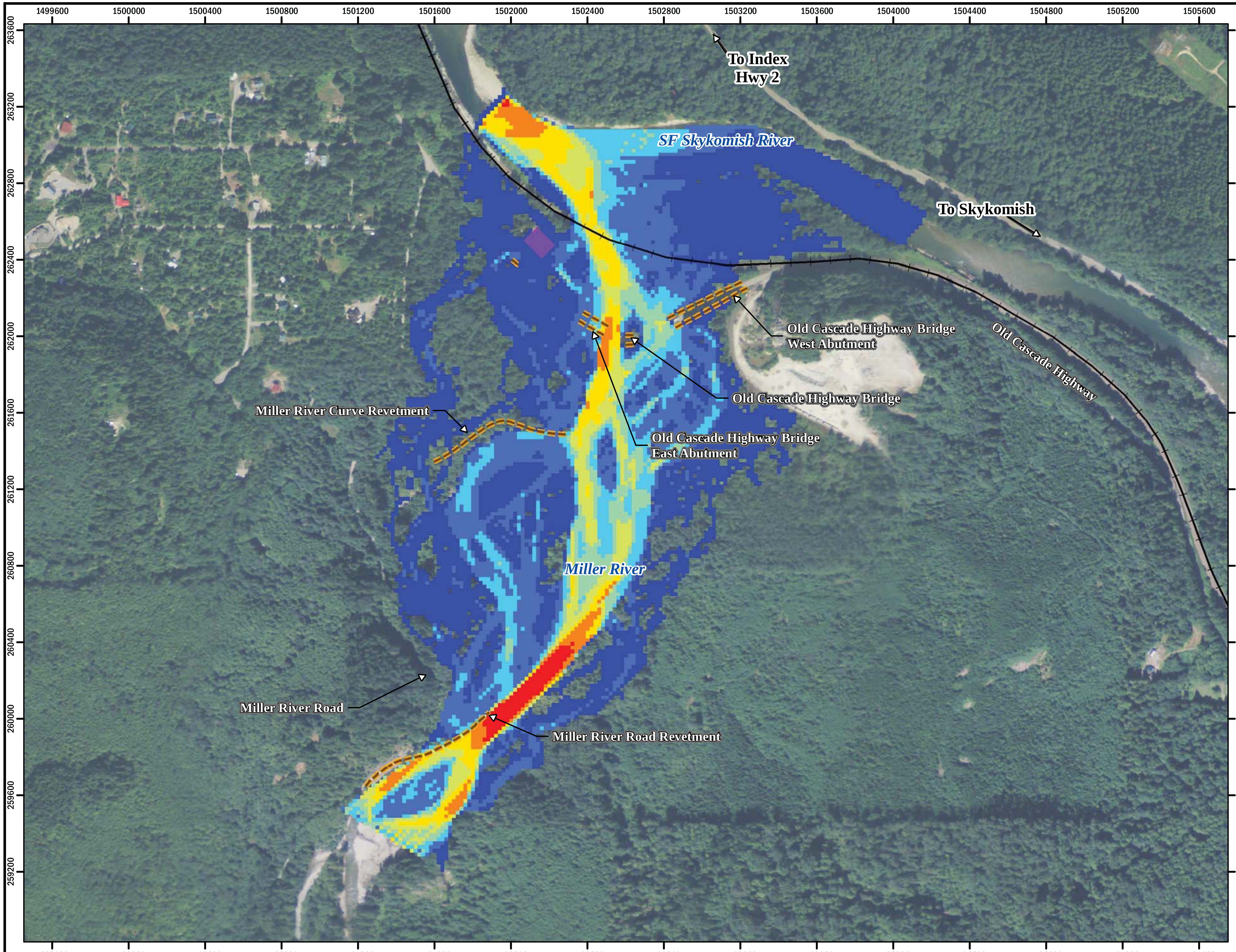


Figure 10.
FLO-2D results - 2-year Miller River flood flow velocities under existing conditions.

Legend

- Monastery
- Riprap to be removed
- Railroad

Velocity (ft/sec)

- 0 to 2
- 2 to 4
- 4 to 6
- 6 to 8
- 8 to 10
- 10 to 12
- 12 to 14
- > 14

N

0 250 500 1,000
Feet

HERRERA

Coordinates: NAD 1983 WA State Plane North (ft)

Produced By: GIS
Project: K:\Projects\10-04766-023\Project\Miller_River_002yr_flood_flow_velocity_existing.mxd (1/22/2013)

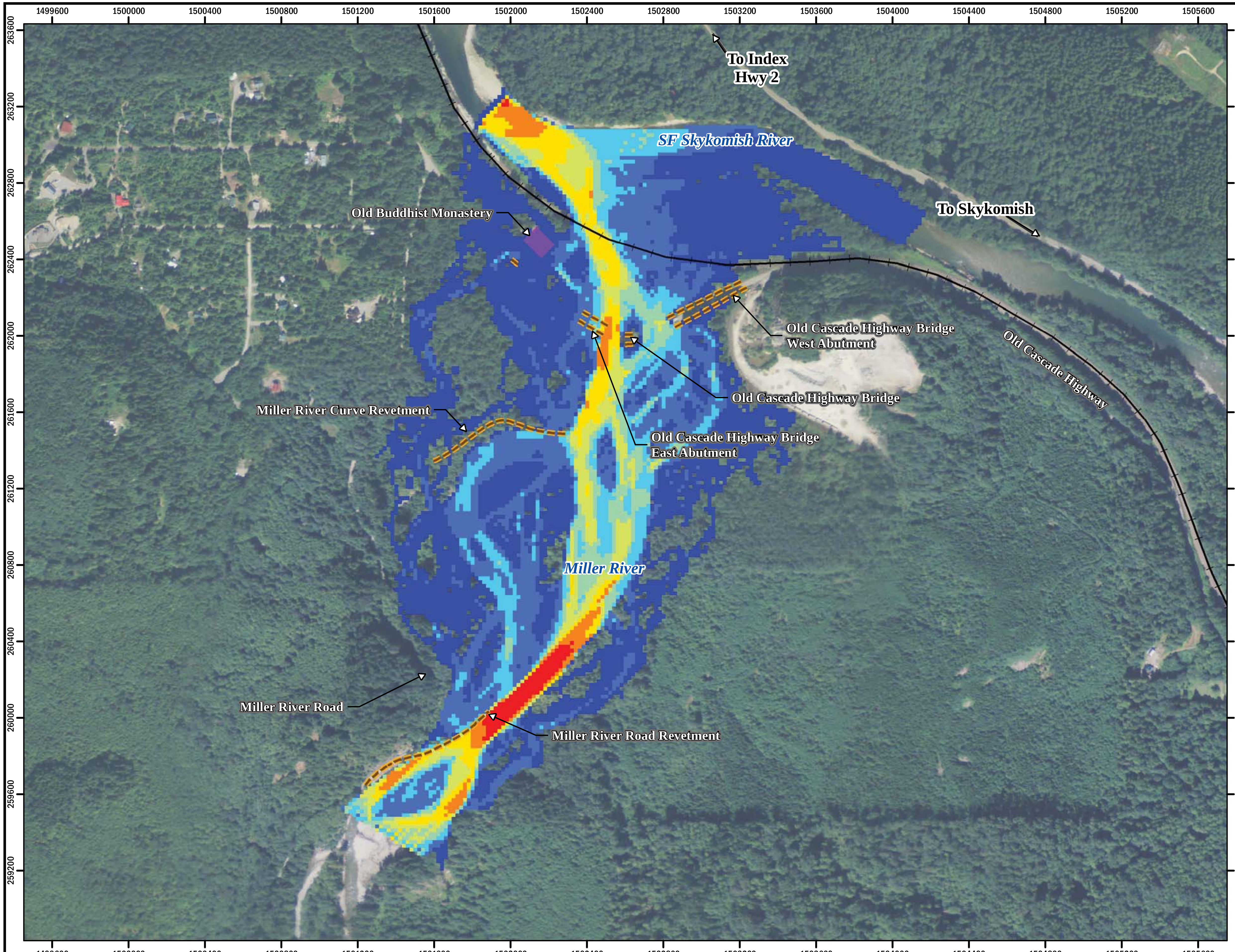


Figure 11.
FLO-2D results - 10-year Miller River flood flow velocity under existing conditions.

Legend

- Monastery
- Riprap to be removed
- Railroad

Velocity (ft/sec)

- 0 to 2
- 2 to 4
- 4 to 6
- 6 to 8
- 8 to 10
- 10 to 12
- 12 to 14
- > 14

N

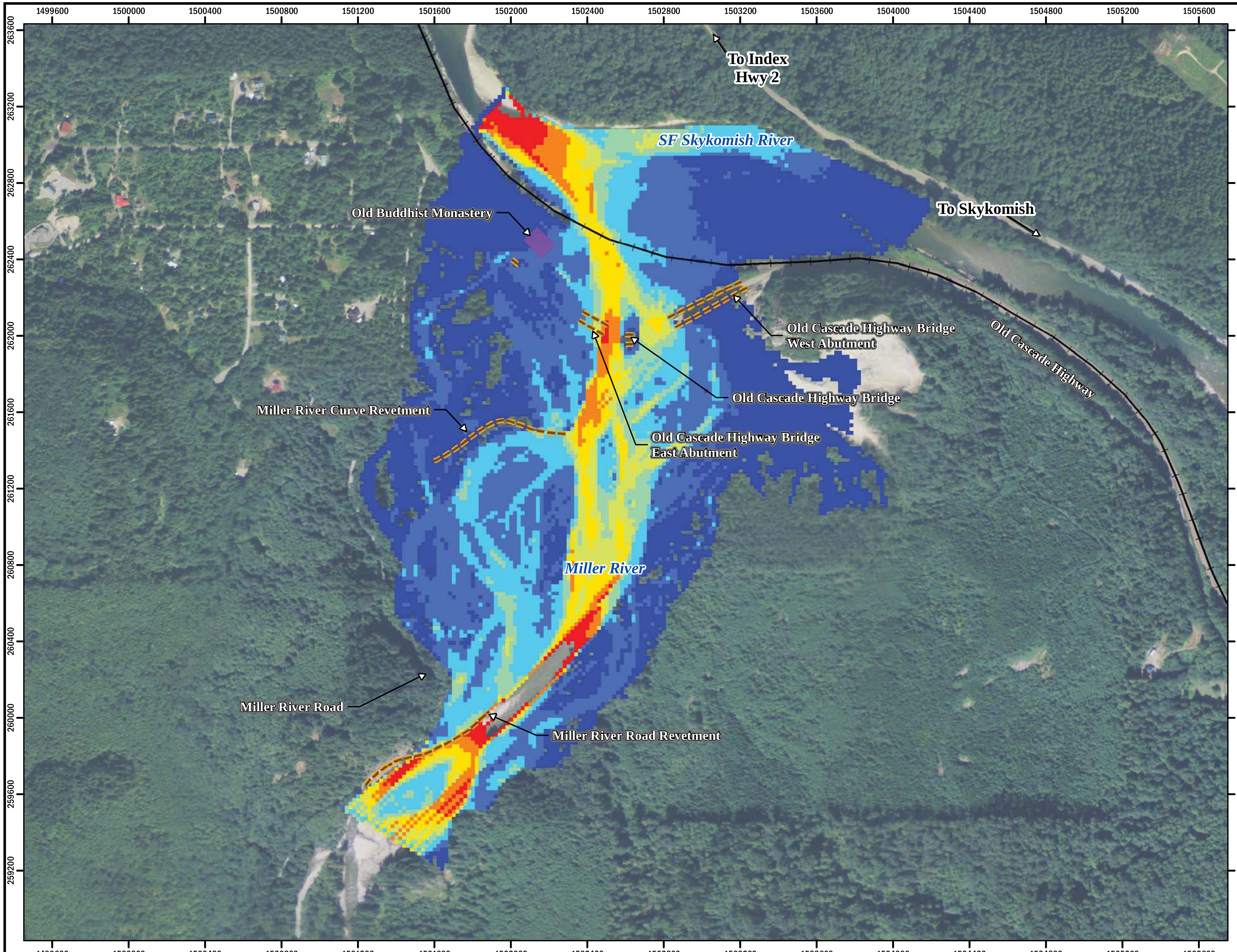
0 250 500 1,000
Feet

HERRERA

Coordinates: NAD 1983 WA State Plane North (ft)

Produced By: GIS
Project: K:\Projects\10-04766-023\Project\Miller_River_010yr_flood_flow_velocity_existing.mxd (1/22/2013)

Figure 12.
FLO-2D results - 100-year Miller River flood flow velocities under existing conditions.



Legend

- Monastery
- Riprap to be removed
- Railroad

Velocity (ft/sec)

- 0 to 2
- 2 to 4
- 4 to 6
- 6 to 8
- 8 to 10
- 10 to 12
- 12 to 14
- > 14

N

0 250 500 1,000
Feet

HERRERA

Coordinates: NAD 1983 WA State Plane North (ft)

Produced By: GIS
Project: K:\Projects\10-04766-023\Project\Miller_River_100yr_flood_flow_velocity_existing.mxd (1/22/2013)

Table 5. Hydraulic Model Results at Selected Key Locations.						
	100-Year		10-Year		2-Year	
Location	Depth (ft)	Velocity (fps)	Depth (ft)	Velocity (fps)	Depth (ft)	Velocity (fps)
BNSF Bridge - Left Abutment	9.41	10.17	6.42	9.71	4.22	7.39
BNSF Bridge - Right Abutment	10.39	10.98	7.52	10.81	5.57	8.66
BNSF Bridge - Center	9.93	11.77	7.12	11.76	5.02	10.88
Side Channel in Alternative 1	11.14	3.24	7.90	2.46	5.17	1.71
Site of Erosion of Existing Road Fill at Left Bank New Avulsion Channel	7.12	3.93	5.38	2.97	3.54	2.31
Left Bank Pre-1996 Channel Inlet	8.84	6.44	8.99	4.69	1.80	2.22
Pre-1996 Channel Outlet	6.87	5.58	4.85	3.89	1.88	1.53
West End of Miller River Curve Revetment	7.69	5.01	5.77	4.65	2.07	2.94
Miller River Gage Site	15.09	14.38	12.56	12.37	6.37	9.59
Center of New Avulsion Channel	9.83	14.84	7.96	13.81	6.19	11.60
Alluvial Fan Apex	14.98	15.38	12.67	13.47	6.41	10.78
Center of Alluvial Fan	11.47	17.12	9.19	15.06	6.31	11.00

Notes:

Pre-1996 Channel refers to the large meander that borders the Miller River Curve Revetment that was the main channel prior to 1996 (Herrera 2009)

The primary source of error to the hydraulic model is from the estimation of the flow rates for the return interval of the events themselves (see *Hydrologic* section for details). While the estimates provided in the *Hydrologic* section are much more sophisticated and accurate as compared to previous estimates, they possess several assumptions that may be invalid to varying degrees (i.e., that Miller River flow can be estimated from a subtraction of the Gold Bar gage flow rate from flows observed at Skykomish and estimated at Index), particularly for the larger events. The establishment of a rating curve at the Miller River gage, as well as a more lengthy stage record there should identify any errors in these assumptions. The hydraulic calculations, though only applicable in average over the 20-foot square area they occupy, should be relatively accurate. They are also qualitatively consistent with geomorphic changes seen from recent flood events.

Proposed Actions

The four separate restoration alternative actions laid out in *Habitat Assessment* are proposed with engineering cost estimates for each below (Figure 13). The alternatives could be implemented separately, in a phased manner or completed simultaneously. Those alternatives that must mitigate geomorphic hazards to ensure their implementation do so by utilizing existing materials on site to protect adjacent flood-prone areas. Reuse of rock is assumed for the more extensive alternatives that could increase geomorphic hazards to existing infrastructure. While there would be more habitat benefit if the rock were removed from the alluvial fan entirely, it is assumed for the purposes of this analysis that the railroad will maintained at all costs (i.e., it will be protected with some form of armoring regardless of the risk to it). Alternative costs include construction work (mobilization, survey, TESC, clearing and grubbing, riprap removal and replacement, and site clean-up), design work (site investigation, hydraulic modeling, design development, and permitting), tax, and a contingency of 50 percent (Appendix 1). The alternative costs also include consultant assistance for the preparation of a JARPA, a SEPA checklist, a critical areas report, a cultural resources analysis, and ESA consultation assistance. A brief discussion of the constraints and benefits to each alternative action is also included below.

Alternative 1 Restoration Actions

Alternative 1 restoration actions are focused on the lowest portion of the project area, just upstream of the Miller River's confluence with the SF Skykomish, within the bounds of the former monastery. The Alternative 1 actions involve removing several remnant water-control structures at the monastery that will not be removed in the near future by the County. The demolition work of the residential structures, their foundations and any above-ground utilities at the monastery will be removed shortly and are not part of this analysis. Design and construction costs associated with the proposed Alternative 1 work are estimated at $372,680.

Alternative Benefits (Outcomes)

The benefits of this alternative are the improved connection between the water features on the monastery property and the Miller River, including Spree Creek. The net result is an expansion of floodplain habitat by about 2 acres. While these water features were not necessarily formed naturally (i.e., they were excavated by people), they should provide quality off-channel habitat over time as existing vegetation conditions are relatively good (see *Habitat Assessment* for details).

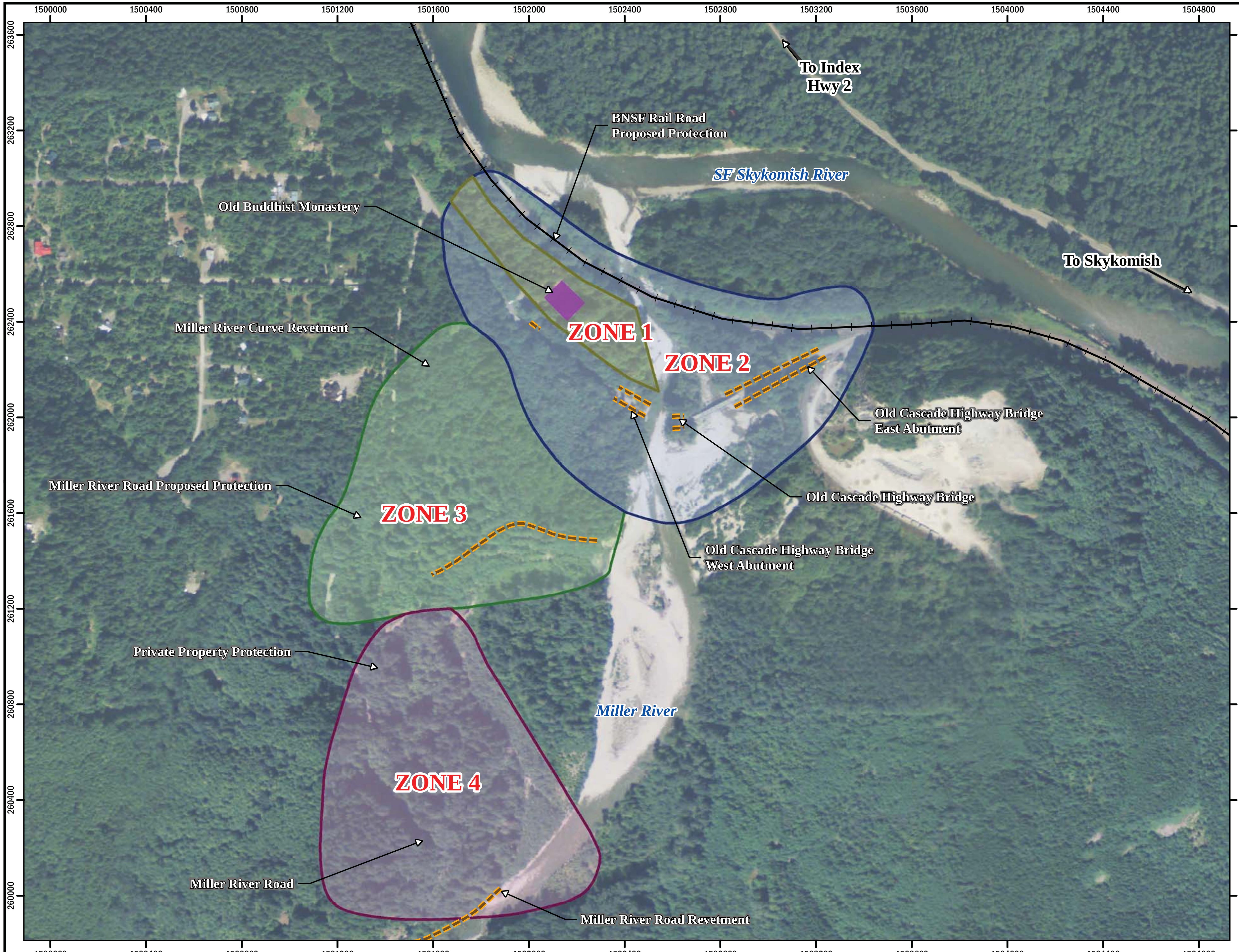
Alternatives Constraints (Potential Impacts)

There are relatively few constraints on this alternative. Since only historical riprap and fill be removed, discovery of cultural resources during construction is not an issue. Since removal is just placed rock, hazardous materials are also not an issue, though it may be helpful to determine if wood lagging in the dams has been treated with creosote. Since the structures were put in place primarily for aesthetic and access purposes there is no increase in geomorphic hazards, particularly if the roadway and the Curve revetment will remain in place.

Alternative 2 Restoration Actions

The Alternative 2 actions involve removing the existing fill and riprap associated with the Old Cascade Highway and Bridge abutments (approximately 2,000 cubic yards of riprap and almost 25,000 cubic yards of fill), and placing the riprap along 650 feet on the upstream side of the currently unarmored railroad embankment on the Miller River left bank that is at current risk to failure. Design and construction costs associated with the proposed Alternative 2 work is

Figure 13.
Miller River restoration alternatives.



Legend

- Riprap to be removed
- Railroad
- Monastery

Alternative

- 1
- 2
- 3
- 4

Note:
Alternative 1: Alternative 1
Alternative 2: Alternative 1 + 2
Alternative 3: Alternative 1 + 2 + 3

N

0 200 400 800
Feet

HERRERA

Coordinates: NAD 1983 WA State Plane North (ft)

Produced By: GIS
Project: K:\Projects\10-04766-023\Project\Miller_River_Base_Map.mxd (1/22/2013)

estimated at $1,408,325. The cost estimate includes removal of road fill, but does include disposal of asphalt or the bridge itself.

Alternative Benefits (Outcomes)

The benefits of this alternative are probably the largest of any single alternative. Approximately 11 acres of disconnected floodplain and 1,700 linear feet of side channels will be reconnected if this alternative is implemented. There will also be an improvement of aquatic habitat complexity and quality in 200 linear feet of the main channel complex (Figure 13). Over time, it is likely that one of the disconnected side channels may eventually become the new thalweg. This would allow the avulsion channel and the former main channel to aggrade, revegetate and become ecologically productive side channels. In short, habitat on the fan would be expanded greatly if the road were to be removed.

Alternatives Constraints (Potential Impacts)

The road has and will continue to protect the railway so long it is in place, though there is clear evidence that it has been and will continue to be gradually lost due to natural processes. The railway prism west of the existing Miller River main channel crossing is not armored. The model results imply high velocities (in excess of 10 feet per second), which is corroborated by observed significant geomorphic changes following recent high flows in the vicinity of the left bank railway bridge abutment.

There is a greater potential for encountering hazardous or culturally significant materials than any of the other alternatives. The road has been in place in some form for nearly 100 years and it may have been located at a historical Native American crossing point. The bridge is relatively newer than the road itself, so there may be old creosote-treated wooden abutments from the original bridge buried in the road prism. The bridge itself is also potentially a cultural resource and the extent to which the abutments would be included in that determination is unknown.

Alternative 3 Restoration Actions

Alternative 3 restoration actions address the middle and left bank portions of the project area. The Alternative 3 actions involve removing approximately 3,400 cubic yards of existing riprap and 48,100 cubic yards of fill that is on the Miller River Curve revetment, and placing that riprap on the east side of the Miller River Road prism. Design and construction costs associated with the proposed Zone 3 work are estimated at $2,885,510.

Alternative Benefits (Outcomes)

The benefits of this alternative are significant. The alternative would reconnect 5.5 acres of disconnected floodplain and approximately 1,000 linear feet of side channels. It would also improve of aquatic habitat complexity and quality in 50 linear feet of the existing main stem. Removing this revetment would reengage these channels, even without removing road (i.e., Alternative 2), though implementing Alternative 2 would improve the performance of this alternative.

Alternative Constraints (Potential Impacts)

The Curve Revetment serves as secondary flood protection to the railway, though its impacts to the railway are mixed. The removal of the revetment would increase the probability of a channel forming that would directly impact the unarmored railway prism. However, removing the revetment would reduce the risk of debris flow from reaching the railway by engaging the full modern fan. Removal may also reduce flood elevations at the bridge itself.

Because the construction itself would be removing relatively recent placed fill (though the date of placement is uncertain) only, the probability of encountering cultural resources or hazardous materials is small.

Alternative 4 Restoration Actions

Alternative 4 actions involve removing 150 lineal feet of the existing riprap and fill that is the Miler River Road revetment that is currently being eroded by the river and blocking a former side channel. The wasted rock would be used to construct a 350-foot long setback revetment in order to protect communities and property on the left bank and the roadway. Design and construction costs associated with this work are estimated at $2,630,320. This alternative does not include acquisition of the privately held parcels along the east side of Miller River Road. Acquisition of these properties might result in minor construction cost savings because the rock acquired from the removal of the Miller River Road revetment could then be end-dumped along Miller River Road rather than placed in a new levee. Moving the rock to the road also might reengage a set of former side-channels that run through these properties.

Alternative Benefits (Outcomes)

The benefits of this alternative would be to reengage a set of side channels at the extreme west edge of the modern Miller River fan. These side channels have mature native vegetation along them, as well as hyporheic input. Some (but not all) of this area is already developed. Therefore acquiring these developed properties and including them in the alternative (rather than protecting them floodwaters) would increase the performance of this alternative.

Alternative Constraints (Potential Impacts)

The primary impact of removing the downstream portion of the Miller River Road Revetment is the reactivation of the side channel that runs along the road. This side channel network would not endanger the developed parcels on the east side of Miller River Road, but it would endanger the developed properties on the east side of the road and the road itself. These impacts could be mitigated if some of the rock removed is wasted alongside the road and in the connection between the side channel and the properties in question. Because the construction itself would be removing relatively recent placed fill (though the date of placement is uncertain) only, the probability of encountering cultural resources or hazardous materials is small.

SUMMARY OF FINDINGS

The following statements can be made based upon the results of the analysis discussed herein:

- There are numerous opportunities to improve aquatic habitat conditions on the Miller River fan. If implemented, these improvements would benefit fish and wildlife species in the lower Miller River as well as in the South Fork Skykomish River.
- Most of the opportunities involve removing existing revetments and using the materials acquired in that process to protect remaining infrastructure on the alluvial fan.
- The largest opportunities are most easily lumped into three phases:
    1. Remove the roadway and use remaining rock to protect the BNSF railroad.
    2. Remove the Miller Curve Revetment.
    3. Remove portions of the Miller River Road revetment and protect the remaining private homeowners on the alluvial fan, if necessary.
- The alluvial fan is completely inundated between Miller River Road and Martin Marietta rock quarry in the 100-year event. Even the 2-year event inundates most side channels in existing conditions.
- Velocities are extremely high throughout the alluvial fan during the largest flood events, validating the known high degree of geomorphic hazard on the alluvial fan.

REFERENCES

Beamer, E.M., J.P. Shannahan, K. Wolf, E. Lowery, and D. Pflug. 2010. Freshwater habitat rearing preferences for stream type juvenile Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*) in the Skagit River Basin: Phase 1 study report.

Carlson, W. and the Skykomish Historical Society. 2009. *Images of America: Upper Skykomish Valley*. Arcadia Publishing, San Francisco.

DNR. 2012. DNR Landslide website. Washington Department of Natural Resources. Available at: https://fortress.wa.gov/dnr/geology/?Site=landslides.

Fonda, R.W. 1974. Forest succession in relation to river terrace development in Olympic National Park, Washington. *Ecology* 55:927–942.

Gregory, S.V., F.J. Swanson, W.A. McKee, and K.W. Cummins. 1991. An ecosystem perspective on riparian zones. *BioScience* 41(8):540-551.

Haring, D. 2002. Salmonid habitat limiting factors analysis. Snohomish River Watershed – Water Resource Inventory Area 7. Washington State Conservation Commission. December 2002.

Herrera. 2007. Assessment of Sediment Delivery and Geomorphic Evolution: Lower Tolt River Floodplain Reconnection Project. Prepared for Seattle Public Utilities by Herrera Environmental Consultants, Inc., Seattle, Washington. July 2007.

Herrera. 2009. Miller River Fan Geomorphic Assessment. Prepared for King County Department of Natural Resources and Parks, Water and Land Resources Division, River and Floodplain Management Section by Herrera Environmental Consultants, Inc., Seattle, Washington. December 2009.

Herrera. 2012a. Draft Geomorphic Assessment: South Fork Skykomish River. Prepared for King County Department of Natural Resources and Parks, River and Floodplain Management Section.

Herrera. 2012b. Draft South Fork Skykomish River Salmon Habitat Information Review and Future Studies Scoping Summary Report. Prepared for King County Department of Natural Resources and Parks, Water and Land Resources Division, River and Floodplain Management Section by Herrera Environmental Consultants, Inc., Seattle, Washington. December 2009.

Hruby, T. 2004. Washington State Wetland Rating System for Western Washington—Revised. Ecology Publication 04-06-025. Washington State Department of Ecology. August 2004.

Jones, J.A. and R.M. Perkins. 2010. Extreme flood sensitivity to snow and forest harvest, western Cascades, Oregon, United States. *Water Resources Research* 46(W12512):10.1029/2009WR008632.

King County. 2011. Miller River Bridge #999W West Approach Roadway Washout Type, Size, and Location (TSL) Feasibility Study Report – Draft. King County Department of Transportation. September 15, 2011.

Lestelle, L.C., W.E. McConnaha, G. Blair, and B. Watson. 2005. Chinook salmon use of floodplain, secondary channel, and non-natal tributary habitats in rivers of western North America. Report prepared for the Mid-Willamette Valley Council of Governments, US Army Corps of Engineers, and Oregon Department of Fish and Wildlife by Mobrand-Jones and Stokes, Vashon, Washington, and Portland, Oregon.

May, C.L. and R.E. Gresswell. 2004. Spatial and temporal patterns of debris-flow deposition in the Oregon Coast Range, USA. *Geomorphology* 57:135-149.

NOAA Fisheries. 2012. Species lists for Puget Sound and Washington, (West Coast Salmon and Steelhead list updated August 11, 201). National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Regional Office, Seattle, Washington. http://www.nwr.noaa.gov/Species-Lists.cfm (accessed October 25, 2012).

O'Brien. 2006. FLO-2D User's Manual, version 2006.01. FLO-2D Software Inc. January 2006.

Pratt, K.L. 1992. A review of bull trout life history. Pages 5-9 in: Howell, P.J. and D.V. Buchanan (eds.). Proceedings of the Gearhart Mountain bull trout workshop. Oregon Chapter of the American Fisheries Society, Corvallis, Oregon.

Snohomish Basin Salmon Recovery Forum. 2005. Snohomish River Basin Salmon Conservation Plan. Snohomish County Department of Public Works, Surface Water Management Division. Everett, Washington. Published June 2005.

Tabor, R.W., V.A. Frizzell, Jr., D.B. Booth, R.B. Waitt, J.T. Whetten, and R.E. Zartman. 2003. Geologic map of the Skykomish River 30- by 60-minute quadrangle. US Geologic Survey, Map I-1963.

US Army Corps of Engineers. 1982. Guidelines for determining flood flow frequency. US Army Corps of Engineers Bulletin 17b.

USFS. 2000. Environmental Baseline Conditions for Foss and Miller Fifth-Field Watersheds. US Forest Service, Pacific Northwest Region, Mt. Baker-Snoqualmie National Forest, Mountlake Terrace, Washington.

USFS. 2009. Miller-Foss Watershed Analysis. US Forest Service, Pacific Northwest Region, Mt. Baker-Snoqualmie National Forest. Mountlake Terrace, Washington. March 2009.

USFWS. 2008. US Fish and Wildlife's Biological Opinion for the Environmental Protection Agency's proposed approval of revised Washington water quality standards for designated uses, temperature, dissolved oxygen, and other revisions. US Fish and Wildlife Service. Issued February 11, 2008.

USFWS. 2012. Listed and Proposed Endangered and Threatened Species and Critical Habitat; Candidate Species; and Species of Concern in King County, Washington. US Fish and Wildlife Service, Central Washington Fish and Wildlife Office. List revised November 1, 2007. http://www.fws.gov/wafwo/speciesmap/KING.html (accessed October 25, 2012).

USGS. 2012. StreamStats. Accessible at: http://water.usgs.gov/osw/streamstats/index.html.

Van Pelt, Robert, Thomas C. O'Keefe, Josh J. Latterell, and Robert J. Naiman. 2006. Riparian forest stand development along the Queets River in Olympic National Park Washington. *Ecological Monographs* 76:277–298.

WDFW. 2012a. SalmonScape. Washington Department of Fish and Wildlife. Available at: http://wdfw.wa.gov/mapping/salmonscape/index.html. Accessed on October 24, 2012.

WDFW. 2012b. Washington State Fish and Wildlife Service Priority Habitat and Species (PHS) Data On the Web for the study area. Available at: http://wdfw.wa.gov/mapping/phs/. Accessed on October 24, 2012.

APPENDIX 1

Engineering Cost Estimates

King County
Lower Miller Restoration Assessment
Planning Level Construction Cost Estimates
Concept Alternatives 1/8/2013

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL PRICE	COMMENTS/ASSUMPTIONS
	ALTERNATIVE 1					**Removal of Old Monestary structures**
1	MOBILIZATION	1	LS	$21,870	$21,870	Mobilization is estimated at 20% of construction cost.
2	DESIGN	1	LS	$100,200	$100,200	Design costs does not include permitting assistance or cultural resources survey
3	SURVEY	1	DAY	$3,600	$3,600	Topo survey of fan done by Rivers Survey On-Call, PGS
4	TEMPORARY EROSION CONTROL	1	LS	$5,210	$5,210	Assume 5% of all const. costs
5	CLEARING AND GRUBBING	1.20	ACRE	$8,000	$9,600	Plants and trees removed for access in all areas
6	FOOT BRIDGE & ABUTMENTS, BERM FILL REMOVAL, HAUL AND PLACEMENT	3,700	CY	$25	$92,500	Assume that haul distance is minimal(<1mi).HEC estimate based on project expereience. $3/cy to place, $15/cy to remove, $2/mi haul
7	SITE CLEANUP	1	LS	$2,000	$2,000	
	CONSTRUCTION TOTAL				**$234,980**	
	TAX	8.6%			**$20,210**	
	CONTINGENCY	50%			**$117,490**	
	TOTAL W/O CONTINGENCY				**$255,190**	
	TOTAL W/ CONTINGENCY				**$372,680**	
	ALTERNATIVE 2					**Removal of Old Cascade Hwy road & bridge, and Spree Creek bridge**
1	MOBILIZATION	1	LS	$126,300	$126,300	Mobilization is estimated at 20% of construction cost.
2	DESIGN	1	LS	$100,200	$100,200	Design costs does not include permitting assistance or cultural resources survey
3	SURVEY	10	DAY	$3,000	$30,000	Topo survey of fan done by Rivers Survey On-Call
4	TEMPORARY EROSION CONTROL	1	LS	$30,070	$30,070	Assume 5% of all const. costs
5	CLEARING AND GRUBBING (Z1)	0.75	ACRE	$8,000	$6,000	Plants and trees removed for access to railroad area
6	RIPRAP REMOVAL, HAUL AND PLACEMENT	2,000	CY	$25	$50,000	Assume that haul distance is moderate (~6 mi).HEC estimate based on project expereience. $3/cy to place, $15/cy to remove, $2/mi haul
7	ROAD FILL REMOVAL AND HAUL	24,700	CY	$22	$543,400	Assume that haul distance is moderate (~6 mi). Assumes that KC is responsible for removing pavement and surfacing. HEC estimate based on project expereience. $15/cy to remove, $2/mi haul
8	SITE CLEANUP	1	LS	$2,000	$2,000	
	CONSTRUCTION TOTAL				**$887,970**	
	TAX	8.6%			**$76,370**	
	CONTINGENCY	50%			**$443,985**	
	TOTAL W/O CONTINGENCY				**$964,340**	
	TOTAL W/ CONTINGENCY				**$1,408,325**	
	ALTERNATIVE 3					**Removal of Miller River Curve Revetment**
1	MOBILIZATION	1	LS	$281,530	$281,530	Mobilization is estimated at 20% of construction cost.
2	DESIGN	1	LS	$100,200	$100,200	Design costs does not include permitting assistance or cultural resources survey
3	SURVEY	10	DAY	$3,000	$30,000	Topo survey of fan done by Rivers Survey On-Call
4	TEMPORARY EROSION CONTROL	1	LS	$67,030	$67,030	Assume 5% of all const. costs
5	CLEARING AND GRUBBING	1.00	ACRE	$8,000	$8,000	Plants and trees removed for access in all areas
6	RIPRAP REMOVAL, HAUL AND PLACEMENT	3,200	CY	$25	$80,000	Assume that haul distance is minimal (< 1mi) .HEC estimate based on project expereience. $3/cy to place, $15/cy to remove, $2/mi haul
7	ROAD & REVETMENT FILL REMOVAL, HAUL AND PLACEMENT	48,100	CY	$26	$1,250,600	Assume that haul distance is moderate (~6 mi). Assumes that KC is responsible for removing pavement and surfacing. HEC estimate based on project expereience. $15/cy to remove, $2/mi haul
8	SITE CLEANUP	1	LS	$2,000	$2,000	
	CONSTRUCTION TOTAL				**$1,819,360**	
	TAX	8.6%			**$156,470**	
	CONTINGENCY	50%			**$909,680**	
	TOTAL W/O CONTINGENCY				**$1,975,830**	
	TOTAL W/ CONTINGENCY				**$2,885,510**	
	ALTERNATIVE 4					**Removal of Miller River Road Revetment**
1	MOBILIZATION	1	LS	$254,710	$254,710	Mobilization is estimated at 20% of construction cost.
2	DESIGN	1	LS	$100,200	$100,200	Design costs does not include permitting assistance or cultural resources survey
3	SURVEY	10	DAY	$3,000	$30,000	Topo survey of fan done by Rivers Survey On-Call
4	TEMPORARY EROSION CONTROL	1	LS	$60,650	$60,650	Assume 5% of all const. costs
5	CLEARING AND GRUBBING	1.20	ACRE	$8,000	$9,600	Plants and trees removed for access in all areas
6	RIPRAP REMOVAL, HAUL AND PLACEMENT	3,700	CY	$25	$92,500	Assume that haul distance is minimal(<1mi).HEC estimate based on project expereience. $3/cy to place, $15/cy to remove, $2/mi haul
7	ROAD & REVETMENT FILL REMOVAL, HAUL AND PLACEMENT	50,400	CY	$22	$1,108,800	Assume that haul distance is moderate (~6 mi). Assumes that KC is responsible for removing pavement and surfacing. HEC estimate based on project expereience. $15/cy to remove, $2/mi haul
8	SITE CLEANUP	1	LS	$2,000	$2,000	
	CONSTRUCTION TOTAL				**$1,658,460**	
	TAX	8.6%			**$142,630**	
	CONTINGENCY	50%			**$829,230**	
	TOTAL W/O CONTINGENCY				**$1,801,090**	
	TOTAL W/ CONTINGENCY				**$2,630,320**	