ASOTIN COUNTY WATERSHED ASSESSMENT:

TECHNICAL DOCUMENT & APPENDICES

Prepared for:

Asotin County Conservation District
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Asotin Working Group

This document was completed by the consulting team with significant input, guidance, and review by the Asotin Working Group. The Working Group includes the following people and agencies:

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KEY FINDINGS & RECOMMENDED RESTORATION STRATEGIES

Background

We present a watershed assessment of four watersheds in the Asotin County Assessment Area (hereafter the *study area*): Alpowa Creek, Asotin Creek, Couse Creek, and Tenmile Creek. The Salmon Recovery Funding Board funded the assessment and the Asotin County Conservation District administered the contract. The goals of the assessment were to determine the:

- characteristics that control the creation and maintenance of fish habitat,
- geomorphic, riparian, and floodplain conditions of the study area ,
- factors that are most likely limiting the productivity and survival of key fish species, and
- restoration strategies that will address the limiting factors.

We used the findings from this assessment to develop a Conceptual Restoration Plan that prioritizes restoration actions across 83 project areas based on the geomorphic conditions, potential benefits to fish, cost effectiveness, landowner and agency support, and compatibility with regional and local recovery goals and objectives. The Conceptual Restoration Plan is presented in a separate report.

This assessment was developed with a focus on Endangered Species Act listed summer steelhead (*Oncorhynchus mykiss*), Chinook salmon (*O. tshawytscha*), bull trout (*Salvelinus confluentus*), and Washington state species of concern, the Pacific lamprey (*Entosphenus tridentatus*). We focused our assessment on the geomorphic, riparian, and floodplain condition of fish bearing streams in the study area, but supplemented these assessments by evaluating the condition of the entire stream network (perennial, intermittent, and ephemeral streams) and using a series of GIS tools to assess beaver dam capacity, floodplain fragmentation, stream temperature, and fish barriers.

Setting and Past Limiting Factors

The study area has several distinguishing features that have a large influence on river character and the potential to restore fish habitat. First, the region is dominated by long, hot summers and annual precipitation is low (< 20") in all but the highest elevations (<40") in the Blue Mountains. Watersheds are short and steep, with streams that generally have narrow valleys and discontinuous or patchy floodplain areas. In streams with headwaters in the Blue Mountains (e.g., Asotin Creek and portions of George Creek), the hydrologic regime is snow-rain dominated and the flows are more consistent. In watersheds that do not have headwaters in the Blue Mountains (e.g., Alpowa, Couse, Tenmile Creeks), the hydrologic regime is groundwater dominated, and flows are often very low or intermittent during the summer months (i.e., sections of stream regularly go dry).

Southeast Washington has some of the most erosion prone soils in the country and soil erosion was a significant problem prior to the 1990s. Intensive agriculture on loess soils with a high erosion potential led to an over-supply of fine sediment into streams that severely degraded spawning habitat. Intensive logging in the headwaters, grazing throughout the watershed, removal of mature riparian forests, and numerous diversion dams for irrigation also led to degradation of fish habitat and rapid decline or complete extirpation of fish populations. Several large floods that happened every 10-20 years in the last century exacerbated the impact on channel, riparian, and floodplain conditions. In 1995, a community led Model Watershed Plan was developed and in the subsequent 20 years restoration projects were implemented to improve upland and stream conditions. Prior to the current assessment effort, channel stability, sediment supply, flow, habitat diversity, temperature, and key habitat quantity were considered the most significant limiting factors on fish productivity.

Assessment Results

Valley Confinement, Reach Types, and Geomorphic Units

The study area is dominated by reach types that are naturally confined or partly confined by the valley walls, and streams often run along steep bedrock cliffs. Valley widths rarely exceed 300' for large streams and 100' on small to medium sized streams. The most common reach types in these valley settings are characterized by a single channel, low sinuosity, moderate to high gradient, and long planar features (e.g., runs and rapids). Floodplains are patchy or discontinuous and pools are often forced by bars or large woody debris (LWD). Multiple channels can exist but they are usually forced by wood also. Wandering gravel bed reaches that commonly have multiple channels and wider floodplains make up only 12% (22 miles) of the study area.

Geomorphic, Riparian, and Floodplain Conditions

There are 182 miles of perennial stream in the study area and we found that 76% of the length had moderate to high geomorphic function (i.e., the expected frequency and type of geomorphic units in a reach type were often observed). Past conservation actions appear to have stabilized many limiting factors, and in general, the geomorphic function was stable or improving in most reaches. Reaches with limited geomorphic function were often due to low habitat diversity, lack of LWD, simplified channel planforms, and infrequent overbank flow. Riparian conditions have recovered well from historic disturbances and we found that along the mainstems of the study streams 44.5% of the riparian areas had moderate function and 43.5% had high to near full function. Riparian areas with limited function were often due to reduced extent of riparian habitat, young riparian canopy, monoculture of species, invasive species, upland encroachment, and conversion to agriculture or development. We identified 498 acres (22%) of disconnected floodplain out of 2,237 acres of potential floodplain we assessed. Disconnected habitat was mainly caused by levees and rip-rap in the lower sections of streams for protection of infrastructure (i.e., houses and roads).

Other Assessments

Direct measurements and models of stream temperature suggests that during cool years (i.e., high flow and/or low air temperature) streams rarely exceed mean maximum weekly temperatures of 64.4 °F, but during warm years (low flow and/or high average air temperatures), the lower reaches of streams can exceed 64 °F for almost 50% of the summer weeks (June to September). However, streams rarely exceed 72 °F even during warm years. An assessment of the capacity to support dam building beaver suggests that there is a high capacity in many areas of the mid to upper elevation reaches and the potential for damage to infrastructure is generally low in these areas. Two partial barriers were identified at the mouth of Tenmile and Couse Creeks. These potential barriers occur when the elevation of the Snake River is low and stream flow across the alluvial fans at the mouth of Couse and Tenmile Creek is low or goes subsurface.

Current Limiting Factors

Based on our assessment, it appears that channel stability (defined as the channel being too unstable) is not an issue in most areas. The flooding, loss of LWD, straightening of many channels, and re-establishment of dense riparian areas dominated by alder has had the opposite effect – channels are "locked" in place and are very efficient at transporting sediment and wood. This situation leads to low habitat diversity and a lack of well sorted gravel and cobble bars. We found no evidence of an over-supply of fine sediment, which is likely due to the extensive investment in erosion control measures on the loess uplands in the past 20 years. Low flows continue to be observed especially in Couse, Tenmile, and George Creeks and their tributaries. However, these watersheds have groundwater dominated hydrologic regimes and are naturally prone to low flows. We suspect that past disturbances have exacerbated the flow conditions, but is unknown by how much. High stream temperatures also continue to be observed in the groundwater dominated streams but, like flow, it is likely that these streams frequently had high stream temperatures due to low flow, high air temperatures, and low precipitation (e.g., flow < 5 cfs, air temperatures > 100 °F, and < 20" precipitation annually). We found that a lack of habitat diversity and key habitats (i.e., LWD and pool frequency, cover, gravel bars, undercut banks, off-channel habitat) continue to be a significant limiting factor. There are two general situations where this occurs: 1) areas where floodplain has been physically disconnected by way of levees or rip-rap and 2) areas where there are no levees or rip-rap, but the stream rarely has overbank flow because of a lack of structural elements in the channel and because the surrounding riparian habitat is not contributing LWD. We characterize this state as a "legacy" effect of past disturbances. The major stressors have been removed (e.g., sediment supply, removal of LWD and loss of riparian areas), the stream is recovering, but it may take several more decades to see improvements without active restoration.

Restoration Strategies

We present a set of restoration strategies to address the limiting factors we identified. We mapped these restoration strategies on 44 restoration reaches across the study area. The restoration strategies are adapted from Roni et al. (2002) which suggest the following prioritization of restoration strategies: 1) protect and maintain natural processes, 2) remove barriers and reconnect disconnected habitats, 3) restore long-term processes (e.g., sediment routing, riparian function, nutrient cycling), and 4) restore short-term processes. We follow this basic prioritization framework but adapt it for the specific limiting factors we identified in the study area.

1) Protect and maintain natural processes

a) ***Protect fragile soils, maintain soil conservation practices, and protect and enhance riparian areas*** - Our assessment suggests that measures to minimize erosion in loess dominated watersheds should continue to be a top priority. Numerous conservation programs are promoted by ACCD and NRCS in the county, and landowners have adopted many best management practices to reduce erosion. These efforts should be continued and enhanced where erosion concerns still exist. Riparian protection and enhancement should also be a priority throughout the study area. Riparian habitat has shown great recovery in many areas, but these habitats can be easily damaged, and many riparian areas have been reduced which also makes them vulnerable to disturbance.

2) Remove barriers and reconnect disconnected habitats

a) ***Barrier removal*** - is paramount to recovering fish populations and should be a top priority for active restoration actions. In Asotin County, it appears most of the fish barriers have been removed (e.g., Headgate Dam was removed completely in 2016). However, there are potential flow barriers at the mouth of Tenmile and Couse Creeks. Addressing these barriers will involve a multi-stakeholder and agency participation.

b) ***Reconnect habitats*** - Disconnected habitats are generally restricted to the lower mainstem reaches where infrastructure density is highest. The disconnection of floodplain reduces the extent of riparian vegetation which can lead to increased water temperatures and reduced input of wood to streams. The confining features increase the velocity of high flows because the water is contained within the channel. These confined channels transport wood more effectively which reduces cover for adult and juvenile fish. Fish are especially susceptible when the flows are high because there is limited velocity refugia in these sections.

c) ***Promote overbank flow*** - We suggest another process that needs addressing is increasing the frequency and duration of overbank flow. This is a similar strategy to "reconnecting habitats" but has some important differences. Unlike reconnecting habitats, promoting overbank flow is appropriate where there are no readily identifiable confining features. This situation is very common in the study area. Successive floods over the last 200 years, removal of riparian areas, straightening of the channel, and removal of LWD have created very efficient "bowling alleys" out of many of the streams. In order to "reconnect" these streams to their floodplains, restoration strategies are needed that promote overbank flow. Strategies that either cause avulsions, deposition, and the slowing of flows would all help to achieve greater overbank flow. The IMW has recently installed almost 700 wood structures in Charley, North Fork, and South Fork Asotin Creeks and demonstrated that overbank flow can be achieved in these systems. Once overbank flow is more common, riparian areas will have the ability to expand (i.e., more water on floodplain), more refuge habitat will be available for fish during high flows, wood recruitment will increase, and groundwater recharge will increase. These responses can lead to improved riparian function, less solar input to streams (less heating), and better sediment sorting and storing (i.e., more gravel bars created for spawning, more sediment trapped on floodplain).

3) Long-term processes

a) *Riparian management* - Many of the mainstems of the study creeks have some form of riparian protection and as a result riparian function is moderate to high in the majority of the study area. However, significant areas are still in need of riparian protection. A variety of riparian management strategies will be required depending on the specific conditions and needs of landowners. In many areas, invasive weeds and/or upland encroachment are impairing the function of riparian areas. Active weed management and planting may be required in these areas. In other areas, grazing pressure is damaging riparian plants or preventing recruitment. Fencing and off-site water developments have been proven to help manage grazing pressure in these situations and have been successfully implemented by ACCD and their partners in the study area.

4) Long-term processes

a) Improve Instream Habitat - A common impairment of fish habitat in Asotin County is low habitat diversity. The limited riparian function, limited floodplain connection, and past floods have all led to low volumes of LWD in the streams. Large wood is a main driver of habitat complexity and its importance in stream processes is no longer in dispute (Roni et al. 2015). There are several alternatives to adding large wood to create habitat complexity. In areas of confinement and high densities of infrastructure (i.e., near towns and bridges), restoration strategies will require engineered approaches to reduce the potential that structures will fail or cause unintended consequences. However, in large portions of the study area where infrastructure is minimal, it may be appropriate to use non-engineered LWD restoration approaches such as post-assisted log structures or whole trees (Wheaton et al. 2012, Carah et al. 2014).

Alternative Strategies

There are a variety of other management strategies that could be beneficial to overall restoration objectives which include:

- Fuel reduction is a necessity across the west. Using a coordinated thinning program could be very effective at meeting fuel reduction, wildlife management, and stream restoration objectives. Snags, Legacy Trees, Openings, Patches, Piles, Shrubs, and Logs (SLLOPPS) is a forest fuels reduction approach that can be used to provide LWD small woody debris material for the benefit of forest wildlife and creating fish habitat (Strong et al. 2016).

- Traditional riparian management actions (i.e., fencing/exclusion) could be substituted in selected areas with controlled grazing that focuses on managing the timing, duration, frequency, and intensity of the grazing. Managed grazing in riparian areas can increase vigor and function and provide landowners with increased cattle production and alternative grazing areas (Swanson et al. 2015, Kozlowski et al. 2016).
- Recognition and use of beavers as nature's engineers is not new, but the increase in beaver management as a part of stream restoration has become very popular in recent years (Pollock et al. 2015, Bouwes et al. 2016b). There is an enormous potential in the study area to achieve multiple objectives at low cost by having beavers do the work. We suspect that many of the perennial streams were home to beaver populations prior to Euro-American settlement. Evidence of beaver activity is still common, and dams have been documented on the mainstem of Charley, North Fork, and South Fork Asotin Creeks. It is speculated that high densities of cougars and poor habitat conditions (long stretches of shallow habitat) are preventing beaver from recolonizing the study area. We propose developing a beaver management plan in conjunction with WDFW and local landowners prior to attempting a reintroduction.
- Nutrient enhancement (e.g., adding fish carcasses or analogs) has the potential to increase the effectiveness of stream restoration actions and this strategy could be implemented as a trial in the study area. There was a much more diverse fish assemblage in the study area historically and much higher densities of returning adults which would have provided substantial marine derived nutrients to the system. The reduced diversity and abundance of anadromous fish could be limiting the current carrying capacity and this could be tested with a trial. Nutrient enhancement has been moderately successful in some areas, but it is not widely used, and it is not clear how effective it is (Harvey and Wilzbach 2010, Childress et al. 2014, Bellmore et al. 2017).

Conceptual Restoration Plan

We used the results from this assessment to develop a Conceptual Restoration Plan in a separate report. The Conceptual Restoration Plan identifies and prioritizes restoration actions in 83 unique project areas within Asotin County. We developed the Conceptual Restoration Plan with input from the Nez Perce tribe, landowners, state and local agencies, Salmon Recovery Funding Board, Bonneville Power Administration, and oversight from Asotin County Conservation District, and the Snake River Salmon Recovery Board.

CONTENTS

LIST OF ABBREVIATIONS

ACCD	- Asotin County Conservation District
AQEA	- Anchor QEA
BDA	- Beaver Dam Analog
BRAT	- Beaver Restoration Assessment Tool
DEM	- Digital elevation model
DoD	- DEM of difference
DOE	- Washington State Department of Ecology
ELR	- Eco Logical Research Inc.
ELJ	- Engineered log jam
ESA	- Endangered Species Act
ESU	- Evolutionary Significant Unit
FSA	- Farm Services Agency
GCD	- Geomorphic change detection
IMW	- Intensively Monitored Watershed
LIDAR	- Light detection and ranging
LWD	- Large woody debris
NHD	- National Hydrography Dataset
NREI	- Net rate of energy intake
NOAA	- National Oceanic and Atmospheric Administration
NRCS	- USDA Natural Resources Conservation Service
PALS	- Post-assisted log structure (i.e., the proposed LWD restoration method)
PCSRF	- Pacific Coast Salmon Recovery Fund
PTAGIS	- PIT Tag Information System
RCAT	- Riparian Condition Assessment Tool
RM	- River mile
RCO	- Washington State Recreation and Conservation Office
RTT	- Regional Technical Team
RVD	- Riparian Vegetation Departure
RVCT	- Riparian Vegetation Conversion Type
SRSRB	- Snake River Salmon Recovery Board

USFS - United States Forest Service

USGS - United States Geological Survey

WDFW - Washington Department of Fish and Wildlife

KEY DEFINITIONS

Engineered structural elements: discrete objects in the valley bottom that are designed and built to remain static and intact following a predicted discharge (e.g., ELJs, levees, rip-rap, culverts).

Geomorphic unit: landforms with a distinct form to process association. Based on morphology, substrate, orientation, and forcing mechanism (building blocks of rivers).

Hydraulic units: spatially separated patches of homogenous substrate and surface hydraulics (synonymous with facies; building blocks of geomorphic units).

Non-engineered structural elements: discrete objects in the valley bottom with a typical design life of 5-10 years.

Structural elements: discrete objects in the valley bottom that directly influence hydraulics (e.g., LWD, bedrock, beaver dams).

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1. INTRODUCTION

1.1. BACKGROUND

The Asotin County Conservation District (ACCD) contracted with Eco Logical Research, Inc. (ELR) to conduct a geomorphic focused *Watershed Assessment* and develop a *Conceptual Restoration Plan* for Alpowa, Asotin, Couse, and Tenmile Creeks (hereafter referred to as the *study area*; Figure 1). We divided the Asotin Creek watershed into the Asotin Creek mainstem and George Creek for much of the assessment because George Creek makes up over 40% of the area of the Asotin Creek watershed, and the two creeks have distinct geomorphic characteristics. The watershed assessment and conceptual restoration plan are part of an overall effort within the Snake River Salmon Recovery Region to develop watershed-based strategic management plans that prioritize restoration projects that will most benefit the recovery of Endangered Species Act (ESA) listed salmon and steelhead and other species of management concern (e.g., AQEA 2011, GeoEngineers 2011). Eco Logical Research, Inc., in partnership with Anchor QEA (AQEA), used existing assessments as a template for conducting a geomorphic focused watershed assessment (hereafter "assessment") of the study area. We used the results from the assessment to develop a Conceptual Restoration Plan we provided in a stand-alone report. The approach we used will provide continuity with regional goals and objectives for stream restoration and species recovery. The ultimate goal of the assessment and conceptual restoration plan is to promote implementation of restoration projects that will improve habitat for steelhead (*Oncorhynchus* mykiss), Chinook salmon (*O. tshawytscha*), bull trout (*Salvelinus confluentus*), Pacific Lamprey (*Entosphenus tridentatus*), and other fish species while maintaining viability of local communities and agricultural producers.

1.2. GOALS & OBJECTIVES

We recognize that regardless of the rigor of the assessments and planning, the success of the project will ultimately hinge on stakeholder support. Therefore, communication and information sharing with local communities, landowners, and land management agencies is critical. We recognize there is a long history of public involvement in watershed restoration in the study area (e.g., ACCD 1995). The ACCD coordinated meetings, input, and review from both the public and Working Group to facilitate collaboration in the development of the assessment and conceptual restoration plan.

The goals of the Asotin County watershed assessment are to:

1) provide a summary and background of historic conditions, limiting factors, and status of fish distribution and habitat requirements,
2) conduct a comprehensive watershed assessment to evaluate the ecological function and geomorphic condition of the study area,
3) identify current impacts to fish and their habitats, and
4) outline potential restoration actions to mitigate current impacts.

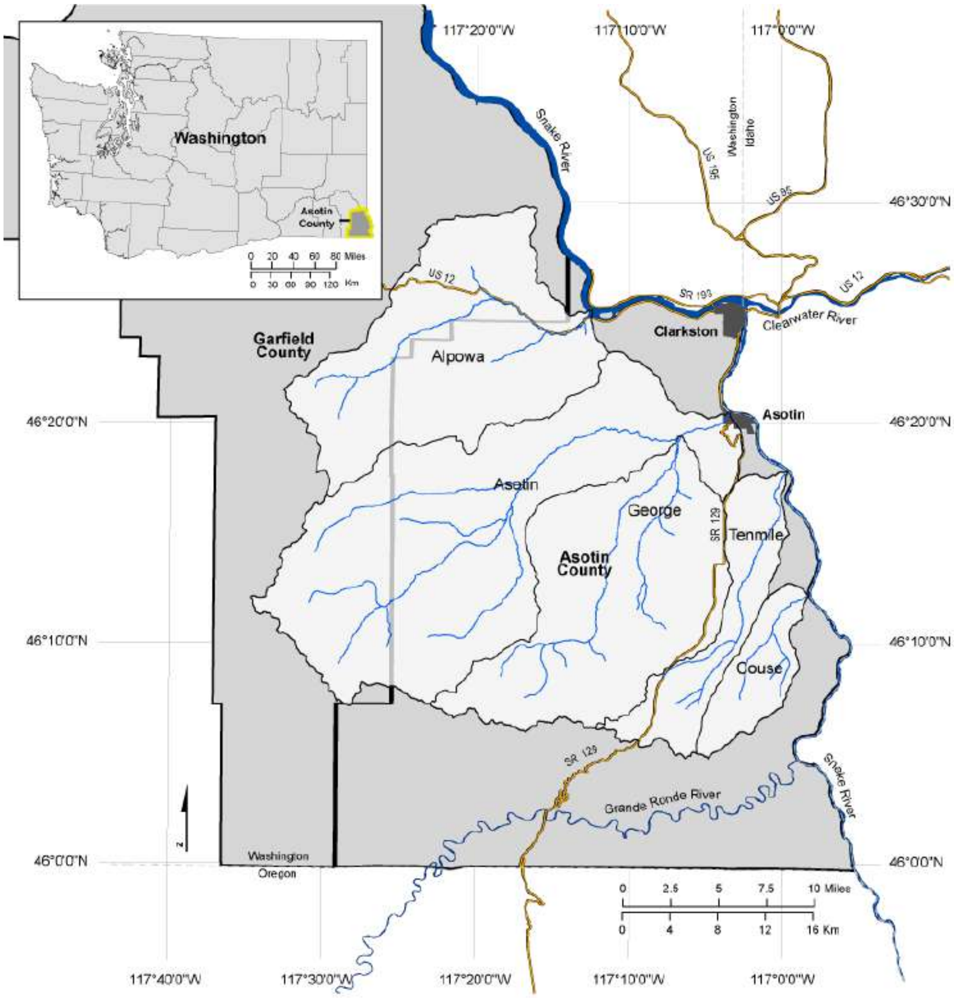

Figure 1. Asotin County and the watersheds included in the geomorphic and conceptual restoration planning process: Alpowa, Asotin, George, Tenmile, and Couse Creeks. Black lines are watershed boundaries, and the thick borders are the boundaries of Asotin and Garfield Counties. The stream layer is a modified perennial network based on the known distribution of steelhead and bull trout (Streamnet.org).

The specific objectives of Asotin County watershed assessment are to:

1. determine the type and location of stream reach types throughout the study area,
2. determine the geomorphic condition of each reach based on site visits, analysis of imagery, 1 m aerial light detection and ranging (LIDAR), and available geographic information system (GIS) data, riparian health and extent, floodplain connectivity,
3. determine what other factors may be impacting fish and their habitats (e.g., upland conditions, water quality),
4. determine the trajectory and recovery potential of geomorphic reaches (i.e., are things improving, stable, or getting worse, and what is the likelihood that restoration actions can improve conditions in 5-25 years), and
5. provide maps and summaries of reach conditions and other features that impact fish and their habitats.

We used results from the assessment to complete a *Conceptual Restoration Plan* contained in a stand-alone report. The goals of the Asotin County Conceptual Restoration Plan are to:

1. use the assessment results, meetings, and workshops with the public and the Asotin Working Group to develop a conceptual restoration plan, and
2. prioritize the locations for potential restoration projects that will lead to substantial improvement of instream habitat and riparian conditions for key life stages and a diversity of life history strategies of ESA listed salmon and steelhead, and other species of concern.

The specific objectives of the Asotin County Conceptual Restoration Plan are to:

1. prioritize each reach for restoration based on benefits to ESA listed fish, geomorphic condition, recovery potential (i.e., likelihood for success), economic, social, and other factors (landowner willingness, potential negative consequences, etc.), and
2. identify a series of high priority restoration projects that have a high likelihood of meeting current funding criteria.

1.3. ASSESSMENT FRAMEWORK

We based the assessment on the River Styles Framework developed by Brierley and Fryirs (2005) which distills an assessment into understanding "… why rivers are the way they are, how they have changed, and how they are likely to look and behave in the future." Many stream classification and assessment frameworks exist, but the River Styles framework provides the most exhaustive explanation of geomorphic and river context, making it ideal for restoration planning (Kasprak et al. 2016). We conducted our assessment to answer these questions and to better understand what restoration actions are appropriate and possible, and where best to apply them. We conducted a variety of assessments at different spatial scales to determine the condition of fish habitats across the stream network (i.e., Assessment Framework; Table 1). We enhanced the River Styles approach (Stage 1-4) for assessing the watershed condition using a set of network scale GIS models and mapping to understand other factors not directly related to geomorphology (e.g., riparian areas, floodplain fragmentation, stream temperature).

The first step (Stage 1) in our assessment was to describe the landscape setting and range of reach types present. The landscape setting (i.e., geology, climate, topography, vegetation) dominates the range of stream and habitat types available to fish and the productive potential of a watershed (Figure 2). Chemical, physical, and biological processes vary spatially and temporally across landscapes which in turn create a mosaic of habitat types (Spence et al. 1996, Beechie and Bolton 1999) and reach types based on landscape setting, valley setting, channel planform, floodplain and in-stream geomorphic units, and the caliber of bed material (Brierley and Fryirs 2005).The range and inherent productivity of habitat types directly relates to the fitness, abundance, and ultimately productivity of fish populations (Figure 2). Individual stocks of salmonids have adapted to the range of habitat conditions produced by particular landscape settings (Waples et al. 2009).

The remaining steps in our assessment focused on two stages: determining the geomorphic condition of individual reaches and conducting assessments of other key factors that influence fish habitat (GIS models and mapping; Stage 2), and recovery potential of each reach (Stage 3). In Stage 4, we prioritize restoration reaches and develop a conceptual restoration plan. The conceptual restoration plan is provided in a separate report.

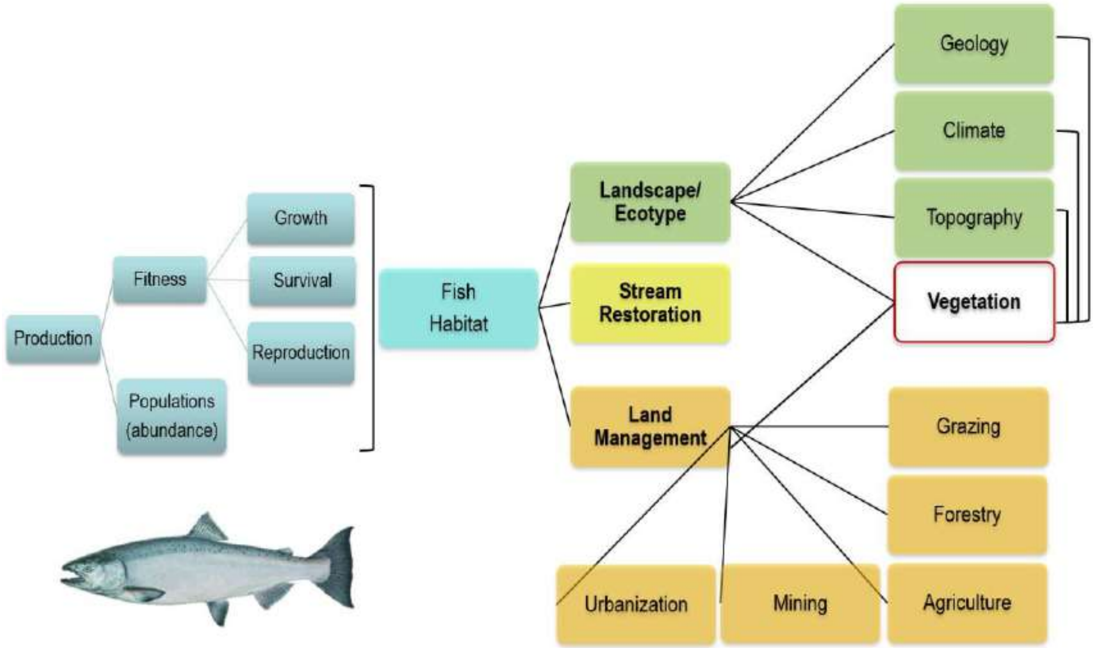

Figure 2. Landscape setting and land management activities that control the physical, chemical, and biological processes that lead to formation, sustainability, and spatial and temporal distribution of fish habitat. The availability of habitat in turn has direct influence on the fitness (e.g., growth, survival, reproductive success), abundance, and ultimately production of fish populations. Figure adapted Spence et al. (1996).

Table 1. Framework for assessing the condition and restoration potential of fish habitat in the Asotin County Watershed Assessment area (Figure 1) and spatial scale at which assessments were conducted. Geomorphic units are the smallest scale assessed and are the building blocks of reach types, streams, and ultimately fish habitat (Wheaton et al. 2015).

			Spatial Scale				
Task	**Stage**	**Description**	**Geomorphic Unit**	**Reach**	**Stream/ Subbasin**	**Landscape Unit**	**Watershed**
Landscape Units	Stage 1	distinct areas defined by topographic, geologic, vegetation, and climatic conditions				■	■
Land Use	Stage 1	identify specific land uses that directly or indirectly impact fish habitat quality or quantity		■	■	■	■
Reach Types	Stage 1	distinct segments of river defined by channel planform, floodplain and in-stream geomorphic units, and the caliber of bed material	■	■	■		
Geomorphic Condition	Stage 2	condition of reach types assessed by valley fragmentation, condition of channel, bed material, and assemblage of geomorphic units	■	■	■		
Riparian Condition Assessment	Stage 2	compare current to historic riparian extent, vegetation composition, and cause of change		■	■		
Beaver Capacity	Stage 2	historic and current capacity to support beaver dams based on stream power and vegetation		■	■		
Large Woody Debris Input	Stage 2	potential large woody debris input using riparian condition, vegetation age, density, size, and slope		■	■		
Stream Temperature	Stage 2	continuous stream temperature for perennial network by correlating satellite derived ground temperature to stream temperature probes & elevation		■	■		
Upland Vegetation	Stage 2	map forest fire potential based on fuel build up, grazing intensity, invasive vegetation, and upland vegetation encroachment on riparian		■	■	■	■
Recovery Potential	Stage 3	capacity for improvement of the geomorphic condition, flow, stream temperature, and other non-geomorphic limiting factors in the foreseeable future (e.g., 5-50 years)	■	■	■		
***** Stage 4 is provided in separate Conceptual Restoration Plan report***							
Management Priorities	Stage 4	develop a restoration prioritization framework with input and participation from landowners and the technical team based on geomorphic condition, recovery potential, potential fish benefits, and other factors	■	■	■	■	■
Management Priorities	Stage 4	develop conceptual restoration project areas in reaches identified as a high priority for restoration		■			

1.4. RESTORATION FRAMEWORK

Acknowledgement of the importance of landscape level processes in creating and sustaining fish habitat has led to a change in how stream restoration is planned and implemented. Historically, landscape level processes were ignored, and design and planning of stream restoration focused on conditions at the reach-scale (Thompson 2005, Doyle and Douglas Shields 2012, Rieman et al. 2015). Reach-scale approaches to restoration often failed to address which processes that create fish habitat are impaired. This led to reconstructed reaches and habitats that were not compatible with the natural potential of the stream, or tried to enforce static habitats that failed to recognize dynamic nature of stream habitats (Kondolf 2000, Kondolf et al. 2007). Actions that are more process-based are now commonly used in stream restoration. The goals of process-based restoration are to: address the root causes of degradation, (2) be consistent with the physical and biological potential of the site, (3) be at a scale commensurate with environmental problems, and (4) clearly articulate expected outcomes for ecosystem dynamics (Beechie et al. 2010).

We used a similar reach prioritization and restoration framework as described by Roni et al. (2002) and used in the Tucannon River Geomorphic Assessment (AQEA 2011) to develop a conceptual restoration plan and identify high priority project areas. The prioritization and restoration frameworks are described in detail in the conceptual restoration plan, but we briefly describe the frameworks here because the frameworks helped focus our assessment. We determined reach prioritization on geomorphic and riparian function, location of a reach within the stream network, potential for geomorphic and riparian recovery, ability to increase fish capacity, and input from landowners and the Working Group (Figure 3). We used the restoration framework to provide a simple hierarchical strategy for implementing restoration actions in specific project areas. In general, protection of high quality habitats and maintenance of natural processes should be the first restoration priority. The second restoration priority is the removal of barriers and reconnection of disconnected habitats because these actions can often provide large benefits by opening access to miles of previously inaccessible habitat (Roni et al. 2008). Restoration of long-term processes is fundamental to achieving lasting and sustainable restoration of stream habitat (Spence et al. 1996). A common example of restoring long-term processes is the removal or realignment of confining features (e.g., roads and levees) to allow the stream access to disconnected floodplain. Removing confining features leads to more interaction between the floodplain and the stream channel which can promote sediment sorting, recharging of the water table, improved riparian conditions, and greater recruitment of nutrients and large wood (Beechie et al. 2008, Bellmore et al. 2013). Restoration of short-term processes are typically the lowest priority in the restoration framework. However, because of the time required to restore long-term processes (e.g., recovery of riparian function can take decades), short-term restoration actions like adding large wood to the stream can be necessary. Addition of wood into the active channel can also enhance floodplain connectivity by promoting channel avulsions, slowing velocities and activating side-channels, and trapping sediment which raises the channel elevation (Wohl 2013, Roni et al. 2015). See the conceptual restoration plan for complete details on how these general frameworks were used to identify priority restoration projects in the study area.

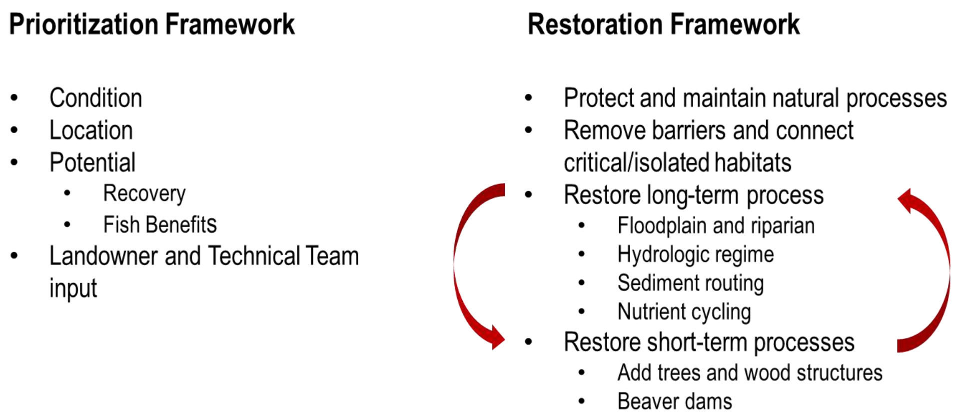

Figure 3. Reach prioritization and project area restoration framework used in the Asotin Watershed Assessment. Adapted from Roni et al. (2002). Red arrows indicate that sometimes short-term processes need to be implemented in order to promote recovery of long-term processes (e.g., adding large woody debris to promote overbank flow and channel avulsions, which can increase floodplain connection and promote riparian recovery). See Bennett et al. (2018) for details on the Conceptual Restoration Plan.

1.5. REPORT ORGANIZATION

The first two sections of this watershed assessment report provide background and description of the Study Area and the Land use and Conservation Efforts in Asotin County and southeast Washington state. Next the Geologic and Watershed Setting section provides the physical context of Asotin County as it relates to geology, soils, hydrology, stream flow, and sediment routing. The Fish Resources section then provides background on the focal fish species (Chinook salmon, steelhead, bull trout, and lamprey), their status, distribution, and habitat requirements. The remainder of the report focuses on the Watershed Assessment Methods and Results (Stage 1-3). We conclude the report with a description of reach characteristics that form the basis for developing the Conceptual Restoration Plan. Details of the assessment methods and results of field surveys, data analyses, and mapping are provided in the following Appendices:

Appendix A – Maps and data summaries

Appendix B – Auxiliary Tables

Appendix C – Auxiliary Figures

Appendix D – Network methods

Appendix E – Confining features by stream and river mile identified with 1 m LIDAR

2. STUDY AREA

The assessment covers most of Asotin County and includes Alpowa[1], Asotin, Tenmile, and Couse Creeks (Figure 1). The lower Grande Ronde River is within Asotin County but will be assessed at a later date. All the creeks in the

[1] Note. Only the lower portion of Alpowa Creek is within Asotin County.

study area flow directly into the Snake River: Asotin, Couse, and Tenmile Creeks enter the Snake upstream of the town of Clarkston, Washington and the confluence of the Snake River and the Clearwater River. Alpowa enters the Snake River downstream of Clarkston (Figure 1). Alpowa Creek is 453 mi, Asotin 470 mi, Tenmile 475 mi, and Couse 482 mi from the ocean. There are eight mainstem dams downstream of the study area: four Snake River dams (Lower Granite, Little Goose, Lower Monumental, and Ice Harbor), and four Columbia River dams (McNary, John Day, The Dalles, and Bonneville).

The study area is within the Columbia Plateau and Blue Mountains level III ecoregion (Omernik 1987, Clarke 1995, Omernik 1995). The area is dominated by deep narrow canyons cut into underlying basalt lithology and surrounded by semi-arid sagebrush steppe and grasslands at lower elevations and open conifer dominated forests at higher elevations. The area is semi-arid, receiving less than 12 in of precipitation at lower elevations (Appendix A. 1). However, the headwaters of Asotin Creek drain from the Blue Mountains and can receive over 45 inches of precipitation. The area is prone to large floods associated with either highly localized, high intensity summer thunderstorms, or winter rain-on-snow or rain-on-frozen ground that causes rapid runoff. Temperatures vary greatly between seasons, with highs in the summer sometimes reaching > 100° F, and winter highs < 32 ° F. The wettest period is from March to June (3-4”/month) and the driest period is during the summer from July to September (1.5”/month).

All of the watersheds in the study area are relatively short (~ < 25 miles long), moderate to high gradient along the mainstems (2-3%), with narrow valley bottoms, and surrounded by steep side hills. The main difference between the watersheds is maximum elevation, land ownership, land cover, land use, and their hydrologic regimes (Table 2, Appendix A.2-6). Asotin Creek and parts of George Creek have a greater proportion of their watershed above 5,000 feet elevation (i.e., headwaters flow from the Blue Mountains), have more public land, less agriculture, and have hydrologic regimes dominated by snow-rain. Couse Creek, Tenmile, and Pintler Creek (a tributary to George Creek) do not exceed 5000 feet elevation, are almost entirely privately owned, the land use is predominately agriculture, and they all have hydrologic regimes dominated by groundwater. In all the watersheds, the proportion of perennial stream miles to intermittent and ephemeral stream miles is very low (~ 0.01%). These differences and the general dry-low flow environment of the area have a profound effect on the geomorphic condition and habitat available for fish. Large portions of Couse, Tenmile, Pintler, and the lower elevations of George Creek regularly go dry and these watersheds tend to be flashy (i.e., short-duration but intense runoff events).

The fish bearing extents of the streams are also influenced by the character of the watersheds. In Asotin Creek and George Creek, steelhead and bull trout distribution extends from the base elevation at the Snake River almost to the top of the watershed (Appendix A. 8). In Couse, Tenmile, and Pintler, the extent of steelhead is restricted to lower elevations because of the hydrologic regime and character of the watersheds. The streams in the study area are generally small to medium sized with most fish bearing reaches being stream order 2-4. The creeks in the study area range in size from 30-40 bankfull width and 1.0-1.5 % gradient (e.g., Asotin Creek, North Fork Creek) to 1-5 feet bankfull width and 5-10% gradient (e.g., upper North Fork, Upper George Creek, and Cougar Creek).

Table 2. Basin characteristics for the Asotin Creek, four Asotin Creek tributaries (George, Charley, North Fork, and South Fork Creeks), and Alpowa, Tenmile, and Couse Creek.

		Asotin Creek Tributaries						
Characteristic	**Asotin Creek***	**George Creek**	**Charley Creek**	**North Fork**	**South Fork**	**Alpowa Creek**	**Tenmile Creek**	**Couse Creek**
Drainage Area (acres)	208,312	82,520	14,419	40,749	25,658	83,770	26,935	15,321
Mean Elevation (feet)	3,350	3,150	3,990	4,280	4,050	2,539	2,910	2,910
Min Elevation (feet)	741	942	1710	1840	1850	741	758	784
Max Elevation (feet)	6,201	5,470	5,580	6,200	5,980	4,701	4,131	3,911
Max Relief (feet)	5,459	4,530	3,870	4,360	4,130	3,960	3,369	3,120
Mean Slope	24	15.4	33.5	39.6	28.7	23	17	24
% Area w/ Slope >30%	36	18.7	56.5	67.5	43.1	33	25	37
% North-Facing Slopes >30%	10	4.13	16.7	18.1	11.9	9	5	7
Percent Forested Area	21	13.7	38.9	43.9	29.8	2	7	4
Mean Annual Precipitation (inches)	22.8	20.7	26.5	29.9	27.5	18.9	18.1	16.9

**** Asotin Creek including George Creek***

3. HISTORY AND LAND USE

The area now delineated as Asotin County and southeast Washington has been occupied by humans for thousands of years. Villages or semi-permanent dwellings have been documented along the major rivers and streams of the area as far back as 4300 years ago (Ames and Marshall 1980). The following section provides a brief overview of the people and land uses in Asotin County and southeast Washington, especially as they relate to possible uses and impacts on fish, fish habitat, and water resources. We also summarize the major restoration actions that have taken place in the County to help set the context for the condition assessment as described in this report.

3.1 NATIVE AMERICAN HISTORY AND LAND USE

The indigenous peoples of southeast Washington refer to themselves as Nimiipúu (“the people”) and have been living in the area for thousands of years (NPT 2003, 2013). Nez Perce, meaning "pierced nose”, is the name given to the Nimiipúu by French Canadian fur traders who visited the area in the late 18th century. The Nimiipúu homeland was extensive and covered parts of Oregon, Washington, Idaho, Montana, and Wyoming. This area reached from Portland, OR in the west to Bozeman, MT in the east, and from almost Spokane, WA in the North to Boise, ID in the south, covering over 13 million acres (NPT 2003). The Nimiipúu territory contained at least 300 village sites located along rivers and places with abundant fish, wildlife, and edible plants. Bands of family members and relatives occupied the villages which were often named by the location of the village (often a river name) and leader of the band. This suggests how important rivers and the fish resources provided by rivers were to the band members.

Trade with neighboring tribes such as the Palouse, Cayuse, Umatilla, and others was common. The Nez Perce acquired horses sometime around 1730 through trade with other tribes and soon became skilled horsemen (Beckham 1995). The vast and productive grasslands within the Nimiipúu territory allowed them to keep large herds of horses and these were used to expand trade and travel. Interaction with fur traders, settlers, and miners increased through the 1800's starting with the Lewis and Clark expedition in 1805 and 1806. Tensions between Nimiipúu and Euro-Americans increased as more settlers and miners entered the Nimiipúu territory and began to claim land. The Nimiipúu first entered into a treaty agreement with the federal government in 1855 when it was clear that they needed to preserve their historic rights to fish, hunt, pasture animals, and practice their customs and religion. The 1855 treaty reduced the Nimiipúu territory to 7.5 million acres, but importantly maintained the rights of Nimiipúu to fish, hunt, collect roots and berries, pasture animals, and erect temporary buildings at all "usual and accustomed places" upon open and unclaimed land (NPT 2003). By the 1860's more settlers and an influx of miners and settlements to support gold mining again created conflict, and the Nimiipúu territory was reduced to 750,000 acres in 1863. The Dawes Allotment Act of 1887 further reduced the territory to 250,000 acres. Despite the loss of their original territory (>98%), the Nimiipúu have never given up their rights to fish, hunt, and gather, and these rights have been upheld in several court decisions (NPT 2003).

The area currently delineated as Asotin County features prominently in the historical use by the Nez Perce. A village was based at the mouth of Asotin Creek and Alpowa Creeks, and numerous trails were used in Asotin County to travel within the area and to other places such as the Tucannon, Snake, and Columbia River for fishing, hunting, gathering other food, and trading. There were also trails up the Clearwater and over Lolo Pass into Montana, where Nimiipúu would hunt buffalo, gather bitterroot, and trade with plains tribes (NPT 2003). Especially important were annual trips to the Celilo Falls along the Columbia River. Well documented congregations of numerous tribes took place at Celilo Falls every summer to capture migrating steelhead, salmon, and lamprey and trade for other items (Landeen and Pinkham 1999). This harvest area and gathering place is thought to be one of the longest permanently used areas by humans in North America.

Nimiipúu traveled extensively within their homeland and throughout the study area. They typically lived along the rivers in the fall and winter, and seasonally traveled to areas based on availability of game, various plants, and migration of salmon, steelhead, Pacific lamprey, and other fishes (Pinkham 2004, NPT 2013). Many of the streams in the assessment area derive from Nimiipúu names. For example, Asotin Creek is the English way of saying "hesuutin" which translates to "with eels". Harvest of salmon, steelhead, lamprey, and suckers within the target watersheds were and continue to be a critical food and cultural resource for the Nimiipúu. It has been estimated that each tribal member consumed almost 600 pounds of fresh, dried and/or smoked salmon per year (Walker 1967, Marshall 1977, NPT 2013). They harvested primarily salmon and steelhead species, but lamprey, trout, whitefish, suckers, sturgeon, pike minnow, and other non-game fish were consumed (NPT 2013). Oral traditions play a central role in Nez Perce culture and stories about fish, and the importance of fish to the Nez Perce play a central role in their oral history (NPT 2003). Band members would camp at fishing areas prior to arrival of migrating fish – stories of fish that were so abundant they could be heard migrating upriver hint at the abundance that has been lost.

The goal of the Nez Perce Tribe and the role of the Department of Fisheries Resources Management (DFRM) is to "restore a balance with nature, bring fish populations and their habitats to healthy conditions, and provide harvest opportunities for tribal members (NPT 2013)." The Nez Perce work with local, state, and federal agencies to promote and conduct fisheries restoration projects, reintroductions, and operate hatcheries in hopes that populations will recover, and harvest rates can be increased for tribal members and residents of the county (NPT 2013).

3.2 EURO-AMERICAN HISTORY AND LAND USE

After the expedition of Lewis and Clark in 1805-06, trappers were likely the first Euro-Americans to explore the Columbia River Basin and the study area (Beckham 1995, Rieman et al. 2015). Since then, there has been a steady increase in development activities and population growth across the Columbia River Basin. Mining, building of the railways, and agriculture peaked in the early 1900s, logging and hydropower development peaked from the mid to late 1900s, and urbanization, climate change, and invasive species continue to be major sources of impact to streams and watershed processes through to present times (Figure 4). The following sections briefly describe the settlement of southeast Washington and Asotin County.

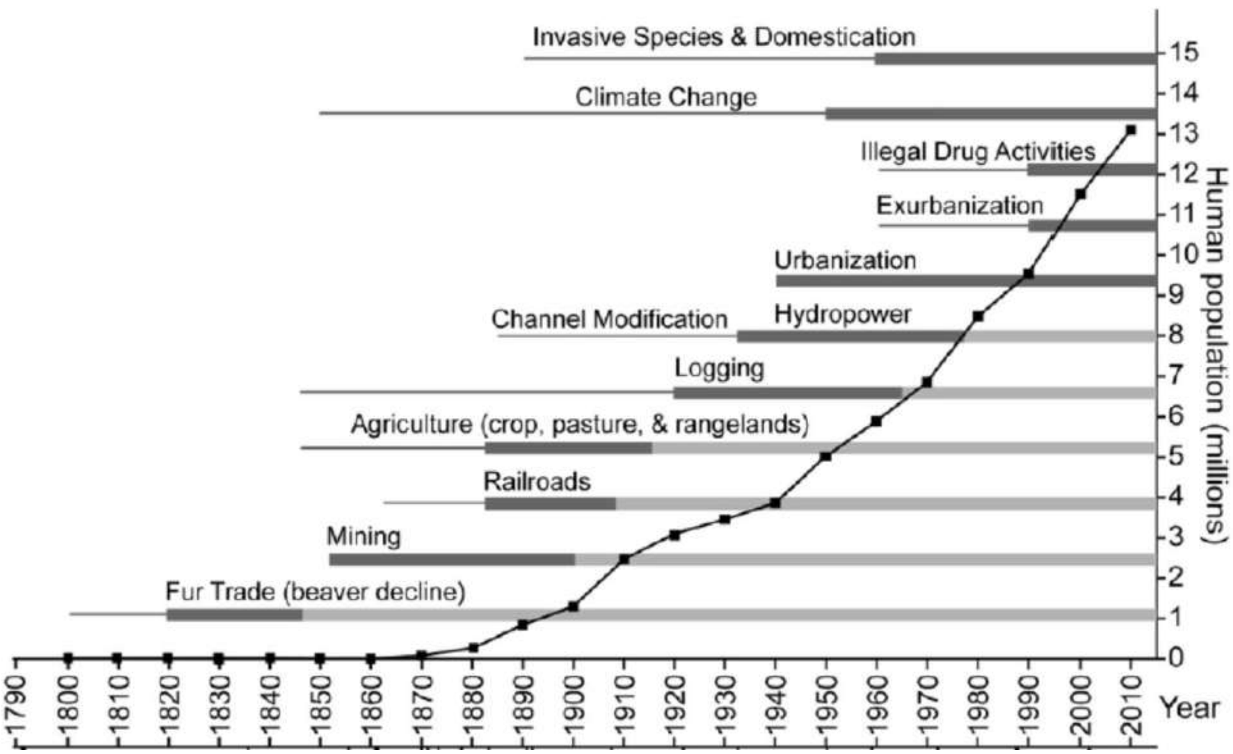

Figure 4. Development (bars) and population change (line) in the Columbia River Basin. Wide dark bars = peak development; wide light bars = continued effects (modified from Rieman et al. 2015, Penaluna et al. 2016).

3.2.1. Lewis and Clark

Lewis and Clark were likely the first Euro-Americans to travel through southeast Washington (Beckham 1995). The Lewis and Clark Expedition began near St. Louis, Missouri in May 1804. By October 1805, they had arrived near what is now Clarkston, WA where they describe the Snake River as “wide and deep.” They continued downstream to the mouth of Alpowa Creek which was the site of a large village, likely shared by the Nez Perce and Palouse tribes. Archaeological excavations in this area have defined a 6000-year occupation sequence and found houses that dated as far back as 4300 B.C. (Adams et al. 1975, Brauner 1976, Ames and Marshall 1980). The expedition left Alpowa and continued down the Snake River to the mouth of the Columbia River. Near Almota, Deadman, and Alkali Flat Creeks, several members of the expedition commented on the extent of dry, barren plains completely absent of timber aside from willow and hackberry. They made similar notes about the absence of timber along the Snake River downstream of Alpowa Creek (UNP 2005). Photographs from the early 1900’s seem to confirm limited woody vegetation along the Snake River in Asotin County. This may be evidence of the impact of the long history of

Native Americans camping along the Snake River and/or the dry, steep banks of the Snake River in this area that have limited floodplain

When Lewis and Clark returned to the area in May 1806, they took an overland route rather than retracing their steps upstream on the Snake River. They traveled up the Walla Walla River from the Columbia River, and then crossed the Tucannon River and Pataha Creek to cross over Alpowa Summit. They likely accessed the Alpowa Watershed by following Stember Creek down to the mouth of Alpowa Creek to revisit the villages they left nearly five months earlier. Lewis, Clark, and several of their Captains described the high plains between the Snake and Clearwater River confluence as being extremely fertile and well covered in ponderosa pine with some western larch and grand fir.

3.2.2. Fur Trade/Pre-settlement

Trappers seeking beaver and otter pelts began to travel through southeast Washington soon after the Lewis and Clark expedition and trapping likely occurred in Asotin, Garfield, and Columbia Counties (Tucker 1940, Ott 1997). In 1818, Britain and the United States signed a joint occupation agreement of the area known as the Columbia District which included present day Washington, Oregon, and parts of Idaho, and Montana. Britain, via the Hudson Bay Company, attempted to discourage Americans from claiming land along the Snake River, which was a key route into the Columbia territory for settlers. The Hudson Bay Company implemented a policy to create a "fur desert" (Ott 1997). From 1824-25 and 1829-30 six expeditions were launched with the explicit intent to trap beaver to near extinction, thereby de-incentivizing American trappers from using the area, and ultimately slowing the rate of American settlers moving to the area (Ott 1997). It is unclear how successful these trapping efforts were, but notes from Peter Ogden, the leader of the expeditions, suggest that they were at least partly successful. Between 1823-1841, 35,000 beavers were trapped out of the Snake River region and the annual trapping rates decreased from highs of 4,500 beaver/year in 1923-24 to 600 beaver/year in 1831-32. Nez Perce were not involved in trapping nearly as much as other tribes in the Columbia Plateau because they identified more with raising horses and cattle, and hunting big game on the plains (NPT 2003). The fur trade dwindled by the 1850's as fur hats in Europe fell out of fashion.

In the 1840-50's, the Nez Perce continued to expand their herds of horses and began to raise cattle more, which allowed them to travel and trade more. Nez Perce were known to drive cattle to Salt Lake City to take advantage of large influxes of setters to Utah (Ott 1997). At the same time, the number of Euro-American settlers coming into southeast Washington was increasing rapidly. These settlers put pressure on the United States government to grant them lands and laws started to be enacted to form official territories (e.g., Oregon Territory was formed in 1848). Discovery of gold in the Clearwater River in 1860 brought miners, settlers, and the development of Euro-American settlements. Development of farms, orchards, towns, and transportation infrastructure increased rapidly from 1860 onward. The Homestead Act of 1862 increased the number of setters that began farming and gave settlers a "base of operation" on which they could build a home, winter cattle and take advantage of the abundant federal lands to graze large herds in the summer (Beckham 1995).

3.2.3. Euro-American Settlement

The first permanent settlement in Asotin County appears to be around 1860. The town of Asotin was established in 1868 and Asotin county was established in 1883 (VSP 2017). Sheep and cattle grazing expanded rapidly with sheep generally grazing the uplands and cattle grazing along streams and rivers (Johnson 1995). Herds of horses were also common and kept by both the Nez Perce and Euro-Americans. Almost 700,000 horses were present in 91 counties east of the Cascade Mountains in the Columbia River basin by 1910 (Beckham 1995). Sheep ranching peaked in this area in 1910 at 6.5 million head, while cattle ranching outpaced sheep in the 1950s, peaking at 4.3 million head in 1987 (Beckham 1995). In Asotin County by 1910, there 555 farms averaging 342.3 acres, with a total of 5,000 horses, 5,000 cattle, and 50,000 sheep (USBC 1913).

We conducted a review of General Land Office Survey (GLOS) notes to assess selected stream crossings that the original surveyors made in Asotin County between 1876 and 1877. We used archived GLOS survey PLATS from the Bureau of Land Management (BLM 2018). We used methods outlined in Dilts et al. (2012) and White et al. (2017). The Public Land Survey System of townships and ranges was established in 1812. Public lands were divided into 6 x 6 mile townships and each township was divided into 36 sections. GLOS crews would map all the section lines and record the distance along the section line of stream crossings, soil quality, vegetation types, and other survey data. Because the townships and section lines were surveyed, the information along the section lines can be spatially referenced in GIS. We reviewed 42 stream crossing surveys and summarized the results by RM along each of the major study creeks (Appendix A. 9). Although these records are often difficult to interpret, the results of our analysis suggest that riparian vegetation along the major creeks in the study area was already converted to pasture (recorded as grass cover) or degraded to gravel and cobble floodplains as of 1877. This may be evidence of the rapid use of a relatively small supply of wood along the lower reaches of the study creeks by settlers moving into the area and building homes and businesses and intensive grazing by horses, sheep, and cattle.

Development of roads, irrigation infrastructure, dry land farming, and logging also increased to support the growing population. The mid elevation productive bunch grass prairie of Asotin County (especially in Couse, Tenmile, and George Creek) began to be developed for wheat production in the 1870's (ACWG 2017). Development was rapid and by the 1930's there were extensive orchards in Alpowa, Asotin, and Clarkston which used water from both the Snake River and the local creeks via diversions and flumes. These activities likely had a dramatic impact on fish and habitat. McIntosh et al. (1994) document that there were at least 13 water diversions in Asotin Creek from 1935-1936, with two of the diversions removing all the water during summer low flows. These diversions dewatered the lower eight miles of Asotin Creek, and a fish salvage operation recovered 250,000 juvenile steelhead and 28 adult Chinook (thought to be the entire run that year).

Logging in the 1930s through to the 1950s was also extensive and reports suggest that almost the entire accessible timber was harvested three times (selective, seed tree, and eventually clearcutting). All these development activities led to extensive erosion problems throughout the study area. In Asotin Creek and forested areas, erosion was mainly due to road development, whereas in the low and mid elevation agricultural lands, erosion was mainly due to farming practices that left many acres prone to sheet and rill erosion (SCS 1980). Fine sediment became a principal threat to fish and fish habitat.

3.2.4. Current Land Use and Conservation

Agriculture is the dominant land use in the Asotin County and the study area and the two most common agricultural activities are cattle grazing (162,462 acres) and dryland farming (84,330 acres; ACWG 2017). As of the 2012 census, there are 185 farms averaging 1,423 acres in size (USDA Census 2012). Cattle grazing occurs on private land and on grazing allotments on USFS land, generally from the spring through the fall. Most cattle are kept along the mainstems of the major creeks during the winter. Logging operations are still continuing in the headwaters of the study area but at much reduced rates and there is some private woodland (14,412 acres).

Restoration initiatives began in the 1980s and increased dramatically after 1995. In 1995, a Model Watershed Plan was developed by local landowners and agencies to reduce soil erosion, improve water quality, and improve instream conditions (ACCD 1995). After the plan was developed, there were many upland conservation practices implemented through programs funded by Washington Salmon Recovery Funding Board (SRFB), Washington Conservation Commission, Washington Fish and Wildlife, Bonneville Power Fish and Wildlife Mitigation Program, and USDA NRCS and Farm Services Agency (FSA). The NRCS and FSA programs alone have invested over $38.6 million in Asotin County conservation programs since 1995-2015 (conservation.ewg.org). The NRCS and FSA mange a number of programs that are designed to protect water quality, reduce soil erosion, and enhance soil quality, such as managing nutrients and pesticides to reduce runoff and reduced- or no-till practices. The most common programs are the Environmental Quality Incentives Program (EQIP), Conservation Reserve Program (CRP), Wildlife Habitats Incentive Program (WHIP), and the Conservation Stewardship Program (CSP). The CRP program is the largest program and has had over 22,000 acres of agricultural land enrolled in mainly native grass, introduced grass, and riparian buffers. Other programs since 1995 have been responsible for fencing at least 87 miles of riparian fencing, 6 miles of terraces and 30 sediment ponds (to reduce sediment reaching streams), 31 off-site watering locations for cattle (to reduce grazing in riparian areas), planting of over 200,000 trees and shrubs (mainly along streams), 40 miles of road decommissioned, and numerous instream projects and other improvements to farm practices (Johnson 2000, Ullman and Barber 2009).

These programs have been very successful in reducing erosion and stabilizing/enhancing riparian areas throughout the region which has led to direct benefits for fish and water quality. We were unable to get monitoring data that is consistent across years to fully understand the trends in habitat conditions, but it is generally appears that 1) erosion issues have been largely mitigated and 2) instream habitat and riparian areas are generally stable and most of the mid to upper elevation areas are improving slowly. However, there are still many legacy effects of development activities (much of which occurred pre-1950) and many stream miles are still in a degraded state (Scott et al. 2011).

4. GEOLOGIC AND WATERSHED SETTING

4.1 GEOLOGIC SETTING

The geologic setting of the study area typifies many of the tributaries to the Snake River in southeast Washington and northeast Oregon in terms of its basic physiographic setting. Three broad geologic attributes set the character of the study area: 1) the underlying igneous bedrock sourced from lava flows which are part of the Columbia River Basalt Group that forms the broad plateau surfaces and uplands; 2) the Snake River Gorge, which sets the base-level control for the target watersheds, 3) the steep canyons that dissect the lava flows with a network of streams draining to the Snake River. Valley bottoms in the larger tributaries have formed discontinuous deposits of shallow alluvium. The Columbia River Basalt Group is a thick sequence of flood basalts that spread throughout northern Oregon, eastern Washington and western Idaho during the Miocene between 6 and 17 million years ago. During the Pliocene (5.4 to 2.4 million years ago) these basalt flows were uplifted, allowing the antecedent streams to form steep-sided canyon walls and hillslopes and formation of high plateaus (Gentry 1991). Many of these high plateaus are mantled by loess (wind-blown sediment) deposits. The Snake River Canyon, at the mouth of target watersheds, was subjected to the cataclysmic Bonneville flood 14,000 to 15,000 years ago. Deposits from the Bonneville flood are overlain by additional flood deposits associated with drainage of Glacial Lake Missoula.

4.2 LANDSCAPE UNITS

We grouped large areas within the study area into distinct landscape units that can be defined as areas with a similar combination of geologic, soil, elevation, topographic, climatic, and vegetation properties. By grouping areas into landscape units, we can predict how streams will function and what basic properties they may have (e.g., transport zones, areas where large woody debris is an important driver of geomorphic diversity in channels, etc.). We described four landscape units in the Asotin Creek drainage (Table 3, Appendix A. 7). The landscape units are largely based on 1:250,000 scale Level IV EPA ecoregions (Omernik and Griffith 2014). We refined some of the landscape unit boundaries based on geologic unit mapping at a finer 1:100,000 scale (Schuster 1993) because geology exerts the greatest control on river character and behavior, the key drivers of geomorphic reach types.

The four landscape units are mesic forest zone, dissected highlands, dissected loess uplands, and lower Snake canyons.

The mesic forest forms the headwaters of the higher elevation target watersheds and is dominated by conifers and native shrubs. The dissected highlands are a transitional zone between the mesic forests and lower Snake canyons. These highlands are characterized by steep valley walls with expansive basalt outcrops and mixed conifer and deciduous forests. The dissected loess uplands are basalt formations topped by deep loess soil deposits. In the last 150 years, the loess uplands have been converted into agricultural areas with a primary focus on wheat. The lower Snake canyons are large, deep valleys with stacked sequences of basalt cliffs comprising the valley margins. This unit contains mostly high order streams (3rd-4th order) and shows great variability in elevation and valley width.

Table 3. Distinguishing characteristics of landscape units in the Asotin Creek drainage.

Parameter	Mesic Forest	Dissected Highlands	Dissected Loess Uplands	Lower Snake Canyons
Landscape Morphology	Steep valleys, largely forested	Plateau dissected by basalt cliffs into deep valleys	Flat plains, dissected by large washes, heavy agriculture	Deep valleys with high relief, often dissected down to basalt formations
Landscape Position	Headwaters of Asotin drainage, Blue Mountains	Between Mesic Forest and Lower Snake Canyons	Valley ridges and basalt plateaus	Extends up mainstems and major tributaries, dissecting uplands
Vegetation	Mostly conifers, riparian is often thick with native shrubs	Mix of conifers and deciduous trees, riparian transitions between shrubs and grasses; valley slopes are often associated with semi-arid shrubs like sagebrush	Mostly plains grasses and low shrubs, heavy agriculture	Mostly deciduous trees, upper riparian sections are mostly native shrubs, lower elevations show encroachment of non-native shrubs and grasses
Geology	Basalt/andesite	Basalt/andesite	Basalt/andesite topped with loess	Basalt/andesite
Relief (ft)	Up to 1000	Up to 1000	Up to 500	1300
Elevation (ft)	4000 – 6200	2600 – 5200	1000 - 3600	600 - 4600
Valley Slope (%)	5 - 15	1 - 4	Flat to <3	1 - 4
Valley Width (ft)	30 - 100	60 - 160	$\geq$ 10	60 – 1000
Stream Examples	NF of North Fork, Cougar Creek	SF of South Fork, upper Charley Creek,	Mill Creek, upper Pintler, Tenmile, and Couse Creeks	Lick Creek, lower Charley Creek, Alpowa Creek

4.3 HYDROLOGY

4.3.1. Hydrologic Regimes and Climate Change

The vast majority (88%) of the 1464 mi (2357 km) of streams dissecting the Asotin Watersheds are ephemeral and intermittent. This is a reflection of the semi-arid climate with most of the area receiving less than 19” of precipitation annually (Appendix A. 1). Of the 174 miles of perennial streams, they can be broken into three current flow regimes: groundwater dominated, snow-rain dominated, and snowmelt dominated (Appendix A. 5). In general, perennial creeks that have headwaters in the Blue Mountains mesic forest landscape unit (e.g. Asotin Creeks and George Creek) tend to have snow-rain dominated flow regimes; whereas subbasins that have headwaters that are sourced in the loess uplands tend to have groundwater dominated flow regimes. The elevation of the headwaters is a dominant control as the Blue Mountains at 4000 to 6000 feet are barely above a reliable snowline and experience a modest snowpack (Table 4), but the Dissected Loess Uplands range from 1000 to 3600 feet above sea level and do not produce reliable snowpack. A mixture of snow and rain provides the majority of flow across the target watersheds (64%), meaning that flows are primarily driven by spring snowmelt, but rain is a significant secondary driver. The upper tributaries of the North Fork of Asotin are primarily driven by snowmelt. Groundwater is locally important and sustains modest perennial flows in streams including Alpowa, Pintler, Tenmile, and Couse Creeks.

The range of hydrologic regimes across the target watersheds is expected to change under predicted climate change scenarios (Appendix A. 6). Higher maximum and minimum temperatures, higher intensity precipitation events, increased frequency of extreme events, and a less reliable snowpack are all expected. As such, the hydrologic regime in the target watersheds is predicted to shift from snow-rain dominated to rain-dominated for many of the mid-sections of the Asotin and George Creek, which are home to the most fish. The loss of a snow-rain dominated flow regime for much of Asotin and George Creeks and reduction of a reliable snowpack in the Blue Mountains would likely decrease summer base flows, increase summer water temperature, and increase the prevalence of subsurface stream sections throughout the study area. This is illustrated in Appendix A. 20 through Appendix A. 23, with a dramatic increase in the number of weeks where stream temperatures are expected to exceed 18 °C. Restoration and management planning should take climate change scenarios into consideration because ESA-listed fish species will be directly affected by the predicted changes in hydrologic regimes.

4.3.2. Stream Flow Monitoring and Annual Statistics

The most consistent and robust flow records exist for Asotin Creek. In Asotin Creek, stream flow is monitored by the United States Geological Survey (USGS), Washington Department of Ecology (DOE), and ELR (Table 4). The earliest discharge records and the longest continual monitoring were collected at Headgate Dam on the mainstem Asotin Creek from 1928-1959 (USGS 13334500). The next longest record of discharge is from a USGS gauge at Kearney Gulch on the mainstem upstream from Headgate Dam (1960-1995; USGS 13334700). Both of these mainstem gauges are no longer active. Active monitoring of discharge on the mainstem Asotin is now done at the mouth (USGS 13335050; not real time), just upstream of George Creek (DOE), and just downstream of the confluence of North Fork and South Fork (USGS 13334450). Mean monthly discharge peaks in May but annual peak discharge can occur anytime from December to June (Figure 5).

Table 4. Discharge records available with the target watersheds and estimates of mean annual and peak flows (cfs) for the period of each gauge station. Estimates are modeled from stage height relationships and estimates from Asotin Creek, Charley Creek, and North and South Fork Asotin Creeks were derived from filling in data gaps with correlations with other nearby gauges.

Stream Name	Mean Annual Flow (cfs)	Peak Flow (cfs)	Agency/Gauge#	Period	Site Location
Asotin Creek	94	6334	USGS 13334500	1928-1959	Headgate dam
			USGS 13334700	1960-1995	Kearney Gulch
			USGS 13335050	1991-present	Highway 129 bridge
			USGS 13334450	2003-present	Below confluence of NF and SF
			DOE 35D100	2005-present	Above confluence of Asotin and George Creeks
Charley Creek	10	89	ELR (water height)	2009-present	Charley Creek just upstream of Asotin Creek Road crossing
North Fork Asotin Creek	45	525	ELR (water height)	2009-present	derived from relationship between South Fork water height gauge and USGS 13334450
South Fork Asotin Creek	14	171	ELR (water height)	2009-present	Mouth of South Fork Asotin Creek just upstream from confluence with North Fork
George Creek	21	99	DOE 35P050	2009-2013	Mouth of George Creek (no longer active)
Alpowa Creek	9.3	112	DOE 35K050	2003-present	Near mouth of Alpowa Creek just upstream from Hwy 12 crossing
Couse Creek	NA	26	DOE 35H050	2003-2013	Near mouth (no longer active)
Tenmile Creek	NA	65	DOE 35J050	2003-2013	Near mouth (no longer active)

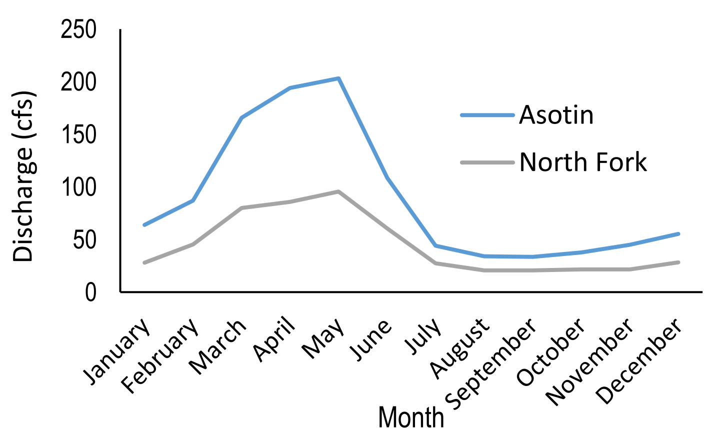

Figure 5. Average monthly discharge (cfs) in Asotin Creek measured at USGS gauge 13335050 at the mouth and North Fork Asotin Creek as determined by subtracting South Fork Asotin Creek discharge from USGS gauge 1334450 just downstream from the confluence of North Fork and South Fork Asotin Creek.

We combined the mainstem monitoring data from all current and historic USGS gauges (13334050, 13334500, and 13334700) to form an 82-year record of peak discharges (1929-2017 with 1983-1989 missing). We had to extrapolate data collected from above the confluence with data collected below the confluence where the years of data collection overlapped (1990-1996) and used regression to back-calculate discharge at the mouth (Figure 6). There were three significant peak flows during the period of record with the maximum peak discharge recorded 6,334 cfs. These large peak floods caused significant damage to properties and fish habitat along the mainstem and tributaries (Figure 7).

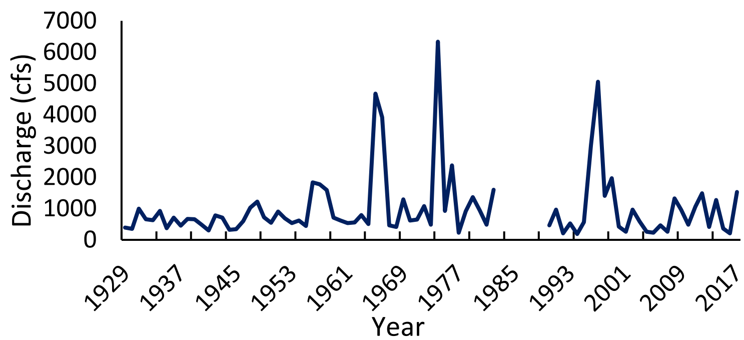

Figure 6. Estimated peak discharge by year at the mouth of Asotin Creek from 1929-2017. Data compiled from USGS gauges 13334500, 13334700, and 1335050). Data were extrapolated from gauges upstream of George Creek by regressing data from years when there was overlap with gauges from upstream and downstream of George Creek.

Figure 7. View looking upstream on mainstem Asotin Creek at Asotin City Park near the mouth: January 1, 1997.

Three tributaries to Asotin Creek have some discharge monitoring: George, Charley, and North Fork and South Fork Asotin Creeks. North Fork Asotin Creek is the continuation of mainstem Asotin Creek upstream of the confluence of South Fork Asotin Creek. North Fork has the second largest mean annual discharge in the study area (Figure 5). George Creek enters Asotin Creek approximately 3 miles from the mouth and makes up almost 40% of the land area of the Asotin Creek watershed. George Creek has the potential to have very large flows but because of the lack of gauge data they have not been documented and we were unable to calculate an annual monthly discharge. As part of the Asotin Creek Intensively Monitored Watershed (IMW), Eco Logical Research, Inc. has operated two water height gauges on South Fork Asotin Creek and Charley Creek since 2009. Estimates of flow in South Fork and Charley Creek are calculated using regular discharge estimates and building a regression with stage height. Charley Creek appears to be dominated by snow-rain inputs based on hydrologic regime analysis (Appendix A. 5), however, it has more consistent flows, and relatively small peak flows compared to South Fork Asotin Creek, and we have observed numerous springs along the lower 12 miles (Figure 8). South Fork is likely more similar to George Creek, and has the potential for high flows but fluctuates widely, and has relatively small base flows for its drainage area.

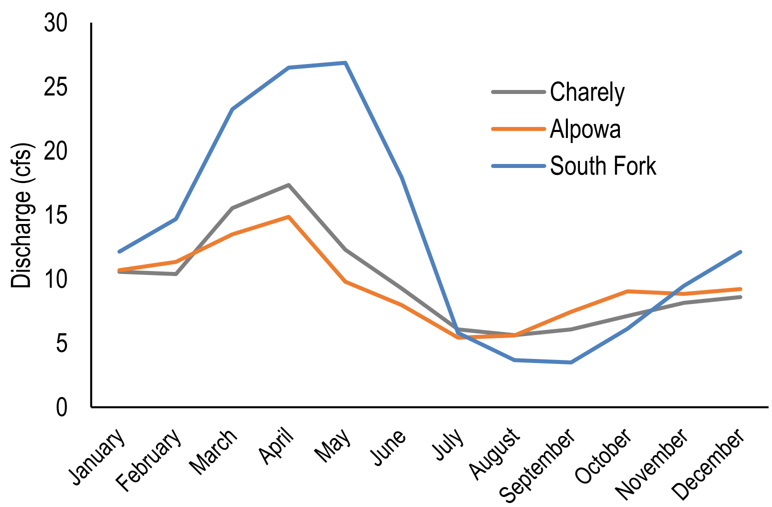

Figure 8. Average monthly discharge (cfs) in Alpowa, Charley Creek, and South Fork Asotin Creek. Charley and South Fork Asotin Creek discharge was determined by monitoring conducted for the Asotin IMW (Bennett et al. 2015) and Alpowa discharge was determined from DOE gauge 35K050.

Alpowa Creek has the second most consistent and complete discharge record (Table 4). Alpowa Creek is a groundwater dominated flow regime and has a relatively consistent discharge pattern compared to the other target watersheds. Peak flows rarely exceed 10-20 cfs and have only exceeded 30 cfs six times in the past 15 years. Stream flow has been measured in Alpowa Creek by DOE since 2003 with a gauge just above highway 12 near the mouth (DOE 35K050). Tenmile and Couse were monitored between sporadically form 2003 and 2013, but most records are available from 2011-2013. There is not enough data to determine a mean annual monthly discharge but we suspect both streams would have lower base flows and more variable seasonal discharge than Charley or Alpowa Creeks.

Relatively few water rights in the target watersheds exist compared to neighboring watersheds like the Tucannon River and Pataha Creek. Analysis as part of the Watershed Resource Inventory Area planning in the Asotin Subbasin (WRIA 35) suggests that water use is 424 acre-feet/year. There are no minimum instream flow designations for the

Asotin subbasin, but the middle mainstem of Asotin Creek has surface water source limitations (SWSLs) of 10 cfs and the lower Asotin Creek has a SWSLs of 70 cfs from April to June and 15 cfs from July to March (HDR 2005).

4.3.3. Floods and Return Intervals

The hydrology of the Asotin Creek watershed is strongly controlled by the semi-arid climate and landscape units described above. The largest floods are either associated with rain-on-snow events or highly localized, high intensity convective summer thunderstorms that may form over a small portion of the watershed, but produce a major localized flood. These types of intense but relatively infrequent disturbance events are typical across the range of salmon and steelhead-bearing streams and can limit local survival for several years (Beechie et al. 2003, Waples et al. 2008).

We used the USGS Stream Stats application to estimate the magnitude of various return interval flows using regional regressions based on drainage area and watershed characteristics (Table 5). Regional regressions tend to overestimate flows in ungauged streams in southeast Washington. Therefore, the absolute predictions from the Stream Stats analyses should be treated with some skepticism, but the relative differences between the subwatersheds are helpful for highlighting the differences between potential peak flows in the target watersheds.

Table 5. Predicted discharge (cfs) based on gauge data and basin characteristics for the main basins within Asotin Creek watershed based on regional regressions using USGS Stream Stats tool.

Return Interval (Year)	Asotin	Alpowa	Tenmile	Couse
2	1490	623	290	184
10	3885	55.5	982	675
25	5460	2910	1511	1070
50	6819	3772	1999	1430
100	8320	4722	2550	1851

4.3.4. HydroGeology

There have been two recent assessments of the hydrogeology and groundwater systems of the target watersheds (Kennedy and Jenks 2005, HDI 2009). The findings from these assessments were:

- Main geologic unit is the Columbia River Basalt Group (CRBG) overlain with deposits of clay, silt, loess, sand, and gravels; underlain with very deep metamorphic rocks
- Three main deposits on the CRBG; alluvial, loess, and cataclysmic flood deposits.
- Groundwater occurrence mainly in suprabasalt sediments which are localized, discontinuous, shallow (5-40' deep), < 50' thick, have high porosity
- Other groundwater occurrence includes Grande Ronde Basalt interflow; trapped between flows; large recharge but low discharge to Snake River (may have high potential yield)
- little evidence of continuity between surface water and ground water in mid to lower watersheds (except for Alpowa Creek); therefore, drawing on groundwater not likely to impact surface flows; groundwater springs more connected to flow in upper watersheds
- water demands in the County are relatively low (365 residences in Asotin and Alpowa, average 2.4 people per residence, ~ 900 residents total in Asotin, Alpowa, and Tenmile)

4.4 SEDIMENT SOURCES AND ROUTING

4.4.1. General Sediment Sources and Characteristics

From a sediment supply perspective, the Asotin is characterized by two dichotomous sources of sediment and two somewhat contradictory sediment 'problems'. The two primary sources of sediment are from weathering of bedrock (primarily basalts from the CRBG) producing relatively coarse boulders, cobbles and gravels, and the much more recent (c. 13,000 to 15,000 years ago from Missoula Floods) cap of fine-grained loess (wind blown silts), which blanketed and mantled the basalt plateaus. Spatially, these two 'sources' are easily visualized as the landscape units of Appendix A. 7, with the 'canyons' exposing the basalt bedrock and 'dissected loess uplands' evacuating some of the easily erodible silts. The relief provided by the Blue Mountains versus the base level imposed by the Snake River, set up roughly 4000 feet of elevation for these streams to pass through in less than 20 miles (from Blue Mountain to Snake). That produces relatively steep stream slopes with high enough stream power when floods pass through to move sediment along. All of the 176 miles of perennial, streams are incised into this bedrock. In general, the further downstream the deeper the basalt canyons, the wider the valleys become (around 500 to 600 feet wide near mouth of Asotin). The valley bottoms of these streams have partially filled with a mix of both sources of sediment providing a third and much more important local source of sediment for contemporary fluvial reworking within and along the modern channels. Within the active stream channel, the 'contradictory' sediment 'problems' are i) a system overwhelmed by fines (i.e. the loess), versus ii) a system so armored with coarse materials that it has difficulty mobilizing much of that sediment in typical, annual floods. We will briefly describe the role these two supplies played.

Where floodplain connectivity is adequate, the valley bottoms are important sinks for some of the fine fraction of sediment yielded from the loess plateau uplands. Some of this fine fraction can become embedded within the coarse cobble bed. The loess soil combined with poor farming practices historically produced excess fine sediment supplies carried as suspended load and historically caused degradation of spawning areas (SCS 1984). Moreover, these were the primary motivation of the Model Watershed (see §3.1.4). However, with implementation of the Model Watershed Plan, farming practices such as no-till have so dramatically improved, that excessive erosion of loess and its delivery downstream is no longer a problem. There is little evidence that there is an over supply of fine sediment in the study creeks currently. Most of the study streams are channelized (i.e., high banks and straight), low sinuosity channels, with very limited structural elements (i.e., wood) which is very efficient at transporting fine sediment out to the Snake River. Better trap efficiency on these fines on floodplains could occur with increased floodplain connectivity

Today, the composition of the streambed for the vast majority of the fish-bearing streams is a very coarse and armored bed comprised of cobble, boulders and gravel. To illustrate this, we summarized simple grain size statistics from CHaMP (Columbia Habitat Monitoring Program) surveys (Table 6). These are confirmed by previous assessments, landscape unit mapping, field validation studies, Intensively Monitored Watershed monitoring sites in George Creek, North Fork and South Asotin Creeks, and Charley Creek (Bennett et al. 2015), and the recent sediment analysis (ESA 2016). These coarse gravels and cobbles are mobile under some larger floods, but not always mobile under typical floods these creeks experience annually. Especially within the simplified and channelized reaches, mobility of local bed sediments is limited. Within the Asotin IMW, we experimented with whether or not diversifying hydraulic conditions with structural additions (i.e. wood), can increase mobility of the bed and increase opportunities for deposition and temporary storage of sediment in active bars. We have found that we can very effectively make these smaller floods more competent and effective at creating diverse habitats and a much more diversified substrate surface composition.

Table 6. Mean substrate distribution based on standard Wollman pebble counts (Wolman 1954) from Asotin Creek Intensively Monitored Watershed project: 2011-2016.

Stream Name	Location	D^{50} (inches)	%Fines < 0.24 (inches)
Charley Creek	Lower 7 miles	1.9	28.0
North Fork Asotin	Lower 7 miles	2.9	8.8
South Fork Asotin	Lower 7 miles	2.5	10.2
George Creek	River mile 2 to 3	2.3	23.4

In addition to the bed, the far more important sources of local sediment include lateral erosion into floodplain deposits, alluvial fans and to a lesser extent colluvial fans and hillslopes. Lateral erosion of banks of floodplains is often characterized as a negative impact, and can be where such lateral erosion contributes unnaturally excessive sediment to the system or threatens infrastructure. However, for many of the partly-confined stream types dominating the Asotin some natural lateral erosion into floodplain deposits is an extremely important local supply of sediment, critical to building important bar features, riffles, and bar-forced pools. Much of these 'lateral' sources of erosion into critical floodplain supplies of sediment have been artificially starved due to installation of levees, rip-rap and colonization and armoring of some of many of the banks by Alder. Another critically important local supply of sediment is lateral erosion into cut-banks of higher surfaces like terraces, fans and non-bedrock hillslopes. Terraces are extremely rare throughout the Asotin, but alluvial and colluvial fans are extremely common. These fans form where steep tributaries join flatter mainstem valleys and dump their loads. The alluvial fans are comprised of rounded alluvial sediment sources delivered from a mix of perennial, intermittent and ephemeral tributaries. The colluvial fans by contrast consist of angular colluvium, on steeper faced fans representing runouts from localized mass-wasting events and debris flows. These fans exert a very strong control on the valley setting and play varying degrees of importance in actively confining the channel's lateral capacity for adjustment. In some cases (e.g. partly confined, fan-controlled reaches), the fans can actually dam up the entire valley creating important sedimentation zones. More-over, if a channel encounters a fan, it often carves out of the fan on the channel's outside bend contributing sediment for local bar development. Most active bars in systems like the Asotin are not the product of sediment from the headwaters, but rather sediment that was sourced a relatively short distance upstream. Reaches that boast more active bars and more complex habitat also have ample local supplies of erodible sediment nearby. In the Asotin, geomorphic change detection as part of the CHaMP monitoring efforts has revealed that most of this material is from lateral erosion into floodplains and fans, as opposed to vertical erosion of the bed.

4.4.2. Sediment Budget Analysis

Southeast Washington has some of the highest recorded rates of soil erosion in the country according to NRI (2015). The Asotin Creek Model Watershed was formed in the 1990s, in part in response to the 'fine sediment' problem. While the loess plateaus make highly productive farmland for growing wheat, they are also a highly erodible soil and when combined with traditional tillage practices, they were delivering unsustainbly high yields of sediment from the plateaus down into the valley bottoms. As a result, two 'sediment budget; studies were previously conducted in the Asotin. A sediment budget is the systematic identification and quantification of sources of sediment, storage of sediment (sinks), and export of sediment within a control volume. However, both studies use relatively simplistic, off-the-shelf simulation models, extremely limited field data, and virtually no direct measurements of sediment fluxes to calibrate. Their results should not be taken too literally, and indicate some rather simple patterns that a basic GIS analysis could also reveal.

The USDA Soil Conservation Service completed a sediment budget in 1995 for the Asotin Creek Model Watershed (ACCD 1995). Based on the Pacific Southwest Interagency Committee (PSIAC) sediment model, George Creek, Pintler Creek, Maguire Gulch, and the middle reaches of Asotin were estimated to have the highest sediment yield within the Asotin Creek watershed. Streams with headwaters in managed croplands (e.g., dissected loess uplands) were determined to have a relatively high sediment contribution because of high erodibility of loess soils. ACCD (1995) calculated with PSIAC that approximately 209 acre feet of sediment moves through the Asotin Creek watershed stream network, but only 24 acre feet (11%) is estimated to reach the Snake River (sediment budget). The reported that embeddedness of gravel substrate in the mainstem of Asotin Creek noticeably increased from the mouth of Charley Creek to the confluence with the Snake River, likely having a negative impact on spawning opportunities for adult salmonids. However, there is a big difference between measuring the condition of the bed, and measuring sediment flux. George Creek had the highest relative sediment delivery of streams in the Asotin Creek watershed (Table 7).

Table 7. Relative proportions of fine sediment delivery estimated by ACCD (1995) from streams in the Asotin Creek watershed to the Snake River. Table reproduced from Model Watershed sediment budget.

Subwatershed	Relative Sediment Delivery to Snake River
Charley Creek	5%
South Fork Asotin Creek	8%
North Fork Asotin Creek	10%
Intermittent tributaries downstream of Charley	23%
George and Pintler Creeks	54%

Environmental Science Associates conducted an assessment of the sediment budgets of the target watersheds in 2015 (ESA 2016). The sediment supply analysis included surveys of the mainstem reaches (fluvial audit), field reconnaissance, sediment sampling, and simulation of sediment budgets using Sediment Impact Analysis Methods (SIAM). The study produced notional average estimates of sediment balance in tons/year by discrete reaches throughout the target watersheds within the limitations of the SIAM model. Furthermore, ESA (2016)reaches were delineated by net sediment balance and described as dominantly net erosion, net deposition, and balanced. Sediment 'hot spots' were identified in the same general locality as those identified in the model watershed sediment budget including George Creek, and mid-Asotin Creek. These hot-spots correspond to wider sedimentation zones, where the valley settings become partly-confined, slopes decrease, and the valleys are broader. Results from the SIAM model were used to inform our stream classification process. The results of ESA's work are summarized below:

- In 1995, 30% of cropland was enrolled in CRP. The ACCD and landowners have implemented improved tillage practices and buffering of upland drainage systems, resulting in a decrease of in upland sediment yields.
- The target watersheds drain an area of relatively youthful geology consisting of loess-mantled tablelands that have been deeply dissected by fluvial action. Natural inputs of both fine and coarse sediment sourced

from the high, steep valley sides and colluvial (sediment produced by hill slope processes) and alluvial (sediment produced by stream processes) valley-fill deposits remain high.
- Steep hillslopes are, in many places, directly connected to the active channel and drainage network, making delivery of colluvial sediment into the drainage system highly efficient.
- Typically low levels of precipitation and runoff, interspersed with infrequent but heavy rainfall and occasional rain-on-snow events, result in low background sediment loads punctuated by episodic transport of large volumes of sediment.
- Restoration actions implemented in the target watersheds should work synergistically with each other and be implemented at over a large spatial scale to have a system-wide impact on sediment yields. Projects should be planned with knowledge of the cumulative or downstream effects of projects previously implemented.

The reality is that sediment budgets are very difficult and costly to implement properly, and can require many years of study to do well. Neither of the 'sediment budgets' previously commissioned represent true and full sediment budgets, but instead practical simulation attempts to quantify some of the terms that go into a sediment budget within the constraints of available data and time. Without comparison to a baseline, or some analysis of how current conditions depart from some expectation, a sediment budget by itself provides no context to judge whether or not the results are 'good', 'bad', 'desirable' or 'undesirable'. There is a tendency in such studies to overemphasize the importance of 'equilibrium' reaches where sediment inputs are balanced by sediment outputs, as if they are somehow better. However, many reach types are naturally in dis-equilibrium. For example, active alluvial fans are typically (at least episodically) characterized by net aggradation, and this is perfectly natural. By contrast, many inactive alluvial fans, which still have streams flowing across them, are actively net degradational and an important source of sediment to mainstems. We think it is more important to characterize current geomorphic conditions in the context of what processes and forms are expected naturally and what are the practical constraints today. Given the episodic nature of sediment fluxes within the Asotin with its flashy flow regime, it is critically important to identify where and how we can work with these geomorphic processes of erosion, transport, deposition and temporary storage of sediment to bring about desired changes and improvement to fish habitat.

5. FISH RESOURCES

The focus of the assessment and restoration plan is to improve conditions for ESA listed salmon, steelhead, bull trout, and Pacific lamprey. In this section, we briefly review historic abundance, recovery goals, status, distribution, habitat requirements, and past limiting factors. This summary was primarily derived from the Asotin Model Watershed (ACCD 1995), USFS stream surveys (USFS 2001, 2014a, b), baseline surveys from WDFW (Mendel et al. 2004, Mendel et al. 2008), Limiting Factors Analysis (Kuttel 2002), Subbasin Plan (ACCD 2004), Ecosystem Diagnosis and Treatment analysis (SRSRB 2011), and Nez Perce Fisheries Management (NPT 2013).

5.1 HISTORIC FISH ABUNDANCE AND RECOVERY GOALS

It is important to put the current distribution and abundance of salmon and steelhead into an historic context. Although there were no records of salmon and steelhead abundance prior to Euro-American development, it is possible to estimate what the abundances might have been (i.e., run reconstruction) using habitat data and estimates of spawning densities from other watersheds prior to dam construction and significant commercial fishing pressure. Pess et al. (*In review*) conducted such a run reconstruction and estimated that Asotin Creek may have supported over 15,000 adult steelhead and Chinook. These numbers are similar to the recovery goals of the Nez Perce which consider full recovery to be ≥ 10,000 for steelhead (Table 8; NPT).

There are no historic abundance estimates for lamprey or defined goals for recovery at this time (NPFRM 2013). However, 50-400,000 lamprey were recorded passing Bonneville dam between 1938-1969 and these numbers are thought to be underestimates because they were day counts and lamprey generally migrate at night (Crandall and Wittenbach 2015). Counts of adult lamprey migrating passed Snake River dams did not begin until the 1990s and by then numbers of returning lamprey were extremely low throughout the Columbia River Basin. Recent counts at Lower Granite Dam (the last Snake River dam before the study area) have recorded < 100 adult lamprey passing (2010-2014).

Table 8. Estimates of historic fish abundance based on run reconstruction from habitat availability and spawning densities (Pess et al. in review). Abundance estimates presented are one third of full capacity.

	Summer/Fall Chinook	Spring Chinook	Coho	Steelhead
Asotin		1,435	-	15,362
Tucannon	89,772	116,297	141,757	71,087
Walla Walla	-	120,507	276,423	133,808

Nez Perce and the Snake River Salmon Recovery Board have developed recovery goals for viable abundance estimates, and sustainable and ecological escapement objectives. Viable abundance estimates suggest the minimum number of adults that need to return to the spawning grounds to prevent extirpation over time and escapement objectives are what managers think are achievable adult returns with continued restoration and conservation strategies (SRSRB 2011, NPT 2013). Sustainable escapement objectives describe the number of returning adults required to sustain harvest. Ecological escapement objectives were derived by subtracting the harvest goals from the upper end of the escapement objectives in the recovery plans (SRSRB 2011) and then raising the remainder by an order of magnitude (NPT 2013). Ecological escapement objectives are similar for Chinook salmon (spring/summer and fall combined) and steelhead compared to Pess et al. (*In review*) estimates of historical abundance (Table 9).

Table 9. Estimate of viable abundance estimates, and sustainable and ecological escapement objectives for Chinook and steelhead in Asotin, Tucannon, and Lolo Creek. Lolo Creek is a tributary to the Clearwater River and was included because it is similar in size to Asotin Creek (SRSRB 2011, NPT 2013).

	Spring/Summer Chinook Salmon			Steelhead		
Stream	Viable Abundance Estimate	Sustainable Escapement Objective	Ecological Escapement Objective	Viable Abundance Estimate	Sustainable Escapement Objective	Ecological Escapement Objective
Asotin	500	2,000	10,000	1,000	2,000	15,000
Lolo Creek	500	6,600	15,000	500	4,200	7,000
Tucannon	750	3,400	22,000	1,000	3,400	15,000

5.2 FISH PRESENCE, STATUS, AND DISTRIBUTION

Three species currently listed as threatened under the Endangered Species Act (ESA) are present in study area: bull trout, spring Chinook salmon, and summer steelhead (ACCD 1995, Mayer et al. 2008, Crawford et al. 2016). Spring Chinook salmon are listed as extirpated, though small numbers of adults spawn every year in Asotin Creek

(Crawford et al. 2016). Lamprey are a species of concern in Washington and current efforts are underway to reintroduce them to Asotin Creek (Schlosser and Peery 2010). There are 12 species of fish thought to occur within the target watersheds (ACCD 2004). Most of these species occur in the lower portion of the Asotin Creek watershed and 25% are non-native species (Appendix B. 3).

Distribution of some fish species has likely changed in the last 150 years. Lamprey and sucker distributions have likely been reduced due to historic dams, barriers, and irrigation diversions. McIntosh et al. (1989) summarized Bureau of Fisheries stream habitat surveys in Asotin Creek mainstem in March 1935 and June 1936 and documented three permanent and 11 temporary barriers (dams and irrigation diversions) and noted that the lower dam at ~RM 0.4 was built for the explicit purpose of stopping suckers from entering Asotin Creek. Headgate Dam at ~ RM 8.1 would divert all the water from Asotin Creek during times of low flow, causing the lower river to go dry. The irrigation diversions and permanent dams likely restricted Chinook salmon, bull trout, and lamprey from migrating upstream because they migrate during low flow periods (summer and fall). The distribution of steelhead was less influenced by fish passage barriers. Adult steelhead migrate during spring high flows when water demands are low and they are able to ascend barriers that are otherwise impassable to other fish (e.g., lamprey, suckers, and whitefish).

We used a combination of GIS data on the fish distribution layers that are available on the Pacific States Marine Fisheries Commission (PSMFC) www.streamnet.org , and redd surveys and juvenile abundance estimates from WDFW, USFS, and our own surveys to determine the current distribution and status of target fish species (Bennett et al. 2015 and unpublished data).

5.2.1. Steelhead

Population Status

Steelhead are the dominant ESA listed species in the target watersheds and have the most extensive distribution (> 90-95% of all salmonids; Appendix A. 8). The steelhead present in the target watersheds are summer “A” run fish that generally migrate up the Columbia River and past Bonneville Dam before August 25 (ACCD 2004). The steelhead are part of the Snake River Evolutionary Significant Unit (ESU) based on genetic characteristics that distinguish the Snake River steelhead from other Columbia River Basin steelhead (ACCD 2004, SRSRB 2006). The steelhead are further grouped into the Lower Snake Mainstem Tributaries Major Population Grouping (MPG), which includes the Tucannon River and nine small tributaries that flow directly into the Lower Snake River (SRSRB 2006). Asotin Creek and the following six tributaries are considered a ***subpopulation*** of the Lower Snake River MPG: Almota, Alpowa, Couse, Steptoe, Tenmile, and Wawawai Creeks. The Asotin Creek steelhead subpopulation is further divided into major spawning aggregations (MSA) and minor spawning aggregations (mSA). The Asotin Creek Watershed and Alpowa are considered MSAs because they are thought to have been able to support at least 500 spawners historically. All other tributaries within the Asotin Creek subpopulation of steelhead are considered mSAs, which indicates they historically supported between 50-500 spawners.

There is a large amount of data available on both the historic abundance and current abundance of steelhead in the target watersheds, especially Asotin Creek (Bumgarner et al. 2003, Mendel et al. 2008, Crawford and Herr 2017). A detailed long-term monitoring study by WDFW of the Asotin Creek steelhead run began in 2004. The survey effort focuses on Asotin Creek but has attempted to collect data on George Creek, Alpowa, Couse, and Tenmile when conditions and support staff/funding are available (see Crawford et al. 2017 for more detail). The study consists of a 5 m rotary screw trap (smolt trap) that is operated in the spring and fall to assess juvenile outmigration and an adult weir that is operated from January to June to enumerate returning spawners. There are also four passive integrated transponder tag (PIT tag) interrogation sites located on the mainstem and tributaries of Asotin Creek that allow detection of PIT tagged fish (Bennett et al. 2015). Three interrogation sites were installed in 2009 (ACB, AFC, CCA) and the fourth was installed in 2010 (ACM). An Intensively Monitored Watershed Project was initiated in 2008 and focused on determining the effectiveness of large woody debris restoration at increasing steelhead production in Charley, North Fork and South Fork Asotin Creeks (Bennett et al. 2015, Bennett et al. 2016, Bouwes et al. 2016a).

Asotin Creek was designated by WDFW as a natural production steelhead reserve after the discontinuation of a hatchery stocking program in 1997 (ACCD 2004). All marked hatchery steelhead that are captured at the WDFW adult weir are removed. The weir is typically operated on the Asotin Creek mainstem 3 miles upstream of the confluence with the Snake River.

Distribution and Timing

Steelhead are present in all of the target watersheds and use the watersheds during all life stages (Figure 9 and 10). Adults begin to enter the target watersheds in late fall to early December and peak spawning takes place in April and May. WDFW has conducted redd surveys throughout target watersheds and has documented active spawning in mainstem Asotin, George, Pintler, Couse, and Tenmile Creeks (WDFW unpublished data; Mendel et al. 2001, 2004, Mendel et al. 2008, Crawford and Herr 2017). Juvenile rearing has also been documented and it is generally accepted that steelhead occupy the majority of accessible habitat in all the streams with perennial flow (Appendix A. 8). The distribution of steelhead, although extensive, is limited in several watersheds during the summer and early fall because of low flows or subsurface flows. In particular, lower sections of George, Pintler, Couse, and Tenmile Creeks can have very low flows during the summer and fall months (Kuttel 2002, ACCD 2004).

Abundance and Age Structure

Asotin Creek has the largest population of steelhead of the target watersheds and had an average of 595 (range 284-1411) adult steelhead estimated to return to spawn upstream of the WDFW adult weir trap on the mainstem of Asotin Creek between 2005-2016 (Table 10, Crawford and Herr 2017). Adults generally spend 1-2 years in the ocean and juveniles rear for 1-4 years before outmigrating. Resident “rainbow” trout (as determined by their small size < 3000 mm) have been observed spawning in areas also used by steelhead, but it is unknown what proportion of the total population is made up of residents.

Table 10. Estimates of naturally reproduced adult steelhead and juvenile outmigrants in Asotin, George, Alpowa, and Tenmile Creeks based on adult weir and rotary screw trap data (Crawford and Herr 2017).

Stream	Natural Adult Steelhead	% Hatchery Adult Steelhead	Juvenile Outmigrants	Survey Period
Asotin	595[1]	3.8	29,006 (spring), 7,289 (fall)	2005-2016
George	221[1]	1.3	NA	2009-2016
Alpowa	168[2]	16.8	NA	2008-2016
Tenmile	40[2]	6.2	NA	2010-2015
Couse*	1 redd/mile[3]	?	NA	2000-2003

[1]*Based mostly on mark-recapture population estimates.* [2] *Based mostly on counts of adults captured.* [3] *Couse Creek data is redds/mile observed during spawning surveys (Mendel et al. 2008).*

5.2.2. Chinook salmon

Spring/summer Chinook salmon were historically present and abundant in some of the target watersheds (SRSRB 2011). The spring/summer Chinook salmon are part of the Snake River Chinook ESU and were listed in 1992 as threatened under the ESA. Spring/summer Chinook salmon are considered extirpated from the target watersheds. However, a small number of spring/summer and fall Chinook spawn in Asotin Creek and Alpowa in some years (WDFW pers comm; IMW surveys). An average of 17 adult Chinook have been captured at the WDFW adult weir between 2004-2016 (15% were hatchery origin; unpublished WDFW data). Adult Chinook enter the stream in mid-May through early July and spawn in August and September. Adults spend 4-5 years in the ocean and juveniles rear in for a year or less in the larger tributaries. Juvenile Chinook salmon are often captured in Asotin Creek at the WDFW smolt trap and during Asotin IMW summer and fall surveys in Charley, and the South Fork and North Forks of Asotin Creek (Bennett et al. 2015). An average of 751 Chinook juveniles have been captured at the WDFW smolt trap each year between 2004-2016 (WDFW unpublished data). Juvenile Chinook have also been captured during electroshocking surveys in Alpowa and Couse Creeks (Mendel et al. 2008). Recent genetic analysis suggests that adult Chinook entering Asotin Creek are of Tucannon River origin (Blankenship and Mendel 2010).

5.2.3. Bull trout

Bull trout spawn in the fall and require cool water temperature, and complex habitat and cover (Al-Chokhachy et al. 2010) (Isaak et al. 2015). There are both resident and fluvial forms of bull trout in the Snake River region (Kuttel 2002, Al-Chokhachy and Budy 2008). Resident forms spend their entire life cycle in tributary streams often at elevations at or above the extent of steelhead (Appendix A. 8Appendix A. 8). Fluvial bull trout are generally larger (>12 inches) and spawn and rear in tributaries, but reside in larger rivers and the mainstem Snake River. Bull trout in the study area watersheds are considered part of the Columbia River Distinct Population Segment, Snake River Recovery Unit and were listed as threatened in 1998 by the USFWS (SRSRB 2011). Bull trout spawning and rearing is mostly limited to the upper watershed in George Creek and Asotin Creek and its tributaries (USFS 2001, Mendel et al. 2008, USFS 2014a, b). However, small numbers of adult bull trout use the lower reaches of Asotin Creek and its tributaries, and migrate between the Snake River and Asotin Creek. Some adult bull trout may even migrate into Asotin Creek to overwinter from other streams outside Asotin Creek.

5.2.4. Lamprey

Pacific lamprey are listed as a species of concern by the WDFW due to dramatically reduced adult returns (Schlosser and Peery 2010). Pacific lamprey have been affected by the same development activities as salmonids, but have received less conservation attention in the past (Crandall and Wittenbach 2015). There are historical Nez Perce accounts of large numbers of lamprey returning to Asotin Creek (NPT 2013). The current status of self-reproducing lamprey is unknown. However, the Nez Perce are conducting a lamprey reintroduction program in Asotin Creek (Raymond Ellenwood, Nez Perce Tribe, Personnel communications). Adult lamprey are captured during their spawning migration up the Columbia and Snake River and held at the Nez Perce hatchery facility over winter and released along the mainstem Asotin in the spring. Both Nez Perce and WDFW have documented juvenile lamprey in the lower Asotin Creek which are presumed to be the off-spring of the reintroduced adults.

Pacific lamprey are anadromous and adults spend 1-3 years in the ocean. Lamprey migrate to tributary spawning areas in late spring and summer and may spend several months holding in streams before they spawn. Spawning usually occurs between February and July. Adult lamprey are attracted to spawning sites by pheromones produced by rearing juveniles and do not home to natal streams like salmon and steelhead (Crandall and Wittenbach 2015). Adult lamprey spawn in gravel and cobble dominated substrate in similar locations as steelhead. Juvenile lamprey rear in natal streams for up to seven years and require silt and sand substrates (Crandall and Wittenbach 2015). In gravel/cobble dominated streams like Asotin Creek, silt and sand deposits are usually found in off-channel habitat or in eddy pools behind structural elements like log jams.

A recent assessment of Asotin Creek was conducted by the US Fish and Wildlife Service to determine the habitat suitability of Asotin Creek for lamprey (Schlosser and Peery 2010). The suitability study suggested that George Creek and its tributaries were likely not suitable habitat for adults or juveniles because sections dewater, temperatures are high, and there is a lack of rearing and spawning habitat. Asotin Creek mainstem appears to have suitable habitat for adults as they use the same habitat as steelhead (clear, cool water, and gravel/cobble substrate).

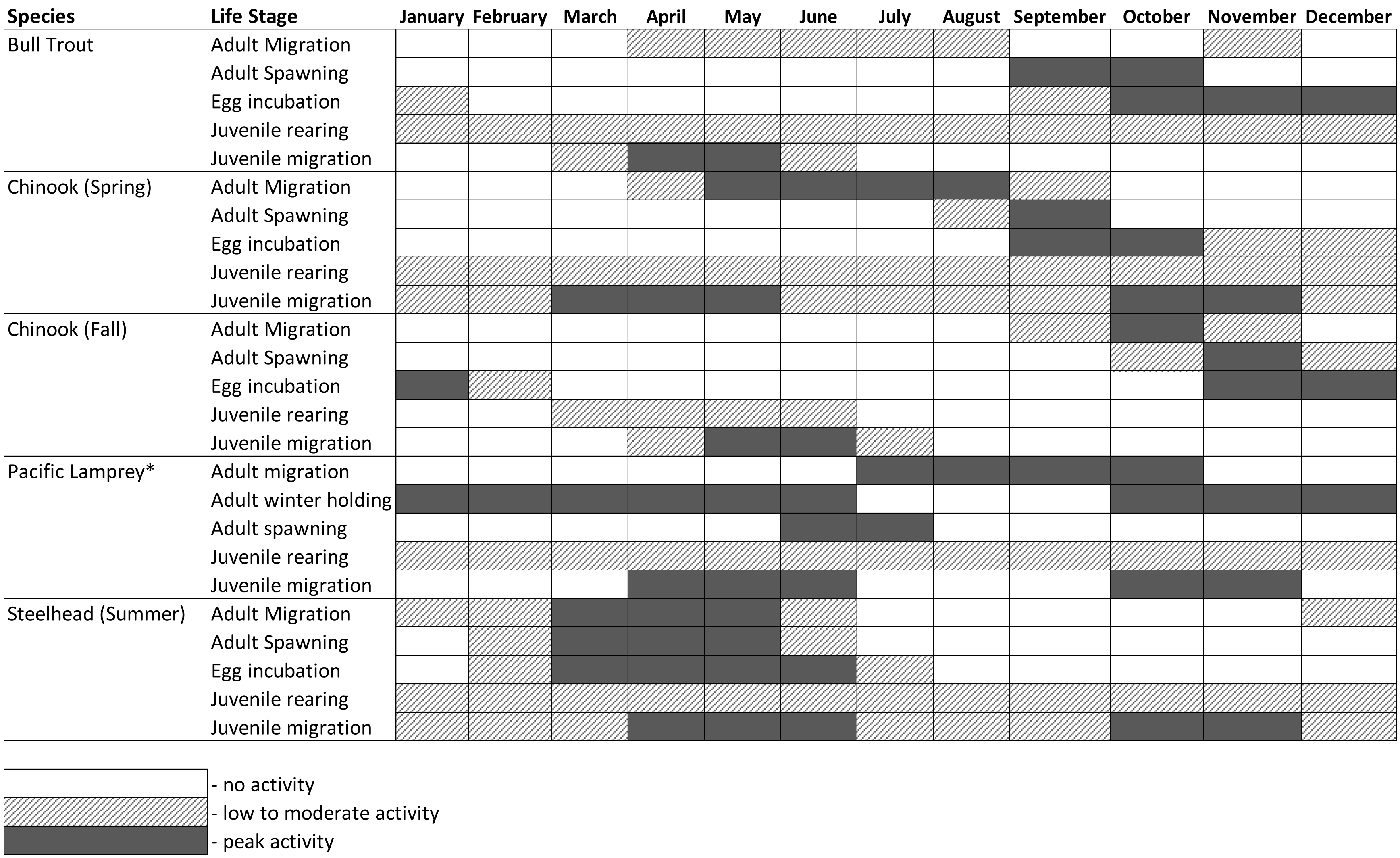

Figure 9. Timing of fish presence by life stage and month for key species in Asotin Creek. Data based on historic and ongoing WDFW surveys. Timing of fish presence is expected to be similar for Alpowa, George, Couse, and Tenmile Creeks if the species is present (see Table 10).

Stream	Geographic Area	RM Start	RM End	Description of Geographic Area	Chinook (spring) Migration	Chinook (spring) Spawning	Chinook (spring) Juvenile Rearing	Chinook (spring) Adult holding	Chinook (fall) Migration	Chinook (fall) Spawning	Chinook (fall) Juvenile Rearing	Chinook (fall) Adult holding	Steelhead Migration	Steelhead Spawning	Steelhead Juvenile Rearing	Steelhead Adult holding	Bull trout Migration	Bull trout Spawning	Bull trout Juvenile Rearing	Bull trout Adult holding
Asotin Creek	Lower	0.0	3.2	mouth to George Creek confluence	■				■	■	■	■	■	■	■	■	■			▨
	Mid	3.2	8.0	George Creek to Headgate	■	▨	■	▨	■	■	■	■	■	■	■	■	■			▨
	Upper	8.0	15.4	Headgate to Forks	■	■	■	■	▨	▨	▨	▨	■	■	■	■	■			▨
George Creek	Lower	0.0	3.2	mouth of Pintler confluence									■	■	■	■				
	Mid	3.2	10.9	Pintler confluence to first river right tributary									■	■	■	■				
	Upper	10.9	~25	tributary junction to headwaters									▨	▨	▨	▨				
Charley Creek	Lower	0.0	0.4	mouth to end of private property (Koch)			▨						■	■	■	■				
	Mid	0.4	7.1	Koch property to end of WDFW property									■	■	■	■				
	Upper	7.1	13.0	USFS boundary to headwaters									▨	▨	▨	▨				
North Fork	Lower	0.0	1.0	mouth to Lick Creek	■	■	■	■					■	■	■	■	■		▨	▨
	Mid	1.0	4.9	Lick Creek to USFS boundary	■	■	■	■					■	■	■	■	■		▨	▨
	Upper	4.9	~20	USFS Boundary to Headwaters	▨	▨	▨	▨					■	■	■	■	■	■	■	■
South Fork	Lower	0	3.6	mouth to Warner Gulch			▨						■	■	■	■				
	Mid	3.6	8.3	Warner Gulch to USFS Boudary									■	■	■	■				
	Upper	8.3	10	USFS Boundary to Headwaters									▨	▨	▨	▨				
Alpowa Creek	Lower	0	3	mouth to confluence with Pow Wah Kee					■	■	■	■	■	■	■	■				
	Mid	3	6.7	Pow Wah Kee to confluence with Stember									■	■	■	■				
	Upper	6.7	20	Stember to Headwaters									▨	▨	▨	▨				
Couse Creek	Lower	0	3.2	mouth to first bridge crossing									■	■	■	■				
	Mid	3.2	5.2	bridge to end of fish distribution									▨	▨	▨	▨				
	Upper	NA	NA	no fish																
Tenmile Creek	Lower	0	1.1	mouth to first bridge crossing									■	▨	■	■				
	Mid	1.1	10.7	first bridge to Mill Creek									■	■	■	■				
	Upper	10.7	15	Mill Creek to headwaters									▨	▨	▨	▨				

☐ - no activity
▨ - low to moderate activity
■ - peak activity

Figure 10. Presence and approximate distribution of Chinook, steelhead, and bull trout starting at the mouth of the target watersheds.

5.3 LINKING FISH HABITAT REQUIREMENTS TO GEOMORPHIC FUNCTION

Geomorphic units directly link to fish habitat requirements because they are the physical units that make up a stream channel, bed, and floodplain features. Here we briefly review the basic habitat requirements of steelhead, Chinook salmon, and bull trout and lamprey and provide a description of the link to geomorphic condition (Appendix B. 1).

Salmon, steelhead, bull trout, and lamprey all require clear, cool water, well-sorted gravel and cobble substrate, cover, food, and the ability to move between different habitat patches to fulfill basic life history requirements. Steelhead have a wider range of habitat characteristics that they can use as they range from large river systems to small headwater streams. Chinook generally require larger rivers to spawn and rear, and bull trout have the most restrictive temperature requirements, and hence are at greater risk of increased stream temperatures. Lamprey have the unique requirement of silt and sand substrates for juveniles to rear in.

We grouped the habitat requirements of these species into three life stage categories: eggs and alevins, fry and juveniles, and adults. The common limiting factors for eggs and alevins are dissolved oxygen (DO), substrate, and temperature. Geomorphic conditions that directly relate to these limiting factors are sediment transport, sorting, and storage. Channel confinement generally leads to greater potential for scour and less stable banks, and poor upland management tends to lead to higher inputs of fine sediment. Higher water temperatures speed the development time of eggs but also reduce DO levels. Riparian condition directly controls stream temperatures.

The common limiting factors for fry and juvenile life stages are food, physical habitat, temperature, and water flow/depth. Riparian condition can directly affect food availability and nutrient inputs and geomorphic units are a direct measure of the physical habitat available to fish (e.g., pools, bars, runs and riffles). Low habitat diversity for fish can be quantified by measuring the diversity and distribution of geomorphic units. Channel shape and slope directly relate to the flow dynamics and depths of habitat units and limited geomorphic function provide insight into the amount and quality for refugia for young fish.

The common limiting factors for adult salmonids are cover, migration barriers, substrate, and temperature. Cover limits predation during spawning, barriers can prevent access to spawning areas, and substrate size of appropriate size and quality is sought out for a spawning location. Degraded geomorphic and riparian conditions often lead to reduced cover (channels are straightened, riparian areas are reduced, inputs of LWD and overhead cover are lost). Substrate quality, quantity, and spatial distribution is directly related to sediment sources, transport, and storage. Fine sediment inputs can be naturally high, but spawning gravels can still be abundant if fine sediment is allowed to settle out in floodplains, or be trapped and sorted in channels with diverse hydraulic conditions.

5.4 LIMITING FACTORS

It is generally accepted that sediment load, channel stability, key habitat quantity, and habitat diversity have been the primary factors limiting the abundance and productivity of steelhead and spring/summer Chinook in the Asotin Creek mainstem and the George Creek watershed (Figure 11, Figure 12). Alpowa, Couse, and Tenmile Creeks were not fully assessed as part of Salmon Recovery Planning due to lack of data. However, it was noted that George, Couse, Tenmile and Pintler Creeks often have large sections that dewater due to a combination of natural and manmade causes. Dewatered sections are partial barriers to fish passage that also reduce the amount of habitat available to steelhead (SRSRB 2011). Restoration actions have been directed at these dewatered sections of stream over the last 10 years and dewatering is still considered a limiting factor. The consensus of the SRSRB (2011) was that steelhead populations outside of Asotin Creek were likely limited by sediment, low flow, a lack of pool habitat, and low habitat diversity associated with scarce large woody debris and anthropogenic confinement, limited riparian function, excessive temperature, and obstructions. It should be noted that the recovery plan recognizes that temperature and flow are both limiting factors; however, both these factors are accepted to be natural in these systems because of the watershed characteristics and hydrologic regime. It is also accepted that low flows and high temperatures have likely been exacerbated by development impacts but to what degree is unknown.

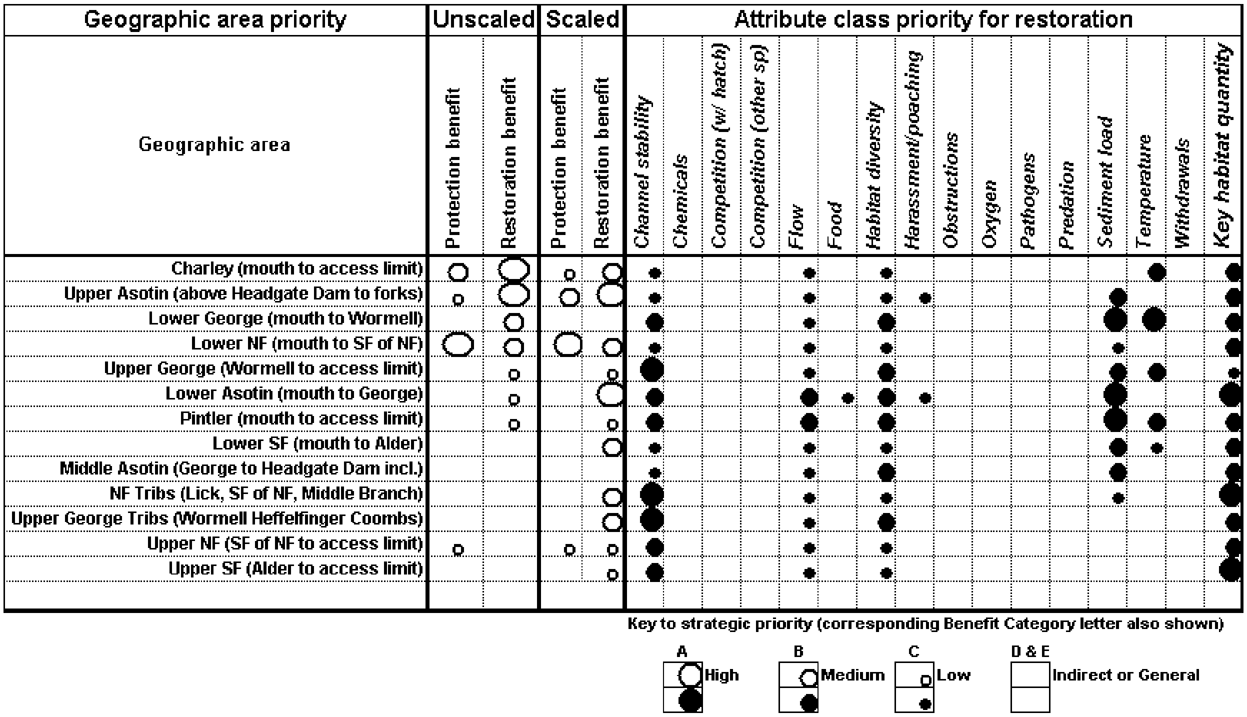

Figure 11. Factors affecting viability of Asotin Creek Steelhead (SRSFB 2011).

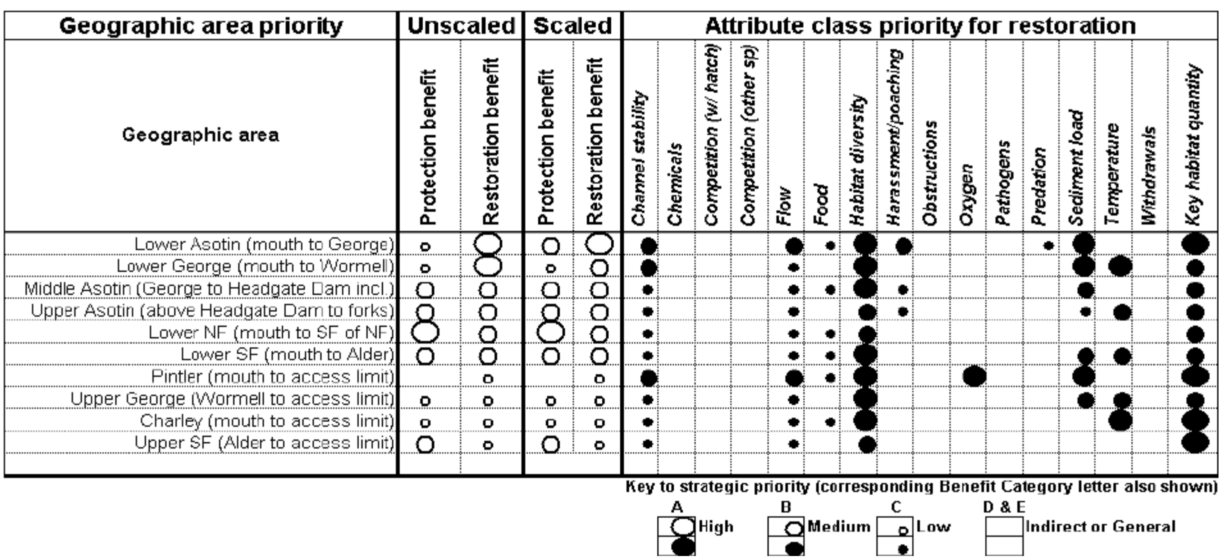

Figure 12. Factors affecting viability of Asotin Creek Spring/Summer Chinook (SRSRB 2011).

6. WATERSHED ASSESSMENT AND RESTORATION PRIORITIZATION METHODS

We used a geomorphic focused watershed assessment and river management approach similar to the River Styles Framework to assess the types of streams in the study area and their condition (Table 1; Brierley and Fryirs 2005). The modified framework we used to implement this assessment is divided into three stages: 1) landscape setting and reach classification 2) geomorphic condition, and 3) recovery potential (Figure 13). The development of a Conceptual Restoration Plan (Stage 4) is provided in a separate report. We conducted the geomorphic assessments within a nested hierarchy from watersheds, to landscape units, reaches, and geomorphic units (landforms).

In Stage 1, we determined landscape controls on valley, and interpreted valley controls on planform and bed material. These larger scale controls formed the basis for identifying geomorphic reach types. In Stage 2, we determined the geomorphic condition of each reach by comparing the current proportion and function of geomorphic units to expected proportion and function. We determined the expected conditions from habitat sampling conducted in the Asotin Creek Intensively Monitored Watershed (Bennett et al. 2015) and from data available from the Columbia Habitat Monitoring Protocol (CHaMP 2014). To make the assessment of geomorphic conditions more holistic (i.e., a watershed assessment), we also modeled riparian condition and floodplain fragmentation, beaver capacity, annual stream temperature, and fish capacity on the perennial stream network. We synthesized the reach classification, geomorphic condition, network models, and GIS data on land cover, land use, and development infrastructure to provide a comprehensive assessment of current stream and floodplain conditions. In Stage 3, we determined current trajectory (i.e., improving, degrading, static) and recovery potential of each reach. Results of Stages 1-3 were used to develop a conceptual restoration plan and prioritize restoration projects with input from landowners and Working Group (Stage 4). We describe the methods for Stages 1-3 in detail below.

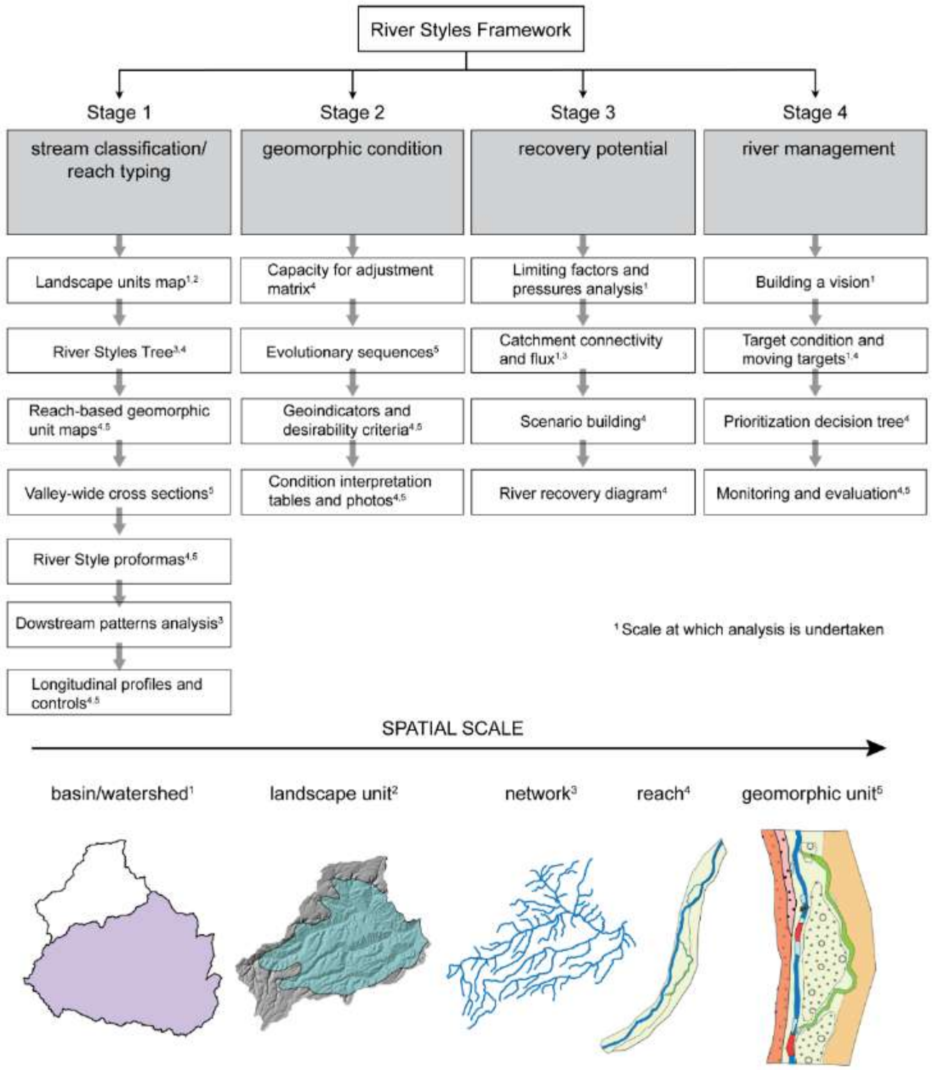

Figure 13. Summary of our modified River Styles framework as described in Brierley and Fryirs (2005) and O'Brien et al. (2017).

6.1 GEOMORPHIC ASSESSMENT - REACH CLASSIFICATION

We used landscape unit mapping as the template on which to identify reach types. We classified reach types using four primary physical parameters: valley setting, channel planform, floodplain and in-stream geomorphic units, and the caliber of bed material (Rosgen 1996, Brierley and Fryirs 2005, Beechie and Imaki 2014). A reach type represents assemblages of the four primary parameters that are relatively distinct over a scale of thousands of feet to miles. We first identified the valley setting by using the Valley Bottom Extraction Tool (VBET) to delineate the valley bottom as a measure of confinement (Gilbert et al. 2016). Valley confinement is a key attribute to determining reach *breaks* (the physical transitions between differing adjacent reach types) because the degree of confinement directly controls the ability of the channel to adjust both laterally and to a lesser degree vertically (O'Brien et al. 2017). We used the delineation of the valley bottom as an input into the Geomorphic Network Analysis Tools (GNAT) to categorize the stream network into categories of confinement: unconfined, partly confined, and confined (Geomorphic Network and Analysis Toolbox (GNAT)). We then used the degree of confinement along with desktop GIS data (LIDAR and NHD stream layers) and aerial imagery analysis (Google Earth and recently acquired imagery) to determine preliminary reach breaks. We also used our experience from determining reach break as part of our Asotin Creek Intensively Monitored Watershed project for the entire Asotin Creek watershed to inform reach breaks in the other target watersheds (Bennett et al. 2015, Camp 2015) and previous work in the Columbia River basin (O'Brien and Wheaton 2014, O'Brien et al. 2017). Reach types were then validated by visiting a subset of reach types and filling out field forms to confirm reach types.

6.1.1. Stacked Long Profiles and Sediment Transport Zones

We created stacked longitudinal profile plots of selected streams to visualize and interpret the controls governing character and behavior of three streams that represent the range of reach types occupied by steelhead (O'Brien and Wheaton 2014). We plotted elevation, upstream catchment area, slope, and stream power, along each profile. The shape of profiles indicates variability in the physical character of the bedrock (lithology) and rates of channel incision versus lateral expansion in valley widths. We inferred process zones and transport regimes primarily from valley setting. Erosion and coarse sediment production are dominant processes in confined valley settings. A balance between sediment storage and throughflow are typical of partly confined valleys, and laterally unconfined valleys generally reflect broad zones of sediment accumulation. Stream power drives changes in channel gradient and discharge, which relates to upstream drainage area.

We constructed each plot using the National Hydrography Dataset plus Version 2 (NHDPlusV2) drainage network (McKay et al. 2012). NHDPlusV2 is a geospatial, hydrologic digital vector dataset that incorporates features of the National Hydrography Dataset (NHD), the National Elevation Dataset (NED), and the Watershed Boundary Dataset (WBD). Unlike NHD, which is a cartographic-based digital dataset, the NHDPlusV2 dataset derives from a 10 meter DEM, allowing many embedded attributes to be utilized. For this exercise, we used the NHD streamlines and WBD layers. We derived upstream catchment area from an available flow accumulation raster. For extracting longitudinal profiles, we segmented the streamlines in increments of 100 m to ensure high-resolution calculations of upstream catchment area and slope. For this operation, and to derive catchment area from the flow accumulation raster at the same intervals, we used the Geospatial Modeling Environment (GME) tool (Beyer 2012).

We calculated stream power at each 100 m segment of stream as a measure of the capability of a river to do work on the bed and banks of the river (Bagnold 1960), where:

$$\Omega = \rho g Q S$$

ρ is the density of water, g is acceleration due to gravity, Q is a characteristic discharge, S is the channel slope, and Ω is stream power in watts. We used a two-year recurrence interval flow for discharge (Q2), given the effectiveness of frequent bankfull flows in modifying and maintaining channel form relative to larger magnitude, and infrequent floodstage flows (Wolman and Miller 1960). We used a regional regression equation obtained from the United States Geological Survey (USGS) National Streamflow Statistics Website (URL: http://water.usgs.gov/osw/programs/nss/pubs.html) to estimate Q.

6.2 GEOMORPHIC ASSESSMENT - REACH CONDITON (RIVER STYLES STAGE 2)

We define a watershed/geomorphic condition assessment as a measure of deviation from the "natural or expected state" of any given landscape or stream reach. Our assessments focused on determining the current condition of the reach types as identified in Stage 1. We also conducted the condition assessment with an emphasis on the **limiting factors** in the Snake River Salmon Recovery Plan (SRSRB 2011) and our understanding of how land use affects stream flow, vegetation (especially riparian vegetation), sediment routing, and how channel form and behavior affect the creation and maintenance of natural/productive salmonid habitat. The geomorphic condition assessment was first conducted using GIS data and aerial imagery. Individual reach types were further divided into segments based on geomorphic condition. Then a subset of reach types and condition categories were visited to perform validation surveys (Appendix A. 9).

6.2.1. Capacity for Reaches to Adjust and River Evolution

The capacity for adjustment of a reach is defined as morphological adjustments caused by natural changes in biological and physical processes that do not result in a wholesale change in the reach type (Brierley and Fryirs, 2005). The capacity for adjustment represents the physical ability for a stream to adjust laterally (and to a lesser extent, vertically) within its confining margins. We used a series of GIS assessments and field visits to several representative sites of a specific reach type to determine a reach's natural capacity for adjustment (Table 11). We then developed a set of geoindicators for three specific components of reach condition: channel and floodplain attributes, channel planform, and bed character (Table 11-12). Geoindicators directly relate to fish habitat characteristics by describing the channel attributes (size, shape, bank, instream vegetation, structural elements), planform (number of channels, sinuosity, lateral stability, geomorphic unit assemblage [i.e., bars, pools, runs, cascades, etc.], riparian vegetation), and bed character (grain size and sorting, bed stability, and sediment regime). Not all geoindicators were assessed for each reach. For example, the number of channels for steep perennial headwaters was not expected to be more than one. We used geoindicators to directly compare current reaches to their expected or reference equivalent. Reference reaches are the best available example of a reach type in a watershed, and are determined using the same geoindicators. However, reference conditions rarely exist, making meaningful comparisons and establishing specific targets for recovering reaches problematic. When a reference reach could not be found, we developed river evolution sequences and used landscapes at various stages of development to infer evolution and approximate a suitable representation of a reference reach type (Appendix C. 1). Evolution sequences are a way to look back at what a reach may have looked like before development and land use pressures altered its form and function.

Table 11. Capacity for adjustment by reach type and valley setting. Capacity for adjustment represents the range of morphological adjustments caused by natural changes in biological/physical processes that do not result in a change in the reach type.

Valley Setting/ Reach Type	Channel Attributes	Channel Planform	Bed Character	Capacity for Adjustment
Confined Valley settings				
Steep Ephemeral Hillslope				Low
Steep Perennial Headwater				Low
Bedrock Canyon				Low
Occasional Floodplain				Low
Partly Confined Valley Settings				
Fan Controlled (DF)				Moderate
Planform Controlled (DF)				High
Wandering Gravel Bed (DF)				High
Unconfined Valley Settings				
Upland Swale				Low
Alluvial Fan				High

	Minimal or no adjustment potential
	Localized adjustment potential
	Significant adjustment potential

Table 12. Example of geoindicators used to measure the geomorphic function of reach types in confined valley settings in the Asotin Creek watershed. See Appendix B for examples of other reach types.

Geoindicator/River Style	Steep perennial headwater	Bedrock canyon	Confined occasional floodplain pockets	Steep ephemeral hillslope
Channel Attributes				
Size	No	Yes	Yes	No
Shape	No	No	Yes	No
Bank	No	Yes	Yes	No
Instream vegetation structure	No	No	Yes	No
Structural elements (e.g. woody debris loading)	Yes	Yes	Yes	Yes
Channel Planform				
Number of channels	No	Yes	No	No
Sinuosity of channels	No	No	No	No
Lateral stability	No	No	Yes	No
Geomorphic unit assemblage	Yes	Yes	Yes	Yes
Riparian vegetation	No	Yes	Yes	No
Bed Character				
Grain size and sorting	Yes	No	Yes	Yes
Bed stability	No	Yes	No	No
Sediment regime	Yes	Yes	Yes	Yes

6.2.2. Determining Geomorphic Condition Categories

We used a series of questions related to channel attributes, channel planform, and bed character to make the final determination of geomorphic condition (Appendix B.6-14). We define geomorphic condition as the degree to which the reach is functioning relative to fully functioning or reference conditions. Presence of relevant geoindicators are used to categorize each reach as having *full, high, moderate,* or *limited* geomorphic function. If the criteria for degree of freedom is met, a check mark [√] is placed in the matrix, if the criteria is not met, a cross [x]. A reach was classified as having *full geomorphic function* with four checks, *high* with three checks, *moderate* with one or two checks, and *limited* with no checks. See Appendix B. 6-14 for a complete list of questions we used to assess geomorphic function.

6.3 GEOMORPHIC ASSESSMENT - RECOVERY POTENTIAL (RIVER STYLES STAGE 3)

In Stage 3, we determined the recovery potential of each reach by leveraging the information obtained in Stages 1-2 (reach classification and geomorphic condition assessments) in two steps. We define the geomorphic recovery potential as the capacity for natural improvement of the geomorphic condition, including attributes critical to ESA listed fish of a reach (e.g., flow, stream temperature, and other non-geomorphic limiting factors) in the foreseeable future (e.g., 5-25 years). We determined the recovery potential in two steps. First, the *trajectory of river change* was determined by projecting the *recovery trajectory* of each reach into a pathway between fully and degraded (i.e., limited) geomorphic function (Figure 14). Trajectory diagrams for reaches provide insight into the condition a reach will be in with and without restoration. Secondly, river recovery potential was determined by assessing

limiting factors in the watershed along with the location of a reach within the stream network and proximity to intrinsic pressures (Figure 15). For example, a naturally unconfined reach that is currently confined by a road or levee would be categorized as having a "*low*" recovery potential if there was little chance of being able to remove the current confinement.

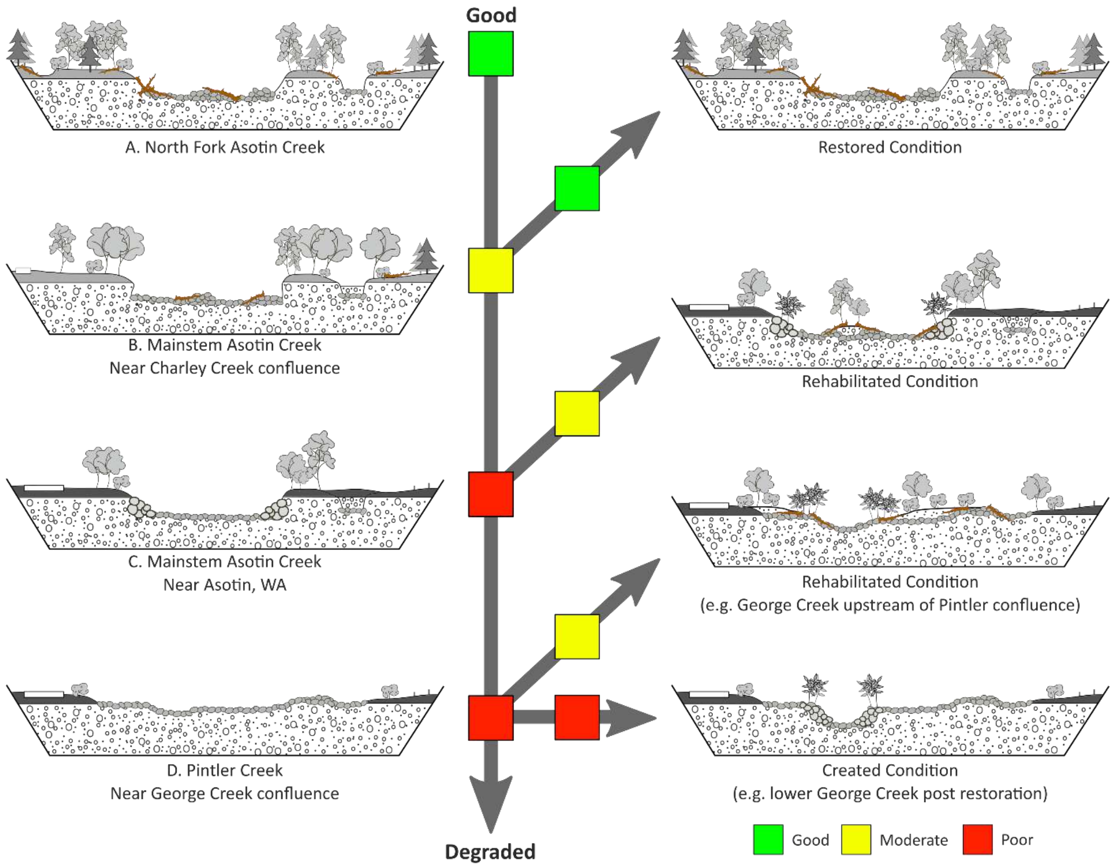

Figure 14. Trajectory of change example for four reach types in target watersheds. Colors represent condition and arrows represent direction of change (up = improving, across = stable or changing to new type of reach, and down = degrading). Current conditions are on the left and potential conditions (change) are on the right.

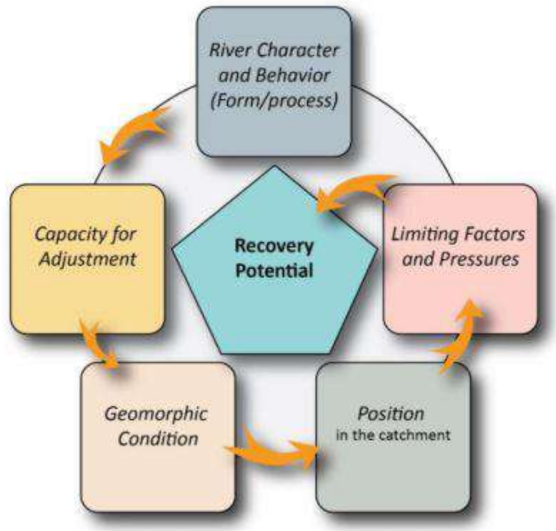

Figure 15. Flow chart showing factors influencing recovery potential of reach types.

The trajectory of river change for every reach type is determined by plotting each variation of a reach type onto an evolutionary diagram that shows conceptual cross sections and their geomorphic attributes, and then using a decision tree to determine the reach's trajectory (Figure 16). The purpose of this component is to make an informed determination of how a reach will likely change if left alone (i.e., no active restoration action taken). At this stage, we also start to determine what restoration actions are appropriate for altering an undesirable trajectory and improving the form and function of a reach. A final determination of a reach's recovery potential is made by processing the above information through a flow chart designed to take into account the inputs depicted in Figure 15. The output from this effort is a network scale map of river recovery potential reported in categories of intact (i.e., fully functioning), high, moderate, and low recovery potential.

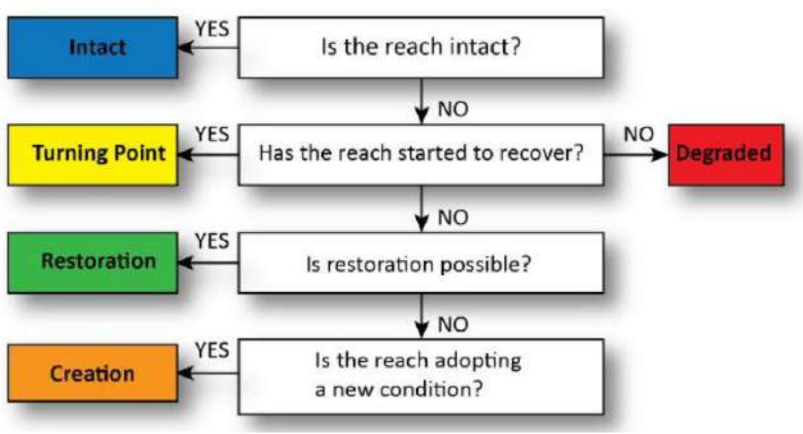

Figure 16. Decision tree for determining trajectory of change for individual reaches.

6.4 SUPPORTING NETWORK ANALYSES AND LANDSCAPE ASSESSMENT

We conducted three other network wide analyses to support our geomorphic assessment: riparian condition, beaver capacity, and stream temperature GIS network models. We did not assess water quality parameters for this assessment other than water temperature but we summarize known water quality issues along with results from the temperature modeling. We also acquired the SRSRB barrier assessment data and plotted the road crossings that were assessed on the perennial stream network to determine if there were any barriers to anadromous or resident fish.

6.4.1. Riparian Condition and Floodplain Fragmentation Assessment

We ran the following GIS network tools to assess riparian and floodplain condition: Riparian Vegetation Departure (RVD) tool, Riparian Vegetation Conversion Type (RVCT), and Riparian Condition Assessment (RCA) tool (Macfarlane et al. 2016). All of these tools rely on the Valley Bottom Extraction tool. We calculated the Riparian Vegetation Departure (RVD) by comparing the current area of native vegetation to the historic area of native vegetation in each 500 m valley bottom polygon using the LANDFIRE dataset (LANDFIRE 2014). The Riparian Vegetation Conversion Type (RVCT) was estimated by comparing the current riparian area by land cover type (agriculture, conifer, grassland, pasture, riparian, shrubs, etc.) to the historic riparian area by land cover type (Appendix C. 2). Land use data was derived mainly from Washington state GIS data portal and floodplain fragmentation is estimated by using the mapped location of roads, railways, and levees bisecting the valley bottom and restricting the river's access to historic valley bottom areas. Results from the RVD and RVCT assessments were then combined with data on land use intensity and floodplain fragmentation to develop an overall riparian condition assessment (RCA). We used a fuzzy inference system to combine the different lines of evidence into a categorical score of riparian function as: full, high, moderate, limited, or very limited function.

We treated confined reaches differently due to the limitations in using LANDFIRE which has a resolution of 30-meter raster cells which spans across the valleys of small, confined streams. Therefore, confined reaches are classified as either *impacted* or *unimpacted* based on land use intensity and floodplain connectivity (typically whether a road was present in the valley bottom or not). We classified a confined reach as unimpacted if a road or other development was upslope of the valley bottom and did not appear to be impacting channel migration or riparian condition.

High Resolution Valley Fragmentation Analysis

Typically, these tools are run using nationally available GIS data including digital elevation models (DEM) that have a 10 m resolution. However, for our analyses we used 1 m DEM for the mainstems of each target watershed that was acquired for Asotin Creek mainstem and the lower 10 miles of North Fork and South Fork Asotin Creek, and Charley Creek in 2012 and the mainstem of George, Couse, and Tenmile Creeks, and lower Alpowa Creek in 2015. We used the 1 m DEM to hand-digitize levees and other confining features to increase the accuracy of our estimate of valley bottom fragmentation. We calculated the percent of connected floodplain by dividing the polygon of valley bottom hand delineated by the total valley bottom identified x 100.

6.4.2. Water Quality

Pollutants

We reviewed water quality sampling by Washington state DOE and assessments of aquatic invertebrates to infer any potential water quality issues that may be impacting fish.

Stream Temperature Assessment

We used a model developed by the Integrates Status and Effectiveness Monitoring Program (ISEMP) to predict stream temperature (McNyset et al. 2015). The model used remotely-sensed Land Surface Temperature (LST) data, day of year, and elevation to predict daily stream temperature every 8 days (average, minimum, and maximum) for every confluence-to-confluence reach in Alpowa Creek, Asotin Creek, and George Creek from 2011-2016 (McNyset et al. 2015). We used data from June 1 to Sept 30 each year to represent the period when high water temperatures were most likely to occur. This period represents 15 unique temperature samples spanning an 8 day period. We summarized the data by calculating the length of stream and number of weeks that the maximum temperature exceeded either 64.4 or 68 °F. Stream temperature data from sites within the Asotin Creek IMW (Bennett et al. 2015) were used to cross-validate the model predictions. With this model we were able to predict how often the stream temperature was likely to exceed critical biological (i.e., lethal temperatures for salmonids) or management temperature criteria (DOE 2002).

We compared 2011 and 2015 summer temperatures models because these two years represent a generally cool year (2011) and hot year (2015) in Asotin Creek. In 2011 the peak and average annual discharge in Asotin Creek were both 56% higher than in 2015, and the summer average and 7-day maximum temperature was 20% lower in 2011.

We also reviewed numerous temperature data sets from within the study area covering the period 2009-2016, and compared them with previous temperature assessments (Bumgarner et al. 2003) to determine if there were any obvious trends in summer temperatures.

6.4.3. Beaver Restoration Assessment Tool (BRAT)

We conducted an assessment of the target watersheds to support dam building beaver using the Beaver Restoration Assessment Tool (Macfarlane et al. 2014). The BRAT tool is used to assess the existing and potential (i.e., historic) capacity of riverscapes to support beaver dam building activities as measured in dams/mile. Capacity is evaluated in GIS using readily available spatial datasets that provide the following lines of evidence (Macfarlane and Wheaton 2013):

1. Evidence of a perennial water source,
2. Evidence of riparian vegetation to support dam building activity (acquired from Riparian Condition Assessment (see above),
3. Evidence of adjacent vegetation (on riparian/upland fringe) that could support expansion and establishment of larger colonies (acquired from Riparian Condition Assessment),
4. Evidence that a beaver dam could physically be built across the channel during low flows, and
5. Evidence that a beaver dam is likely to withstand typical floods.

Factors that can potentially limit beaver from realizing the full capacity such as land use activities (e.g., roads or farming) and potential human conflicts (e.g., irrigation diversions, settlements) were also incorporated into the assessment by including available GIS layers on land ownership, roads, and infrastructure. Rules in BRAT assume that the closer the stream is to roads and infrastructure the higher the probability of conflict. The final output from the BRAT model is Beaver Management, Conservation, and Restoration Zone Model (hereafter Management Model). The Management Model incorporates the potential and existing capacity model and the conflict model and categorizes the watershed based on seven specific conservation and restoration objectives: 1) currently inhabited by beaver or in good shape but under-occupied (Low Hanging Fruit), 2) lack riparian vegetation but can recover quickly if management is changed (Quick Return), 3) low current use but potential sites (Long-term Possibility), 4) Unsuitable: Naturally limiting, 5) Unsuitable: Anthropogenically Limiting, 6) High potential to support beavers but potential conflicts (Living with beaver high source), and 7) Low potential to support beavers but potential conflicts (Living with beaver low source).

6.4.4. Fish Passage

We assessed potential fish passage problems by reviewing a barrier assessment that was conducted for the majority of road crossings within the anadromous fish bearing reaches in southeast Washington (WWCC 2009). We also assessed the condition of the mouth of Couse Creek and Tenmile Creek because they had previously been identified as potential barriers (G. Mendel, Personal Communications).

In this section we present the results of assessments and network GIS analyses conducted based on the watershed assessment framework (Table 1). We restrict our presentation of results of reach-based assessments to the perennial stream network because the focus of the plan is fish habitat. However, we present results based on assessments of the entire 1:24,000 NHD stream layer (i.e., perennial, intermittent, and ephemeral streams) and at the watershed scale (i.e., land use and vegetation management) where they have direct or indirect potential to impact fish habitat.

7. WATERSHED ASSESSSMENT RESULTS

In this section we present the results of assessments and network GIS analyses conducted based on the watershed assessment framework (Table 1). We restrict our presentation of most of our results to the perennial stream network because the focus of the plan is fish habitat.

7.1 GEOMORPHIC ASSESSMENT RESULTS

7.1.1. Reach Types (Stage 1)

We identified 182 miles of perennial stream in the study area (Appendix A. 10). The perennial stream layer is composed of seven reach types in three valley settings: confined, partly confined, and unconfined (Table 13). The most common valley settings for perennial streams across the study area are partly confined (47%) and confined (51%). Confined valley settings are the most common in each target watershed (range 54-75%) except Asotin Creek, which is dominated by the partly confined valley setting (79%). The *confined valley with occasional floodplain pockets* reach type is the most common perennial reach type (61-75%) in each target watershed except Asotin Creek. The most common reach type in Asotin Creek was the *partly confined planform controlled* reach type. The full NHD stream network is 1,465 miles and contains two ephemeral reach types not present in the perennial stream layer: *unconfined upland swales* and *confined steep ephemeral hillslopes* (Appendix A. 10 and Appendix A. 11). Together, *confined steep ephemeral hillslope* reaches (41%) and unconfined reaches (19%) make up 60% of the full NHD stream network. See Appendix C.5 for reach type decision tree that describes differences between the reaches.

Reach type Description - Confined Valley Setting

Steep perennial headwater reach types are present only in the upper reaches of the watersheds extending from the Blue Mountains. Although most reaches are perennial, their hydrology is highly dependent on snowmelt; however, flows may spike in individual subbasins due to high intensity, localized summer storms. Peak flows in these reaches are short because the upstream drainage area is relatively small. These reaches are very steep (>10% gradient) with regular, localized inputs of colluvium from the surrounding hillslopes. This results in the development of long rapids broken up by brief cascades and forced pools. Most of the reaches are in the mesic forest landscape unit with high LWD loading, which forces most pools and traps sediment. Although there may be occasional pockets of floodplain present, these areas are only accessed in extreme floods. The bed is comprised primarily of boulders and cobble with sands and fines commonly deposited in the wake of in-channel structural elements.

The *Bedrock Canyon* reach type occurs infrequently in the drainage, primarily because one of its defining characteristics is the complete lack of a floodplain. The channel is mostly bordered by bedrock, although the bed usually contains a mixed load of boulder, cobble, and gravel. The gradient is steep (5-10%) and the planform is restricted by exposed basalt outcroppings, forcing the river to align to the valley margin. These reaches are found in some minor tributaries and on some sections of the mainstem of Asotin Creek. Small bedrock canyons can be the source of large amounts of sediment during intense, local storm events because of the high valley constriction and proximity to loess sediment sources. For example, the Bedrock Canyon section on Warner Gulch (an ephemeral tributary to the South Fork of Asotin Creek) has experienced multiple documented localized storms which brought in large amounts of sediment deposits to the South Fork of Asotin Creek.

The *Confined occasional floodplain pockets* reach type is the most common reach type in confined valley settings of the project area. It occurs throughout the drainage where confined valleys have developed small areas where the floodplain is accessible, often downstream of tributaries and fan-forced knick points, but is dominant in George Creek and its tributaries. Access to the floodplain may occur infrequently and in small pockets, but may be well developed and store fine grained sediment. The most common geomorphic units are rapids, runs, and forced pools. The streambed is comprised of coarse, often angular substrate, and is stable during bankfull floods. Bedrock is the primary control in these reaches, forcing most of the pools at knick points or brief lengths of high confinement in the channel.

The *Steep ephemeral hillslope* reach type represents 41% of the total stream length in the project area. However, these are not fish-bearing reaches and many rarely have surface flow. These channels are completely confined by the adjacent hillslopes and basalt outcrops and are aligned to the valley. Many reaches begin as Upland swales along the tops of the dissected loess uplands and dissected highlands, and then rapidly increase in slope and confinement as they dissect the basalt layers to reach the higher order tributaries. The instream geomorphic units are step-pool sequences and cascades, with occasional plunge pools. The bed material texture is coarse and angular, consisting primarily of colluvium from the adjacent hillslopes. Even though these reach types are ephemeral, they may contribute large amounts of sediment to perennial reaches and can be affected by upland land use.

Reach Types - Partly Confined Valley Setting

The *Planform controlled with discontinuous floodplain* reach type occurs where the valley widens slightly but is still partly confined. These rivers abut the valley margin 10-50% of the time, and have a low to moderate sinuosity. Multiple high-stage flood channels are common, indicating periodic overbank flow that rework the valley floor. Large floods often force the active channel to shift in areas where it is not pinned against bedrock. These reaches store local slugs of sediment that are mobilized during high flow events, giving rise to shifting channel topography. The floodplain is discontinuous, but well developed with fine grains and a healthy riparian zone. Large woody debris is the primary forcing mechanism for pool and bar development. Cutbanks are common where the channel is migrating laterally and provide an important source of sediment and woody debris.

The *Wandering gravel bed with discontinuous floodplain* reach type is only present on the North Fork and mainstem of Asotin Creek and lower George Creek. The valley in these reaches is slightly sinuous, and the channel can be moderately sinuous with many side channels and anabranches. This reach type is very dynamic, and the main channel shifts often during floods, sometimes reoccupying paleochannels in the floodplain during flood events. The majority of the floodplain is fine grained and typically has a wide riparian zone. These rivers have the sediment load and hydraulic capacity to rework the channel frequently leading to the development of complex bars and habitats, and deposit large gravel and cobble sheets. Beaver dams and ponds occur in this reach, increasing the density of side channels and stored fine sediment in some areas.

The *Fan controlled with discontinuous floodplain* reach type is most common on Charley Creek and Couse Creek where large fans from ephemeral tributaries commonly force the channel to one side of the valley. Most of the debris fans occur on south facing slopes, forcing the channel to the south valley wall, and the river does not have the competence to erode their deposits in typical floods. With debris fans on one side of the valley emanating from tributary sources and bedrock outcrops on the other, these reaches are confined 50-90% of the time. However, they may exhibit localized sinuosity when given the lateral freedom, or in some cases, transition into a planform controlled river style. The planform of these channels is highly stable; however, LWD, roots, and bedrock lead to complex instream geomorphology. The imposition of fans also forces the river into the opposite channel margin leading to occasional 5-8-meter-high cutbanks into terraces or other fans.

Reach Types - Laterally Unconfined Valley Setting

The *Upland swale* reach type is the second-most predominant reach type within a project area. The channel is discontinuous with intermittent ponds and wetlands, and the valley is filled with fine sediment. The Upland swale is found among smooth-sided rolling hills in the dissected loess uplands. Long, shallow swales converge to create larger, smooth-sided depressions in the landscape to form this reach. In the Asotin Creek watershed, most of these reaches are within areas of high agricultural use, and some of the naturally occurring wetlands have been converted into sediment retention ponds.

The *Alluvial fan* reach type is specific to the mouths of rivers where the main channel is flowing over its own fan. The stream's own alluvial deposits accumulate at the mouth of streams in reaction to the mainstem's base level. At the mouth, the river may appear as a single channel, or develop multiple distributaries and flood runners as it attempts to rework deposits. Depending on the primary sediment size in the upstream sections of river, large fan-shaped or arcuate sheet deposits act as remnants of past floods (e.g. sand or gravel sheets). Pools are usually forced by LWD, roots, and riparian vegetation, but can be rare. Long, deep runs are common and usually associated with low gradient sections of the fan and channel spanning LWD. These reaches are battling between reaching a base level at its confluence with the trunk stream, and eroding through massive sediment deposits from large historic floods.

Long Profiles Results

We created long profiles of the main stems of Alpowa, Asotin (including North Fork Asotin Creek), Tenmile, and Couse Creeks to illustrate how landscape units, valley setting, sediment dynamics, and stream power change along mainstems of target watersheds (Appendix C. 7). These profiles will be used for informing the conceptual restoration plan and prioritizing project locations.

Table 13. Characteristics and attributes of valley settings and reach types in the Asotin Watershed Assessment Area.

		River Character			
Confinement Setting - Reach Type	**Landscape Unit**	**Channel Planform**	**Geomorphic Units**	**Bed Material Texture**	**River Behavior**
Confined - Bedrock Canyon	Lower Snake canyons	Single channel, aligned to valley, highly stable	Little or no floodplain. Sequence of cascades and rapids	Bedrock-boulder-colluvium at higher elevations	Very steep, incised channel mostly confined by basalt cliffs on both sides. The floodplain is almost entirely absent and there is no opportunity for lateral adjustment. May be present in low order ephemeral and intermittent streams, but is also common in the lower Snake canyons.
Confined - Steep Perennial Headwater	Mesic forest/dissected highlands	Single channel, aligned to valley, highly stable	Discontinuous floodplain, cascades, rapids, step-pools	Bedrock-boulder-large cobble	Very steep channel, often groundwater dominated, but flow variability is reliant on snowmelt so most of these rivers are intermittent. Limited ability for lateral adjustment. Flushes colluvial deposits from high elevations of the Blue Mountains. Only the large floods extend out of the channel and into the floodplain.
Confined - Occasional Floodplain Pockets	Dissected highlands/lower Snake canyons	Single channel, low sinuosity, highly stable	Discontinuous pockets of floodplain, bedrock outcrops, pool-riffle, rapids, bars	Bedrock-boulder-cobble	Steep channel, often intermittent at high elevations, with alternating assemblage of bedrock forced pools and pool-riffle-rapid sequences. Floodplain is accessed during bankfull floods, but little work is done to the channel. Found in narrow valleys, largely confined by basalt cliffs and often scoured vertically to bedrock.
Confined - Steep Ephemeral Hillslope	All, but primarily dissected highlands, lower Snake canyons	Single channel, aligned to valley, highly stable	Step-pool, cascade	Bedrock-boulder-cobble-gravel-sand	Ephemeral, bedrock-controlled channel, aligned to the valley, and confined by adjoining hillslopes. Coarse bed material texture with highly angular colluvium eroded and transported downstream from adjacent hillslopes. Dominated by step-pool sequences, cascades, and occasional plunge pools.

Partly Confined - Wandering Gravel Bed with Discontinuous Floodplain	Lower Snake canyons	One to many channels, jump channel changes, moderately stable	Discontinuous floodplain, pool-riffle, rapids, bars, frequent paleo channels	Cobble-gravel-boulder	Mostly straight valley. The main channel will suddenly change at greater than bankfull floods, but is otherwise stable. A mostly cobble-gravel bed is reworked often, creating multiple bar formations. Flood channels are very common across the floodplain and are commonly inundated during bankfull floods. Bar forced pool-riffle sequence are common between short sections of rapids.
Partly Confined - Planform Controlled with Discontinuous Floodplain	Mostly lower Snake Canyons	1-3 channels, moderate sinuosity, jump channel changes, moderately stable	Discontinuous floodplain, pool-riffle, runs, rapids, complex bars	Bedrock-cobble-gravel	Channel exhibits low-moderate sinuosity, but can be restricted on occasion by bedrock. Found in wider but still partly confining valleys. Multiple channels may develop in some areas, but one channel will always contain most flow. Larger than bankfull floods will often force sudden alterations to the primary channel. Floodplain is well developed, although discontinuous. Sediment cycles between transport and storage zones, creating complex bars in some areas.
Partly Confined - Fan Controlled with Discontinuous Floodplain	Lower Snake canyons	Single channel, straight, highly stable	Discontinuous floodplain, rapids, step-pool, occasional cascades or large steps in channel	Boulder-cobble	Found in valleys with frequent large fan deposits that ultimately impose the channel into its current position. The erodibility of the lower Snake canyons has resulted in long sections of river where these fans are abundant and may even force the channel up against the basalt cliffs on the opposite valley margin. They may exhibit localized sinuosity, but are more often straight and are highly stable due to the coarse sediment in the debris fans. The constriction points from these fans create sections of high channel slope.
Unconfined - Upland Swale	Dissected loess uplands, dissected highlands	Continuous channel, moderately stable	Continuous floodplain, cascades, step pools, rapids	Loess soils-sand-gravel	Channel is discontinuous with intermittent ponds and wetlands. Valleys are unconfined, shallow, and exhibit a rolling hill topography. Flushes loess soils and agriculture land, but fine sediment can be stored as fill in the ponds and wetlands.
Unconfined - Alluvial Fan	Lower Snake canyons	1 to multiple channels, wide valley, avulsive, low stability	Continuous floodplain, forced pools, runs, side channels, dammed pools	Sand-gravel-cobble	Found at the mouths of some rivers where the main channel is flowing over its own fan. These rivers are at the base of a confined or partly confined valley that acted mostly as a transport zone. When the river enters a wide-open valley at its mouth, the bed material is dumped, and the river is forced to frequently rework the material to reach its base level. LWD from upper river sections tend to stack up here, leading to forced pools, dammed pools, and long deep runs. The bed material is highly dependent on the dominant material from upstream reaches.

7.1.2. Reach Type Summary

- Perennial stream network is much smaller (12%) than entire network
- Most of perennial stream reaches are in confined or partly confined valley settings
- Floodplain areas are mostly discontinuous (i.e., on one side of the valley or other) and in small pockets; so there is limited floodplain habitat in general
- Places that are unconfined tend to be either upland swales that are ephemeral (common reaches) or multi-threaded alluvial valleys that tend to be large sediment deposition zones that frequently dewater (rare reaches)
- Steelhead abundance and distribution is generally restricted to *confined with occasional floodplain* (43%), *partly confined planform controlled with discontinuous floodplain* (34%), and *partly confined wandering gravel bed with discontinuous floodplain* (12%)

7.1.3. Geomorphic Condition Assessment Results (River Styles Stage 2)

Overall, 75% of the perennial stream network has moderate (42%) to high (33%) geomorphic function (Appendix A. 12). We did not identify any full function reaches in the study area. The high function reaches tend to be located in the upper elevation areas of the perennial network (e.g., upper North Fork Asotin Creek and upper George Creek). Moderate condition reach types were generally on a positive trajectory (i.e., improving conditions) because of past restoration actions, especially riparian enhancement and/or fencing. Each reach type tended to have predictable attributes that resulted in being designated as high, moderate, or limited geomorphic function. Limited to moderate geomorphic function confined reach types (e.g., *confined with occasional floodplain*) tended to have over-widened or incised (trenched) channels, floodplains fragmented by development, bed material that was armored and poorly sorted (Table 14). Limited to moderate geomorphic function partly confined reach types tended to be disconnected from the floodplain, entrenched or over-widened, poorly sorted substrate, and low geomorphic and hydraulic complexity. Limited to moderate geomorphic function unconfined reach types tended to be anthropogenically confined, hydrologically disconnected from downstream reaches by impoundments, or exposed to excessive sediment loads. See Appendix A. 14 for geomorphic condition results on the entire NHD network.

Table 14. Geomorphic conditions generally associated with high, moderate, and limited geomorphic function for a) confined with occasional floodplain, b) partly confined wandering gravel bed with discontinuous floodplain, and c) partly confined with discontinuous floodplain.

a) Partly confined planform controlled with discontinuous floodplain

	Good Condition	Moderate Condition	Poor Condition
Channel Attributes	Relatively low width:depth ratio with local variability. Most geomorphic complexity is structurally forced by wood, vegetation, and bedrock outcrops when the channel is near the valley margin. The channel is symmetrical when traversing between valley margins, and asymmetrical on bends and against bedrock at the valley margin. Islands and bars are frequent with varying vegetation levels.	Relatively high width:depth ratio, with local variability. Mostly symmetrical channel with occasional high, eroding banks. Bars and islands are rarely vegetated, and mostly comprised of large substrate. Geometry is mostly symmetrical. Limited woody debris. Some exotic macrophytes may be present.	Very high or very low width:depth ratio; channel may be over widened where banks are unstable, or incised where banks are armored. Slumped or undercut banks are frequent, otherwise is an entirely symmetrical geometry. No woody debris. Limited instream woody vegetation and abundant exotic macrophytes.
Channel Planform	Usually single, but sometimes multiple channels forced by organic structural elements. Low sinuosity along valley margin, moderate sinuosity when traversing to opposite valley margin. Moderate lateral stability, and adjusting when conditions permit. Planar features are separated by forced bar and pool complexes. Riparian zone is relatively wide with mix of cottonwoods, alders, and native conifers.	Almost always single channel and low sinuosity. Laterally unstable with accelerated bank scour, but limited lateral expansion. Mostly planar geomorphology, with some forced pools and bars. Occasional private levees restrict access to floodplain. Limited riparian zone with mixed native and exotic canopy. Much of the floodplain has been converted for agriculture.	Single channel with low sinuosity. Laterally unstable, but no room for expansion. Almost entirely planar channel units with occasional pools. Floodplain has been converted to agriculture or urban use. Very limited riparian cover.
Bed Material	Well-sorted bed material with well-defined facies typically forced by structural elements. Bars are comprised of gravel and smaller classes. The channel bed is stable and sediment flux is balanced. Sediment transfer zone with pockets of storage.	Poorly sorted bed material with pockets of defined texture around infrequent structural elements. Limited roughness due to lack of instream vegetation and woody debris. Bed is stable and the sediment flux is balanced. Sediment transfer zone.	Homogenous bed material, mostly large clasts armoring the bed. Sediment is poorly sorted with limited pockets of defined texture. Unstable bed is incising in most areas. Sediment transfer zone.
Photograph	**Upper Charley Creek** 	**Middle South Fork Asotin Creek** 	**Middle Asotin Creek** 

b) Partly confined wandering gravel bed with discontinuous floodplain

	Good Condition	Moderate Condition	Poor Condition
Channel Attributes	Relatively low width:depth ratio across the bankfull channel. Geomorphic complexity at the reach scale revolves around the development and working of mid-channel and point bars. Most pools are either forced by bars or LWD. The channel is mostly asymmetrical as it wanders across the valley bottom. Islands and bars are frequent with varying vegetation levels, representing relative timelines for the creation of bars and islands.	Relatively high width:depth ratio across the bankfull channel with local variability. Geomorphic complexity is still relatively high, but typically occurs in pockets between planar features and most often forced by structural elements such as LWD and bedrock outcrops. Bars are smaller and less frequent, mid-channel bars are the most apparent contrast to good condition, as the higher width:depth ratio limits room for bar development.	Very high width:depth ratio. Geomorphic complexity is very low with brief pockets of dynamic features typically forced by rare structural elements such as LWD. Bars are rare, small, and alternate bars are the most common. Planar units such as runs and rapids are the dominant geomorphic unit. Channel is symmetrical with steep and tall channel margins.
Channel Planform	Usually one dominant channel with multiple side channels, especially in sections with a lower gradient. Sinuosity in the main channel and secondary channels is typically moderate. Chutes that create the very common diagonal bar geomorphic unit are typically straight. Lateral stability is moderate as meander bends are slow to traverse laterally; however, avulsions that create a new main channel are common during large flow events. Long dynamic sections with low-gradient are separated by relatively short sections of rapids and cascades. The riparian zone typically covers the entire floodplain and dominated by cottonwood, alder, and mixed conifers at higher elevations.	Usually one dominant channel; side channels are far less common. Channel may be straightened and entrenched, limiting its ability to migrate laterally and access the floodplain. Laterally stability is high, especially in entrenched portions of the channel where compacted cobble/gravel matrix is exposed and armors the banks. While there are still dynamic sections with high complexity, they are typically less frequent and dependent on LWD loading to maintain geomorphic complexity. Riparian zone may be limited where the channel is entrenched and the water table has lowered.	Usually single thread, entrenched channel. Sinuosity is low and the channel is typically confined against the valley margin, levees, rip-rap, infrastructure, or its own entrenched, armored channel. Laterally stability is very high, although channel avulsions may still occur. Floodplain is mostly disconnected and upland vegetation encroachment is common as the water table is lowered.
Bed Material	Well sorted bed material with well-defined facies typically maintained by channel planform and structural elements. Bars are comprised of gravel and smaller classes, but larger floods can result in large cobble sheet deposits that develop into islands. The channel bed is stable and sediment flux is balanced. Long-term depositional zone.	Generally, bed material is poorly sorted with pockets of defined facies near structural elements and gradient breaks. Bar material is more skewed to larger classes, but typically sizes typically taper. The channel bed is typically stable, but large floods may cause local degradation in entrenched sections. Still dominantly a depositional zone over long reaches.	Bed material is poorly sorted and consists of a uniformly distributed cobble/gravel matrix. The channel bed is relatively stable. Sediment transfer zone.
Photograph	**Middle North Fork Asotin** 	**Lower North Fork Asotin** 	**Mainstem Asotin near town** 

c) Confined with occasional floodplain

	Good Condition	Moderate Condition	Poor Condition
Channel Attributes	Low width:depth ratio. Geomorphic complexity is high, but the total number of different geomorphic units is low compared to more dynamic reach types. Units are typically forced by LWD, boulders, and bedrock outcrops. The channel is typically symmetrical, but will be asymmetrical on the occasional meander bends. Macrophytes and mosses are fairly common. LWD (in forested areas) and boulder density is high.	Relatively low width:depth ratio, asymmetrical channel. Macrophytes and mosses may still be common. Geomorphic complexity is relatively low with sparse pockets of diverse habitat. LWD and boulders are relatively rare.	Very low width:depth ratio, symmetrical channel with high banks. Macrophytes are less common, but sedges and rushes may become more prevalent on inset floodplain surfaces. LWD is rare, but boulders may be more prevalent as they are typically exposed or dislodged from the bank when the channel is most degraded.
Channel Planform	Single thread channel with low sinuosity and occasional meanders. Floodplain pockets are small but frequent and easily accessible during bankfull floods. Gradient is relatively high, and dominant geomorphic units are runs, rapids, riffles, forced pools, and forced bars. Laterally stability is typically high; however, floodplain pockets often erode and new pockets develop during larger floods. Riparian vegetation is typically dense, but species composition is dependent on precipitation levels (e.g., canopy species may not be prevalent, but shrubs typically are).	Usually single thread channel, wider sections will have multiple shallow channels. Sinuosity is low. Gradient varies with lower gradient sections separated by headcuts. Dominant geomorphic units are runs and rapids. Lateral stability varies and often low on one side while high on the other as the channel responds to disturbance. Riparian vegetation varies and still primarily dependent on precipitation levels.	Single thread channel with very high lateral stability. Geomorphic units assemblage is dominated by planar units, most common are runs, rapids, and cascades. Riparian vegetation on the floodplain is sparse or non-existent; however, as inset floodplain surfaces develop, shrubs, willows, and alders may be present.
Bed Material	Bed material is well-sorted by geomorphic unit with pockets of well-defined facies near structural elements. Sediment transfer zone.	Bed material is poorly sorted except around structural elements. Sediment transfer zone.	Bed material is poorly sorted. Sediment transfer zone.
Photograph	**Mill Creek** 	**Upper Alpowa Creek** 	**Charley Creek** 

7.1.4. Geomorphic Condition Summary

Watershed Conditions

- 76% of the study area has moderate to high geomorphic function

Reach Type Conditions

- Confined Reaches
    - Generally have high geomorphic function because they have a relatively low capacity for adjustment and land use impacts are limited in these reaches.
- Partly Confined Reaches
    - Generally are have limited to moderate geomorphic function because they have a moderate to high capacity for adjustment, the floodplain may be fragmented reducing discontinuous and occasional floodplain areas, or impairing function and/or maintenance. Large woody debris tends to be well below reference conditions and dominated by small and fast decomposing alder (e.g., Charley, lower North Fork and South Asotin Creeks, portions of Alpowa, Couse, upper George, and Tenmile). These are the key reaches for fish abundance and distribution.
- Unconfined Reaches
    - Generally in limited to moderate geomorphic function because they have a relatively high capacity for adjustment and typically occur in agricultural areas (*Upland Swales*) or near residential development (*Alluvial fans*).

Common Causes of Impairment

- low diversity of geomorphic units (i.e.., more runs and fewer pools, bars, side-channels), low frequency of structural elements (primarily LWD), channelization, limited connection to floodplain, low riparian function (limited extent, young age, low species diversity), low thalweg variability

7.1.5. Recovery Potential Results (River Styles Stage 3)

Among the priority reaches in the target watersheds, 74.2% have a high recovery potential, 20.4% have a moderate recovery potential, and 5.4% have a low recovery potential (Appendix A. 14). The bulk of reaches with low recovery potential are located in lower George and Asotin Creeks. Many of the reaches in the study area are recovering due to past conservation practices and changes in land management. Recovery potential is particularly high for upper reaches in most streams in the study area. Stream reaches that have a particularly low recovery potential are the reaches that run dry most summers on lower George, Pintler, Couse, and Tenmile Creeks. These reaches have had large natural disturbances in the past, are geomorphically active areas, and have naturally low summer flows. There has been some attempt to alter the reach type by creating a new condition in these areas – but it remains to be seen how successful these strategies will be.

7.2 RIPARIAN CONDITION AND FLOODPLAIN FRAGMENTATION RESULTS

Our riparian and floodplain assessment provided estimates of riparian vegetation departure (RVD), riparian vegetation conversion type (RVCT), overall Riparian Condition (RCA), and an estimate of valley bottom fragmentation due to development (e.g., roads, levees, rip-rap, and infrastructure). These estimates were developed for both the perennial stream network and the entire NHD stream network (except the valley fragmentation estimate using 1 m DEM which was only conducted on the mainstem perennial network where 1 m data was available).

7.2.1. Riparian Vegetation Departure (RVD)

There was a significant reduction in the current riparian area compared to the historic riparian area across the study area (Appendix A. 15). We identified that 52% (91.5 stream miles) of the riparian area along the perennial stream network had a large departure (33%), or a significant departure (19%) from historic conditions. We classified a large departure as a > 66% reduction in riparian area and a significant departure as a 33-66% reduction in the riparian area. The reduction in riparian area tended to be greater in lower elevation areas and in Alpowa, Couse, and Tenmile Creeks. Asotin Creek had the most highest riparian functioning with 62% (42.2 stream miles) of riparian area having minor (21%), or negligible (41%) departure from the historic riparian area. We classified minor departures as a 10-33% reduction and negligible departures as a < 10% reduction in riparian area.

Photo 1. Example of a large departure from historic riparian conditions along Charley Creek in the Asotin Creek watershed. The riparian area is thin and grassland and sage brush has encroached to within a few feet of the channel on both sides of the creek.

7.2.2. Riparian Vegetation Conversion Type (RVCT)

Approximately 50% of the historic riparian area has been converted to another land cover across the study area (Appendix A. 16). The most common loss of riparian vegetation was a conversion to grassland/shrub land cover which accounts for 24% of vegetation conversion across the study area. Grassland/shrub land cover is often associated with upland vegetation encroachment within disconnected floodplains. Conifer encroachment (14%) and development (8%) were the next most common conversion types across the study area. Conversion to invasive species was especially high in George Creek (9%) and conversion to agriculture was highest (5%) in both Alpowa and Tenmile Creeks.

7.2.3. Riparian Condition Assessment (RCA)

Fragmentation of the floodplain was assessed and combined with the results of the departure (RVD) and conversion (RVCT) assessments to get an overall riparian condition of the perennial stream network. Thirty two % of the riparian areas in the perennial stream network were classified as unimpacted across the study area (Appendix A. 17). These unimpacted reaches were in confined valley settings and could not be fully assessed with Riparian Assessment tool because the LANDFIRE data was too coarse (30 m raster data) to determine changes in riparian vegetation. Confined reaches that were classified as impacted made up 14% of the study area. Fully functioning riparian areas accounted for 13% across the study area with Asotin Creek having the highest amount of fully functioning riparian (24%) and Alpowa having the least (4%). See Appendix A. 18 for riparian condition results for the entire NHD network.

7.2.4. High Resolution Floodplain Connection Analysis

We had 1 m resolution DEM data for 76 miles (43%) of the perennial stream network which we used to digitize levees and other features confining streams and limiting floodplain connection. The 76 miles of floodplain accounted for a maximum extent of 1,739 acres of potential floodplain habitat (Appendix A. 19). We estimated that 22% (498 acres) of the historic floodplain (i.e., valley extent) were disconnected across the study area. George Creek, Couse Creek, and Tenmile Creeks had relatively low amounts of disconnected floodplain ($\leq$ 10%) whereas Asotin and Alpowa Creeks had relatively high amounts of disconnected floodplain (25-47%). Only the lower Alpowa Creek was assessed for fragmentation because of the extent of the 1 m DEM data available which inflates the amount of disconnected floodplain relative to the extent of the perennial stream network. Disconnected floodplain was more common in the lower reaches near development and along the mainstem Asotin Creek.

7.2.5. Riparian Condition Summary

- Valley bottom along mainstem sections of target watersheds generally < 100-300 feet
- Valley fragmentation is present in some sections of wandering gravel bed mainstem sections but recovery potential is low due to housing and cattle operations using these areas;
- RCA analyses suggests Alpowa and Asotin Creek riparian function is moderate to high; George, Tenmile, and Couse have limited to moderate riparian function; land conversion to grassland/shrubs, development, and conifer encroachment appears to be the main reason for decreased riparian function
- However, a significant amount of riparian degradation may be due to the poor channel conditions which currently promote rapid runoff with little or no overbank flow. This leads to a narrow band of riparian along the reach, which further exacerbates the problem because the channel cannot adjust laterally, which leads to increased channelization. As the stream bed becomes more entrenched, the water table lowers, allowing upland vegetation to encroach into areas formerly dominated by riparian species

7.3 WATER QUALITY RESULTS

7.3.1. Pollutants

The lower portion of Asotin Creek and much of Alpowa Creek exceed Washington state fecal coliform standards for water quality (HDR 2006, WADOE 2015). Failing sewage systems and livestock feeding and grazing operations are the sources of contamination. We are unaware of any negative effects of current fecal coliform levels on fish populations. Water quality appears to be generally good in the upper reaches of most of the study area based on some limited samples of aquatic invertebrates collected at IMW sites (S. Bennett, unpublished data) and by the USFS (Dowdy 2002) that had abundant mayflies and stoneflies.

7.3.2. Temperature Assessment Results

We used results from a temperature model based on remotely-sensed Land Surface Temperature (LST) data, day of year, elevation, and data from a set of stream temperature probes used by the Asotin IMW (Bennett et al. 2015) to predict daily stream temperature every 8 days (average, minimum, and maximum) for every confluence-to-confluence reach in the study area (McNyset et al. 2015). We used the mean maximum 8-day stream temperature predictions for the summer (June-September) in the perennial stream network for Alpowa and Asotin Creek. We selected a year that had high stream flows and lower air temperatures (2011) to compare to a year with low stream flows and higher air temperatures (2015). In 2011 (cool year), 28% of Alpowa Creek, 23% Asotin Creek, and

19% of George Creek exceeded 64.4 °F at least once in three or more weeks[2] (Appendix A. 20). However, only 12% of Alpowa Creek and 0% of Asotin and George Creeks exceeded 68 °F in 2011 (Appendix A. 21). In 2015 (a warm year), 69% Alpowa Creek, 62% Asotin Creek, and 59% of George Creek exceeded 64.4 °F in three or more weeks (Appendix A. 22) and 59% of Alpowa Creek, 19% of Asotin Creek, and 24% of George Creeks exceeded 68 °F for three or more weeks (Appendix A. 23).

We also summarized numerous temperature data sets available in the watershed from DOE stream gauge sites and IMW survey sites. Asotin Creek exceeded the average 7-day maximum water temperature of 72 °F on average 7.6 days/year based on six years of summer temperature data (Appendix B. 16). Asotin Creek above George Creek, Alpowa Creek near the mouth, and South Fork Asotin Creek near the mouth all exceeded 72 °F approximately 2-3 days/year. No other streams in the study areas exceeded average 7-day maximum temperatures of 72 °F.

Stream temperature data from various gauges in the study area were reviewed (Appendix C.8 and Appendix C.9). These data confirmed that water temperatures are relatively warm in the lower river. Average maximum stream temperatures did exceed 72 °F in lower Tenmile and Alpowa Creeks, but not Asotin Creek or George Creek during the period of 2011-2013 (Tenmile) and 2011-2016 (Alpowa, George, and Asotin). Average stream temperatures for all data reviewed did not exceed 70 °F.

7.3.3. Water Quality Summary

- Water temperatures continue to exceed optimal ranges for salmon and trout during rearing in the lower reaches of Alpowa, Asotin, George, Couse, and Tenmile Creeks in some years (i.e., low flow)
- However, optimal temperatures are generally exceeded for short periods and overall mean temperatures for most stream reaches are at or near optimal conditions
- Lethal stream temperatures are rare except for areas that dewater
- Steelhead in the study area are adapted to low flow conditions with higher average stream temperatures than populations west of the Cascade Mountains; however, when the geomorphic conditions are degraded, warm temperature may be more of a limiting factor

7.4 BEAVER RESTORATION ASSESSMENT RESULTS

The current capacity for dam building beaver is relatively high across all watersheds (Appendix A. 24). Asotin Creek has the greatest current capacity to support beaver with 61% of the stream miles (109 miles) able to support frequent (6%) to pervasive (45%) beaver dam densities. Couse Creek has the lowest capacity to support frequent (17%) and pervasive (2%) beaver dam densities. In general, the lower elevations of each watershed had low to rare capacities. Historic capacities were higher and there was a shift to larger proportions of the watersheds being able to support the highest densities of beaver (18%; Appendix A. 25). The conflict potential results indicate almost 40% of the study area has a 25 to > 75% conflict potential (Appendix A. 26). High areas of conflict potential occur in the lower Alpowa, Pintler, George, Charley, and Asotin Creeks, and upper Couse Creek, Mill Creek, and Charley Creek. The conflict potential analysis is a first pass of the potential issues. If beaver restoration was to be implemented, a review of these results would be advised. For example, much of Charley Creek has a road along it, which is why it is being flagged as having a high potential conflict. However, the road is typically outside the valley bottom and WDFW now owns much of lower Charley Creek which would reduce the potential conflict. The beaver management zone assessment suggests that there are numerous potential reaches that could be sites for beaver reintroduction or simulation of beaver dams with beaver dam analogs (Appendix A. 27). The management zone

[2] A week in this analysis represents an 8 day period where an average, minimum, and maximum temperature was predicted for each segment of stream. There were 15 unique 8 day periods from June 2 to September 30 each year.

also flags several areas that would likely not be suitable for beaver reintroduction including lower Pintler and George Creek because these sites have characteristics that naturally limit beaver occupation (e.g., intermittent flows).

7.4.1. Beaver Restoration Assessment Summary

- Current and historic beaver capacity appears to be relatively similar, suggesting that past riparian restoration actions have improved the vegetation cover in riparian areas
- There is moderate to high conflict potential in portions of the watershed that have houses or roads
- However, at least 37% of the study area appears to have high potential to support more beavers with a low probability of conflict

7.5 FISH BARRIERS

One potential fish barrier was identified along the perennial stream network during the 2008-2009 SRSRB sponsored survey of road crossings throughout the target watersheds (Appendix A. 28). In addition, the alluvial fan at the mouth of Couse and Tenmile Creek is a potential barrier for juvenile steelhead during low flows and may be a significant threat during fall migration periods when water levels are only slightly elevated. Assessing restoration options at these sites is recommended.

8. ASSESSMENT SUMMARY AND GOALS FOR RESTORATION

8.1 ASSESSMENT SUMMARY

The study area has several distinguishing features that have a large influence on our findings and the potential to restore fish habitat. First, the region is dominated by long, hot summers, and low annual precipitation. Watersheds are short and steep, with streams that generally have narrow valleys and discontinuous, or patchy floodplain areas. In streams headwatered in the Blue Mountains (Asotin Creek), stream flows are snow-rain dominated. In watersheds not headwatered in the Blue Mountains, flows are dominated by groundwater, and have very low or intermittent flows during the summer months.

We assessed over 182 miles of perennial stream in the study area and found that 76% of the length had moderate to high geomorphic function. Past conservation actions appear to have stabilized many limiting factors and in general, geomorphic conditions are stable or improving in most reaches. Reaches with limited geomorphic function were often due to low habitat diversity, lack of LWD, simplified channel planforms, and limited access to the floodplain. We found that in general, riparian areas were recovering with 67% of the perennial stream network having moderate to near fully functioning riparian habitat. Reaches with limited riparian function were often due to reduced extent of riparian habitat, young riparian canopy, monoculture of species, invasive species, upland encroachment, and conversion to agriculture or development. The moderate to high function of the riparian areas provides a large proportion of the watershed that could support beavers with limited conflict potential. However, we identified 498 acres (22%) of disconnected floodplain across the study area out of 2,237 acres of potential floodplain, and stream temperatures are still less than optimal in many lower elevation reaches. Below, we describe restoration strategies to improve degraded habitat conditions for the benefit of fish populations and to meet restoration goals specific to the study area (SRSRB 2011). More detailed restoration actions will be presented in the Conceptual Restoration Plan.

8.2 RESTORATION GOALS

The recovery goals of the SRSRB (2011) are to "… to have all extant populations at either viable (low risk) or highly viable status, with representation of all the major life history strategies present historically, and with the abundance, productivity, spatial structure and diversity attributes required for long-term persistence". The restoration strategies we are proposing to meet these goals are consistent with the strategic guidelines for restoration adopted by SRSRB (2011), and include actions that have a long "life span", distribute benefits across a range of environments, and blend immediate actions (not necessarily process-based) with long-term actions that deal with root causes of habitat impairment. The Snake River Salmon Recovery Board developed a set of general restoration objectives for the major spawning areas (MaSA) in the Asotin Creek study area (Table 15). We propose that these objectives be reviewed based on the results of our assessment and that revised objectives be used in the Conceptual Restoration Plan.

Table 15. Summary of habitat factors and associated objectives for Asotin Assessment Study Area Major Spawning Areas (MaSA). Reproduced from SRSRB (2011).

MaSA	Priority	Habitat Factor and Objective
Alpowa Creek	I.	Riparian > 80% of maximum
	II.	Embeddedness < 10%
	III.	Temperature $\leq$ 4 days > 72 °F
	IV.	Large Woody Debris > 1 piece per channel width
Asotin	I.	Large Woody Debris > 1 piece per channel width
	II.	Embeddedness < 10%
	III.	Bed scour reduce to < 10 cm
	IV.	Riparian > 75-90% of maximum
George	I.	Embeddedness < 10%
	II.	Large Woody Debris > 1 piece per channel width
	III.	Riparian > 75% of maximum
	IV.	Temperature $\leq$ 4 days > 72 °F

9. RESTORATION STRATEGIES

We present a set of restoration strategies to address the limiting factors we identified. We also provide a summary of what limiting factors potential restoration strategies and actions may address (Table 16). We mapped these restoration strategies on 44 restoration reaches across the study area. The restoration strategies are adapted from Roni et al. (2002) which suggest the following prioritization of restoration strategies (Figure 3): 1) protect and maintain natural processes, 2) remove barriers and reconnect disconnected habitats, 3) restore long-term processes (e.g., sediment routing, riparian function, nutrient cycling), and 4) restore short-term processes. We follow this basic prioritization framework but adapt it for the specific limiting factors we identified in the study area. Below we describe these restoration strategies, how they fit into our framework and how the strategies will address current SRSRB (2011) restoration goals and other potential goals that may be considered in the Conceptual Restoration Plan.

9.1 PROTECT AND MAINTAIN NATURAL PROCESSES

9.1.1. Protect fragile soils, maintain soil conservation practices, and protect and enhance riparian areas

Our assessment suggests that measures to minimize erosion in loess dominated watersheds should continue to be a top priority. Numerous conservation programs are promoted by ACCD and NRCS in the county, and landowners have adopted many best management practices to reduce erosion. These efforts should be continued and enhanced where erosion concerns still exist. Riparian protection and enhancement should also be a priority throughout the study area. Riparian habitat has shown great recovery in many areas, but these habitats can be easily damaged and many riparian areas have been reduced which also makes them vulnerable to disturbance. We identified protection reaches based on the assessment results and the location of the reach within the watershed (Appendix A. 29). We also suggest the protection reaches are potential places to implement a trial beaver reintroduction (see alternative restoration strategies below).

9.2 REMOVE BARRIERS AND RECONNECT DISCONNECTED HABITATS

9.2.1. Barrier removal

Barrier removal is paramount to recovering fish populations and should be a top priority for active restoration actions. In Asotin County, it appears most of the fish barriers have been removed (e.g., Headgate Dam was removed completely in 2016). However, there are potential flow barriers at the mouth of Tenmile and Couse Creeks. Addressing these barriers will involve a multi-stakeholder and agency participation.

9.2.2. Reconnect habitats

Disconnected habitats are generally restricted to the lower mainstem reaches where infrastructure density is highest. The disconnection of floodplain reduces the extent of riparian vegetation which can lead to increased water temperatures and reduced input of wood to streams. The confining features increase the velocity of high flows because the water is contained within the channel. These confined channels transport wood more effectively which reduces cover for adult and juvenile fish. Fish are especially susceptible when the flows are high because there is limited velocity refugia in these sections.

9.2.3. Promote overbank flow

We suggest another process that needs addressing is increasing the frequency and duration of overbank flow. This is a similar strategy to “reconnecting habitats” but has some important differences. Unlike reconnecting habitats, promoting overbank flow is appropriate where there is no readily identifiable confining features. This situation is very common in the study area. Successive floods over the last 200 years, removal of riparian areas, straightening of the channel, and removal of LWD have created very efficient “bowling alleys” out of many of the streams. In order to “reconnect” these streams to their floodplains, restoration strategies are needed that promote overbank flow. Strategies that either cause avulsions, deposition, and the slowing of flows would all help to achieve greater overbank flow. The IMW has recently installed almost 700 wood structures in Charley, North Fork, and South Fork Asotin Creeks and demonstrated that overbank flow can be achieved in these systems. Once overbank flow is more common, riparian areas will have the ability to expand (i.e., more water on floodplain), more refuge habitat will be available for fish during high flows, wood recruitment will increase, and groundwater recharge will increase.

These responses can lead to improved riparian function, less solar input to streams (less heating), and better sediment sorting and storing (i.e., more gravel bars created for spawning, more sediment trapped on floodplain).

9.3 LONG-TERM PROCESSES

9.3.1. Riparian management

Many of the mainstems of the study creeks have some form of riparian protection and as a result riparian areas have moderate to high function in the majority of the study area. However, significant areas are still in need of riparian protection. A variety of riparian management strategies will be required depending on the specific conditions and needs of landowners. In many areas, invasive weeds and/or upland encroachment are impairing the function of riparian areas. Active weed management and planting may be required in these areas. In other areas, grazing pressure is damaging riparian plants or preventing recruitment. Fencing and off-site water developments have been proven to help manage grazing pressure in these situations and have been successfully implemented by ACCD and their partners in the study area.

9.4 SHORT-TERM PROCESSES

a) Improve Instream Habitat - A common impairment of fish habitat in Asotin County is low habitat diversity. Limited riparian function, limited floodplain connection, and past floods have all led to low volumes of LWD in the streams. Large wood is a main driver of habitat complexity and its importance in stream processes is no longer in dispute (Roni et al. 2015). There are several alternatives to adding large wood to create habitat complexity. In areas of confinement and high densities of infrastructure (i.e., near towns and bridges), restoration strategies will require engineered approaches to reduce the potential that structures will fail or cause unintended consequences. However, in large portions of the study area where infrastructure is minimal, it may be appropriate to use non-engineered LWD restoration approaches such as post-assisted log structures or whole trees (Wheaton et al. 2012, Carah et al. 2014).

9.5 ALTERNATIVE STRATEGIES

There are a variety of other management strategies that could be beneficial to overall restoration objectives which include:

- Fuel reduction is a necessity across the west. Using a coordinated thinning program could be very effective at meeting fuel reduction, wildlife management, and stream restoration objectives. Snags, Legacy Trees, Openings, Patches, Piles, Shrubs, and Logs (SLLOPPS) is a forest fuels reduction approach that can be used to provide LWD small woody debris material for the benefit of forest wildlife and creating fish habitat (Strong et al. 2016).
- Traditional riparian management actions (i.e., fencing/exclusion) could be substituted in selected areas with controlled grazing that focuses on managing the timing, duration, frequency, and intensity of the grazing. Managed grazing in riparian areas can increase vigor and function and provide landowners with increased cattle production and alternative grazing areas (Swanson et al. 2015, Kozlowski et al. 2016).
- Recognition and use of beavers as nature's engineers is not new, but the increase in beaver management as a part of stream restoration has become very popular in recent years (Pollock et al. 2015, Bouwes et al. 2016b). There is an enormous potential in the study area to achieve multiple objectives at low cost by having beavers do the work. We suspect that many of the perennial streams were home to beaver populations prior to Euro-American settlement. Evidence of beaver activity is still common and dams have been documented on the mainstem of Charley, North Fork, and South Fork Asotin Creeks. It is speculated that high densities of cougars and poor habitat conditions (long stretches of shallow habitat) are

preventing beaver from recolonizing the study area. We propose developing a beaver management plan in conjunction with WDFW and local landowners prior to attempting a reintroduction.

- Nutrient enhancement (e.g., adding fish carcasses or analogs) has the potential to increase the effectiveness of stream restoration actions and this strategy could be implemented as a trial in the study area. There was a much more diverse fish assemblage in the study area historically and much higher densities of returning adults which would have provided substantial marine derived nutrients to the system. The reduced diversity and abundance of anadromous fish could be limiting the current carrying capacity and this could be tested with a trial. Nutrient enhancement has been moderately successful in some areas, but it is not widely used, and it is not clear how effective it is (Harvey and Wilzbach 2010, Childress et al. 2014, Bellmore et al. 2017).

Table 16. Steelhead and spring Chinook salmon limiting factors addressed by proposed restoration strategies. Dots indicate restoration actions that may reduce or eliminate the influence of limiting factors.

Restoration Categories (Specific Actions)	Channel Stability [1]	Flow	Habitat Diversity	Sediment Load	Temperature	Key Habitat Quantity	Obstructions [2]	Nutrients/Production	Flood Damage
Riparian protection and enhancement									
Riparian planting	•	•	•		•				
Riparian enhancement (see instream structures)	•	•	•	•	•	•		•	•
Instream structures (adding structural elements)									
High-density LWD - Post-assisted log structures	•	•	•	•	•	•		•	
Live trees and/or dead trees (key pieces)	•	•	•	•	•	•		•	
Engineered log jams	•	•	•	•	•	•		•	
Boulders	•	•	•			•		•	
Improve channel and floodplain function									
Activating/creating side-channels	•		•	•	•	•		•	
Removing/setback confining features (levees, rip rap, infrastructure)	•		•	•	•	•			
Instream structures (adding structural elements)	•	•	•	•	•	•		•	
Passage Improvement									
Engineered structural elements			•			•	•	•	
Activating/creating side-channels	•		•	•	•	•		•	•
Barrier removal		•	•			•	•		
Beaver reintroduction/management									
Beaver dam analogs	•	•	•	•	•	•		•	
Reintroduction	•	•	•	•	•	•		•	
Beaver management	•	•	•	•	•	•		•	
Nutrient enhancement									
Salmon carcasses and/or carcass analogs								•	
Levee and rip rap removal/flood channel development									
Widen rip rap sections where possible		•	•	•				•	•
Develop flood channels to accommodate floods		•	•	•				•	•
Biological									
Reintroduction of lamprey, chinook, and coho								•	

[1] it appears that in the past channel stability has been defined as "positive" for fish but we contend that bank instability (as defined by adjustment of the channel due to erosion and avulsions) can be positive if it occurs within the natural conditions and frequency of the reach type where it occurs.

[2] potential flow related barrier at mouth of Couse and Tenmile and one culvert crossing in Lick Creek

10. RESTORATION REACH SUMMARIES

Below we describe the character, condition, and fish use of restoration reaches. The restoration reaches were determined using a combination of reach type, condition, location, and restoration recommendations. Maps of LIDAR imagery, valley bottom extent, and anthropogenic confining features are provided by river mile in Appendix E. Summary tables of the valley setting, reach types, hydrologic regime, geomorphic function, riparian function, recovery potential, fish species life stage and use, and recommended restoration strategies by restoration reach type are provided in Appendix F. Note river mile designations are approximate and were estimated with NHD data.

10.1 ALPOWA CREEK

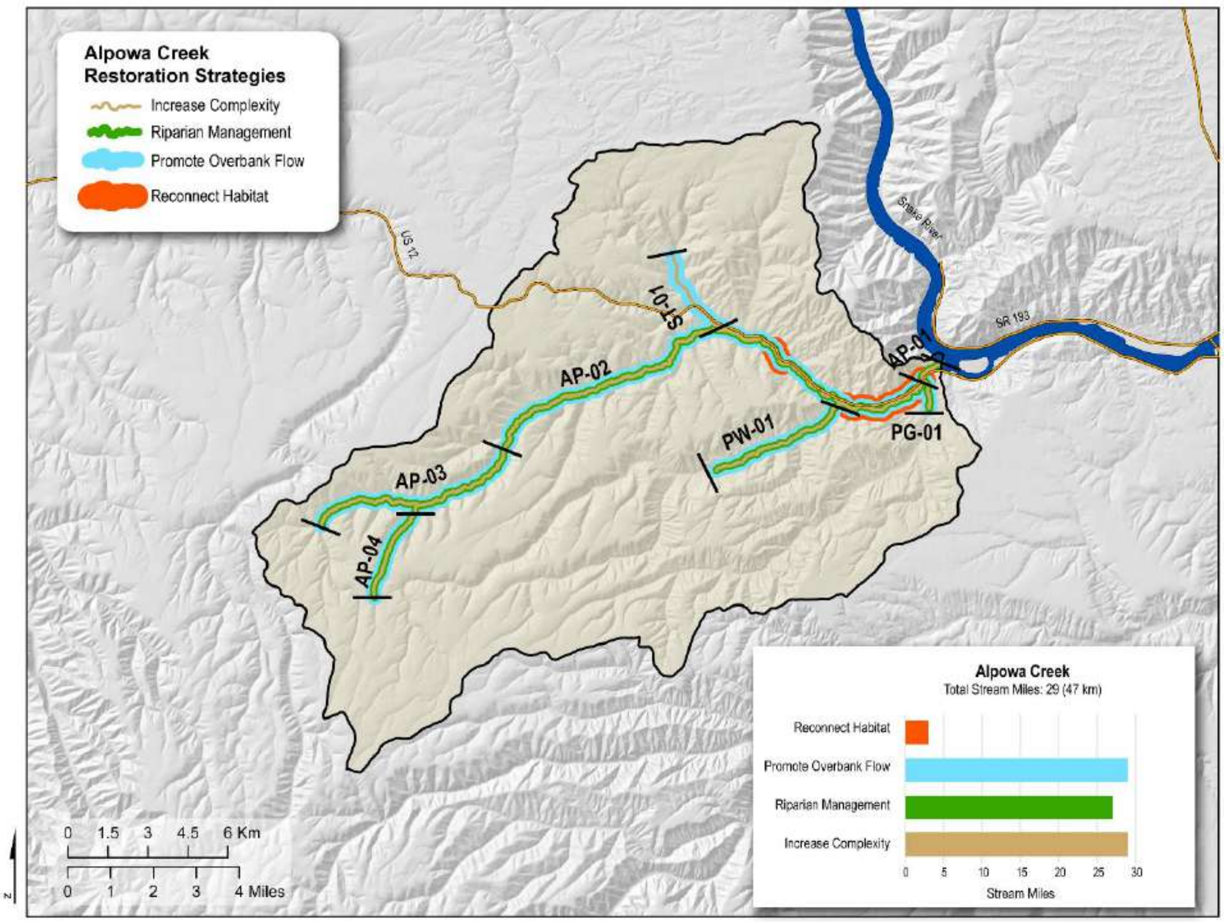

Figure 17. Restoration strategies and reach breaks for Alpowa Creek. Reach breaks are labeled by stream and reach number: AP_01 = Alpowa Creek restoration reach 1. Restoration strategies are defined in Section 9.

10.1.1. Reach: AP_01 – RM 0.0 to 0.6

Dominant Reach Type: Alluvial Fan

General Description

Reach **AP_01** begins at the confluence with the Snake River at RM 0.0 and ends at RM 0.6 where Alpowa Creek passes under the Highway 12 and historic Chief Timothy bridges. Shortly downstream of the bridges, the stream exits the Alpowa watershed and dissects its own fan before entering the Snake River. Alpowa Creek watershed has high proportions of loess soils and as such maintaining and expanding erosion control measures is recommended.

Figure 18. View of the channel under relatively dense canopy cover in reach AP_01.

Hydrology

There are no significant hydrologic inputs in this reach. A flow gauge operated by DOE is located at the top of this reach and has recorded a mean annual discharge of 9.6 cfs and a max discharge of 60 cfs over a period of 14 years. Alpowa Creek is a hydrologically stable, groundwater dominated system.

Geomorphic Function - moderate

This reach represents a classic example of the alluvial fan reach type. There are typically 1-3 channels dissecting the fan, and the floodplain vertically aggrades during high flows. It is likely that the fan is longitudinally longer than it was historically due to a backwater effect from Lower Granite Dam on the Snake River. However, this effect has not surpassed the stream's competence to work sediment deposits and maintain surface flow throughout the year. Substrate in the channel and floodplain is dominated by fine sediment, but the primary channel does have pockets of cobbles and gravels for most of the reach. There is very little LWD in this reach.

Floodplain Connection – moderate

Highway 12 crosses this reach and there is a bridge from the old highway just upstream that is partly confining this reach. There are no other significant confining features in this reach.

Riparian Function – moderate

As the alluvial fan has extended further into the Snake River over the last few decades, tree species have slowly propagated downstream as well. The lower half of this reach is dominated by sedges, rushes, grasses, and shrubs, and there are no canopy species. The upper half is dominated by box elder, alder, and cottonwood trees with a lush understory of native shrubs. There is upland vegetation encroaching into the riparian buffer near the Highway 12 bridge crossing.

Fish Habitat and Use

Steelhead and Chinook travel through this reach during migratory periods, and some likely spawn and rear here as well. Some pockets of gravel and cobble are exposed, but there is little hydraulic diversity to promote sediment sorting, so spawning potential is low. Cover for juveniles is rare, and the best examples are typically small jams composed of small woody debris.

Restoration Strategies and Recommendations

Increase channel complexity by adding structural elements to promote sediment sorting to improve spawning habitat and increase cover for rearing salmonids. A predation impact study should also be highly considered in this reach. During migratory periods several species of predatory birds (e.g., white pelicans) congregate at the base of the fan, likely to feed on juvenile steelhead. However, the impact of the predation is not known. Continued upland management is recommended to reduce fine sediment inputs to this reach.

Table 17. Restoration recommendations for Alpowa Creek reach AP_01.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	Medium	Continue/expand erosion control, protect riparian and springs
Connect disconnected habitat	Low	Disconnected habitats are generally not present. Promote overbank flow.
Long-term processes	Medium	Riparian management
Short-term processes	High	Review potential predation issue, increase channel complexity

10.1.2. Reach: AP_02 – RM 0.6 to 13.9

Dominant Reach Type: Partly Confined Planform Controlled with discontinuous floodplain pockets, confined with occasional floodplain pockets

General Description

Reach **AP_02** begins at the Highway 12 bridge crossing at RM 0.6 and ends at RM 13.9. The stream flows through several working ranches and a large orchard, so the floodplain has largely been converted to agricultural uses.

Highway 12 parallels the stream until 7.0 near the confluence with Stember Creek. The Asotin County boundary ends around RM 4.1 and no LIDAR was collected upstream.

Hydrology

Alpowa Creek is groundwater dominated and has the most stable flows among the target watersheds. There are several large intermittent tributaries entering this reach including Page Creek (RM 0.7), Pow Wah Kee Gulch (RM 3.0), Stember Creek (RM 6.7), and Clayton Gulch (RM 6.2). Although these tributaries have substantial drainage areas (e.g., Pow Wah Kee Gulch is 31 square miles), their hydrologic contribution is minimal except for spring flow periods and localized storm events. However, there is likely groundwater and spring contributions from these drainages, helping keep water temperatures stable during the year.

Geomorphic Function – limited to moderate

This reach has limited geomorphic function from RM 0.6 to 9.6, mostly stemming from anthropogenic impacts. The channel is incised, and most of the substrate is embedded or completely covered by fine sediment. There is evidence on the floodplain and channel margins of multiple channels in wider sections, but in most areas, the channel has been reduced to a single thread. LWD is relatively rare in this reach despite a dense, but thin, riparian canopy. Small woody debris jams are the primary mechanism for creating and maintaining fish habitat, but are also rare throughout the reach. Geomorphic Function improves in the upper section of this reach from RM 9.6 to 13.9. Generally, the upper section is less incised, more sinuous, the substrate is less embedded, and pools are more prevalent.

Floodplain Connection – low

Much of the floodplain has been converted to agriculture and rural residential development. There are extensive levees and rip-rap throughout the reach (particularly from RM 0.6 to 9.6), and the stream channel is incised and single thread, further disconnecting the floodplain.

Riparian Function - moderate

Riparian function is mostly moderate; however, the majority of historic vegetation has been lost or converted to upland encroachment and agriculture. The thin riparian buffer reduces the potential for LWD recruitment into the channel, but is sufficient to shade the channel and moderate stream temperatures. It should be noted that the riparian function and density of canopy species has greatly improved over the last couple of decades, primarily because of landowner’s efforts.

Fish Habitat and Use

Steelhead and Chinook spawn and rear in this reach and travel through during migratory periods. The stream morphology is dominated by long and often deep planar runs, so rearing habitat is particularly limited. High embeddedness throughout the reach limits available spawning habitat. Stable flows and moderate stream temperatures in the summer provide good rearing conditions, but cover and habitat complexity is limited.

Restoration Strategies and Recommendations

There may be some opportunity to reconnect habitats in the lower section of this reach but there is an active orchard and residential area that require flood protection. Other long-term strategies include managing riparian areas by fencing, developing off-site water sources, and management of grazing. Short-term strategies required are increasing channel complexity throughout much of the reach. Structures should be placed with the intention of creating more pools, sorting sediment to increase spawning and concealment habitat, and providing cover for juvenile salmonids. When possible, structures should also aim to promote floodplain connection.

Table 18. Restoration recommendations for Alpowa Creek reach AP_02.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	Medium	Continue/expand erosion control, protect riparian and springs
Connect disconnected habitat	High	Adjust confining features and/or connect historic side-channels (RM 0.6-3.0) and promote overbank flow.
Long-term processes	Medium	Riparian management (fencing, manage invasive vegetation, off-site water, grazing management)
Short-term processes	High	Increase channel complexity

10.1.3. Reach: AP_03 – RM 13.9 to 19.6

Dominant Reach Type: Confined Occasional Floodplain Pockets

General Description

Reach **AP_03** begins at RM 13.9, just upstream of Dresser Spring, and extends to RM 19.6, upstream of Kidwell Gulch. The reach is located entirely within private lands. Access to this reach is limited to private ATV trails and primitive roads. Grazing and some agriculture are the primary land uses. There are multiple seeps, springs, and small wetlands throughout the reach.

Figure 19. View of reach AP_03.

Hydrology

The hydrologic regime in this reach is snow-rain dominated and maintains stable surface flow throughout the year. There are several seeps and springs contributing flow and moderating stream temperatures.

Geomorphic Function – high

This reach generally has high geomorphic function. In some areas, the channel has been straightened, but it is rarely incised. Floodplain pockets are usually accessible and appear to be inundated regularly. Substrate in the channel bed is dominated by gravel and cobble, and fine sediment embeddedness is lower than downstream reaches. LWD is limited in this reach.

Floodplain Confinement – low

There are very few examples of anthropogenic confinement in this reach.

Riparian Function – moderate

Most of this reach has a dense, but thin, riparian buffer dominated by immature alder. However, there are sections where riparian vegetation is limited, and upland vegetation is encroaching into the floodplain (e.g., RM 15.5 to 17.3 and 18.5 to 19.6). The extent and composition of riparian vegetation generally increases moving upstream. Seeps and springs originating from hillslopes and small ephemeral tributaries are heavily vegetated.

Fish Habitat and Use

Steelhead spawn and rear in this reach and travel through during migratory periods. Cover for juvenile salmonids is rare, and typically limited to overhanging grasses, boulders, and occasional small wood jams.

Restoration Strategies and Recommendations

The top recommended action in this reach is to improve instream channel complexity using non-engineered structural elements. LWD should be added in high densities throughout the entire reach to improve geomorphic and hydraulic diversity, ultimately creating more pools, and providing cover for juvenile salmonids. When possible, structures should also aim to promote floodplain connection.

Restoration Strategies and Recommendations

Table 19. Restoration recommendations for Alpowa Creek reach AP_03.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	High	Continue/expand erosion control, protect riparian and springs
Connect disconnected habitat	Low	Disconnected habitats are generally not present. Promote overbank flow
Long-term processes	Medium	Riparian management (manage invasive vegetation)
Short-term processes	High	Increase channel complexity, beaver management

10.1.4. Pow Wah Kee Gulch

Reach PW_01 – RM 0.0 - 3.0

Dominant Reach Type: Partly Confined Planform Controlled with Discontinuous Floodplain

General Description

Reach **PW_01** enters Alpowa Creek on the right bank at RM 3.0. Pow Wah Kee Gulch is a long watershed that parallels Alpowa Creek to the south and has intermittent flows. There is a large spring near the top of the reach at RM 3.0. The reach is located entirely within private lands and grazing is the primary land use in this reach. Access to this reach is limited by a primitive road that parallels the stream.

Hydrology

The hydrologic regime in this reach is dominated by groundwater, but sections typically go subsurface in early summer. A large spring at the top of the reach helps to maintain surface flow for approximately 1.5 RM.

Geomorphic Function – limited to moderate

Geomorphic function is limited, primarily by a lack of LWD, low floodplain connection, and poor sediment sorting and bed characteristics. Geomorphic function slightly improves near the spring, with a small increase in LWD frequency and hydraulic diversity.

Floodplain Confinement – moderate

Not fully assessed – no LIDAR

Riparian Function – limited to moderate

Riparian function varies throughout the reach, and is typically in better condition near springs and seeps. Riparian vegetation is mostly limited to the channel margin, and upland vegetation is encroaching into the floodplain in most areas.

Fish Habitat and Use

Likely provides some refuge habitat for juveniles during high flows. The capacity for year-round fish use is likely low due to sections with subsurface flow and very limited structural cover. Fish extent is limited to lower 1-1.5 miles based on Streamnet.org.

Restoration Strategies and Recommendations

Table 20. Restoration recommendations for Pow Wah Kee Gulch reach PW_01.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	Medium	Protect riparian and springs
Connect disconnected habitat	Low	Disconnected habitats are generally not present. Promote overbank flow
Long-term processes	Medium	Riparian management
Short-term processes	High	Increase channel complexity

10.2 ASOTIN CREEK

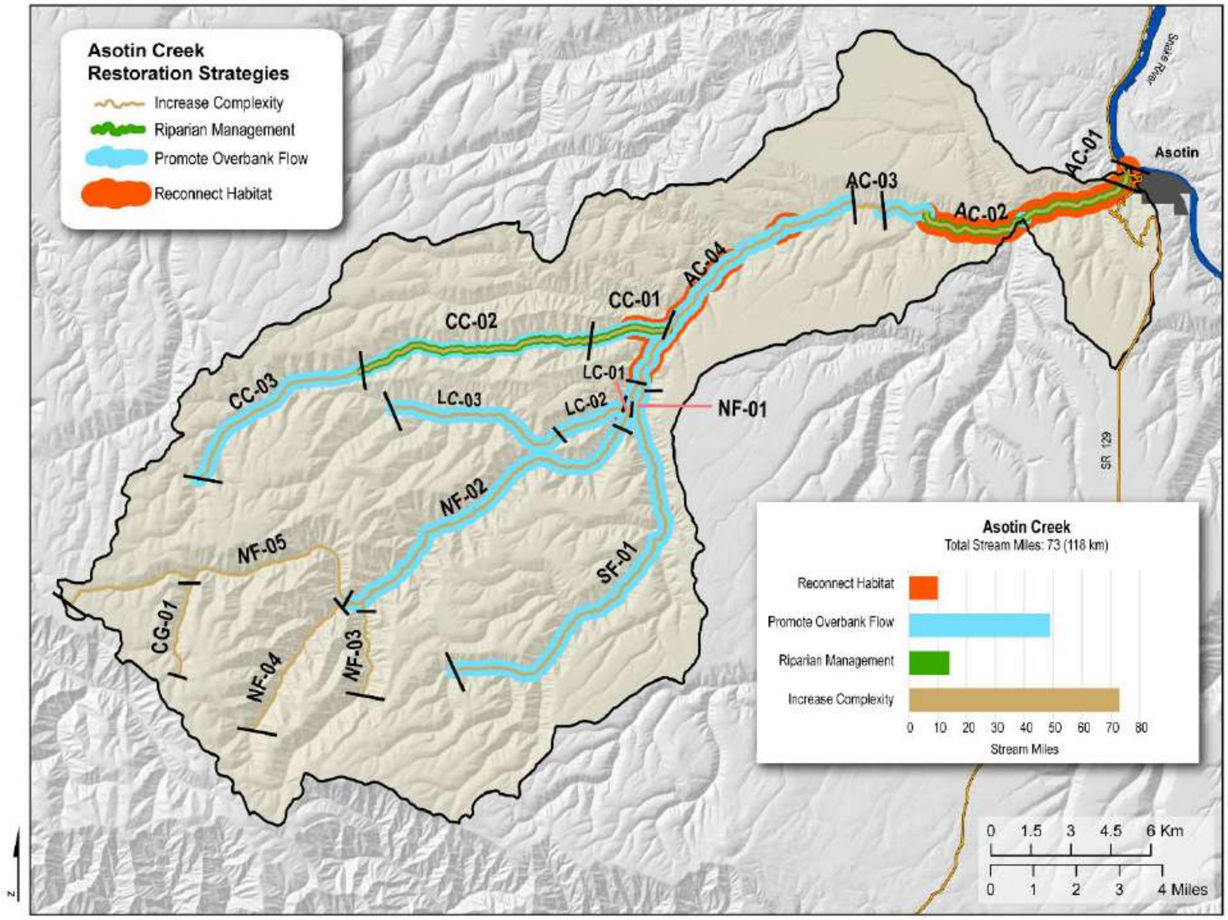

Figure 20. Restoration strategies and reach breaks for Asotin Creek. Reach breaks are labeled by stream and reach number: AC_01 = Asotin Creek restoration reach 1. Restoration strategies are defined in Section 9.

10.2.1. Reach: AC_01 – RM 0.0 to 0.4

Dominant Reach Type: Alluvial Fan

General Description

Reach **AC_01** is located from the mouth of Asotin Creek to the upstream end of Asotin City Park at RM 0.4. The reach is surrounded by urban infrastructure, with a narrow riparian zone consisting primarily of red alder. Although the valley bottom in this reach is the widest example in the study area, the channel is confined on both banks by rip-rap and levees to protect infrastructure. The stream flows under a bridge for Washington State Highway 129 and past the city of Asotin's sewage treatment plant before entering the Snake River.

Figure 21. Reach AC_01 on the mainstem of Asotin Creek looking upstream from the Highway 129 bridge during a high flow event. The channel is confined on both sides by rip-rap, restricting floodplain access.

Hydrology

Hydrology in this reach is snow-rain dominated and there are no major incoming perennial streams to this short reach. However, there is likely some backwater effect from the Snake River and Lower Granite Dam during high flows. The backwater effect creates an artificial base level at the mouth of Asotin Creek.

Geomorphic Function - limited

Geomorphic function is limited because the channel has been straightened and reduced to a single thread with little geomorphic diversity. The reach is dominated by runs, although occasional mid channel bars exist. Substrate in the channel is poorly sorted and consists mostly of cobble, except near structural elements which are rare.

Floodplain Confinement – high

Historically, this channel would have had access to 1000+ feet of the valley bottom to connect to its floodplain and migrate laterally. Currently, the channel is confined to about 50 feet by rip-rap and levees to protect city infrastructure and private property from high flows.

Riparian Function - limited

The channel is lined by a thin row of canopy trees (primarily alder). From RM 0.0 to 0.2, 64% of riparian is near fully functioning. However, from RM 0.2 to 0.4, only 1% of the historic riparian vegetation remains.

Fish Habitat and Use

Chinook and steelhead spawn and rear in this reach. Chinook, steelhead, and bull trout also use this reach during migratory periods. There is very little LWD and very few opportunities for velocity refuge during high flows.

Historically, there would have been multiple channels and abundant LWD that provided cover from predators and protection from high water velocities. Lamprey migrate through this reach and likely rear here as well, but little information on their distribution and abundance is available.

Restoration Strategies and Recommendations

Because of the proximity of this reach to urban infrastructure, there is little that can be done to improve the overall geomorphic and riparian function of this reach. Full recovery would require rip-rap and levee removal to create lateral accommodation space and increase floodplain access. Therefore, these actions would essentially require moving county, city, and private structures way from the channel. To improve fish habitat, engineered structural elements are recommended in the channel to improve habitat complexity, sort sediment, and provide predator and velocity refuge for fish.

Table 21. Restoration recommendations for Asotin Creek mainstem reach AC_01.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	High	Protect Riparian
Connect disconnected habitat	High	Adjust confining features and/or connect historic side-channels
Long-term processes	Medium	Riparian management (manage invasive vegetation)
Short-term processes	High	Increase channel complexity

10.2.2. Reach: AC_02 – RM 0.4 to 7.3

Dominant Reach Type: Wandering Gravel Bed with Discontinuous Floodplain, Planform Controlled with Discontinuous Floodplain, and Confined with Occasional Floodplain Pockets

General Description

Reach **AC_02** is located between the upstream end of Asotin City Park and a bedrock canyon section of Asotin Creek at RM 7.3. The channel has been straightened and confined by rip-rap and levees to protect private property from high flow events. The reach begins in a residential area and passes through several working ranches in the widest parts of the valley. Near the top of the reach, the valley becomes more confined and passes through more residential parcels. The channel does move laterally across the valley bottom occasionally, but is often confined against the valley wall or Asotin Creek road. George Creek, a significant perennial tributary, enters the reach at RM 3.2. Levees and rip-rap are less frequent upstream of George Creek.

Hydrology

The hydrologic regime in this reach is snow-rain dominated. There are several small intermittent and ephemeral tributaries in this reach. Their hydrologic contribution is mostly limited to rare storm events that flush water and sediment into the reach. Although the hydrologic effects of the small tributaries may be brief, there is evidence from large alluvial fans at RM 4.8 and 6.1 that they can contribute substantial discharge and sediment. George Creek enters this reach at RM 3.2, contributing a significant amount of discharge and sediment.

Geomorphic Function – limited to moderate

The channel has been reduced to single thread and straightened in most of the reach. Geomorphic and hydraulic diversity is low and there are very few structural elements aside from occasional LWD and a few engineered boulder structures. Geomorphic function in this reach varies from limited to moderate.

RM 3.2 to 5.9 is a planform controlled with discontinuous floodplain reach type with limited function primarily due to the lack of floodplain connectivity and geomorphic diversity. Because much of the channel has been pinned against the southern valley border, it has been reduced to a straight, single threaded channel with little access to the floodplain during regular high flow events. There is very little LWD or other structural elements present.

From RM 5.9 to 7.3, the reach is in moderate condition. There is very little LWD present in the channel, except for occasional large jams. Colluvial inputs from the steep ephemeral hillslopes on the north side of the valley have been completely cut off due to the presence of Asotin Creek Road. In confined reaches, colluvium provides an important source of structural elements that maintain hydraulic and geomorphic diversity in the channel.

Floodplain Confinement - high

Aside from the mouth of Asotin Creek, this reach includes the widest valley bottom and historic floodplain among the target watersheds from the beginning of the reach to the George Creek confluence at RM 3.2. However, the channel has been effectively cut off from the floodplain for most of the reach. From RM 0.4 to 5.9 the river has levees and rip-rap along both banks, severely limiting access to the floodplain. There are a few opportunities for floodplain connection that appear to have been inundated recently. From RM 5.9 to 7.3, the valley bottom is less wide, and the natural width constriction is the primary control for this confined with occasional floodplain pocket reach type. Because of the more constricted valley, there are inherently fewer opportunities for floodplain connection unlike the wider portion of the reach downstream. However, the current floodplain pockets that exist are only accessed during large flood events because the channel is entrenched.

Riparian Function – moderate to full

The extent of riparian vegetation in this reach is variable, ranging from 36-100% of full function. There are some examples in the middle and upper end of the reach where the riparian function is still $\geq$ 80% or more full (e.g., RM 1.8 – 2.4, 3.5 – 4.4, 5.2 – 5.5, and 6.0 – 7.3). However, there are several long sections where riparian vegetation is limited to a thin extent along the channel margin. Alder and cottonwood are the dominant canopy species in this reach and likely provide adequate shade to the stream channel.

Fish Habitat and Use

Chinook and steelhead spawn and rear in this reach. Chinook, steelhead, and bull trout also use this reach during migratory periods. There is very little LWD and hydraulic diversity, limiting opportunities for suitable rearing habitat. Pools are rare and typically created along the lateral edge of the channel near bedrock walls at the valley margin. Lamprey migrate through this reach and likely rear here as well, but little information on their distribution and abundance is available.

Restoration Strategies and Recommendations

Because of the proximity to urban infrastructure and working ranches, there is little that can be done to improve the Geomorphic Function of this reach from river 0.4 to 3.2. However, if interested landowners can be identified, there may be opportunities for rip-rap removal and levee setbacks to create pockets of improved condition and fish habitat. Widening the channel and improving floodplain access is highly recommended. If such projects are not feasible, improving instream habitat through engineered structural elements to increase cover, pool habitat, and improve sediment sorting is recommended.

Although the section upstream of the George Creek confluence consists of two reach types of variable condition within this reach, the recommendation restoration actions are similar. From RM 3.2 to 5.9, there appear to be multiple opportunities to access historic side channels and reconnect the floodplain through levee removal and engineered structural elements. Where infrastructure limits floodplain connection as an option, engineered structural elements in the stream channel are recommended to increase geomorphic and hydraulic diversity.

From RM 5.9 to 7.3 the valley is confined with inherently little opportunity for floodplain access. Therefore, the top recommended action is engineered structural elements in the channel to increase geomorphic and hydraulic diversity, and push water onto the contemporary low-lying floodplain pockets during high flow events. Because this is a confined reach that would historically have had more colluvial input from adjacent hillslopes, boulders should be the primary structural element additions. The dense canopy in this section also makes it a good target for direct felling of large trees to improve hydraulic diversity and increase cover for fish.

Table 22. Restoration recommendations for Asotin Creek mainstem reach AC_02.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	High	Protect Riparian
Connect disconnected habitat	High	Reconnect disconnected side-channels and promote overbank flow
Long-term processes	High	Riparian management
Short-term processes	High	Increase channel complexity

10.2.3. Reach: AC_03 – RM 7.3 to 8.3

Dominant Reach Type: Bedrock Canyon

General Description

Reach **AC_03** is located from RM 7.3 to 8.3 in a constricted valley where the channel is 100% confined by the valley walls. The channel's shape and sinuosity are completely controlled by the valley margin and has no floodplain.

Hydrology

The hydrologic regime in this reach is snow-rain dominated. There are several small ephemeral tributaries in this reach that likely have a negligible contribution to discharge and sediment except for rare storm events.

Geomorphic Function - moderate

The primary limiting factors contributing to this reach's Geomorphic Function are a lack of geomorphic and hydraulic diversity. Although the channel flows alongside a road, the sinuosity is still imposed by the valley margin. Therefore, the primary impact the road might have on this reach's Geomorphic Function is limiting colluvial inputs from the north hillslopes because colluvium collects in the roadside ditch rather than in the channel.

Floodplain Confinement – low

This reach is naturally confined with inherently little floodplain

Riparian Function – high to full

The riparian function in this reach is 60-80% full. Vegetation is limited in some areas and likely maintained to avoid interfering with traffic on the road near the river left bank. However, the river right bank is densely occupied by alder and cottonwood trees.

Fish Habitat and Use

Chinook and steelhead spawn and rear in this reach. Chinook, steelhead, and bull trout also travel through this reach during migratory periods. There is very little LWD and hydraulic diversity, limiting opportunities for suitable rearing habitat. Lamprey likely use this reach, but their abundance is unknown.

Restoration Strategies and Recommendations

Restoration actions in this reach should focus on instream geomorphic and hydraulic diversity to improve rearing and migratory habitat. Engineered structural elements are recommended to provide breaks in water velocity for migrating salmonids during high flows, and pool habitats with cover during low flow periods. Structures placed in this section will have to be well-secured to reduce the risk of damaging Asotin Creek Road during large flood events.

Table 23. Restoration recommendations for Asotin Creek mainstem reach AC_03.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	Medium	Protect Riparian
Connect disconnected habitat	Low	Disconnected habitats are not present
Long-term processes	Low	NA
Short-term processes	High	Increase channel complexity

10.2.4. Reach: AC_04 – RM 8.3 to 15.4

Dominant Reach Type: Planform Controlled with Discontinuous Floodplain and Wandering Gravel Bed with Discontinuous Floodplain

General Description

Reach **AC_04** begins at the upstream end of a bedrock canyon at RM 8.3 and ends at the confluence of the North and South Forks of Asotin Creek at RM 15.4. For much of this reach, the stream channel is pinned against the valley wall and has limited access to the floodplain. The stream flows through working ranches and the site of the historic Headgate Dam at RM 9.1, which was removed in 2016 because it was a partial barrier to salmonid migration. There are several levees from RM 8.3 to 9.7 in the floodplain and near the channel margin that restrict access to remnant side channels.

From RM 10.3 to RM 12.3 the reach flows through a working ranch. There is little LWD or other structural elements in the channel, but a few large jams force access to side channels and increase channel sinuosity. The channel planform is influenced along the reach by relatively large fans from incoming drainages.

The valley in the upper portion of this reach widens beginning at RM 12.3. This section flows through about 0.7 miles of land owned by WDFW where the stream has multiple side channels, diverse instream geomorphology, plentiful LWD and has high geomorphic function. Upstream of this section, the valley remains wide but the channel is often entrenched, pinned against the valley wall, and has limited access to the floodplain.

Figure 22. Asotin Creek mainstem at approximately RM 10. Stream has good shade from alder dominated riparian area. Habitat complexity is moderate with some pools and LWD, but side-channels are rare, banks are relatively high, and floodplain access is limited.

Hydrology

A small pond with a put-and-take fishery at the West end of Headgate County Park is filled by pumping water from the stream seasonally, but the hydrologic impacts are likely negligible. Two substantial tributaries enter the channel within this reach. Dry Gulch enters the reach around RM 13.4 and is a large ephemeral drainage that can route a large amount of water and sediment to the channel during localized, high intensity storms. Charley Creek is a perennial, groundwater dominated that enters this reach around RM 14. There are also several large ephemeral tributaries. These tributaries are only activated during rare, intensive storms, but some are relatively large drainages so could have large impacts on discharge and sediment input when active.

Geomorphic Condition – poor to moderate

There is some LWD, but it is typically restricted to small jams along the channel margin, so the jams have limited positive impact on geomorphic and hydraulic diversity. The channel substrate is mostly a uniform cobble/gravel matrix, uniformly distributed through the reach. The legacy effects of developing and operating headgate dam undoubtedly affected this section's geomorphology and planform.

From RM 9.8 to 12.3, the reach is in moderate geomorphic condition. The primary factors limiting the geomorphic condition of this reach is floodplain connection and instream geomorphic and hydraulic diversity. Where LWD exists in the channel, there is often complex instream habitat, secondary channels, and evidence suggesting recent access to the floodplain.

From RM 12.3 to 13.0, the reach is in good condition, and represents one of the best examples of the wandering gravel bed reach type on the mainstem of Asotin Creek. However, it is still LWD limited and instream geomorphic and hydraulic diversity is not ideal. The rest of the reach is in moderate geomorphic condition, primarily limited by a lack of floodplain connection and instream geomorphic and hydraulic diversity. In some sections the channel is entrenched and pinned against the valley wall, so it has limited opportunities to access the floodplain. Most of the reach is a single thread channel with a planar bedform and poor sediment sorting.

Floodplain Confinement – moderate

Some sections of this reach are highly confined. For, example most of the channel from RM 8.3 to 9.7 is confined by levees and rip rap against the valley wall, ultimately resulting in a single thread, entrenched channel with severely limited access to the floodplain. There are significant opportunities to reconnect disconnected side-channels in this reach.

Riparian Condition – good to intact

Portions of this reach have a good riparian buffer with a healthy mix of alder and cottonwood trees and a dense understory of native shrub species. However, upland vegetation and invasive weed encroachment into the historic floodplain is a concern throughout the reach, especially in areas with a thin riparian buffer. The lack of regular floodplain inundation and historic channelization has likely contributed to the decline of riparian vegetation in some areas. Alder trees are the dominant canopy species and at their current density may be crowding out other native species.

Fish Habitat and Use

Chinook and steelhead spawn and rear in this reach. Chinook, steelhead, and bull trout also travel through this reach during migratory periods. Headgate Dam was suspected to be a partial fish barrier, but it was removed in 2016 and the channel upstream was reconstructed for grade control and to improve fish passage. Overall, there is little LWD and hydraulic diversity, limiting opportunities for suitable rearing habitat.

Restoration Strategies and Recommendations

From RM 8.3 to 9.8, the top recommended action is to remove some of the levees, and create side channels and flood channels to access the historic floodplain. There are several historic side channels that could be access during bankfull events with well-placed engineered structural elements. In addition, invasive weed control is highly recommended to reduce competition of native vegetation once the floodplain is reactivated. Instream engineered structural elements are recommended to improve geomorphic and hydraulic diversity. Unsecured LWD may cause a hazard by accumulating at the downstream end of this reach as the stream channel enters a bedrock canyon reach during extreme high flows.

From RM 9.8 to 13.0, the top recommendation is a mixture of engineered and non-engineered structural elements to improve geomorphic and hydraulic diversity. Because the channel planform and floodplain access is relatively good for most of the reach, overall conditions for river health and fish habitat would greatly improve with the addition of structural elements. Engineered structures should target access to historic side channels to improve floodplain connectivity, while unsecured LWD should be placed in high densities to improve fish habitat. The channel planform and dense riparian vegetation should limit the risk of using unsecured LWD because it is likely to get hung up. In the areas with dense riparian cover, alder trees could be felled opportunistically directly into the channel rather than importing LWD from outside sources. LWD in the channel would also improve sediment sorting, creating more frequent pockets of gravel substrate suitable for spawning.

From RM 13.0 to 15.4, the top recommended action is to enhance the floodplain by improving connectivity and managing vegetation. There are many historic side channels in the valley bottom that could be engineered to be accessed during regular bankfull flow events (2 year recurrence interval). In addition, there are low-lying areas in the floodplain that appear to be historic wetlands (particularly around the Charley Creek confluence) and should be reactivated. Invasive weed and upland vegetation control should be a priority, especially as the floodplain is reconnected with the channel to decrease competition with native trees and shrubs. Engineered structural elements are recommended to improve geomorphic and hydraulic diversity, and can be placed to target historic side and flood channels to improve floodplain access as well. In areas with a dense riparian buffer, selective felling of trees into the channel should be considered to increase LWD loading.

Table 24. Restoration recommendations for Asotin Creek mainstem reach AC_04.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	Medium	Protect Riparian
Connect disconnected habitat	High	Reconnect disconnected side-channels and promote overbank flow
Long-term processes	High	Manage non-native riparian vegetation
Short-term processes	High	Increase channel complexity

10.3 CHARLEY CREEK

10.3.1. Reach: CC_01 – RM 0.0 to 2.0

Dominant Reach Type: Laterally Unconfined Alluvial Fan and Partly Confined Planform Controlled with Discontinuous Floodplain

General Description

Reach CC-01 begins at the mouth of Charley Creek where it enters the mainstem of Asotin Creek at approximately RM 14 on the mainstem. The first 0.2 miles of the reach is an alluvial fan that enters the main Asotin Creek valley below Asotin Creek Road. The fan has multiple channels as it crosses the mainstem valley and enters Asotin Creek. One of the channels has been armored with rip-rap and is a restoration site implemented as part of the Model Watershed. The stream flows through a large stand of mature alder trees and there are numerous small wetlands bordering the fan. Upstream and downstream of the fan are ranches with large pastures that border the fan. The stream flows through a concrete open top culvert with a cattle guard to pass under Asotin Creek Road.

From RM 0.2 to 2.0 upstream of the Asotin Creek Road, the stream enters a narrow valley with steep side hills. A house with out-buildings, cattle loading ramp, and small corrals border the right bank of Charley Creek upstream of the road crossing for < 0.1 mile. The remainder of the reach is now owned by WDFW. The stream flows mostly against a steep bedrock cliff on the right bank. Riparian fencing borders both sides of the stream and is in a CREP contract. The Asotin IMW has a PIT tag interrogation site above the road used to detect adult and juvenile PIT tagged fish entering and leaving the stream. Inside the riparian fencing is a dense stand of shrubs and trees with some patches of blackberry. There is a rough single lane gravel road that runs along the left side of the valley for over 10 miles. The road generally stays above the valley bottom but does encroach into the valley bottom in a few locations. Access is restricted by a locked gate at the entrance at Asotin Creek Road and controlled by WDFW and USFS. Local ranchers use the road seasonally to move cattle to grazing allotments. The lower reaches of Charley Creek were used to winter cattle and horses until WDFW purchased the property. Sections of stream that were not fenced in the past have been overgrazed, and now these areas have been invaded by weeds. ACCD and USFS have implemented intensive weed control and planting programs in these areas.

Figure 23. Riparian enhancement area along Charley Creek above Asotin Creek road. Note road is above the valley bottom.

Hydrology

The hydrologic regime in this reach is snow-rain dominated. However, Charley Creek is heavily influenced by groundwater inputs as evidenced by numerous springs, cool stream temperatures (cooler than other Asotin tributaries in the summer and warmer in the winter), and relatively consistent flows. The Asotin Creek IMW project installed a water height gauge near the Asotin Creek Road crossing in 2009 and has developed a rating curve for the gauge. The average stream flow is 10 cfs and often Charley Creek has higher base flows than South Fork Asotin Creek despite the South Fork watershed being almost twice the area and reaching a higher elevation. No perennial tributaries enter this reach.

Geomorphic Function - moderate

Geomorphic function is moderate because the alluvial fan is only partially constricted below Asotin Creek Road. Abundant gravel in the fan suggests that high flows in Charley Creek are transported through the fan and likely migrate into the mainstem Asotin. Upstream of the fan in the planform reach type, the geomorphic function degrades to limited due to low hydraulic and geomorphic diversity, limited LWD, poor substrate sorting, and limited floodplain connection. The bridge crossing at RM 0.2 is a major confining feature in this reach.

Floodplain confinement - high

Anthropogenic floodplain confinement is limited to RM 0.0 to 0.4, and is caused by levees protecting Asotin Creek Road, and residential infrastructure at the mouth of Charley Creek. Floodplain connection is low throughout the rest of the reach due to relatively deep channel incision and a lack of LWD to promote overbank flow.

Riparian Function - limited

Riparian function is moderate due to the age of the riparian vegetation and some encroachment by adjacent pastures. The fan is dominated by young small diameter (6-12”) alder with a low diversity understory. There are some wetlands adjacent to the fan with cattails and other aquatic vegetation. The planform reach from RM 0.4 to 2.0 has limited to moderate function due to large patches of non-native blackberry in the understory, immature canopy, and encroachment by grass and upland shrubs. Young alder and some large cottonwood dominate the canopy and in general the floodplain is narrow and has little evidence of frequent connection to the channel (i.e, lack of fine sediment deposits). However, existing vegetation is dense and provides good shade and cover for the stream.

Fish Habitat and Use

Charley Creek supports a relatively large number of spawning steelhead despite its small size. Spawning surveys by WDFW and PIT tag detections at the interrogation site have found that almost 10% of the adult steelhead entering Asotin Creek (not including George Creek) use Charley Creek. Since 2010, a minimum average of 45 adult steelhead have migrated into Charley Creek. Spawning surveys suggests the entire reach is used for spawning and juvenile steelhead have been captured throughout the reach. Bull trout and Chinook juveniles have been captured in the lower reach of Charley Creek, but are rare.

Restoration Strategies and Recommendations

SRSRB reviewed the road crossing in this reach and noted that it could be a partial barrier. However, a road realignment would be necessary to replace the culvert with a bridge or bottomless arch culvert. At this time, fish appear to be able to freely navigate the crossing, but we recommend that it be reviewed periodically. The alluvial fan is actively transporting gravel and functioning fairly well. The planform section of this reach upstream of the road crossing is between the Charley Creek Road on the left bank and private property on the right bank, limiting recovery potential for 50-100 yards. Relocation of the road out of the valley bottom or widening of the channel onto private property would be required to improve the geomorphic condition of this small area. Upstream to the end of the reach there is more opportunity to increase habitat complexity and reduce floodplain confinement on the left bank because the road is mostly above the valley bottom.

We recommend no restoration actions from RM 0.0-0.2. Charley Creek is currently being used as part of the Asotin Creek IMW to test the effectiveness of additions of LWD to improve instream habitat and increase steelhead production. At this time, we recommend that no further restoration actions be taken in this reach until the IMW is completed. Once the IMW is completed, from RM 0.2-0.3, we recommend moving the road out of the valley bottom on the left bank or accessing some of the private property on the right bank to provide more space for the stream. From RM 0.3- 2.0 we recommend a combination of instream habitat improvement and floodplain enhancement. Instream wood additions should be designed to increase habitat complexity, increase sinuosity, and activate historic side-channels and reconnect to floodplain areas. Riparian planting should occur in conjunction with instream work, and target areas that are inundated/reconnected.

Table 25. Restoration recommendations for Charley Creek reach CC_01.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	Medium	Protect Riparian and springs
Connect disconnected habitat	Low	Disconnected habitats are generally not present
Long-term processes	Medium	Riparian management (manage invasive vegetation and enhance native vegetation)
Short-term processes	High	Increase channel complexity

10.3.2. Reach: CC_02 – RM 2.0 to 7.9

Dominant Reach Type: Partly Confined Fan Controlled with Discontinuous Floodplain

General Description

Reach **CC_02** begins at RM 2.0 and ends at RM 7.9. The assessment area from RM 2.0 to 7.0 is within state-owned property, and from RM 7.0 to 7.9 is within USFS property. There are numerous fans in the valley from intermittent and ephemeral tributaries throughout the reach. The creek generally lacks the competence to move material from the toe of the fans, so the planform of the channel is heavily influenced. Remnant excessive sediment in the valley bottom still exists from historic dams at RM 3.6 and 5.2. Charley Creek road follows the creek for the entire reach, but is decommissioned starting at RM 7.4, and is behind state-operated gates, so vehicle access is by permission only. The road is mostly located outside of the valley bottom and has little impact on the stream. A LWD restoration project related to the Asotin Creek IMW was implemented within this reach in 2014, and there has been documented improvements to fluvial processes and fish habitat as a result.

Figure 24. Typical condition of Charley Creek with recovering riparian habitat and low instream diversity

Hydrology

The hydrologic regime is snow-rain dominated; however, Charley Creek is heavily influenced by groundwater as evident by numerous springs and stable annual flows. There are no perennial tributaries in this reach, but there are numerous ephemeral tributaries.

Geomorphic Function – limited to moderate

Geomorphic condition is generally moderate throughout this reach. In many areas, hydraulic and geomorphic diversity is low, the channel is incised, LWD is limited, substrate is embedded by fine sediment, and floodplain interaction is limited. Locations near remnant feed lots and corrals typically have limited geomorphic function with deeper incision, less LWD, and simple channel morphology. The channel upstream of the remnant dams is still working through legacy sediment deposits, but this has created some unique and complex habitats with high hydraulic and geomorphic diversity. Geomorphic condition generally improves moving upstream through this reach.

Floodplain Confinement – low

There is little anthropogenic confinement restricting floodplain connection in this reach. The remnant dams are still mostly intact and impose local confinement in the valley bottom. In areas where Charley Creek road is directly against the channel, the valley bottom is naturally narrow with little inherent floodplain connection. Other areas where floodplain connection is low, is due to deep channel incision and low abundance of LWD.

Riparian Function – moderate

Riparian function throughout this reach is generally moderate, and areas with limited riparian function are typically near old feed lots and corrals where grazing activity was high. Immature alder are the dominant canopy species, but cottonwood groves are present in small patches. Conifers are typically present where the hillslope and fans are adjacent to the channel margin, but their prevalence greatly increases upstream of RM 5.2. Many riparian planting projects have been implemented within this reach over the last two decades, so riparian function is expected to continue improving over time. Upland and invasive vegetation is encroaching into the floodplain in several areas, particularly near the old feed lots and corrals.

Fish Habitat and Use

Steelhead spawn and rear in this reach. Stable flows and cold water temperatures help maintain good rearing conditions for juvenile steelhead; however hydraulic diversity is low in many areas. Opportunities for cover and deep pool habitats are rare. Fish habitat in this IMW restoration section has improved after the addition of LWD, with increased pool and cover density. Bull trout and Chinook juveniles have been observed in this reach, but are rare.

Restoration Strategies and Recommendations

The top recommendation for this reach is to add LWD to increase channel complexity and promote overbank flow. Because floodplain connection is primarily a result of channel incision, LWD additions are recommended to increase sediment aggradation in the channel and push water onto the floodplain during high flow events. Riparian management, including invasive vegetation treatments, should also be highly considered. The remnant dams in the reach should be assessed to determine the feasibility of removal, as they artificially increase confinement and limit floodplain connection. The riparian zone should be protected because its condition will improve naturally, and canopy species will eventually begin contributing LWD to the channel. The upper section of this reach would be a good candidate for beaver management as a restoration tool.

Table 26. Restoration recommendations for Charley Creek reach CC_02

Restoration Framework	Priority	Recommendations
Protect and maintain existing	Medium	Protect Riparian and springs
Connect disconnected habitat	Medium	Assess old dams for complete removal
Long-term processes	High	Riparian management (manage invasive vegetation and enhance native vegetation)
Short-term processes	High	Increase channel complexity, beaver management

10.3.3. Reach: CC_03 – RM 7.9 to 13.0

Dominant Reach Type: Confined with Occasional Floodplain Pockets, Partly Confined Planform Controlled with Discontinuous Floodplain

General Description

Reach **CC_03** is located from RM 7.9 to 13.0, and is entirely within USFS property. The decommissioned USFS road 060 follows the creek. The reach begins in a partly confined valley, but confinement increases near RM 9.6, causing a wholesale change in reach type. USFS road 060 ends at RM 10.7 where it joins USFS road 4206, which is not decommissioned, and follows the creek until RM 12.4.

Hydrology

The hydrologic regime in this reach is snow-rain dominated, but Charley Creek is heavily influenced by groundwater inputs. There are several ephemeral tributaries throughout the reach. Starting near RM 9.6, small perennial headwater tributaries become common until the top of the reach.

Geomorphic Function – high

This reach has high geomorphic function and near full function in sections. Geomorphic and hydraulic diversity is relatively high. Areas where the remnant USFS road is within the valley bottom or adjacent to the channel are generally less complex, but are rare instances throughout the reach. LWD frequency is lower than expected based on this reach's position in the basin and abundance of canopy species in the riparian zone.

Floodplain Confinement – low

Floodplain confinement was not fully assessed due to the lack of LIDAR in this reach. However, floodplain connectivity is adequate and there is ample evidence of recent floodplain inundation throughout the reach.

Riparian Function – unimpacted

Logging has the potential to affect this reach; however, there are riparian buffers present, so there is likely negligible impact to the stream. Conifers are the dominant canopy species.

Fish Habitat and Use

Steelhead rear throughout this reach, but spawning significantly decreases moving upstream. However, adult steelhead have been observed as far up as RM 11.0. Pools and cover for juveniles is limited to areas with LWD jams which are relatively infrequent from RM 7.9 to 12.4.

Restoration Strategies and Recommendations

Table 27. Restoration recommendations for Charley Creek reach CC_03.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	Medium	Protect Riparian and springs
Connect disconnected habitat	Low	Disconnected habitats are generally not present
Long-term processes	Low	Protect processes
Short-term processes	High	Increase channel complexity, beaver management

10.4 NORTH FORK ASOTIN CREEK

10.4.1. Reach: NF_01 – RM 0.0 to 0.8

Dominant Reach Type: Partly Confined Wandering Gravel Bed with Discontinuous Floodplain

General Description

Reach **NF_01** begins at the confluence with the South Fork Asotin Creek and extends to RM 0.8. A large storage shed and wheat field maintained by WDFW is located near the mouth of the creek. Along the stream, between the channel and the wheat field, from RM 0.0 to 0.1 is a WDFW operated firing range. Asotin Creek Road continues past the confluence and follows the entire reach. The reach is entirely within state-owned lands.

Figure 25. Typical low diversity section in the lower North Fork Asotin Creek with large alder dominating the riparian. Note the boulders on river left are remains of old restoration structure.

Hydrology

The hydrologic regime in this reach is snow-rain dominated. The North Fork of Asotin Creek is the largest subwatershed among the target watersheds after George Creek. In contrast to George Creek, the North Fork maintains stable base flows with cold water temperatures and does not go subsurface.

Geomorphic Function – moderate

Geomorphic function is moderate due to low hydraulic and geomorphic complexity, limited LWD, poor sediment sorting, limited floodplain connectivity, and infrequent side channels.

Floodplain Confinement – moderate to high

There is a wheat field on river left of this reach that acts like a confining feature and reduces floodplain connectivity. The valley bottom is relatively wide from RM 0.0 to 0.3, but is not connected to the channel during high flow events.

Riparian Function – high

The riparian buffer in this reach is relatively wide and dominated by immature alder. Cottonwood groves are present in small patches. Some conifers are present from RM 0.3 to 0.8, but in relatively small numbers. The wheat field limits the extent of the riparian zone from RM 0.0 to 0.3.

Fish Habitat and Use

Steelhead and Chinook spawn and rear in this reach. Bull trout have been observed, but their abundance and distribution are not well-known. Lamprey distribution and abundance is unknown.

Restoration Strategies and Recommendations

The top recommendation for this reach is to reconnect the channel to the floodplain where the wheat field is located. LWD additions are also recommended to increase channel complexity and promote overbank flow.

Table 28. Restoration recommendations for North Fork Asotin Creek reach NF_01.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	Medium	Protect Riparian
Connect disconnected habitat	High	Reconnect disconnected side-channels and remove rip-rap. Promote overbank flow
Long-term processes	Medium	Riparian management
Short-term processes	High	Increase channel complexity

10.4.2. Reach: NF_02 – RM 0.8 to 10.1

Dominant Reach Type: Partly Confined Wandering Gravel Bed with Discontinuous Floodplain

General Description

Reach **NF_02** begins at the confluence with Lick Creek at RM 0.8 and extends to RM 10.1 at the confluence of the North and Middle Forks of the North Fork of Asotin Creek. The North Fork Asotin Creek trail follows the creek for the entire reach and is a popular recreation area. A parking lot is located at RM 0.9 and is the starting location for the North Fork Trail.

Hydrology

The hydrologic regime in this reach is snow-rain dominated.

Geomorphic Function – moderate to high

The geomorphic function in this reach varies from moderate to high, with some areas near full function. The variability of geomorphic function within this reach is indicative of natural recovery taking place. Geomorphic processes related to hydraulic interactions with structural elements such as LWD are the primary limiting factor. The stream in this reach has the competence to recover quickly, but there is very little structure within the channel to increase hydraulic and geomorphic diversity.

Floodplain Confinement – low

Other than the parking lot at the bottom of this reach, there are no examples of anthropogenic confinement.

Riparian Function – high to full

Riparian function in this reach is high and is dominated by immature alder with many cottonwood groves. As elevation increases towards the top of this reach, conifers become much more prevalent.

Fish Habitat and Use

Steelhead, Chinook, and bull trout spawn and rear in this reach. Water conditions are suitable for rearing, but limited LWD results in infrequent pools and low amounts of cover for rearing juveniles. LWD and pool frequency increase moving upstream to the top of the reach. Bull trout abundance increases upstream.

Restoration Strategies and Recommendations

The top recommendation for this reach is to increase channel complexity through LWD additions. Increasing LWD density will improve hydraulic and geomorphic complexity, ultimately creating more diverse habitats for salmonids of all life stages. Secondly, the riparian area should be protected because the riparian area in this reach represents one of the best examples in the target watersheds. This reach may provide an opportunity to use beavers as a restoration tool to increase channel complexity and floodplain interaction.

Table 29. Restoration recommendations for North Fork Asotin Creek reach NF_02.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	Medium	Protect Riparian and springs
Connect disconnected habitat	Low	Disconnected habitats are generally not present
Long-term processes	Low	Recovering
Short-term processes	High	Increase channel complexity, beaver management

10.4.3. Reach: NF_03 – RM 0.0 to 2.3 (South Fork of North Fork)

Dominant Reach Type: Partly Confined Planform Controlled with Discontinuous Floodplain

General Description

Reach **NF_03** is the lower 2.3 RM of the South Fork of the North Fork of Asotin Creek. The reach is entirely located within USFS property and access is extremely limited.

Hydrology

The hydrologic regime in this reach is snow-rain dominated.

Geomorphic Function – high

This reach has high geomorphic function. The floodplain is inundated regularly, side channels are regularly present, created, and maintained, and hydraulic and geomorphic diversity is relatively high. LWD is higher than many areas in the target watersheds, but still below reference conditions.

Floodplain Confinement – low

There are no anthropogenic features restricting access to the floodplain.

Riparian Function – unimpacted

The riparian zone is mostly unimpacted and dominated by a mix of conifers, alder, and cottonwood.

Fish Habitat and Use

Steelhead and bull trout spawn and rear in this reach.

Restoration Strategies and Recommendations

The recommendations for this reach are to increase LWD frequency and protect the riparian area. This reach would be an excellent opportunity to use beaver as a restoration tool to increase LWD frequency and channel complexity.

Table 30. Restoration recommendations for South Fork of North Fork reach NF_03.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	Medium	Protect Riparian and springs
Connect disconnected habitat	Low	Disconnected habitats are generally not present
Long-term processes	Low	Recovering
Short-term processes	High	Increase channel complexity, beaver management

10.4.4. Reach: NF_04 – RM 0.0 to 3.8 (Middle Fork of North Fork)

Dominant Reach Type: Partly Confined Planform Controlled with Discontinuous Floodplain

General Description

Reach **NF_04** is the lower 3.8 RM of the Middle Fork of the North Fork. The reach is located entirely within USFS property and access to this reach is extremely limited.

Hydrology

The hydrologic regime for this reach is snow-rain dominated.

Geomorphic Function – high

This reach has high geomorphic function. The floodplain is inundated regularly, side channels are regularly present, created, and maintained, and hydraulic and geomorphic diversity is relatively high. LWD is higher than many areas in the target watersheds, but still below reference conditions.

Floodplain Confinement – low

There are no anthropogenic features restricting access to the floodplain

Riparian Function – unimpacted

The riparian zone is mostly unimpacted and dominated by a mix of conifers, alder, and cottonwood.

Fish Habitat and Use

Steelhead and bull trout spawn and rear in this reach.

Restoration Strategies and Recommendations

The recommendations for this reach are to increase LWD frequency and protect the riparian area. This reach would be an excellent opportunity to use beaver as a restoration tool to increase LWD frequency and channel complexity.

Table 31. Restoration recommendations for Middle Fork of North Fork reach NF_04.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	Medium	Protect Riparian and springs
Connect disconnected habitat	Low	Disconnected habitats are generally not present
Long-term processes	Low	Recovering
Short-term processes	High	Increase channel complexity, beaver management

10.4.5. Reach: NF_05 – RM 10.1 to 17.4 (North Fork of North Fork)

Dominant Reach Type: Partly Confined Planform Controlled with Discontinuous Floodplain

General Description

Reach **NF_05** is the upper extent of the North Fork of Asotin Creek. More specifically, it is the North Fork of the North Fork of Asotin Creek. It begins at the confluence with the Middle Fork of Asotin Creek at RM 10.1 and ends at RM 17.4. The reach is entirely located within USFS property and access is extremely limited.

Hydrology

The hydrologic regime for this reach is snow-rain dominated.

Geomorphic Function – high

This reach has high geomorphic function. The floodplain is inundated regularly, side channels are regularly present, created, and maintained, and hydraulic and geomorphic diversity is relatively high. LWD is higher than many areas in the target watersheds, but still below reference conditions.

Floodplain Confinement – low

There are no anthropogenic features restricting access to the floodplain

Riparian Function – unimpacted

The riparian zone is mostly unimpacted and dominated by a mix of conifers, alder, and cottonwood.

Fish Habitat and Use

Steelhead and bull trout spawn and rear in this reach, but their abundance is unknown.

Restoration Strategies and Recommendations

The recommendations for this reach are to increase LWD frequency and protect the riparian area. This reach would be an excellent opportunity to use beaver as a restoration tool to increase LWD frequency and channel complexity.

Table 32. Restoration recommendations for North Fork of North Fork reach NF_05.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	Medium	Protect Riparian and springs
Connect disconnected habitat	Low	Disconnected habitats are generally not present
Long-term processes	Low	Recovering
Short-term processes	High	Increase channel complexity, beaver management

10.5 LICK CREEK

10.5.1. Reach: LC_01 – RM 0.0 to 0.2

Dominant Reach Type: Unconfined Alluvial Fan

General Description

Lick Fork road borders the reach on river left as well as a large parking/camping area. The start of the North Fork Asotin Creek trail begins here and a rough access road used by hikers, horses, bikes, and WDFW/USFS staff crosses Lick Creek at a ford 100 yards from its confluence with North Fork Creek. A wheat field managed by WDFW borders the creek on river right. The stream has been realigned to flow straight down Lick Fork road. Historically it flowed into the North Fork Creek valley and then ran parallel to North Fork Creek, entering several hundred yards downstream from where it currently enters.

Figure 26. Lick Creek ford just upstream of confluence with North Fork Asotin Creek during spring high flow.

Hydrology

There are no other streams entering this reach.

Geomorphic Function – limited

Geomorphic function is limited due to a parking lot adjacent to this reach which diverts the stream channel. This artificially increases confinement and alters the sediment balance from depositional to erosional. The stream is channelized, LWD is limited, and sediment sorting is poor.

Floodplain Confinement – high

The realignment and road currently confine the stream.

Riparian Function – impacted

Fish Habitat and Use

Juvenile steelhead and Chinook likely use the lower reaches of Lick Creek for refuge during high flows in the mainstem; however, Lick Creek is not recognized as fish bearing.

Restoration Strategies and Recommendations

It would be a significant project to realign the road and stream to historic conditions, but this would allow a continuous, large section of floodplain to be reconnected.

Table 33. Restoration recommendations for Lick Creek reach LC_01.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	Medium	Continue/expand erosion control, protect riparian and springs
Connect disconnected habitat	Moderate	Assess potential to adjust confining features
Long-term processes	Moderate	Riparian management
Short-term processes	High	Increase channel complexity

10.5.2. Reach: LC_02 and LC_03 – RM 0.2 to 6.4

Dominant Reach Type: Confined Valley Occasional Floodplain Pockets

General Description

Because this long reach has a frequently used forest access road along the north side, it will likely not fully recover soon. However, the channel would likely react quickly to instream restoration work as the riparian continues to recover. This reach would benefit from LWD additions.

Hydrology

No stream entering this reach.

Geomorphic Function – limited

These reaches have limited geomorphic function primarily due to incision, limited LWD, and limited opportunities for floodplain connection, even though floodplain pockets are abundant. Lick Fork road is adjacent to the creek, and its primary impact is limiting colluvial inputs from south facing hillslopes. Colluvium is an important and common structural element in confined reach types.

Floodplain Confinement – moderate

Lick Fork Road follows entire length of reach, but does not have a continuous impact on floodplain confinement as most of the road is on the toe of the adjacent hillslope.

Riparian Function – impacted

The riparian habitat is well developed but has a narrow extent in sections because of the road.

Fish Habitat and Use

These reaches are outside the known extent of fish distribution; however, it is possible that steelhead spawn and rear in these reaches.

Restoration Strategies and Recommendations

The top recommendations for these reaches are to increase channel complexity and promote overbank flow by aggrading the stream bed. Invasive vegetation management and riparian planting projects should also be considered. Planting projects should be implemented in conjunction with strategies that promote overbank flow.

Table 34. Restoration recommendations for Lick Creek reach LC_02.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	Medium	Protect Riparian
Connect disconnected habitat	Low	Assess potential to adjust confining features, promote overbank flow
Long-term processes	High	Riparian management
Short-term processes	High	Increase channel complexity

10.6 SOUTH FORK ASOTIN CREEK

10.6.1. Reach SF_01 – RM 0.0 to 10.9

Dominant Reach Type: Partly Confined Planform Controlled with discontinuous floodplain pockets

General Description

Reach **SF_01** begins at the confluence with the North Fork Asotin Creek and extends 10.9 miles upstream. The reach is entirely within public lands. South Fork Creek Road follows the creek until RM 3.6 where it crosses the creek near the confluence with Warner Gulch. A WDFW maintenance shed is located near the confluence with Warner Gulch, and a recreational access trail continues past the shed and follows the creek for the rest of the reach, crossing several times. In general, the stream is channelized with few opportunities for floodplain access during bankfull events (2 year recurrence interval). However, flood channels and paleo channels are common on the floodplain. The reach is in a partly confined valley and channel complexity is low, especially where LWD is limited.

Figure 27. South Fork Asotin Creek with typical recovering riparian and low diversity habitat.

Hydrology

Headwaters for **SF_01** begin in the Blue Mountains and the hydrologic regime is snow-rain dominated. Surface flows are maintained throughout the year, but base flows in the summer can fall to below one cfs. Warner Gulch is an ephemeral tributary that enters the reach at RM 3.6. Warner Gulch has recently experienced several high-intensity rain storms that caused brief floods that contributed large amounts of sediment to the South Fork of Asotin Creek. A large unnamed intermittent tributary enters the reach at RM 4.4 and typically retains surface flow until early summer.

Geomorphic Function – limited to high

SF_01 is in moderate geomorphic function until RM 9.1, primarily due to a lack of hydraulic and geomorphic complexity, poor sediment sorting, limited floodplain connection, and low LWD density, but has limited geomorphic function from RM 3.6 to 4.6. The fan from Warner Gulch, and the South Fork Creek Road bridge crossing, create a brief pinch point that has likely contributed to a back-log of sediment upstream. The reach has high geomorphic function from RM 9.1 to 10.9, and is primarily limited by LWD density.

Floodplain Connection – moderate

There are few areas where anthropogenic confinement is limiting floodplain connection in this reach. However, the stream is often channelized, reducing interaction with the floodplain. When LWD is present in high densities, floodplain connection improves. In many areas, soil on the floodplain is shallow and cobble sheets are exposed.

Riparian Function – moderate to high

Riparian function is generally in moderate condition until RM 3.8, just upstream of the confluence with Warner Gulch. Although the riparian zone is typically dense, it is dominated by immature alder. Upstream of RM 3.8, the riparian function is high, and a greater diversity of canopy species are present.

Fish Habitat and Use

Steelhead use this reach for migration, spawning, and rearing. Chinook likely spawn here in low numbers, and juveniles have been observed through IMW survey efforts in low numbers. Bull trout migrate through the lower portions of this reach, but are known to spawn and rear in the upper portions of the reach. Lamprey use is unknown.

Restoration Strategies and Recommendations

The top recommended action from RM 0.0 to 9.1 is to add LWD to increase hydraulic and geomorphic diversity, improve sediment sorting, and increase interaction with the floodplain. It would still be appropriate to add LWD from RM 9.1 to 10.9; however, the potential for natural LWD recruitment and current LWD densities are higher than in lower sections. Protecting current riparian vegetation is recommended throughout the reach to allow time for alders to mature and the next successional species take hold (e.g., cottonwood and conifers). Over time, the alders will be a source of natural LWD recruitment. Management for invasive vegetation is recommended for several areas where upland vegetation is encroaching into the floodplain.

Table 35. Restoration recommendations for South Fork Asotin Creek reach SF_01.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	High	Protect Riparian
Connect disconnected habitat	Moderate	Disconnected habitats are generally not present. Promote overbank flow
Long-term processes	High	Riparian management
Short-term processes	High	Increase channel complexity, beaver management

10.7 GEORGE CREEK

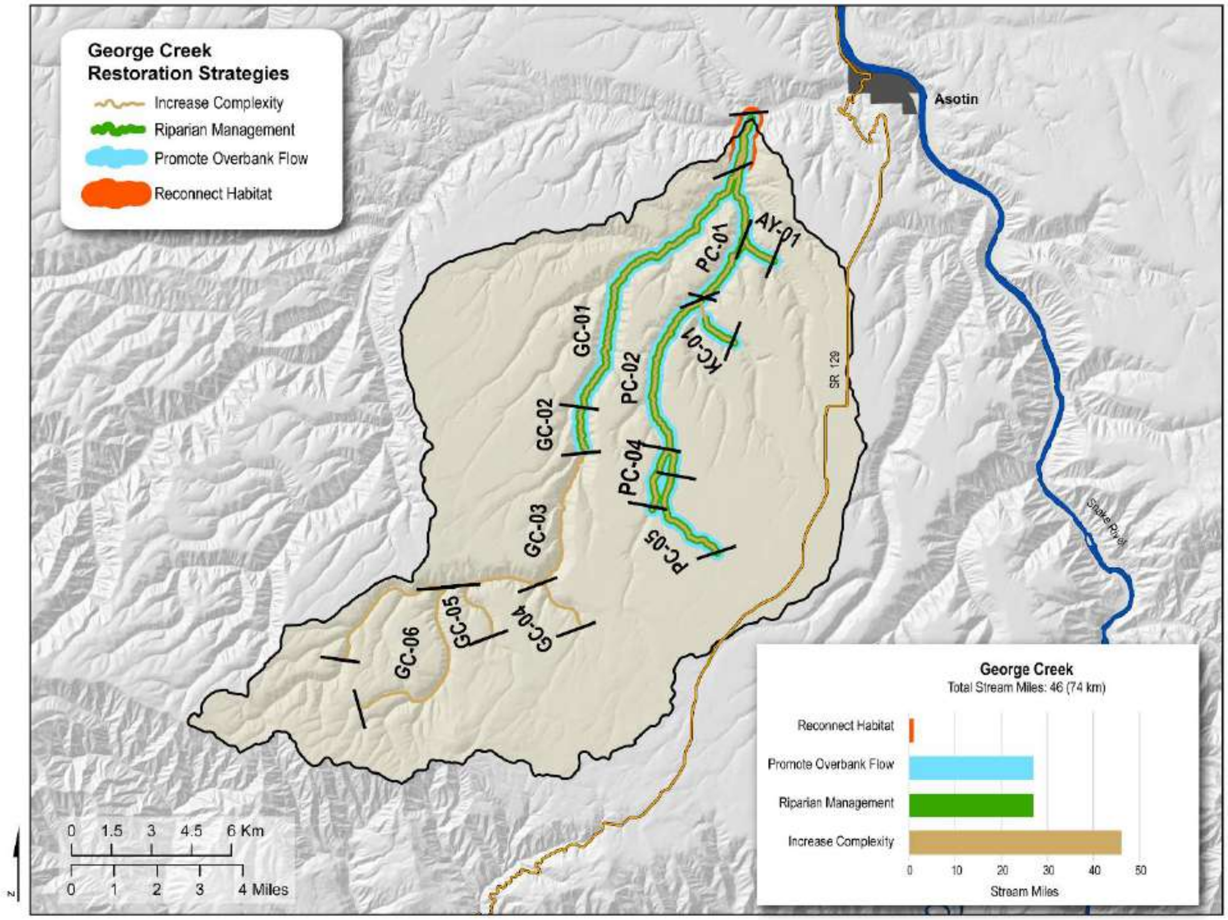

Figure 28. Restoration strategies and reach breaks for George Creek. Reach breaks are labeled by stream and reach number: GC_01 = George Creek restoration reach 1. Restoration strategies are defined in Section 9.

10.7.1. Reach: GC_01 – RM 0.0 to 9.2

Dominant Reach Type: Wandering Gravel Bed and Planform Controlled with Discontinuous Floodplain

General Description

Reach **GC_01** begins at the confluence with the mainstem of Asotin Creek and ends 9.2 miles upstream at the confluence with a small unnamed ephemeral tributary. Near the upstream end of the reach, the valley becomes more confined. This reach flows through multiple residential parcels, working ranches, and is within state owned property for about 70% of its length. The flow in several sections goes subsurface during the summer and these areas can have very little riparian vegetation.

Figure 29. Lower George Creek at site of a created meander reach.

Hydrology

Although this reach is perennial, relatively long segments of stream go subsurface or are puddled during summer months. The stream gauge operated by WADOE near the mouth of George Creek from 2009-2013 did not produce reliable peak flow data. However, it is clear from our personal observations during spring flows since 2008 and supporting observations from local landowners and agency personnel, that George Creek regularly experiences large floods that can span nearly the entire valley bottom.

Surface flow duration during summer months from RM 0.0 to 1.3 appears to have increased following the creation of a meander in 2006. Floods have altered much of the original meander section, and the stream may go subsurface in summer months between RM 0.6 and 1.0.

From RM 2.4 to 9.2, the stream varies between surface and subsurface flow during summer months. The presence of surface flow is likely correlated with springs originating from intermittent and ephemeral tributaries. There are no perennial tributaries in this reach, so the hydrology is largely driven by winter and spring precipitation. Therefore, it is likely that surface flow becomes more regular near the upper end of the reach.

Geomorphic Function – limited to moderate

This reach is a wandering gravel bed with discontinuous floodplain reach type with limited geomorphic function from RM 0.0 to 3.2. From RM 0.6 to 1.4, a new reach type was created to address excessive amounts of large sediment in the valley bottom causing the stream to go subsurface. Although the project appears to be successful in terms of improving fish passage, the channel shape, planform, and bed character are not sustainable under the current watershed controls and boundary conditions. From RM 1.4 to 2.5, the primary limiting factors are low geomorphic and hydraulic complexity, mostly associated from a lack of structural elements. Anthropogenic pressures are also impacting this section, reducing planform complexity and limiting access to the floodplain. From RM 2.5 to 3.2, the reach has limited geomorphic function, primarily due to a lack of structural elements, limited planform complexity, low geomorphic and hydraulic complexity. Many LWD structures were added to this section recently, so the condition may improve given adequate high flow events.

From RM 3.2 to 9.2, the stream is a planform controlled with discontinuous floodplain reach type in moderate condition. The primary limiting factors are lack of geomorphic and hydraulic diversity, most likely attributed to a lack of structural elements. The channel planform is appropriate for most of the reach, but there are missed opportunities for side channel and floodplain access due to low amounts of LWD. This section is dominated by planar geomorphic units such as runs and glides, and the few pools are typically forced by LWD or small boulder ribs. LWD density is especially low from RM 6.0 to 9.2.

Floodplain Confinement – low to high

The primary limiting factors from RM 0.0 to 0.6 are high artificial confinement, lack of floodplain connection, low geomorphic and hydraulic diversity, and a lack of structural elements. There are several localized confining features just upstream of the confluence with Pintler Creek around private property.

Riparian Function – limited to moderate

Riparian function in this reach highly variable. There are several segments (some 1 mile long) where as little as 21% of the historic riparian vegetation currently exists (e.g., RM 2.4 – 3.4 and 7.4 – 8.3). Interestingly, the RCA model predicts that the seemingly barren section from RM 0.6 to 1.3 has departed very little from its historic extent. Currently, the only true riparian vegetation from RM 0.6 to 1.3 are willows planted during the meander creation. Riparian vegetation in the rest of the reach upstream of RM 1.3 is dominated by alder and cottonwood. The most common cause for riparian departure throughout the reach is a conversion to invasive vegetation.

Fish Habitat and Use

Steelhead spawn and rear in this reach, and juveniles likely migrate through, either to upper sections that maintain surface flow, or to the mainstem of Asotin Creek to rear. Bull trout are present in the upper reaches (GC_03 to 06) and likely migrate through this reach. It is unlikely that bull trout rear within this reach due to high water temperatures during summer months.

Restoration Strategies and Recommendations

The stream channel is artificially confined from RM 0.0 to 0.6; however, there are several residential parcels that need to be protected from high flows, so reconnecting the floodplain is not a feasible option. A meandering reach was created in 2006 from RM 0.6 to 1.3. The lower portion of this meander is filling with gravel and flow is starting to leave the created channel during high flows. The best strategy in this reach would be to allow the stream to function naturally (i.e., form multiple channels), rather than trying to create an unnatural single meander.

From RM 1.3 to 3.2, the channel has low diversity and the floodplain is poorly connected. There is also a residence that confines the floodplain. A WDFW restoration project was completed in 2013 from RM 2.4 to 3.2. Numerous large trees and wood structures were added to the channel and floodplain. This restoration treatment is more compatible with natural river behavior and this entire section could be monitored to see how well it performs. The channel has low diversity, low LWD, and recovering riparian from RM 3.2 to the top of the reach at RM 9.2. The recommended restoration strategy would be to promote overbank flow and increase habitat diversity.

Table 36. Restoration recommendations for George Creek reach GC_01.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	Medium	Continue/expand erosion control, protect riparian and springs
Connect disconnected habitat	Low	Assess confining features in the lower 0.5 miles and at confluence with Pintler Creek. Remainder of the reach has no significant confining features. Promote overbank flow
Long-term processes	Medium	Riparian management (fencing, manage invasive vegetation, off-site water, grazing management)
Short-term processes	High	Increase channel complexity

10.7.2. Reach: GC_02 – RM 9 to 10.3

Dominant Reach Type: Partly Confined Planform Controlled with Discontinuous Floodplain

General Description

Rockpile Creek enters this reach at RM 9.2. Rockpile Creek is a substantial tributary that brings in a lot of sediment (potentially flow during spring melt) and marks the bottom of GC_02.

Hydrology

There are numerous ephemeral and intermittent tributaries in this reach.

Geomorphic Function – moderate

The lower end of this reach is adjusting to the active sediment inputs from Rockpile Creek. Accumulated sediment from the fan creates a pinch point in the valley bottom, which forces sediment accumulation upstream. There is limited LWD in the channel and floodplain which reduces the stream's ability to sort these sediment inputs.

Floodplain Confinement – low

There are very few confining features in this reach.

Riparian Function – moderate

Canopy vegetation density is variable, but covers most of the stream in this reach. The canopy is dominated by immature alder with occasional cottonwood groves. Vegetation density is lowest in the middle of the reach and highest near the top and bottom near large tributary confluences.

Fish Habitat and Use

Steelhead spawn and rear in this reach and bull trout likely migrate through this reach.

Restoration Strategies and Recommendations

The top recommendation for this reach is to increase channel complexity through LWD additions. Adding LWD will increase hydraulic and geomorphic complexity in the short term, and increase local stream competence to transport larger substrate in the long term.

Table 37. Restoration recommendations for George Creek reach GC_02.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	Medium	Continue/expand erosion control, protect riparian and springs
Connect disconnected habitat	Low	There are very few confining features in this reach. Promote overbank flow
Long-term processes	Medium	Riparian management (fencing, manage invasive vegetation, off-site water, grazing management)
Short-term processes	High	Increase channel complexity

10.7.3. Reach: GC_03 to GC_06 – RM 10.3 to 20.1

Dominant Reach Type: Confined Valley Occasional Floodplain Pockets, Confined Steep Headwater

General Description

Reach GC_03 to GC_06 are small tributaries that make up the headwaters of George Creek. Access is limited to private roads for GC_04 and GC_05. The upper portions of GC_03 and GC_06 begin in USFS property.

Hydrology

The hydrologic regime in these reaches is snow-rain dominated.

Geomorphic Function – high

These reaches are have high geomorphic function.

Floodplain Confinement – low

There are no anthropogenic features confining the floodplain.

Riparian Function – unimpacted

The riparian zone in these reaches is mostly unimpacted. Logging has likely occurred in the past, but appropriate riparian buffers exist, so impact to stream processes is minimal.

Fish Habitat and Use

Steelhead spawn and rear in these reaches, and juveniles likely migrate through to upper sections that maintain surface flow, or to the mainstem of Asotin Creek to rear. WDFW and USFS have documented bull trout in these reaches

Restoration Strategies and Recommendations

The top recommendation for this reach is to increase channel complexity through LWD additions. These reaches may also be opportunities for using beaver management as a tool to increase channel complexity and increase water retention which may improve summer base flows for downstream reaches.

Table 38. Restoration recommendations for George Creek reach GC_03 to GC_06.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	Medium	Continue/expand erosion control, protect riparian and springs
Connect disconnected habitat	Low	There are very few confining features in this reach. Promote overbank flow
Long-term processes	Low	Riparian management (fencing, manage invasive vegetation, off-site water, grazing management)
Short-term processes	High	Increase channel complexity, beaver management

10.8 PINTLER CREEK

10.8.1. Reach: PC_01 – RM 0.0 to 3.6

Dominant Reach Type: Confined with Occasional Floodplain Pockets

General Description

Reach **PC_01** begins at the confluence with George Creek. From RM 0.0 to 0.6, the reach is a Wandering gravel bed with discontinuous floodplain reach type, where there is one dominant channel with several side channels, but only 1-3 may be active at a time. The stream regularly goes subsurface from RM 0.0 to 0.6 after spring flows recede in the summer. A natural pinch point in the valley near RM 0.6 marks the beginning of a confined valley setting, changing the reach type to Confined with occasional floodplain pockets. Most of the reach is within WDFW property.

Figure 30. Lower Pintler Creek just above the confluence with George Creek. Flows in this section go dry each year.

Hydrology

Ayers Gulch and Kelly Creek enter this reach at RM 1.7 and 3.6, respectively. Both are intermittent and extend from the dissected loess uplands. The dominant hydrologic regime in **PC_01** is groundwater, although this reach regularly experiences large floods caused by spring snow melt.

Geomorphic Function – limited to moderate

Geomorphic function in this reach is mostly in limited primarily due to a lack of hydraulic and geomorphic diversity, poor sediment sorting, and low LWD densities. From RM 1.4 to 2.3, geomorphic function is moderate and primarily limited by low hydraulic and geomorphic diversity.

Floodplain Connection – low

Although the floodplain is accessed regularly during high flow events, the lack of structure on the floodplain limits the retention of fine sediment and water.

Riparian Function – moderate

Riparian function from RM 0.0 to 0.6 is limited. Land use is likely a contributing factor, but the lack of structure of the floodplain (e.g., trees, LWD) limits soil development and water storage on the floodplain and channel margins. These conditions are severely limiting the establishment of riparian plants.

Fish Habitat and Use

Steelhead primarily migrate through this reach. There is likely some spawning and rearing, but survival is expected to be limited because of low summer base flows and high summer water temperatures.

Restoration Strategies and Recommendations

The top recommended action for **PC_01** is to add LWD to increase channel and floodplain complexity from RM 0.6 to 3.6. Adding LWD to the channel will slow water transport times, improve habitat complexity for juveniles, and improve sediment sorting, creating more spawning opportunities for adult salmonids. LWD additions are also recommended for the floodplain, as the increased structure will increase the retention of water and fine sediment and improve riparian function over time.

Table 39. Restoration recommendations for Pintler Creek reach PC_01.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	Low	Continue/expand erosion control, protect riparian and springs
Connect disconnected habitat	Low	There are very few confining features in this reach. Promote overbank flow
Long-term processes	High	Riparian management (fencing, manage invasive vegetation, off-site water, grazing management)
Short-term processes	High	Increase channel complexity

10.8.2. Reach: PC_02 – RM 3.6 to 8.7

Dominant Reach Type: Confined with Occasional Floodplain Pockets

General Description

Reach **PC_02** begins at the confluence with Kelly Creek and extends upstream to RM 8.7. The valley setting is confined, and the channel is almost always single thread. The valley widens for brief sections, creating floodplain pockets that are regularly accessed during high flow events. The entire reach is within private lands with very limited access and grazing is the primary land use.

Hydrology

The hydrologic regime in reach **PC_02** is dominated by groundwater; however, spring flows typically result in floods over bankfull. A large intermittent tributary enters the reach near RM 7.9 and there are several ephemeral tributaries throughout the reach. Summer base flows are typically less than 1 cfs, and sections of this reach may go subsurface or become puddled.

Geomorphic Function – moderate

The geomorphic function in this reach is moderate and primarily limited by low LWD density, instream hydraulic and geomorphic diversity, and poor sediment sorting.

Floodplain Connection – moderate

The floodplain in this reach is in moderate condition. There are naturally limited opportunities for floodplain connection because of high valley confinement. The primary factor limiting floodplain condition is the lack of structural elements on the floodplain, which reduces the retention of water and fine sediments stored.

Riparian Function – moderate to high

Riparian function in this reach is mostly moderate, but there are several examples of sections with high function. Immature alder trees dominate the canopy and natural recruitment is low. Upland vegetation is encroaching up to the channel margin in some areas.

Fish Habitat and Use

Steelhead migrate through this reach. They also spawn and rear throughout the reach. Juvenile survival may be low due to the lack of cover and inadequate summer base flows. Spawning opportunities are limited due to poor sediment sorting.

Restoration Strategies and Recommendations

The top recommended action for reach **PC_02** is to increase channel complexity by adding LWD. Adding LWD will promote local scour and deposition to improve critical pool and spawning habitats, and slow water transport times to extend summer base flows downstream. LWD is particularly recommended near floodplain pockets to improve floodplain connection. This reach may also have opportunities for beaver management.

Table 40. Restoration recommendations for Pintler Creek reach PC_02.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	Moderate	Continue/expand erosion control, protect riparian and springs
Connect disconnected habitat	Low	There are very few confining features in this reach. Promote overbank flow
Long-term processes	Moderate	Riparian management (fencing, manage invasive vegetation, off-site water, grazing management)
Short-term processes	High	Increase channel complexity, beaver management

10.8.3. Reach: PC_03 – RM 8.7 to 11.2

Dominant Reach Type: Confined with Occasional Floodplain Pockets

General Description

Reach **PC_03** begins at RM 8.7 and ends at the upstream extent of known steelhead distribution at RM 11.2. The entire reach is located within private lands and access is limited. There is a private access road to residences in the middle of the reach.

Hydrology

The hydrologic regime is dominated by groundwater and the channel typically maintains surface flow. There are no major tributaries to this reach; however, the mainstem of Pintler Creek extends further upstream into the dissected loess uplands.

Geomorphic Function – limited to moderate

Geomorphic function is moderate from RM 8.7 to 10.1 and is primarily limited by low LWD densities. The reach has limited geomorphic function from RM 10.1 to 11.2 and is primarily limited by low LWD densities, low hydraulic and geomorphic diversity, poor sediment sorting, and limited floodplain connection. Although confined reaches naturally have a limited floodplain, the floodplain pockets in this reach are further limited by anthropogenic development.

Floodplain Connection – moderate

Floodplain connection in this reach is moderate primarily because of the naturally limited opportunities for floodplain development. Residential and agricultural infrastructure in the upper section of the reach further limits opportunities for floodplain development.

Riparian Function – limited to moderate

Riparian function from RM 8.7 to 10.1 is moderate and dominated by shrubs and immature alder. Some floodplain pockets have small cottonwood groves and conifers along the valley margin. Riparian function from RM 10.1 to 11.2 is limited due to the effect human development on the riparian zone. Upland and invasive vegetation is encroaching into the valley bottom and channel margins throughout this reach.

Fish Habitat and Use

Steelhead spawn and rear in this reach. The reach may be a summer refuge for juvenile steelhead because surface water is present during the summer low flow period, whereas flow in upstream and downstream reaches frequently goes subsurface. Bull trout use in this reach is unknown, but they may be present.

Restoration Strategies and Recommendations

The top recommended action for this reach is to add LWD to increase channel complexity to improve juvenile steelhead habitat. Controlling invasive vegetation is also highly recommended to reduce recruitment and propagation in reaches downstream. From RM 10.1 to 11.2, riparian vegetation plantings and floodplain pocket development or protection should be considered. Adding LWD throughout the reach will also slow water transport times and increase summer base flows for downstream reaches. As riparian function improves, this reach may present opportunities for working with beaver to improve summer base flows downstream.

Table 41. Restoration recommendations for Pintler Creek reach PC_03.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	High	Continue/expand erosion control, protect riparian and springs
Connect disconnected habitat	Moderate	There are very few confining features in this reach. Promote overbank flow
Long-term processes	High	Riparian management (fencing, manage invasive vegetation, off-site water, grazing management)
Short-term processes	High	Increase channel complexity, beaver management

10.8.4. Reach: PC_04 to 05

Dominant Reach Type: Confined with Occasional Floodplain Pockets

General Description

PC_04 is an unnamed tributary to Pintler Creek at RM 8.7. **PC_05** is an extension of Pintler Creek starting at RM 11.2 and going to RM 12.8.

Hydrology

The hydrologic regime is dominated by groundwater and the channel typically maintains surface flow. There are no major tributaries to this reach; however, the mainstem of Pintler Creek extends further upstream into the dissected loess uplands.

Geomorphic Function – limited to moderate

Geomorphic function is moderate from RM 8.7 to 10.1 and is primarily limited by low LWD densities. The reach has limited geomorphic function from RM 10.1 to 11.2, primarily due to low LWD, hydraulic and geomorphic diversity, and poor floodplain connection and sediment sorting. Although confined reaches naturally have a limited floodplain, the floodplain pockets in this reach are further limited by anthropogenic development.

Floodplain Connection – moderate

The floodplain in this reach is in moderate condition primarily because of the naturally limited opportunities for floodplain development. Residential and agricultural infrastructure in the upper section of the reach further limits opportunities for floodplain development.

Riparian Function – limited to moderate

Riparian function from RM 8.7 to 10.1 is moderate and dominated by shrubs and immature alder. Some floodplain pockets have small cottonwood groves and conifers along the valley margin. Riparian function from RM 10.1 to 11.2 is limited, due to human development limiting the extent of the riparian zone. Upland and invasive vegetation is encroaching into the valley bottom and channel margins throughout this reach.

Fish Habitat and Use

Steelhead spawn and rear in this reach. Because the hydrology in this reach is relatively stable, it may be a summer refuge for juvenile steelhead migrating from lower reaches that go subsurface or become puddled. Bull trout use in this reach is unknown, but they may be present.

Restoration Strategies and Recommendations

The top recommended action for this reach is to add LWD to increase channel complexity to improve juvenile steelhead habitat. Controlling invasive vegetation is also highly recommended to reduce recruitment and propagation in reaches downstream. From RM 10.1 to 11.2, riparian vegetation plantings and floodplain pocket development or protection should be considered. Adding LWD throughout the reach will also slow water transport times and increase summer base flows for downstream reaches. As riparian function improves, this reach may present opportunities for working with beaver to improve summer base flows downstream.

Table 42. Restoration recommendations for Pintler Creek reach PC_04 to PC_05.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	High	Continue/expand erosion control, protect riparian and springs
Connect disconnected habitat	Moderate	There are very few confining features in this reach. Promote overbank flow
Long-term processes	High	Riparian management (fencing, manage invasive vegetation, off-site water, grazing management)
Short-term processes	High	Increase channel complexity, beaver management

10.9 TENMILE CREEK

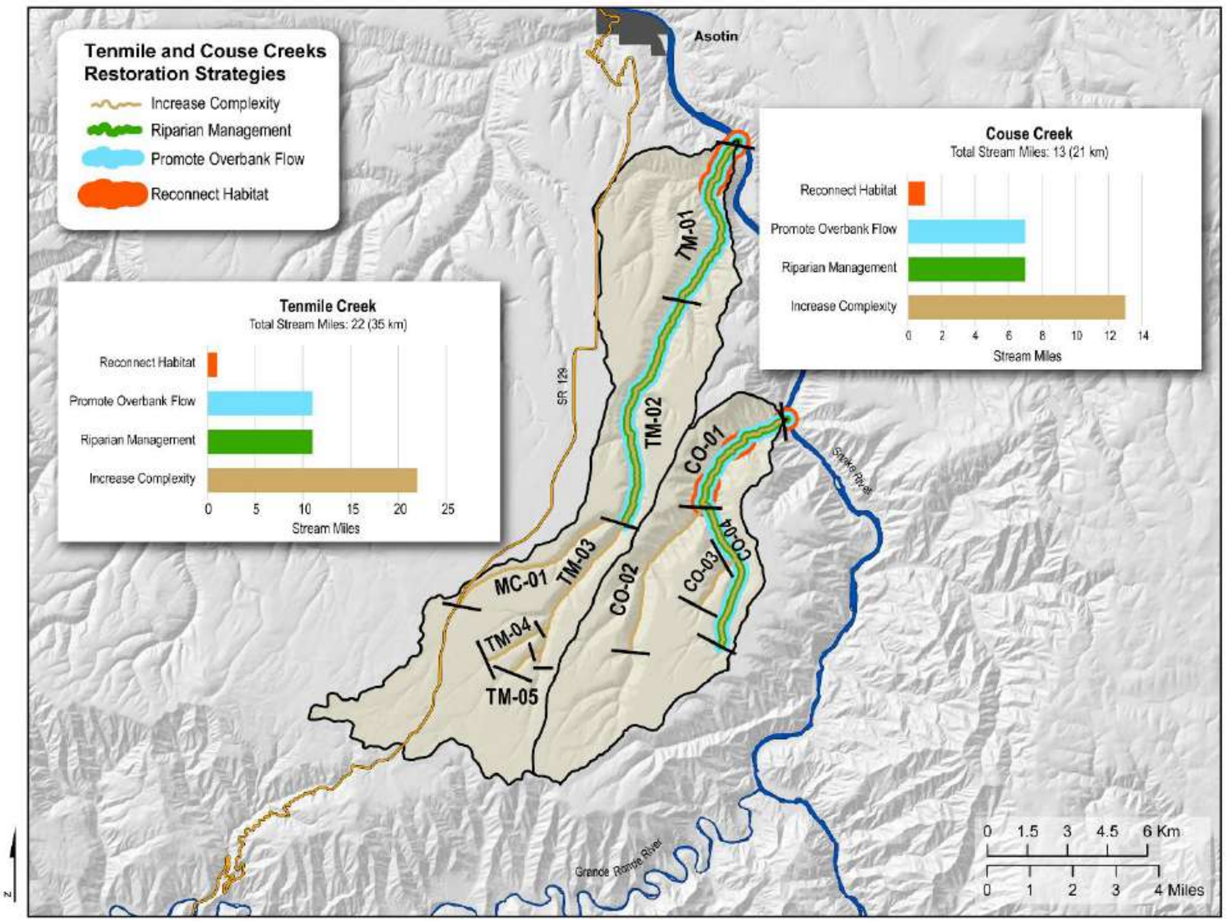

Figure 31. Restoration strategies and reach breaks for Couse and Tenmile Creeks. Reach breaks are labeled by stream and reach number: TM_01 = Tenmile Creek restoration 1. Restoration strategies are defined in Section 9.

10.9.1. Reach: TM_01 – RM 0.0 to 4.5

Dominant Reach Type: Alluvial Fan, Planform Controlled with Discontinuous Floodplain, and Confined with Occasional Floodplain Pockets

General Description

Reach **TM_01** is located from the mouth of Tenmile Creek to about RM 4.5. The reach begins as an alluvial fan surrounded by private infrastructure with several levees to help contain high flows and protect private property. The reach crosses under several private and public bridges, creating pinch points in the channel and floodplain. Land use in this reach is primarily grazing and agriculture and intensity decreases upstream of Beckman Gulch at RM 1.1. The floodplain is well developed upstream of Beckman Gulch except from RM 2.2 to 2.8 where the valley is much more confined. The stream parallels the Snake River and is separated from it by Weissenfels Ridge.

Figure 32. Alluvial fan at the bottom of reach TM_01 as Tenmile Creek enters the Snake River.

Figure 33. Reach TM_01 upstream of Beckman Gulch depicting the riparian canopy dominated by young alder. LWD in the channel is typically small and rare.

Hydrology

There are no perennial tributaries in this reach. Beckman Gulch enters at RM 1.0 and is a large intermittent tributary that drains a relatively substantial portion of the loess uplands. Portions of this reach upstream of Beckman Gulch typically go dry or become puddled during late summer months. Several small ephemeral tributaries enter this reach, some extending into the dissected loess uplands.

Geomorphic Function – limited to moderate

There is very little LWD present in this reach; however small woody debris accumulates in small jams on bar surfaces and channel margins. Tenmile Creek transports a relatively large amount of sediment for its size, and much of the sediment is deposited at the confluence with the Snake River. The regulated flow regime of the Snake River may have reduced its competence to erode the toes of alluvial fans of incoming tributaries such as this one on Tenmile Creek. Therefore, if the sediment accumulating at the mouth of this reach is not removed naturally, the fan sets an artificial base level, causing sediment to accumulate upstream from the proximal end of the fan.

The channel is mostly entrenched from RM 0.2 to 1.7, limiting access to the floodplain during bankfull flood events (2 year recurrence interval). The most disconnected section is from RM 0.2 to Beckman Gulch at RM 1.0. Upstream of Beckman Gulch, the channel is still entrenched but has frequent access to low-lying floodplain pockets. LWD is common on the floodplain but very little is in the channel, resulting in uniform sediment distribution and low hydraulic diversity. Pools are rare and typically occur on the outside of meander bends, often at the base of tree roots. The channel is dominated by planar units with poor complexity.

From RM 1.7 to 2.1, the channel is wide and braided as it tries to rework large sediment deposits and has very little riparian vegetation. The valley upstream of this section is confined and acts a sediment transport zone. During high flow events, sediment is deposited rapidly as the valley transitions from confined to unconfined beginning at RM 1.7. This section has limited function because it is almost completely devoid of structural elements, is laterally unstable, has low hydraulic diversity, and an unstable channel bed. From RM 2.1 to 4.5, geomorphic function is moderate because the valley width varies, causing short areas of sediment deposits similar to the lower section. LWD is prevalent in the floodplain, but limited in the channel.

Floodplain Confinement – high

From RM 0.0 to 1.5, this reach would have historically had a much wider lateral extent to distribute flow and sediment during flood events. Currently, the channel is confined by levees on both sides. Weissenfels Ridge Road parallels the stream along the valley margin, but does not appear to have a substantial impact on channel confinement.

Riparian Function - moderate

Riparian function in this reach is relatively high, but over 70% of riparian vegetation has been lost or converted to agriculture. The canopy is dominated by cottonwood and alder, and willows are common. Much of this reach is currently protected through CREP, and several planting projects have been completed or are underway.

From RM 0.2 to RM 1.2, over 70% of the historic riparian vegetation has been lost. However, this section is currently protected through CREP and several planting projects are underway. Most of the loss in riparian vegetation is in the floodplain as the channel is well-shaded by a thin alder-dominated canopy. Riparian vegetation covers most of the valley bottom from RM 1.2 to RM 1.7 and is still dominated by young alder trees. In the blown-out section from RM 1.7 to 2.1, there is very little riparian vegetation shading the channel, but there have been substantial planting efforts on the floodplain to increase canopy cover. Riparian function varies moving upstream from high to limited, typically coinciding with changes in the valley width.

Fish Habitat and Use

Steelhead may spawn and rear in this reach and certainly migrate through to reach upstream portions of Tenmile Creek and Mill Creek. The large amount of deposition at the mouth of this reach may be a barrier to migrating juveniles during low flows, particularly during fall migration. The lack of structural elements such as LWD in the channel contributes to low geomorphic and hydraulic diversity. There are very few pools, and cover is often limited to occasional undercut banks.

Restoration Strategies and Recommendations

Tenmile Creek is prone to short-duration, intense floods, which is typical of parallel, elongate watersheds; therefore, removing the levees in this reach would likely put private property at risk. The primary concern at the mouth of Tenmile Creek is the possibility of a migratory barrier caused by sediment accumulation near the Snake River confluence. Dredging was a frequent practice in this reach to keep a clear fishway for migrating salmonids, but this has not occurred for roughly 20 years. There is little that can be done to improve the overall condition of the alluvial fan portion of this reach, but it is highly recommended that a barrier assessment be conducted. If the fan is a barrier to migration, dredging could be considered as an option to improve fish passage.

The top recommended strategy in this reach is to reconnect habitats if possible and/or promote overbank flow and increase structural complexity. Adding LWD from RM 1.7 to 2.2 could trap pockets of fine sediment and improve conditions for reestablishing riparian vegetation. Overall, increasing the density of structural elements would reduce sediment transport time, allowing the blown-out sections to recover more quickly. LWD structure placement should focus on improving instream habitat and reconnecting the floodplain. Increasing the density of structural elements would also slow surface water transport time and promote more hyporheic and groundwater exchange, likely prolonging summer base flows and reducing water temperature during summer months.

Table 43. Restoration recommendations for Tenmile Creek reach TM_01.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	Medium	Continue/expand erosion control, protect riparian and springs
Connect disconnected habitat	Low	Assess potential barrier at the mouth, adjust confining features and/or connect historic side-channels (RM 0.0-1.5). Promote overbank flow
Long-term processes	Medium	Riparian management (fencing, manage invasive vegetation, off-site water, grazing management)
Short-term processes	High	Increase channel complexity

10.9.2. Reach: TM_02 – RM 4.5 to 10.7

Dominant Reach Type: Partly Confined Planform Controlled with Discontinuous Floodplain

General Description

Reach **TM_02** begins at RM 4.5 at a large alluvial fan from a river right tributary and ends at RM 10.7 at the confluence with Mill Creek. Rangeland is the primary land use in this reach. There are multiple private primitive roads to and paralleling this reach, making access to this remote reach difficult. Fans from steep ephemeral hillslopes regularly push the channel from either side of the valley margin, but the stream appears to have the competence to move the material, creating large cut banks at the toe of the fans.

Hydrology

There are no perennial tributaries in this reach, but there are several small ephemeral drainages extending from the dissected loess uplands. Sections of this reach are puddled or dry during late summer months.

Geomorphic Function - moderate

The channel varies from entrenched to braided through this reach as the stream attempts to rework large pockets of sediment deposition. Large sections of this reach are likely recovering from historic flood events and land use disturbance and typically appear braided with very few structural elements in the channel. Typically, these sections also have puddled or no surface flow during late summer months. Channel substrate is uniformly distributed and poorly sorted, primarily composed of unembedded cobbles. Boulders act as the primary instream structural element, but rarely occur in clusters or ribs, so their morphological impact is minimal.

Floodplain Confinement – low

There are very few confining features in this reach.

Riparian Function - moderate

Up to 100% of the riparian vegetation in sections of this reach have been lost. Where the stream goes subsurface, upland vegetation encroachment is a concern due in part to a lack of regular floodplain inundation. Riparian vegetation from RM 5.6 to 7.1 is nearly 100% fully functioning; however, patches of healthy riparian like this are rare in the reach. Alder are the dominant canopy species in this reach, but there are several cottonwood groves and patches of willow.

Fish Habitat and Use

Steelhead may spawn and rear in this reach and certainly migrate through to reach upstream portions of Tenmile Creek and Mill Creek. Capacity in this reach is likely limited due to long sections going dry during late summer. Instream habitat is limited by the lack of structural elements to create and maintain pools and provide cover for rearing salmonids. Stream temperature may be an issue during summer and fall months in areas with limited riparian cover.

Restoration Strategies and Recommendations

The top restoration strategy in this reach is to improve water retention to extend summer base flows through this reach and downstream. Although this reach should be a high priority in the Tenmile Creek watershed, positive effects of restoration may take several years to decades to achieve. Increasing structural elements in the channel aimed at increasing hyporheic and groundwater exchange and reconnecting the floodplain are the top recommended actions. Beaver translocation in sections identified as suitable by the BRAT model should also be considered.

Table 44. Restoration recommendations for Tenmile Creek reach TM_02.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	Medium	Continue/expand erosion control, protect riparian and springs
Connect disconnected habitat	Low	Disconnected habitats are generally not present. Promote overbank flow
Long-term processes	Medium	Riparian management (fencing, manage invasive vegetation, off-site water, grazing management)
Short-term processes	High	Increase channel complexity, beaver management

10.9.3. Reach: TM_03 – RM 10.7 to 14.8

Dominant Reach Type: Confined with Occasional Floodplain Pockets

General Description

Reach **TM_03** begins at the confluence with Mill Creek at RM 10.7 and ends at RM 14.8. The valley becomes confined upstream of the confluence with Mill Creek. The valley is straight, but the stream channel maintains low sinuosity and has access to relatively small pockets of floodplain. Rangeland is the dominant land use.

Hydrology

This reach ends near the headwaters of Tenmile Creek and several small intermittent tributaries enter this reach near its upstream extent. The headwaters begin mostly in the dissected loess uplands, but are near the higher elevations of the dissected highlands. Hydrology is primarily driven by winter snow and rains retained as shallow groundwater. Inputs are still fairly low, which is typical of the dissected highlands and dissected loess uplands.

Geomorphic Function - high

This reach has high geomorphic function; however, there is very little LWD in the channel and floodplain. Like most reaches on Tenmile Creek, even where the riparian vegetation is dense, the riparian composition is dominated by young (<20 year old) alder. Therefore, there is little opportunity for local LWD recruitment.

Floodplain Confinement – low

There are very few confining features in this reach.

Riparian Function - unimpacted

Riparian function appears unimpacted; however, the canopy composition is dominated by young alder which will need time to grow before making significant LWD contributions to the reach.

Fish Habitat and Use

Salmonid use in this reach is unknown; however, it is likely that steelhead do spawn and rear this far up Tenmile Creek considering there are records of their presence in Mill Creek. There is perennial flow here, so it may act as an over-summer refuge for juveniles waiting for fall or spring floods to migrate downstream.

Restoration Strategies and Recommendations

The top recommended action in this reach is beaver relocation. The BRAT model suggests most of this reach is highly suitable for beaver dams to persist, and there are ample food sources. The priority for the upper portions of the Tenmile Creek should be to retain water to extend summer base flows and reduce summer water temperatures for downstream reaches. Beaver dams in high densities could help meet both of these goals. If beaver relocation in this reach is not feasible, beaver dam analogs or post-assisted log structures can simulate similar effects as natural beaver dams in respect to water retention.

Table 45. Restoration recommendations for Tenmile Creek reach TM_03.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	Medium	Continue/expand erosion control, protect riparian and springs
Connect disconnected habitat	Low	Disconnected habitats are generally not present. Promote overbank flow
Long-term processes	Medium	Riparian management (fencing, manage invasive vegetation, off-site water, grazing management)
Short-term processes	High	Increase channel complexity, beaver management

10.9.4. Reach: TM_04 and TM_05 (unnamed tributaries)

Dominant Reach Type: Confined with Occasional Floodplain Pockets

General Description

Hydrology

No inputs to these ephemeral reaches.

Geomorphic Function – moderate to high

These reaches have moderate to high geomorphic function. Flow and sediment transport in TM_06 is likely affected by a large pond at the top of the reach.

Floodplain Confinement – low

There are very few confining features in this reach.

Riparian Function –unimpacted

Riparian function is relatively unimpacted with a mix of shrubs, wetland vegetation, and mixed canopy species.

Fish Habitat and Use

Salmonid use in this reach is unknown; however, it is likely that steelhead do spawn and rear this far up Tenmile Creek considering there are records of their presence in Mill Creek. There is perennial flow here, so it may act as an over-summer refuge for juveniles waiting for fall or spring floods to migrate downstream.

Restoration Strategies and Recommendations

The top recommended strategy for these reaches is increase channel complexity. The BRAT model suggests most of this reach is highly suitable for beaver dams to persist, and there are ample food sources.

Table 46. Restoration recommendations for Tenmile Creek reach TM_04 to 05 (unnamed tributaries of Tenmile).

Restoration Framework	Priority	Recommendations
Protect and maintain existing	Medium	Continue/expand erosion control, protect riparian and springs
Connect disconnected habitat	Low	Disconnected habitats are generally not present
Long-term processes	Medium	Riparian management
Short-term processes	High	Increase channel complexity, beaver management

10.10 MILL CREEK

10.10.1. Reach: MC_01 – RM 0.0 – 4.7

Dominant Reach Type: Confined with Occasional Floodplain Pockets

General Description

Reach **TM_04** is a major perennial tributary to Tenmile Creek named Mill Creek. The stream flows through the town of Anatone, and the upper portion of this reach follows Highway 129 as it dissects into the lower snake canyons. Access to the reach is restricted to private roads.

Hydrology

The hydrologic regime in this reach is snow-rain dominated with perennial flows.

Geomorphic Function – high

Geomorphic function is mostly high. The stream changes character after flowing under Mill Creek Road and becomes more confined. LWD is lower than expected until the confluence with Tenmile Creek.

Floodplain Confinement – low

There are very few confining features in this reach.

Riparian Function – unimpacted

Riparian function is unimpacted in this reach. Much of the reach is enrolled in CREP.

Fish Habitat and Use

Steelhead spawn and rear in this reach and have even been observed in the upland swale section of the reach.

Restoration Strategies and Recommendations

The top recommended action in this reach is beaver relocation. The BRAT model suggests most of this reach is highly suitable for beaver dams to persist, and there are ample food sources. The priority for the upper portions of the Tenmile Creek should be to retain water to extend summer base flows and reduce summer water temperatures for downstream reaches. Beaver dams in high densities could help meet both of these goals. If beaver relocation in this reach is not feasible, LWD additions would be beneficial, but less effective at meeting goals.

Table 47. Restoration recommendations for Mill Creek reach MC_01.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	Medium	Continue/expand erosion control, protect riparian and springs
Connect disconnected habitat	Low	Disconnected habitats are generally not present
Long-term processes	Medium	Recovering
Short-term processes	High	Increase channel complexity, beaver management

10.11 COUSE CREEK

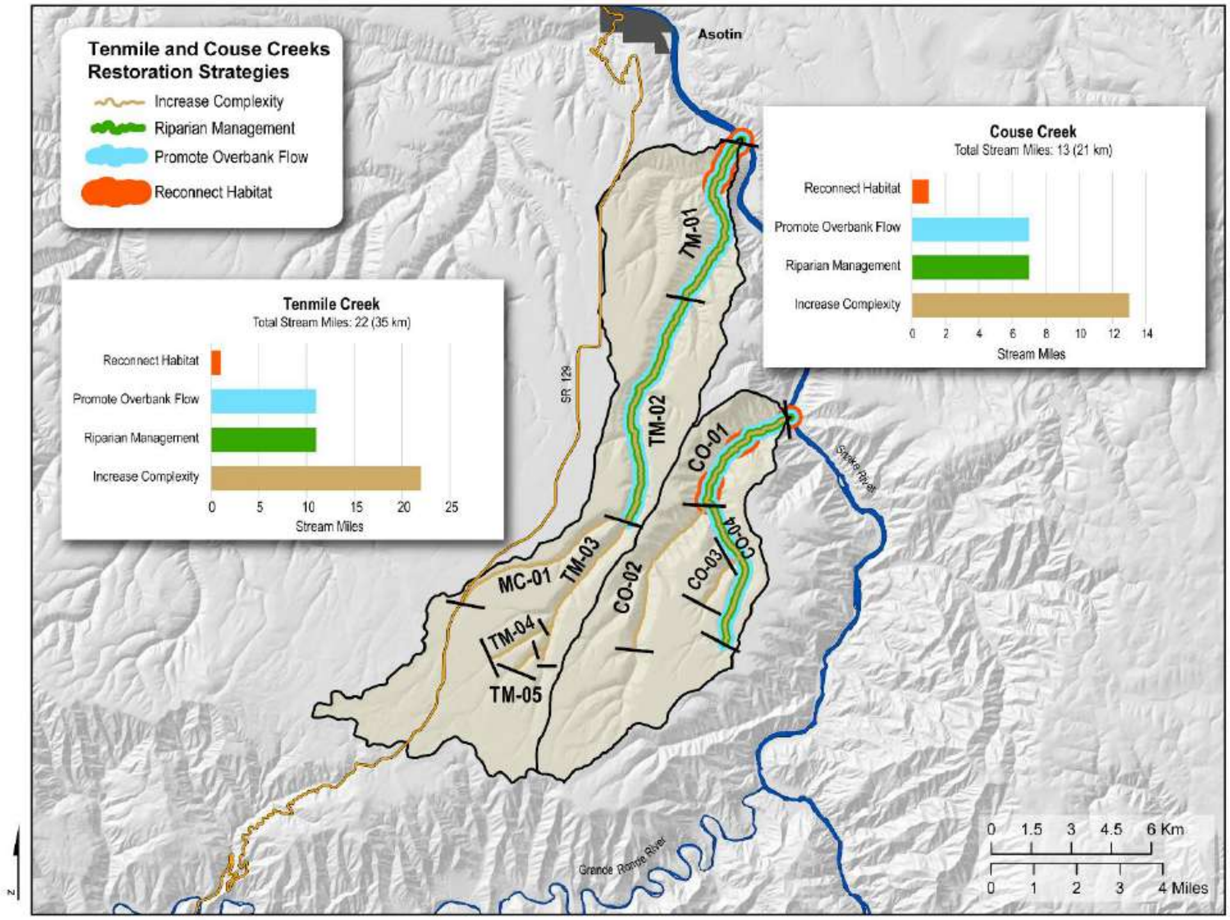

Figure 34. Restoration strategies and reach breaks for Couse and Tenmile Creeks. Reach breaks are labeled by stream and reach number: CO_01 = Couse Creek restoration 1. Restoration strategies are defined in Section 9.

10.11.1. Reach: C0_01 – RM 0.0 to 3.2

Dominant Reach Type: Unconfined Alluvial Fan, Partly Confined Fan Controlled with Discontinuous Floodplain, and Confined with Occasional Floodplain Pockets

General Description

Reach **CO_01** begins at RM 0.0 at the confluence with the Snake River, and ends at Montgomery Gulch at RM 3.2 where Couse Creek Road leaves the main channel. The alluvial fan section of the reach is very short (~0.5 miles), and begins where the channel crosses Snake River Road. The valley bottom is well-vegetated until RM 1.6, but has very few trees until the end of the reach. Couse Creek is the smallest of the four target watersheds, but has the highest average relief. The channel receives a lot of colluvial inputs from incoming hillslopes but lacks the competence to work most of it, resulting in a large back-log of angular sediment. The stream flows through a working ranch, but nearly half of the creek is enrolled in CREP.

Figure 35. Lower Couse Creek just upstream of confluence with the Snake River. Flows in this section go subsurface each year.

Hydrology

There are no perennial tributaries in this reach, but there are substantial steep ephemeral hillslopes. The stream goes subsurface from RM 1.8 to the top of the reach during summer months.

Geomorphic Function – limited to moderate

Fans from incoming steep ephemeral hillslopes are the primary physical control on the planform of the channel in this reach. The relatively extreme relief of the adjacent hillslopes also provides substantial amounts of colluvium that the stream lacks the competence to transport in regular floods. In addition, the valley becomes more constricted around RM 1.8. The combination of these factors has contributed to a back-log of sediment, excess of cobble/gravel sheets, distributaries, and subsurface flow. The remains of a historic lumber mill in this reach, suggests significant prior logging activity in the Couse Creek watershed. The removal of legacy trees in the drainage is the primary reason there is an extreme lack of LWD in the channel and floodplain, and likely contributed to the reach's current condition.

Floodplain Confinement - low

There are small confining features at the mouth, RM 1.3 to 1.5, and at the bridge crossing at the confluence of Couse Creek and Montgomery Gulch (RM 3.1 to 3.2). Other confining features in this reach are natural debris fans.

Riparian Function – moderate to high

Most of the valley bottom to RM 1.6 is well-vegetated and dominated by alder and cottonwood. From RM 1.6 to 3.2, riparian vegetation is almost non-existent with the exception of occasional willows and other shrubs. Small patches of riparian canopy species exist at the base of the hillslopes near springs. Accumulation of sediment in this reach causes the water to go subsurface frequently, making it difficult for riparian species to establish and persist.

Fish Habitat and Use

Steelhead spawn and rear in this reach, and likely migrate through to get to the upper reaches. An adult steelhead was observed in one of the isolated pools during a site visit in July when the stream had already gone subsurface. Juvenile survival is likely low because surface flow is limited for most of this reach after spring flows.

Restoration Strategies and Recommendations

A barrier assessment should be completed at the mouth of Couse Creek because it is a potential barrier to adult and juvenile migration (upstream and downstream), particularly during fall migration or sub-normal spring flows. Confining features could be removed or setback to reconnect small pockets of floodplain. The top restoration strategy should be to increase channel complexity and promote overbank flow as this reach often runs dry. Addition of structural elements could help to restore riparian areas and trap sediment.

Table 48. Restoration recommendations for Couse Creek reach CO_01.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	Medium	Continue/expand erosion control, protect riparian and springs
Connect disconnected habitat	Moderate	Assess potential barrier at the mouth, adjust confining features and/or connect historic side-channels (RM 0.6-3.0). Promote overbank flow
Long-term processes	High	Riparian management (fencing, manage invasive vegetation, off-site water, grazing management)
Short-term processes	High	Increase channel complexity

10.11.2. Reach: CO_02 – RM 3.2 to 7.4

Dominant Reach Type: Confined with Occasional Floodplain Pockets

General Description

Reach **CO_02** begins at the confluence with Montgomery Gulch at river 3.2 and ends at RM 7.4. The reach is only accessible from the mouth by walking up the basin, although there is a small private double-track trail entering the reach around RM 5.5. The reach extends nearly to the headwaters of Couse Creek in the dissected loess uplands.

Hydrology

The lower ~0.2 miles of this reach typically go subsurface during summer months, but the rest of the reach is typically perennial. There are no perennial tributaries in this reach, but a substantial intermittent tributary enters at RM 5.5. This reach is largely groundwater dominated.

Geomorphic Function - high

Geomorphic function is mostly high; however, like the rest of Couse Creek, there is limited LWD. The lack of structural elements has reduced the channel's ability to access the floodplain pockets during bankfull floods (2 year recurrence interval).

Floodplain Confinement – low

There are very few confining features in this reach.

Riparian Function - moderate

Most of the valley bottom throughout this reach is covered in riparian vegetation, but there are pockets with substantial upland vegetation encroachment. Typically, these are floodplain pockets that are not frequently inundated.

Fish Habitat and Use

Steelhead use this reach for spawning and rearing and Chinook juveniles have even been captured (Mendel et al. 2008). Because this reach maintains flow throughout the summer, it may provide refuge for juveniles from the dry and puddled reach downstream.

Restoration Strategies and Recommendations

The top recommended restoration strategy is increasing habitat complexity and promotion of overbank flow. Promotion of water retention should be the priority for the upper reaches of Couse Creek to extend base flows and lower water temperatures during the summer. The BRAT model suggests this reach is suitable to support beaver dams, and in high enough densities could provide benefits to surface flow downstream.

Table 49. Restoration recommendations for Couse Creek reach CO_02.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	Medium	Continue/expand erosion control, protect riparian and springs
Connect disconnected habitat	Low	Disconnected habitats are generally not present. Promote overbank flow
Long-term processes	Low	Protect processes
Short-term processes	High	Increase channel complexity, beaver management

10.11.3. Reach: CO_03 and CO_04 – RM 3.2 to 6.9

Dominant Reach Type: Confined with Occasional Floodplain Pockets

General Description

These two reaches are intermittent to ephemeral and are dominated by shrubs and upland vegetation. However, there is evidence of a channel and cobble gravel substrate.

Hydrology

There are no significant inputs in these reaches.

Geomorphic Function – moderate

A road follows both reaches for most of their length. There is a residence at in the upper end of CO_03 and the road along reach CO_04 continues up steep switchbacks to the plateau uplands. Neither road is directly impacting the valley bottom of these reaches.

Floodplain Confinement – low

There are very few confining features in this reach.

Riparian Function - impacted

The riparian assessment suggests that these reaches supported more riparian vegetation historically.

Fish Habitat and Use

No fish in these reaches

Restoration Strategies and Recommendations

Table 50. Restoration recommendations for Couse Creek reach CO_03 and CO_04.

Restoration Framework	Priority	Recommendations
Protect and maintain existing	Medium	Continue/expand erosion control, protect riparian and springs
Connect disconnected habitat	Low	Disconnected habitats are generally not present. Promote over bank flow
Long-term processes	Low	Protect processes
Short-term processes	Moderate	Increase channel complexity

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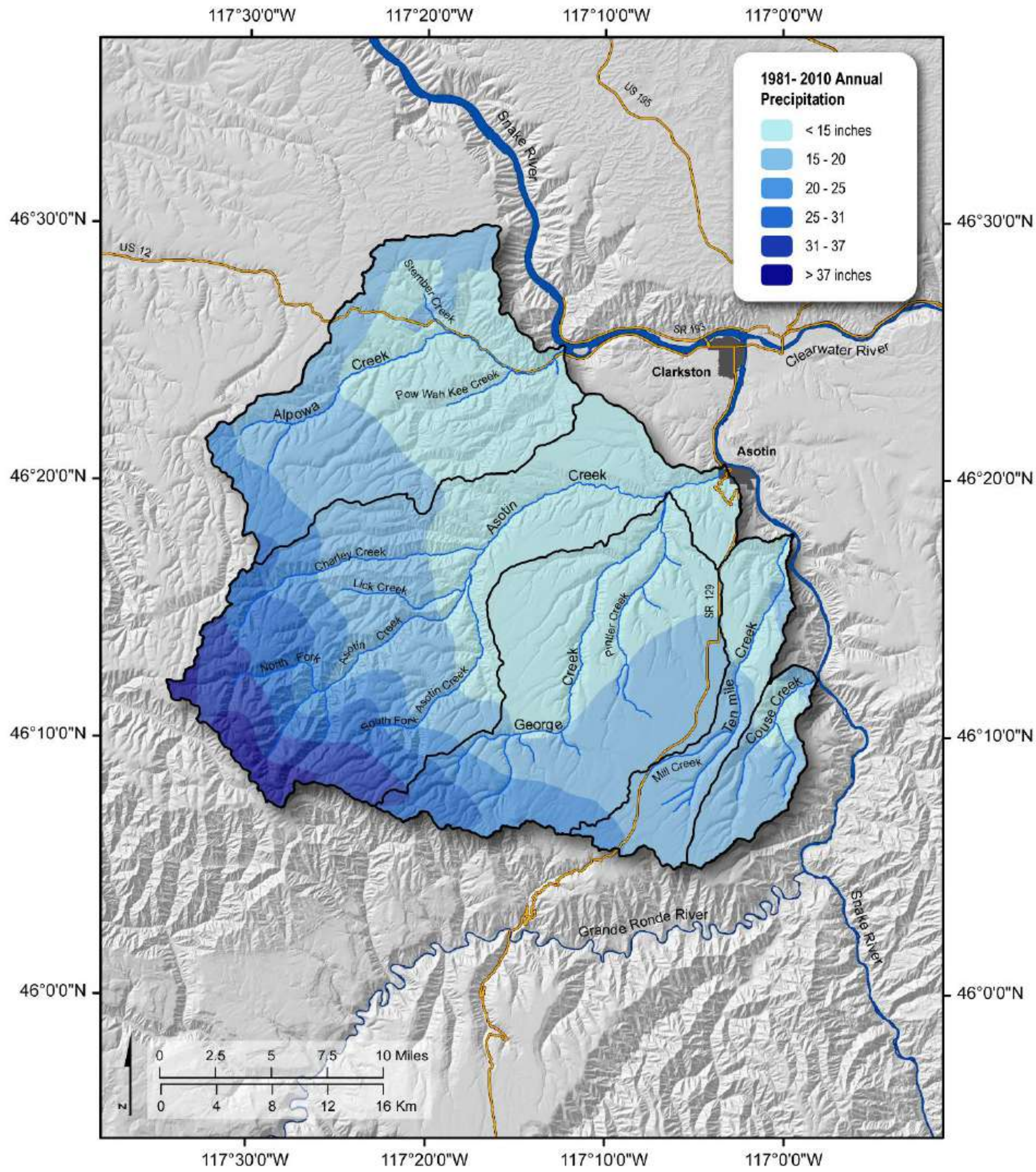
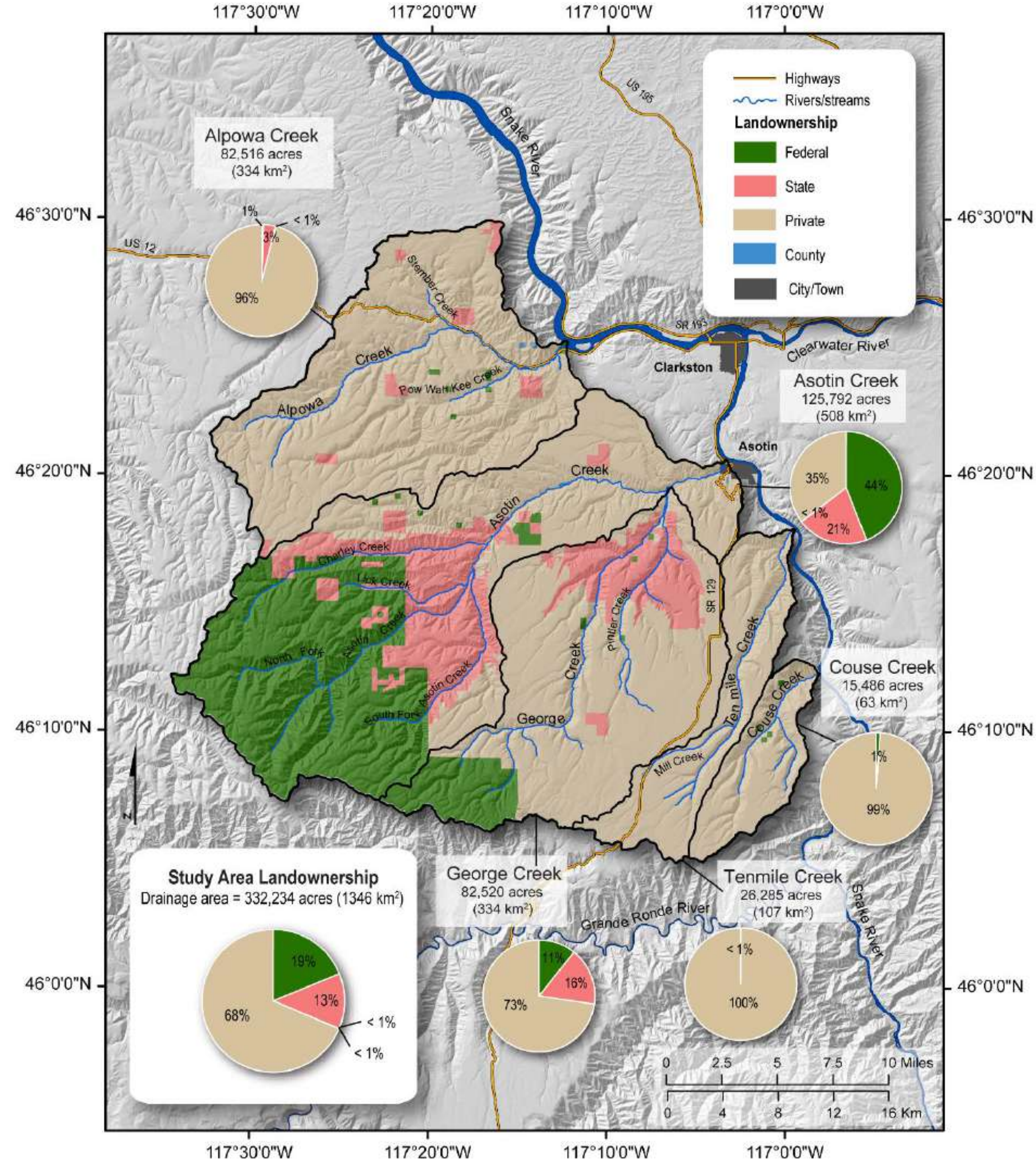
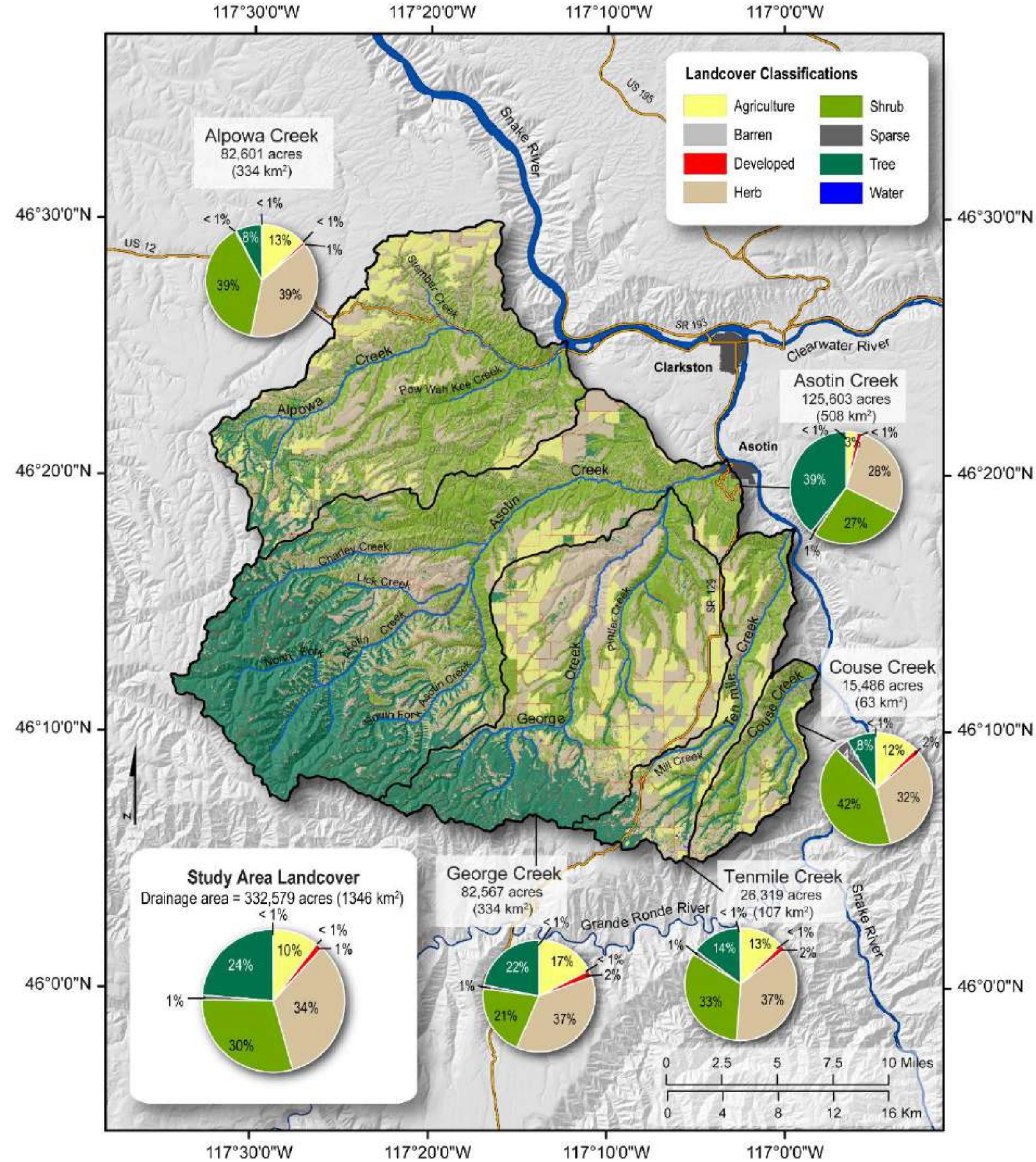
APPENDIX A – MAPS AND DATA SUMMARIES



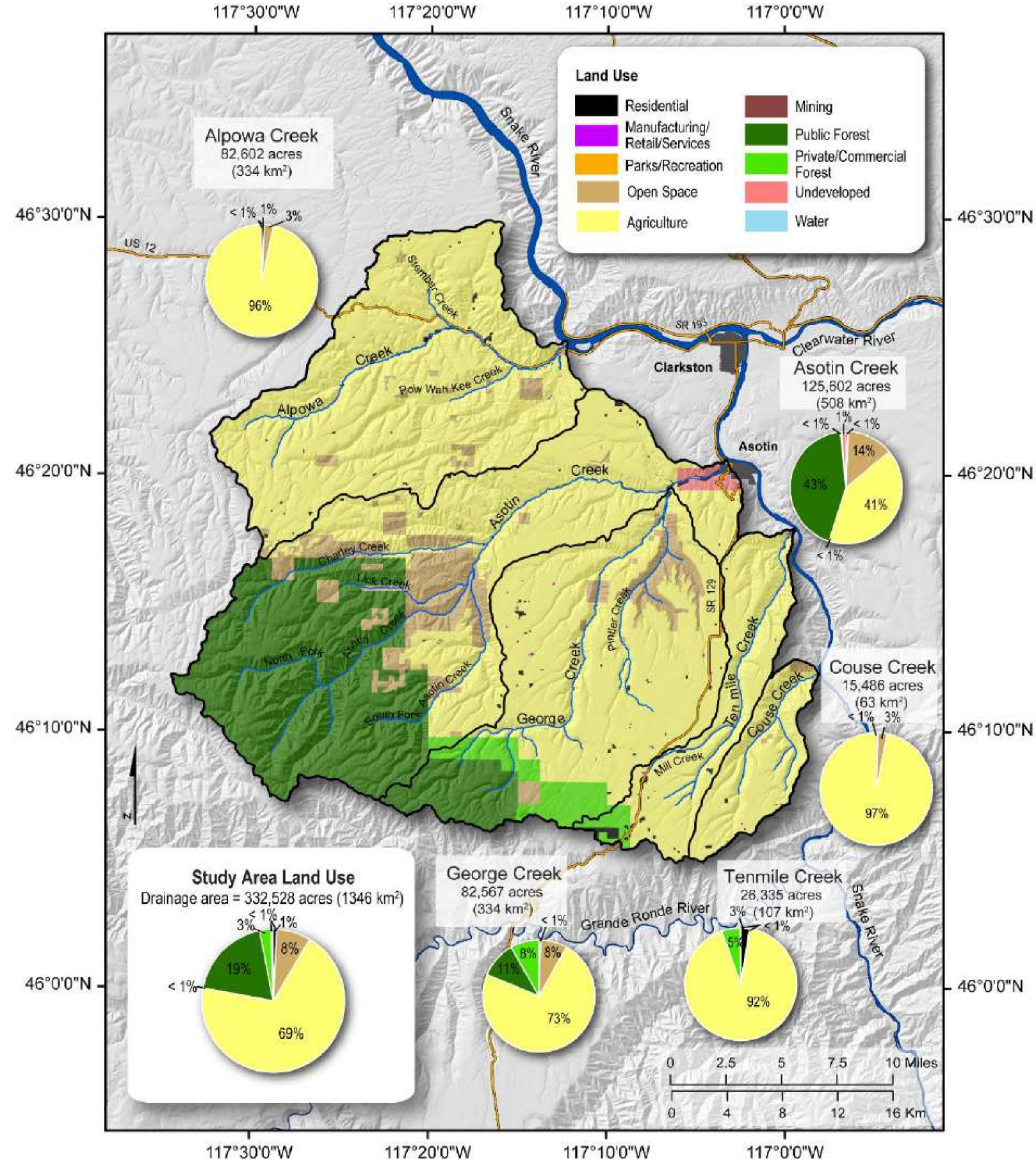
Appendix A. 1. Mean annual precipatation across Asotin County (PRISM 2016).



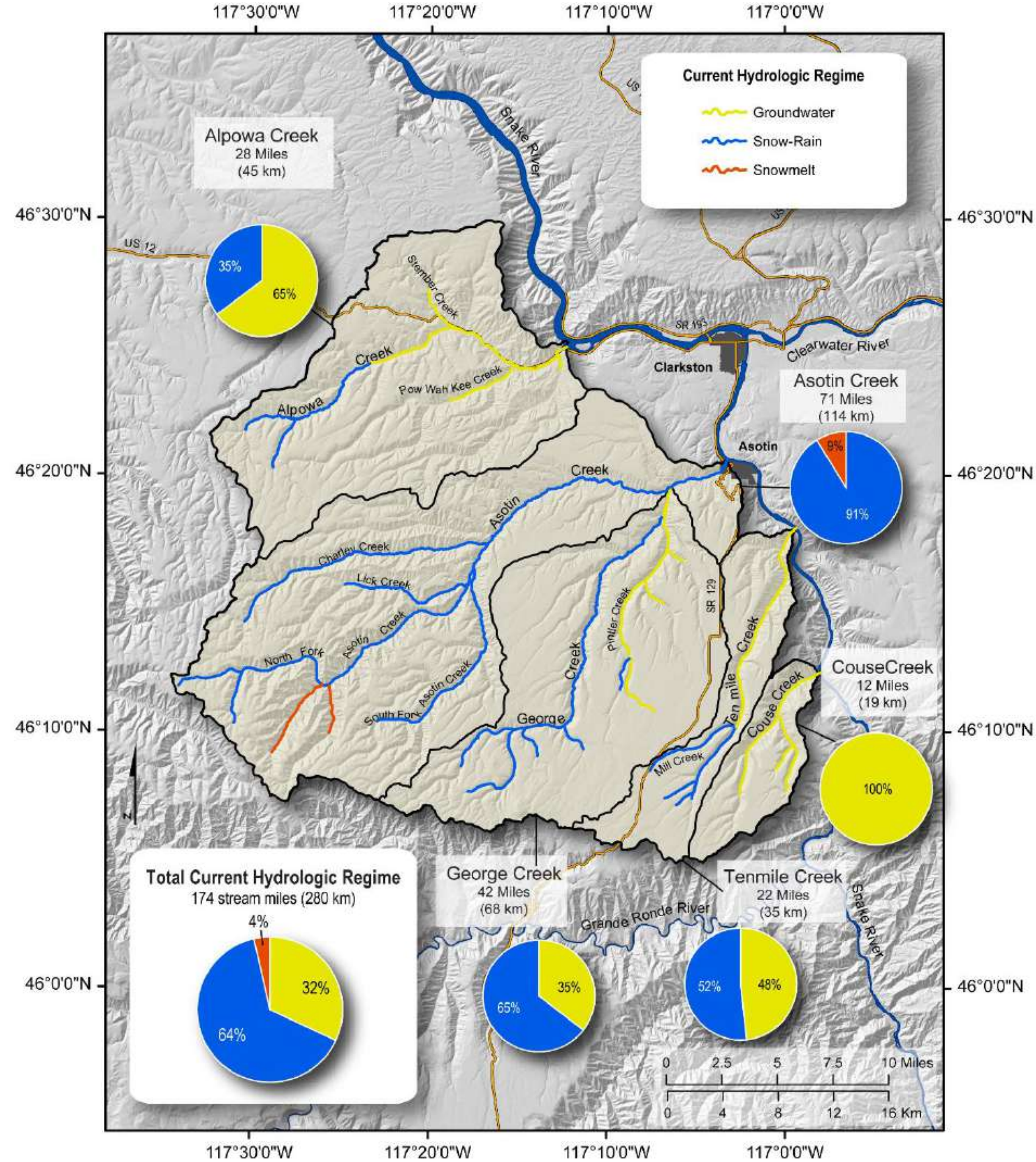
Appendix A. 2. Landownership by watershed for the Asotin Creek Assessment study area (USDA 2016).



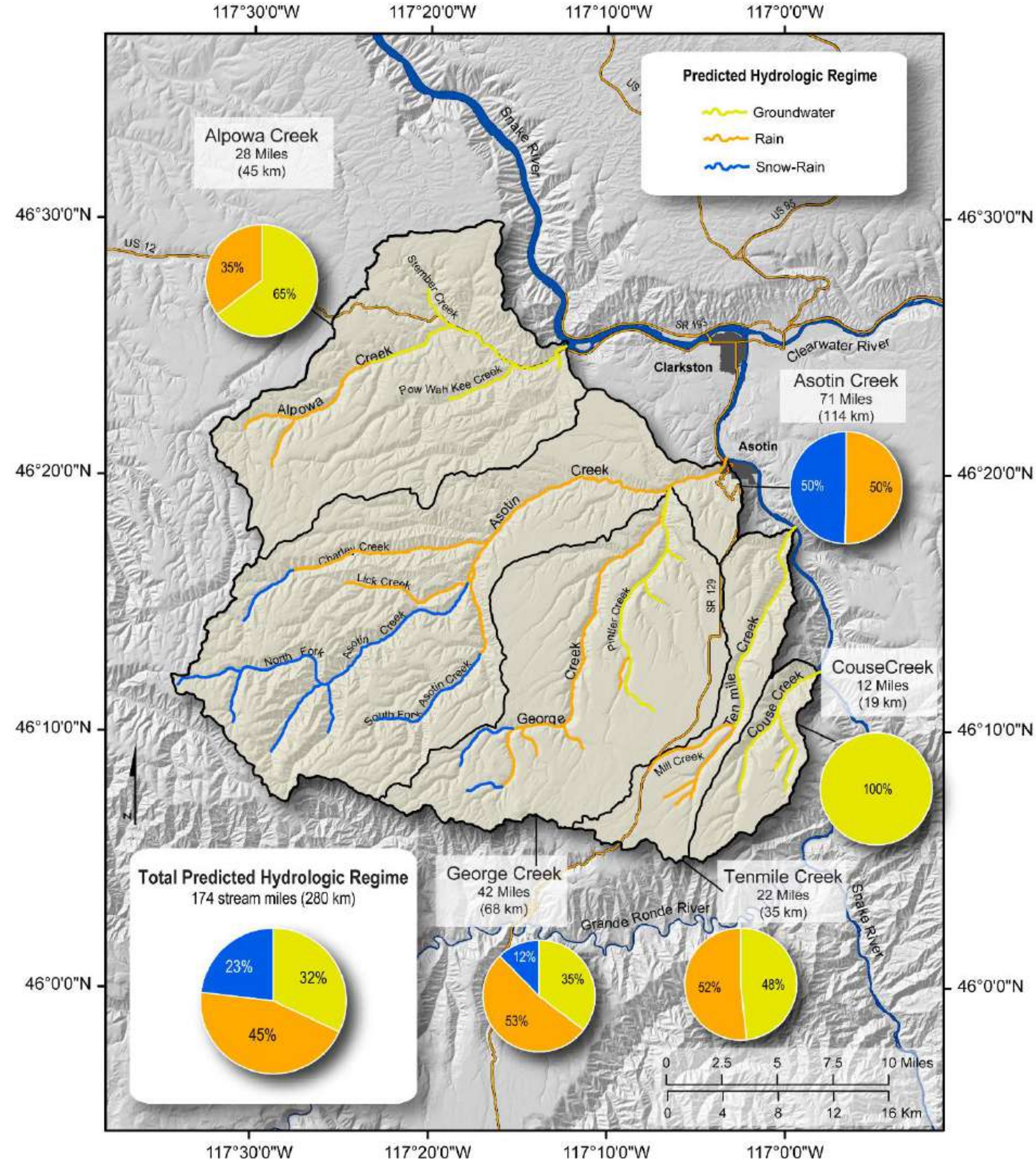
Appendix A. 3. Land cover classifications for the Asotin Assessment study area (USEPA 2013).



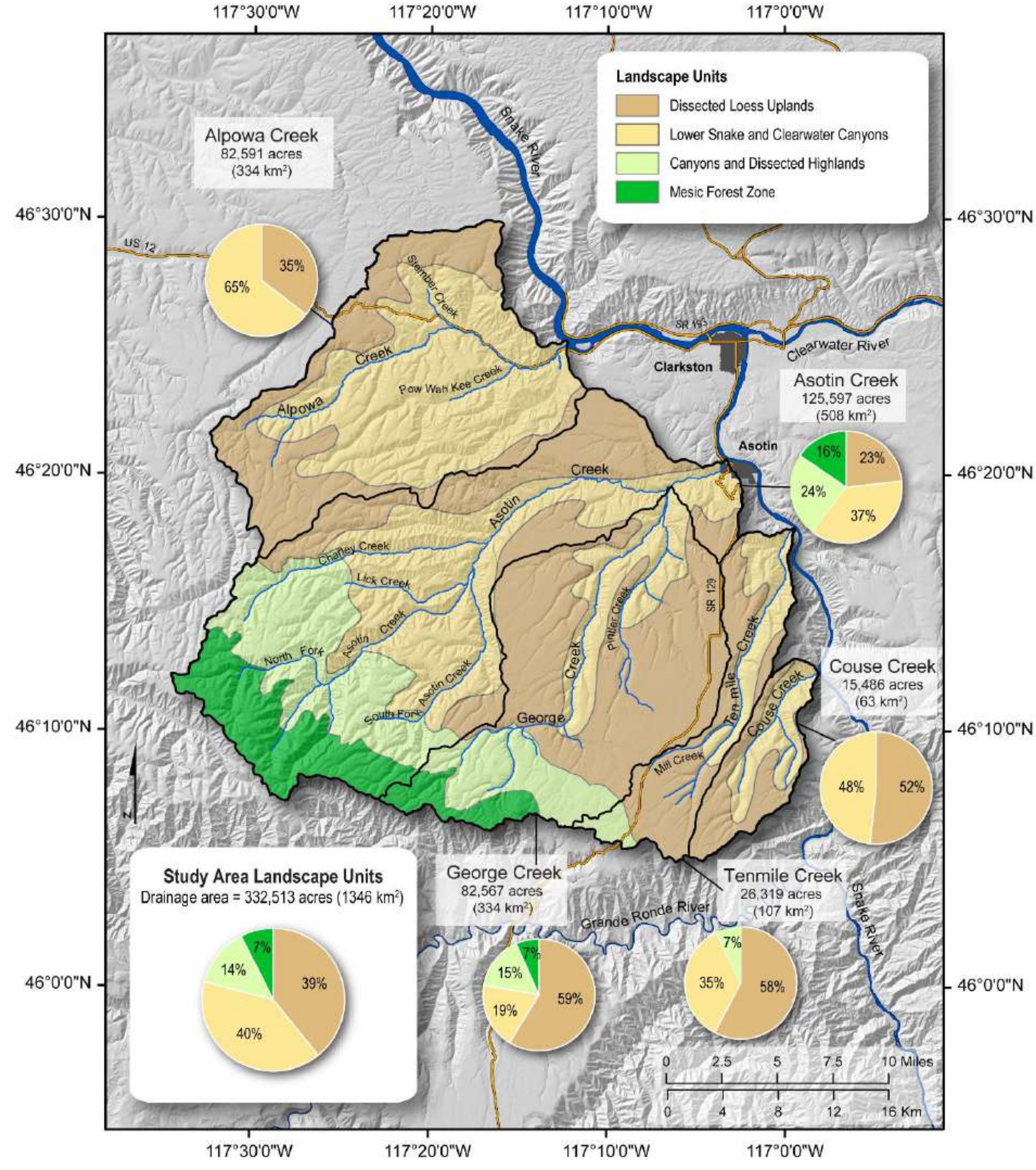
Appendix A. 4. Land use classification for Asotin Assessment study area (DOE 2010).



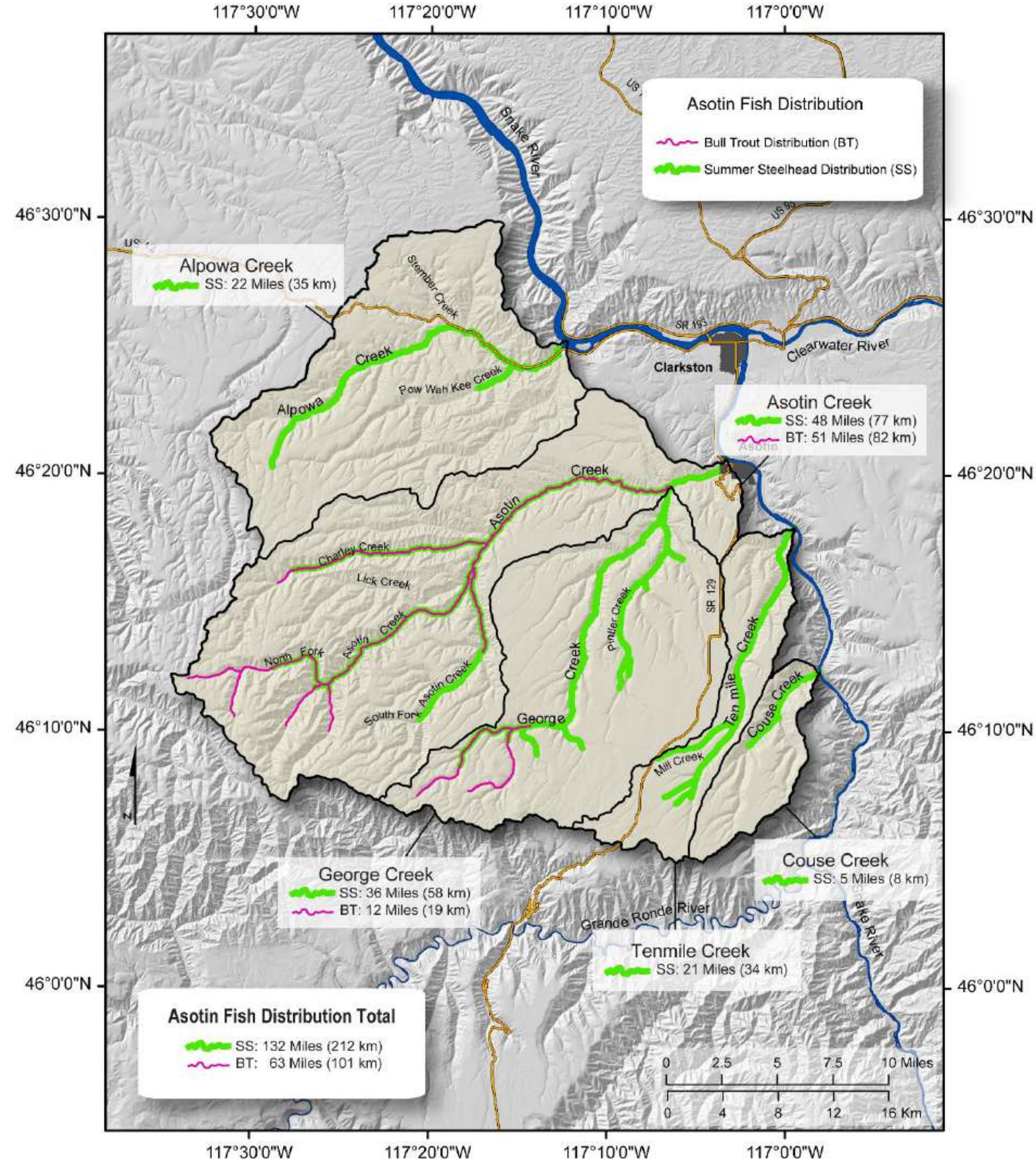
Appendix A. 5. Hydrogeomorphic classification of Washington state rivers based on analysis by Liermann et al. (2012). Current hydrologic regime classified as groundwater, snow-rain, or snowmelt dominated.



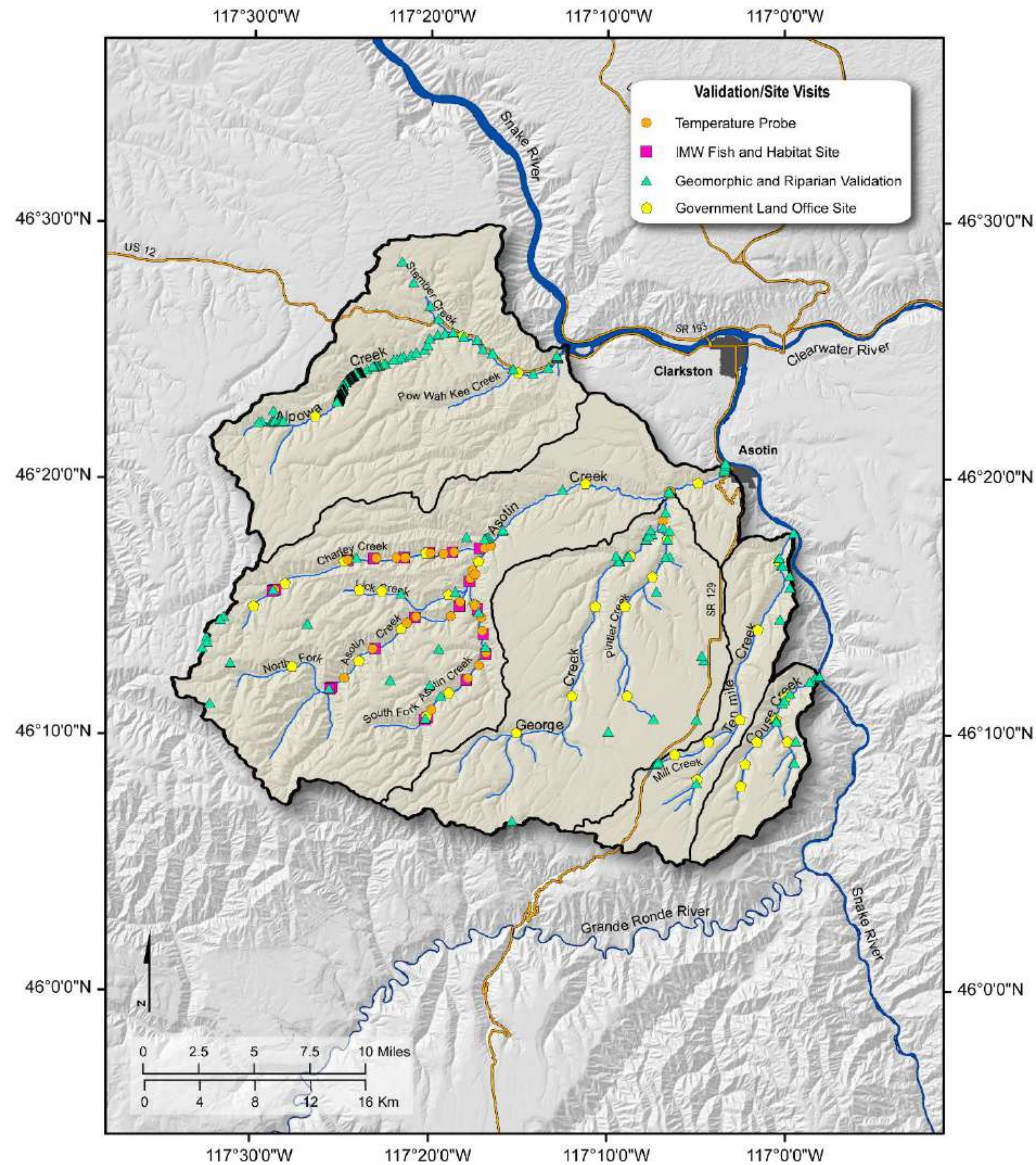
Appendix A. 6. Hydrogeomorphic classification of Washington state rivers based on analysis by Liermann et al. (2012). Predicted under a common climate change scenario where the climate hydrologic regime classified as groundwater, snow-rain, or snowmelt dominated.



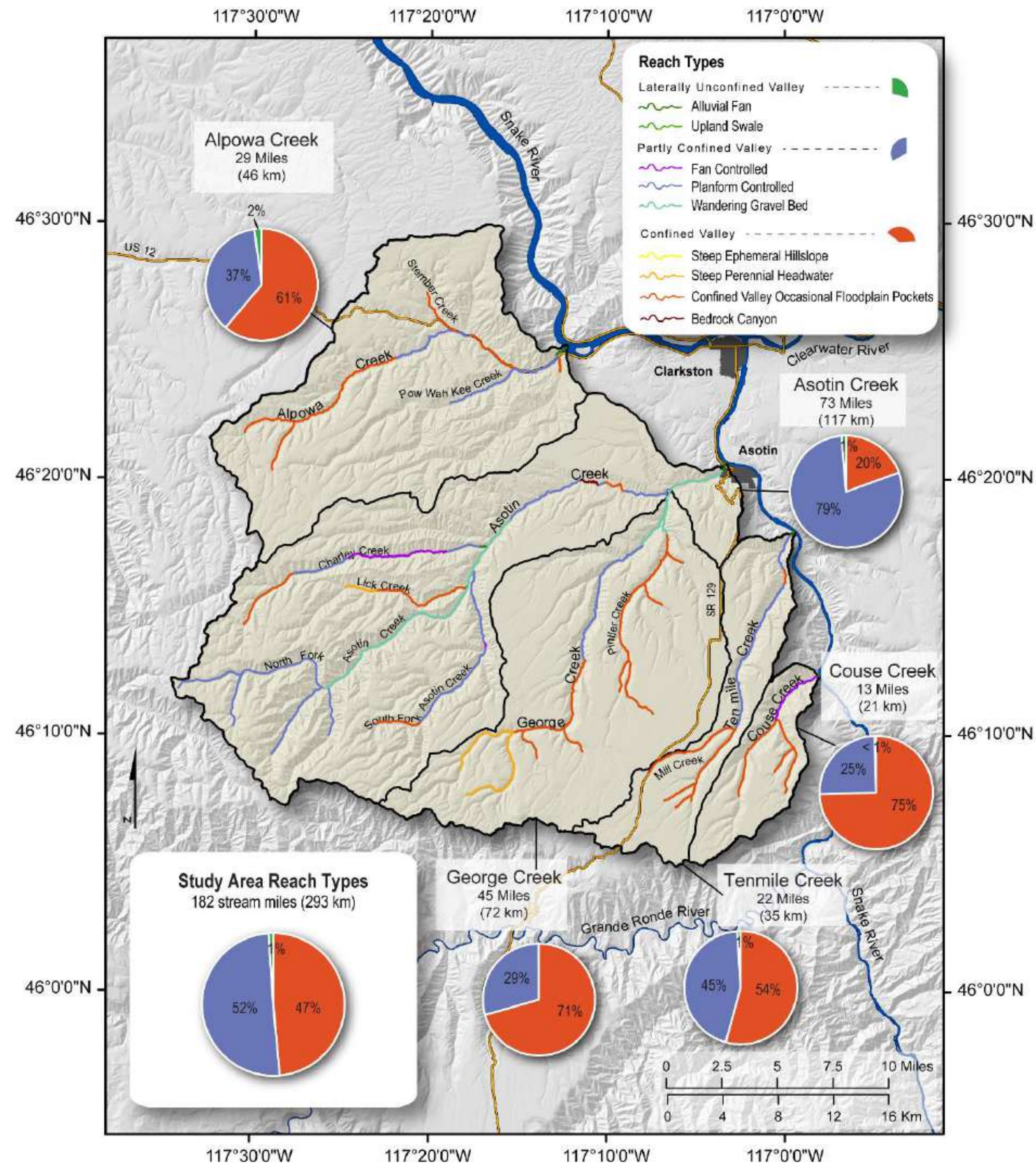
Appendix A. 7. Landscape units that represent areas with unique geologic, soil, elevation, topography, climate, and vegetation characteristics. Mapping based on EPA Ecoregion mapping (Omernik and Griffith 2014) and geologic mapping (Schuster 1993).



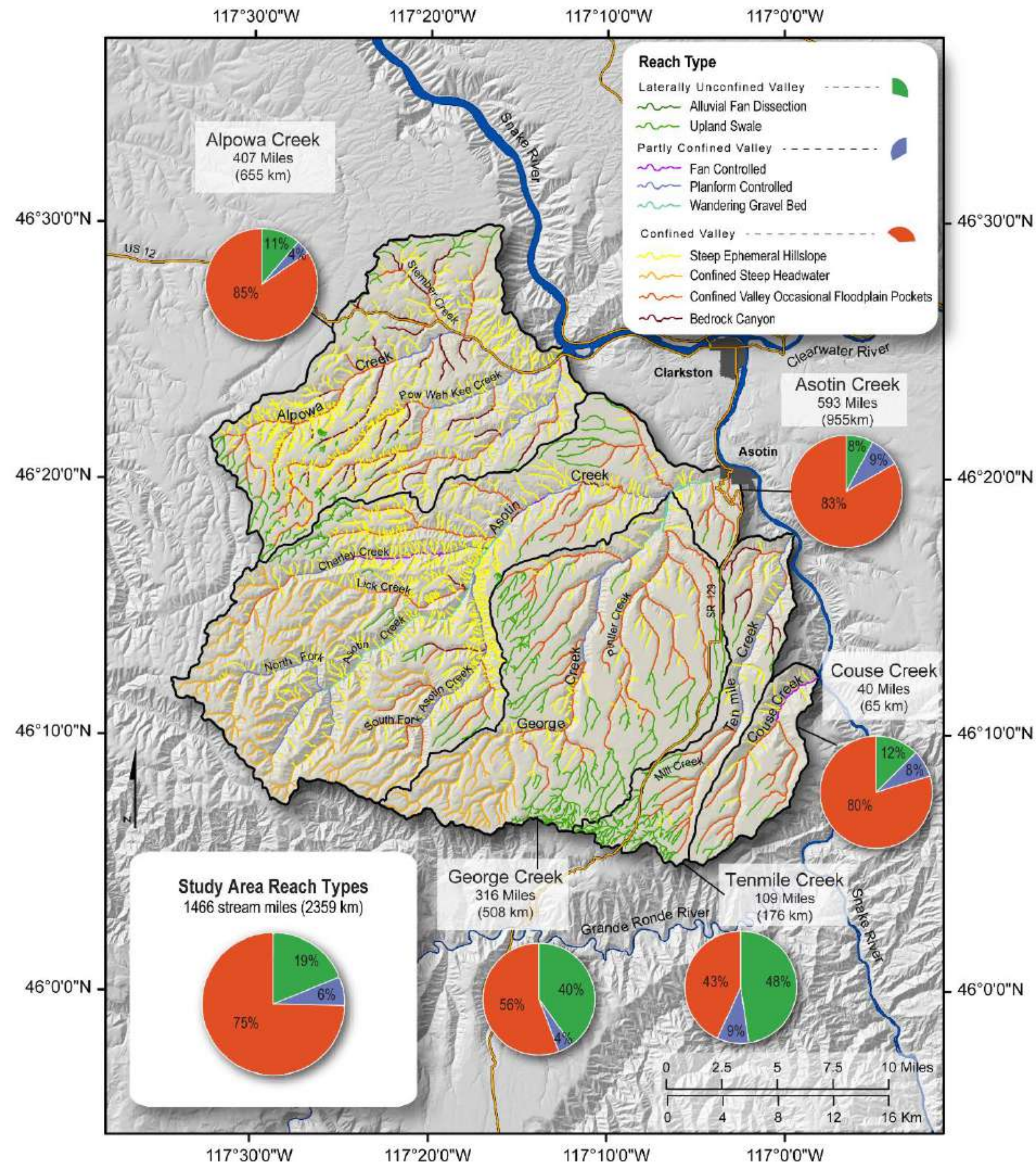
Appendix A. 8. Distribution of steelhead and bull trout including known migration, rearing, and spawning extents (Streamnet.org). Spring Chinook salmon do migrate, rear, and/or spawn in the mainstem Asotin Creek, upper Asotin Creek tributaries, and Alpowa Creek, but in very low numbers.



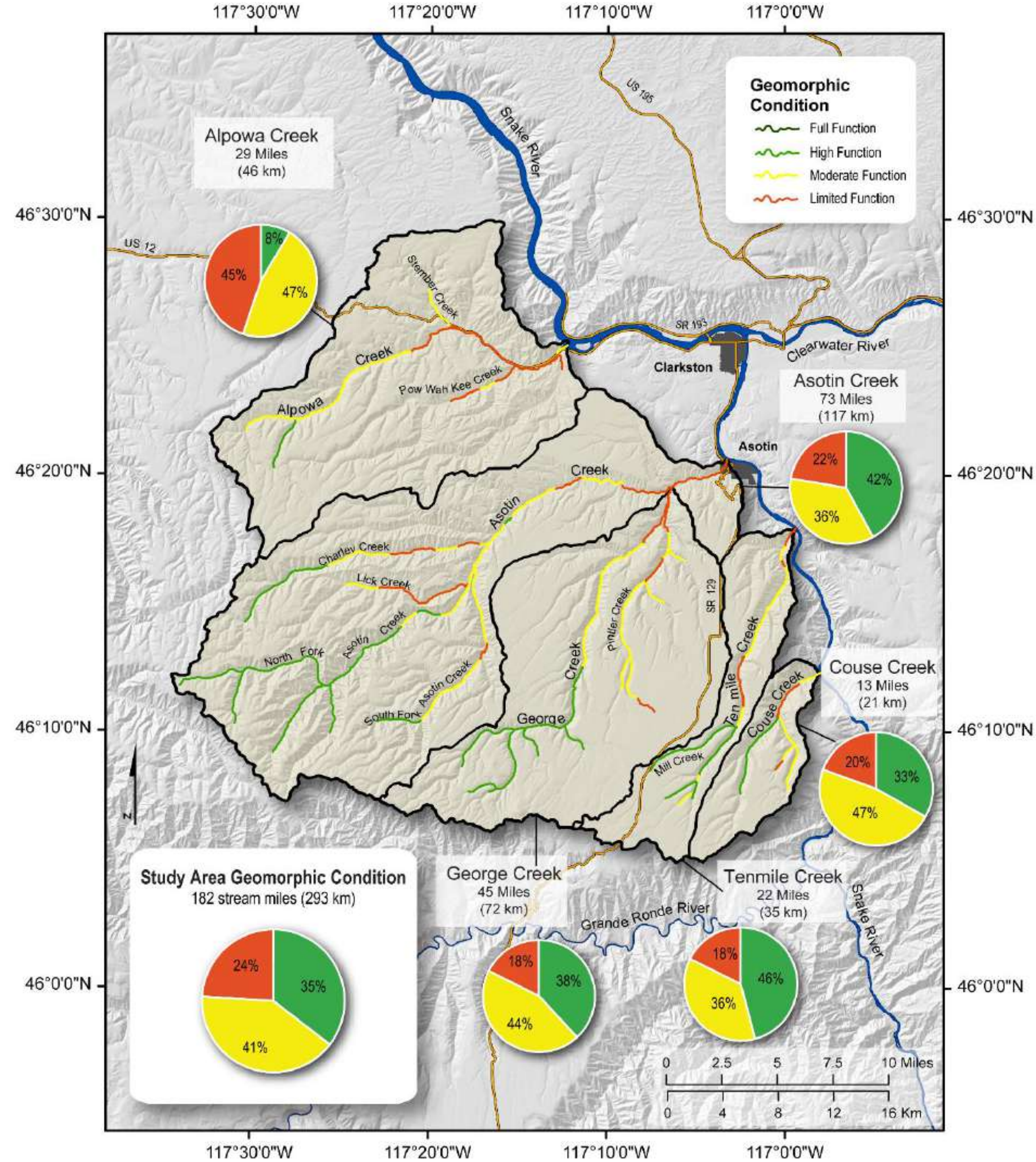
Appendix A. 9. Location of geomorphic and riparian assessment validation sites, Asotin Creek Intensively Monitored temperature probes, fish, and habitat monitoring sites (2008-2017), and General Land Survey township and range transect survey notes at selected stream crossings (BLM 2018).



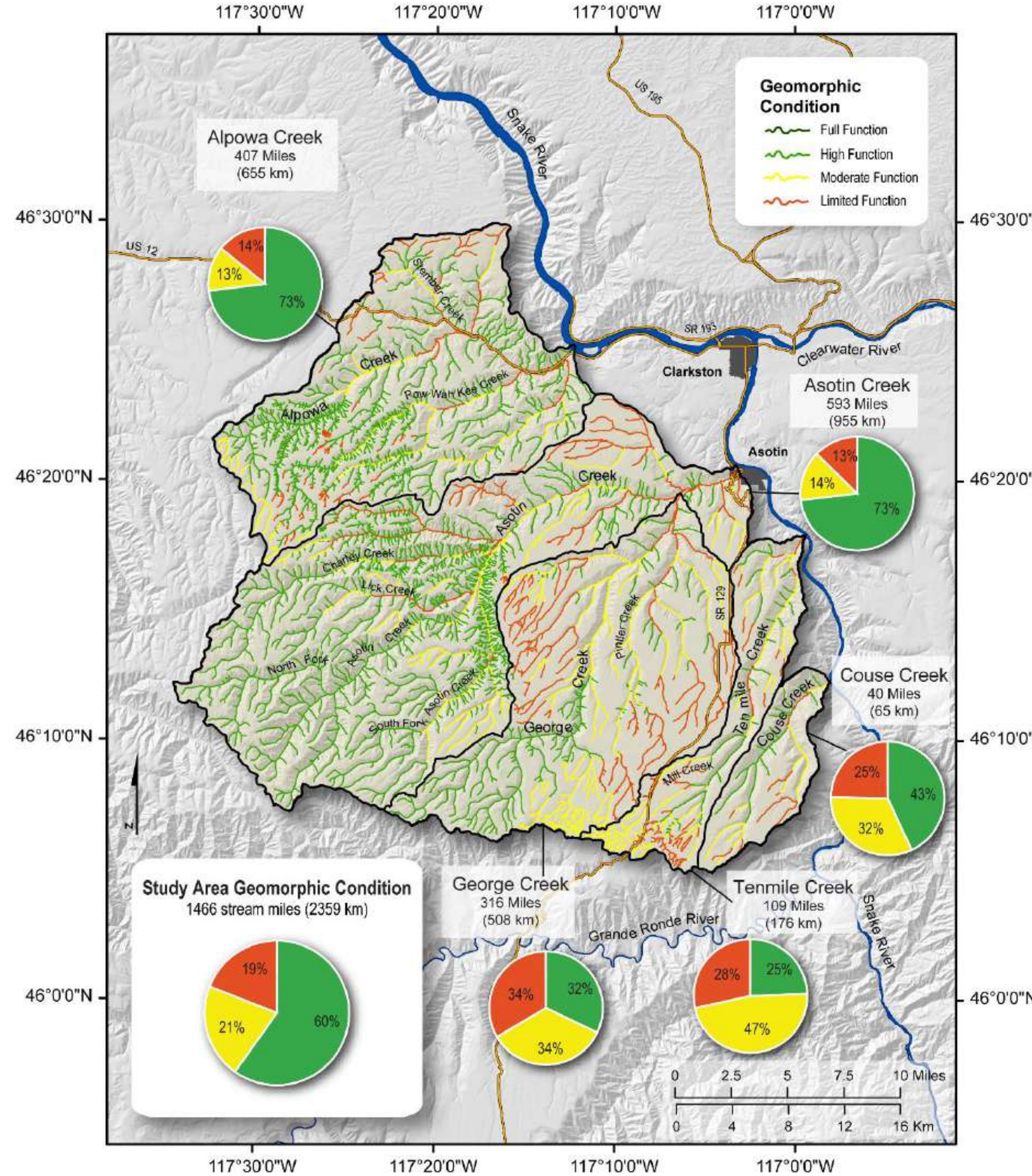
Appendix A. 10. Valley confinement (pie charts) and reach types (colored stream segments) for the perennial network of the Alpowa, Asotin, Tenmile, and Couse Creek (O'Brien et al. 2014, 2017).



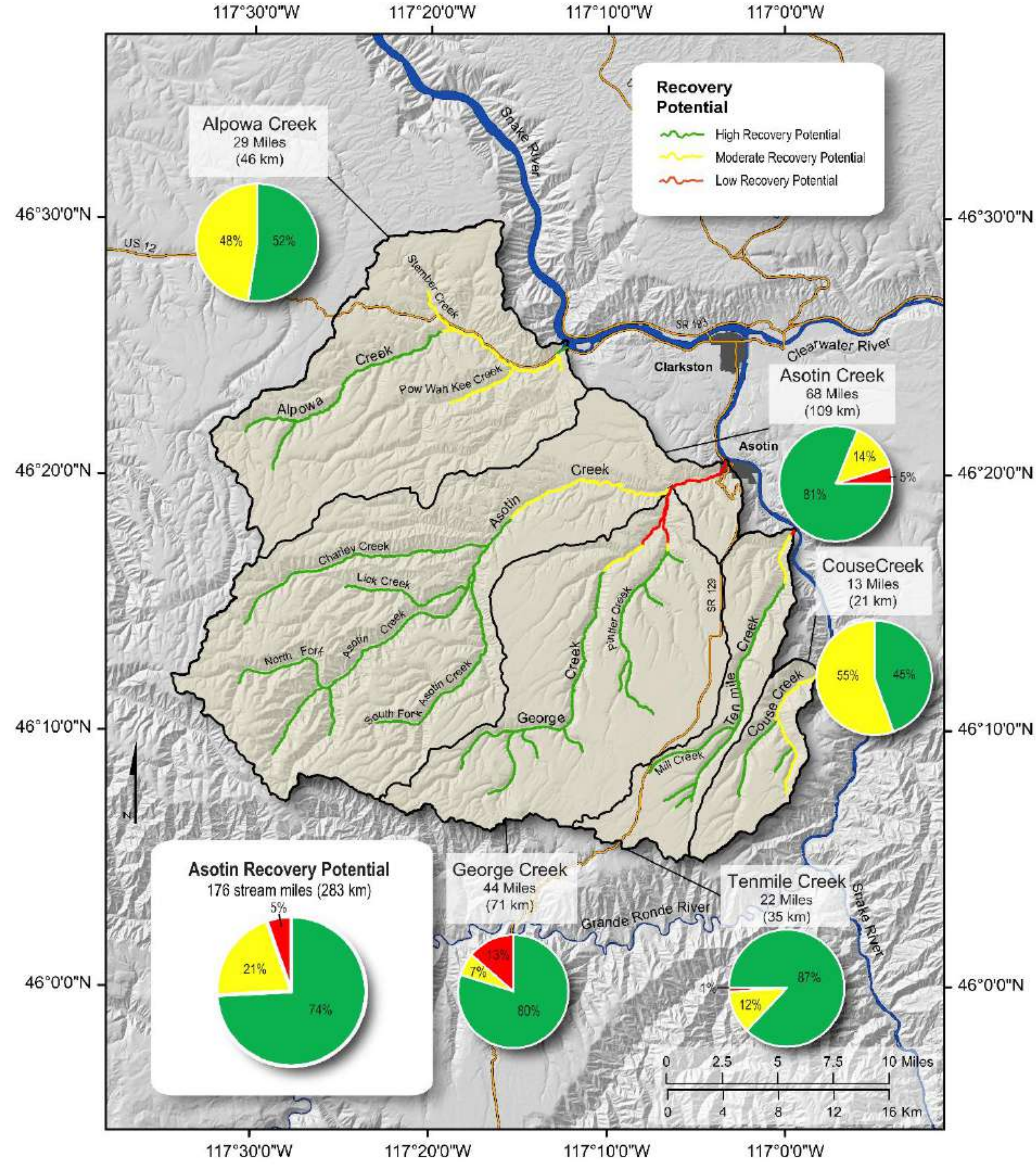
Appendix A. 11. Valley confinement and reach types for the entire NHD stream network by target watershed (O'Brien et al. 2014, 2017).



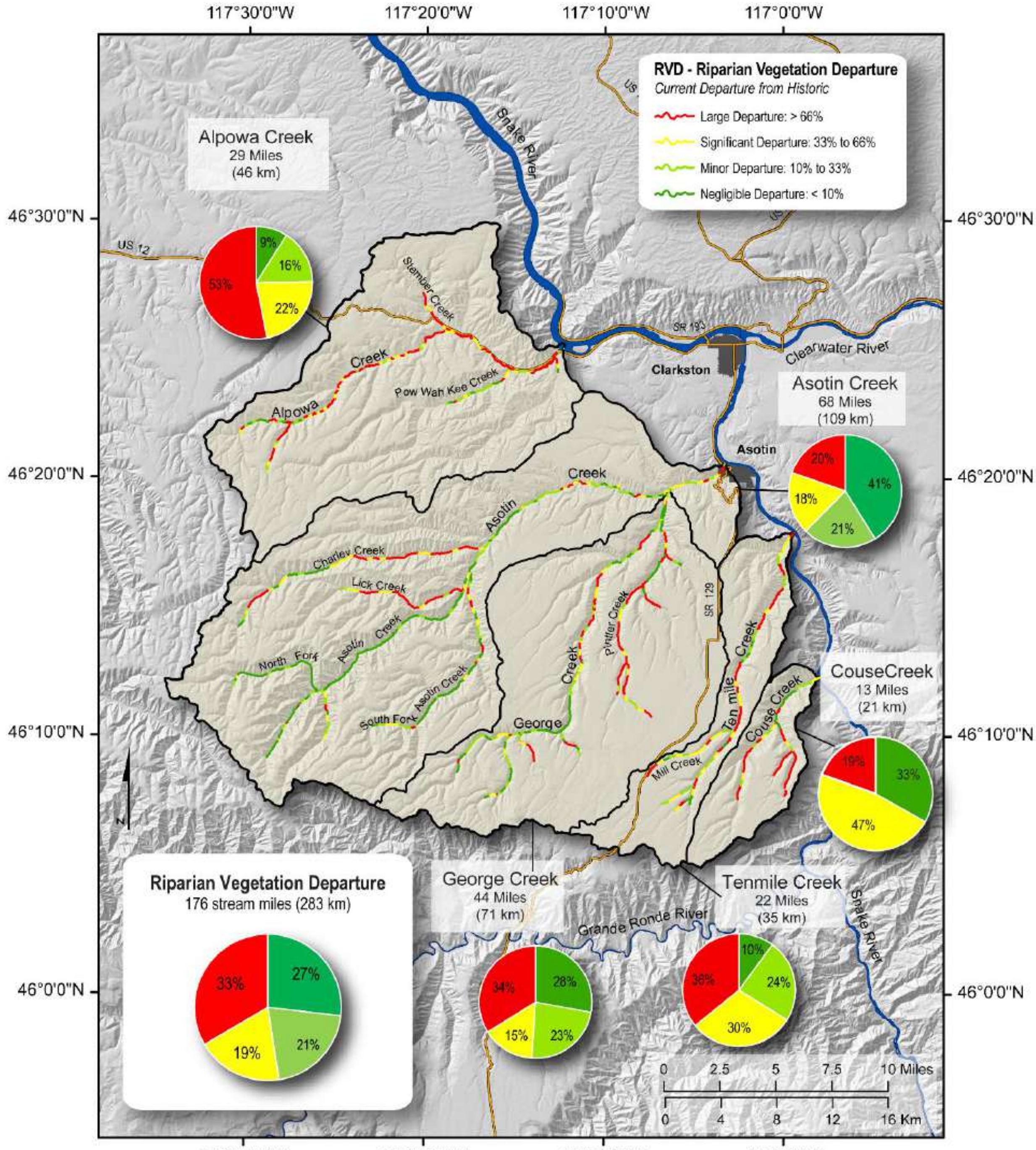
Appendix A. 12. Geomorphic function of the perennial stream network by target watershed. Note - we did not identify any reaches in the full function category (O'Brien et al. 2014, 2017).



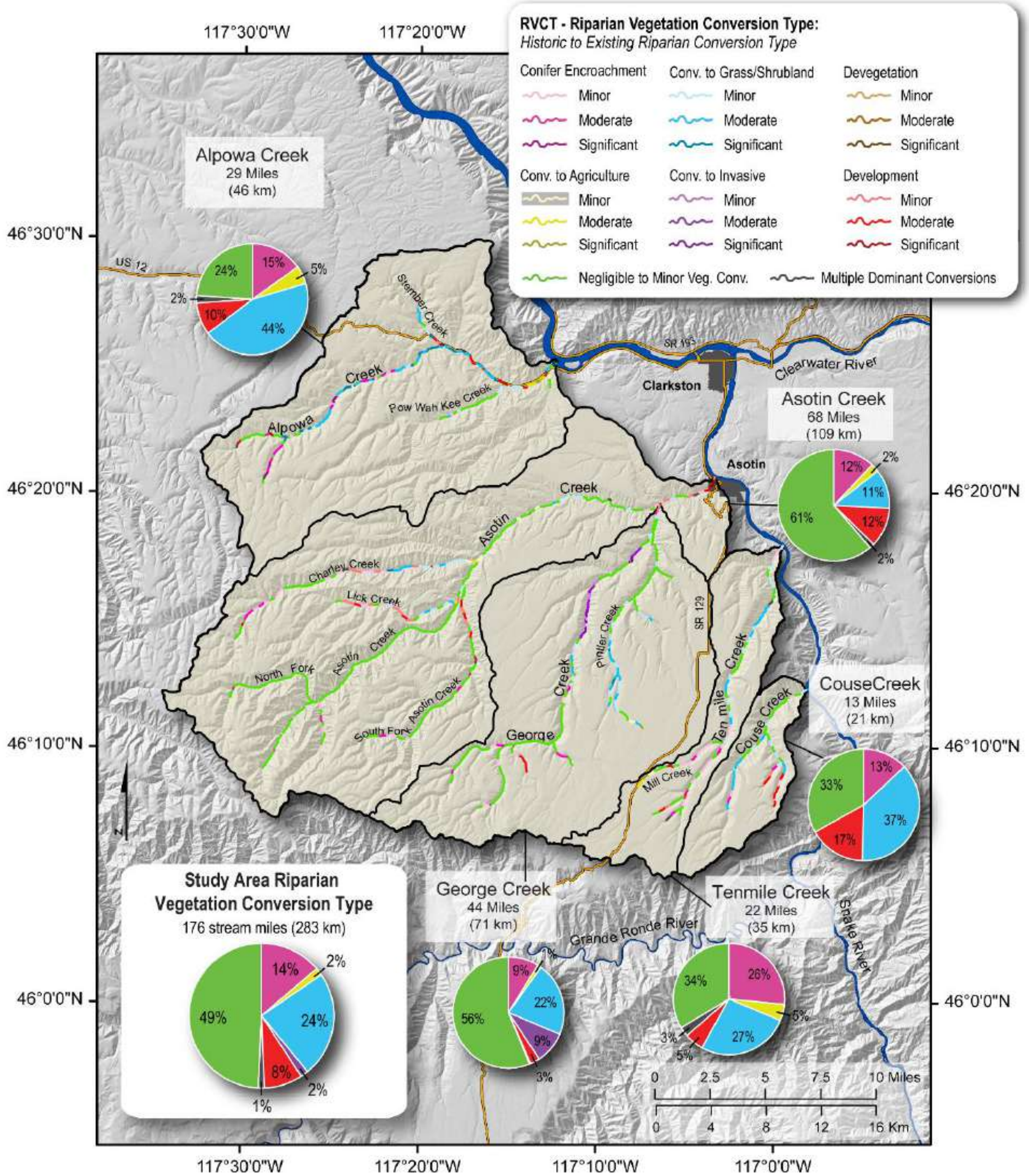
Appendix A. 13. Geomorphic function of the entire NHD stream network by target watershed. Note - we did not identify any reaches in the full function category (O'Brien et al. 2014, 2017).



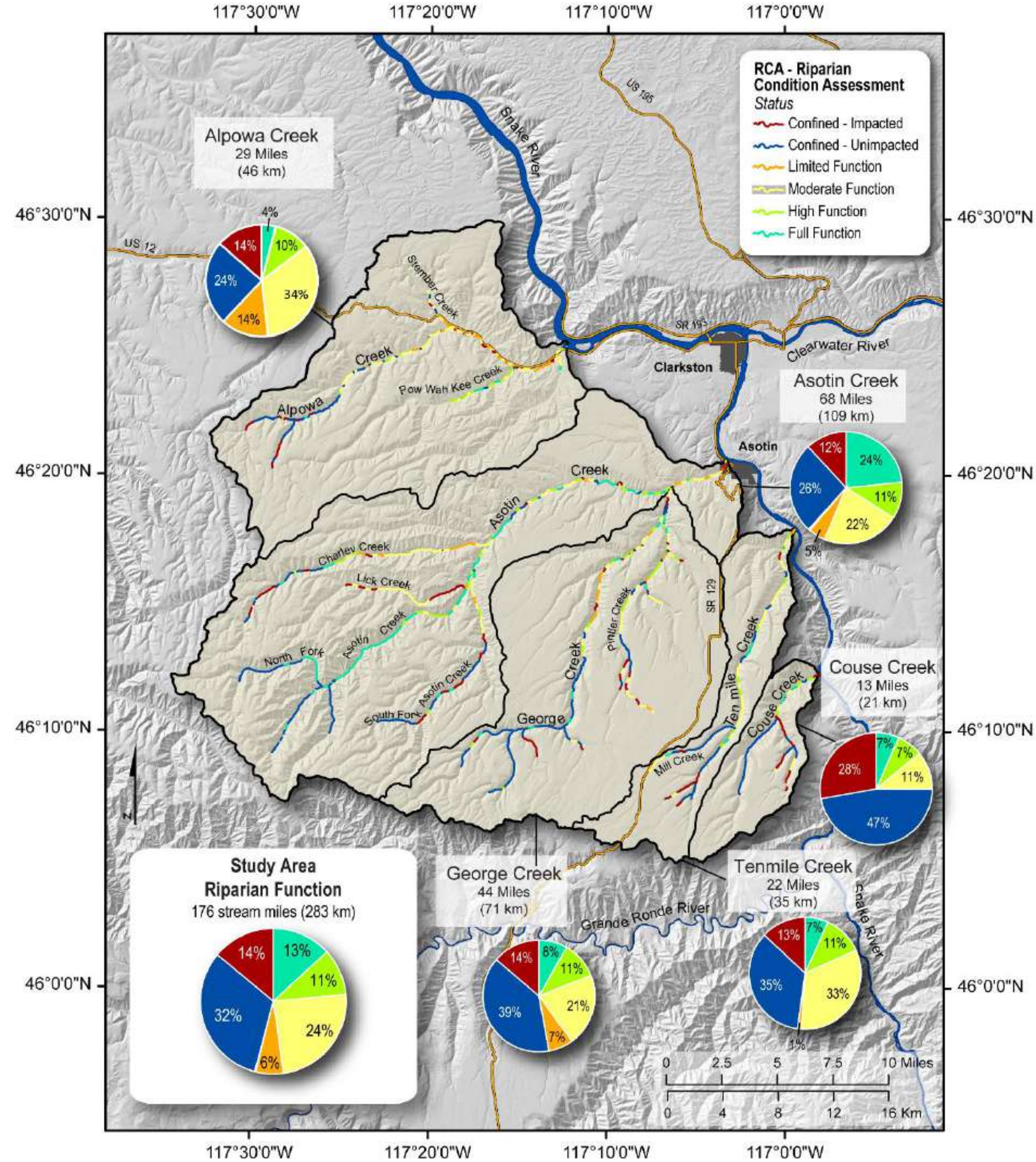
Appendix A. 14. Recovery Potential Assessment (O'Brien et al. 2014, 2017).



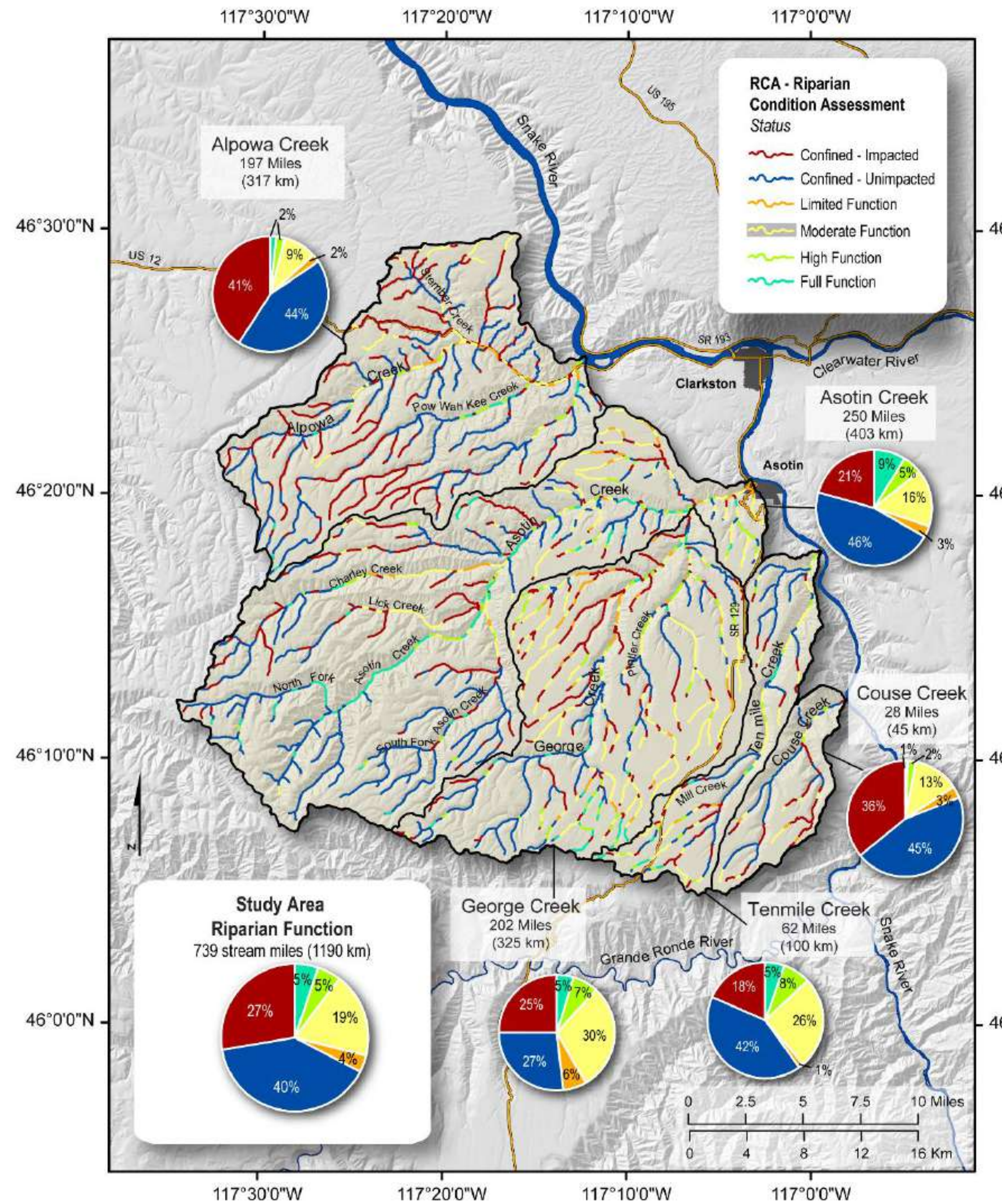
Appendix A. 15. Riparian Vegetation Departure Assessment (RVD). Vegetation departure was estimated from the difference between the current riparian extent and the historic riparian extent using LANDFIRE vegetation data (Macfarlane et al. 2016).



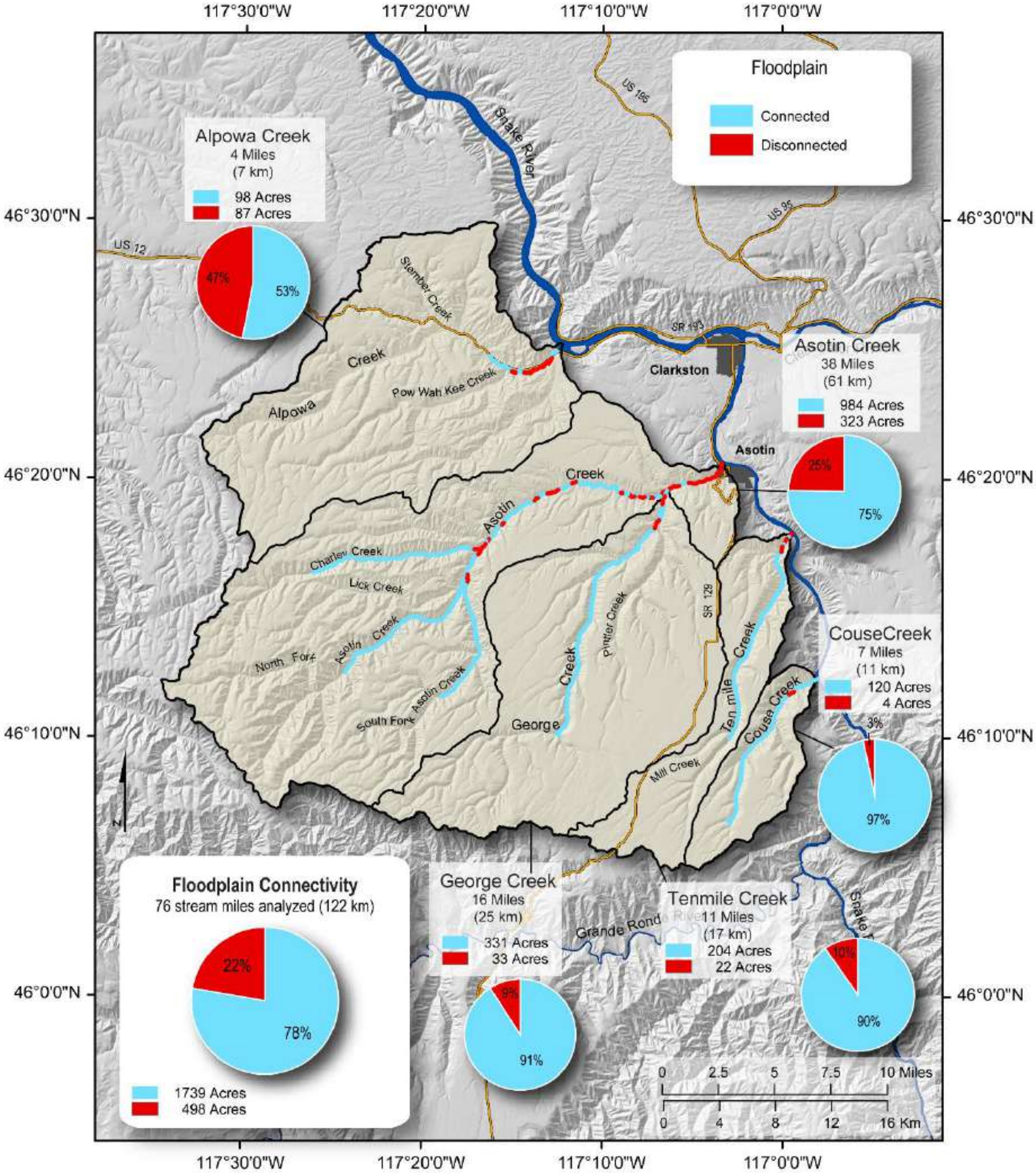
Appendix A. 16. Riparian vegetation conversion type assessment (RVCT). Vegetation conversion type was estimated from the difference between the current riparian composition and the historic riparian composition using LANDFIRE vegetation data (e.g., historic willow dominated riparian converted to alfalfa cover would be labeled as "Conversion to Agriculture"; Macfarlane et al. 2016).



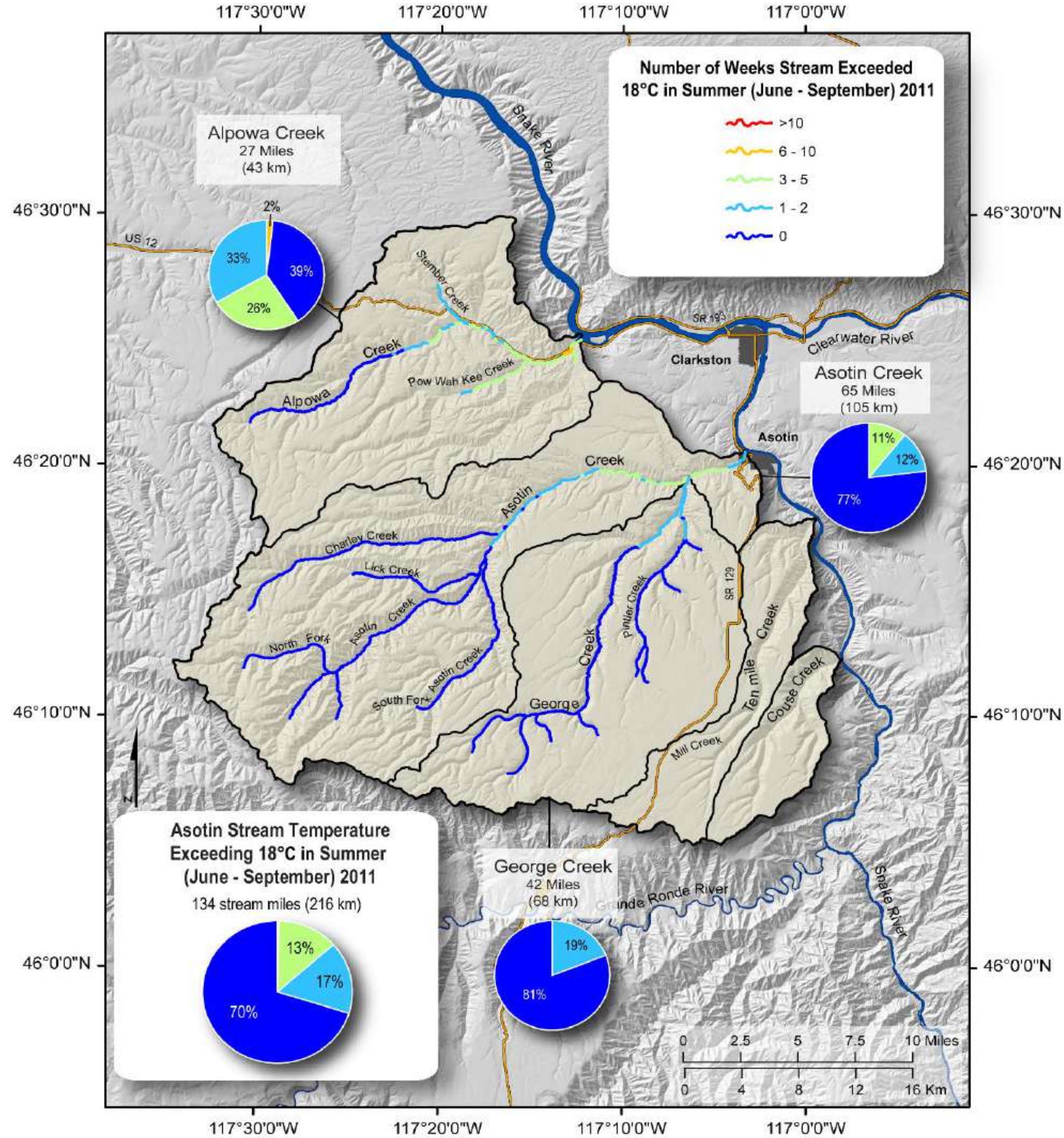
Appendix A. 17. Riparian Condition Assessment (RCA) on the perennial network. Resolution of data required classifying small streams in narrow valley settings (i.e., confined) as either impacted or unimpacted based on presence of development (e.g., roads or infrastructure). All other streams were classified based on estimated riparian function (Macfarlane et al. 2016).



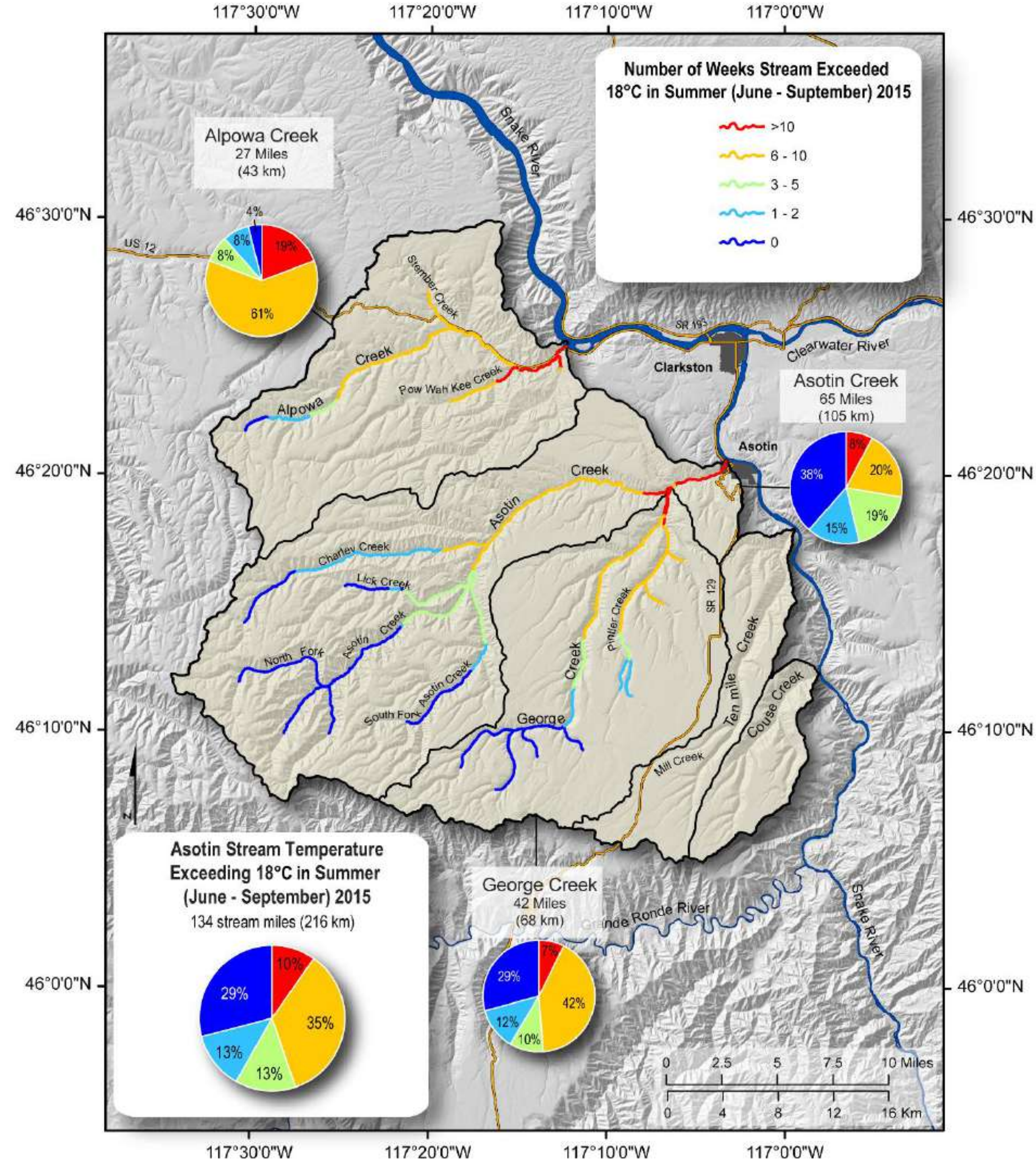
Appendix A. 18. Riparian Condition Assessment (RCA) on NHD network. Resolution of data required classifying small streams in narrow valley settings (i.e., confined) as either impacted or unimpacted based on presence of development (e.g., roads or infrastructure). All other streams were classified based on estimated riparian function (Macfarlane et al. 2016).



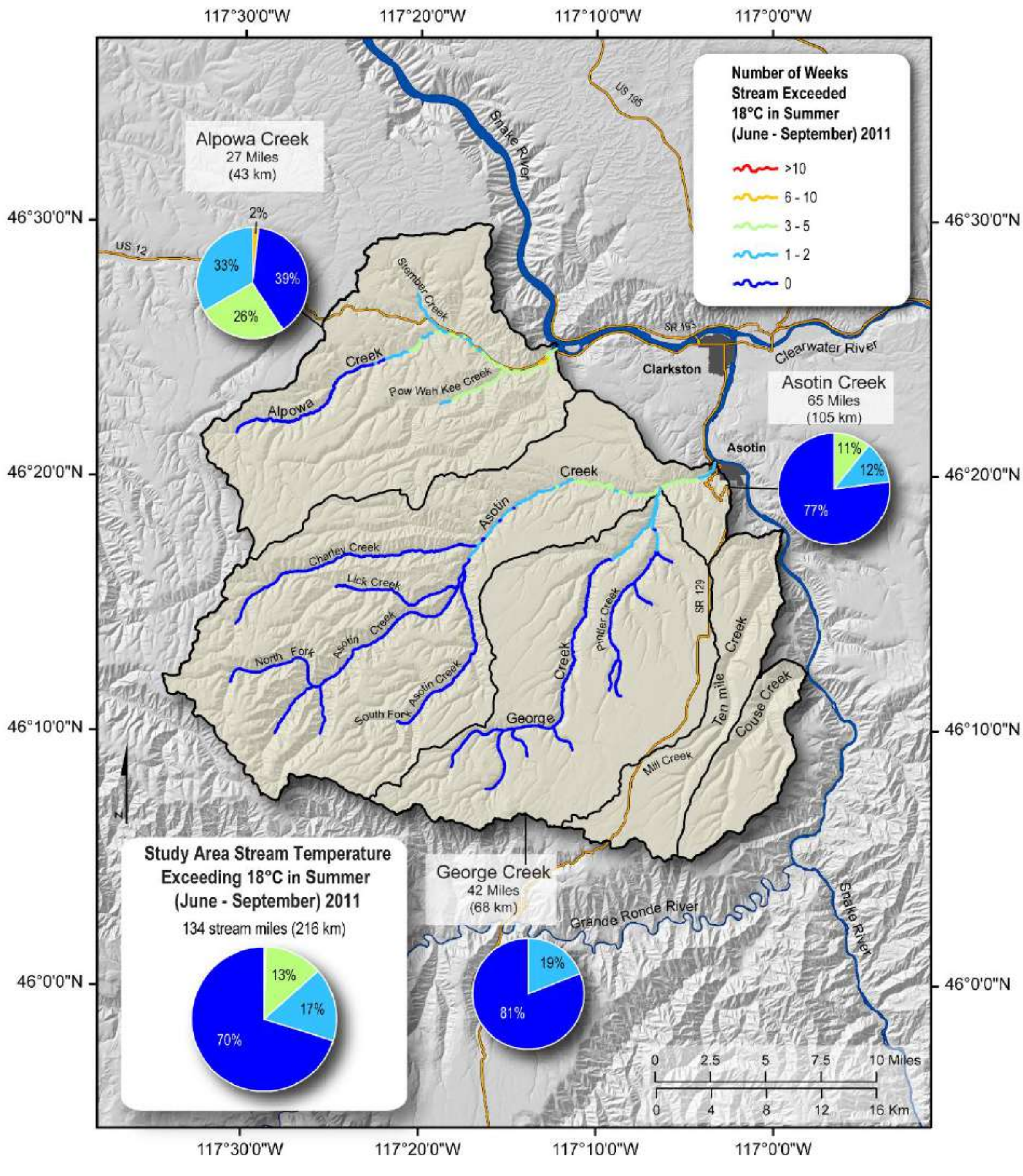
Appendix A. 19. Floodplain Connectivity Assessment. The amount of floodplain (valley bottom) disconnected due to development activities (roads and infrastructure) was estimated by the Riparian Assessment Tools (Appendix A. 7-9). We refined the estimate of disconnected floodplain by using existing hand digitized levees and rip-rap locations using 1 m digital elevation data to delineate a new valley bottom layer. The percent disconnected floodplain was estimated by dividing the new valley bottom layer by the original valley bottom extent x 100.



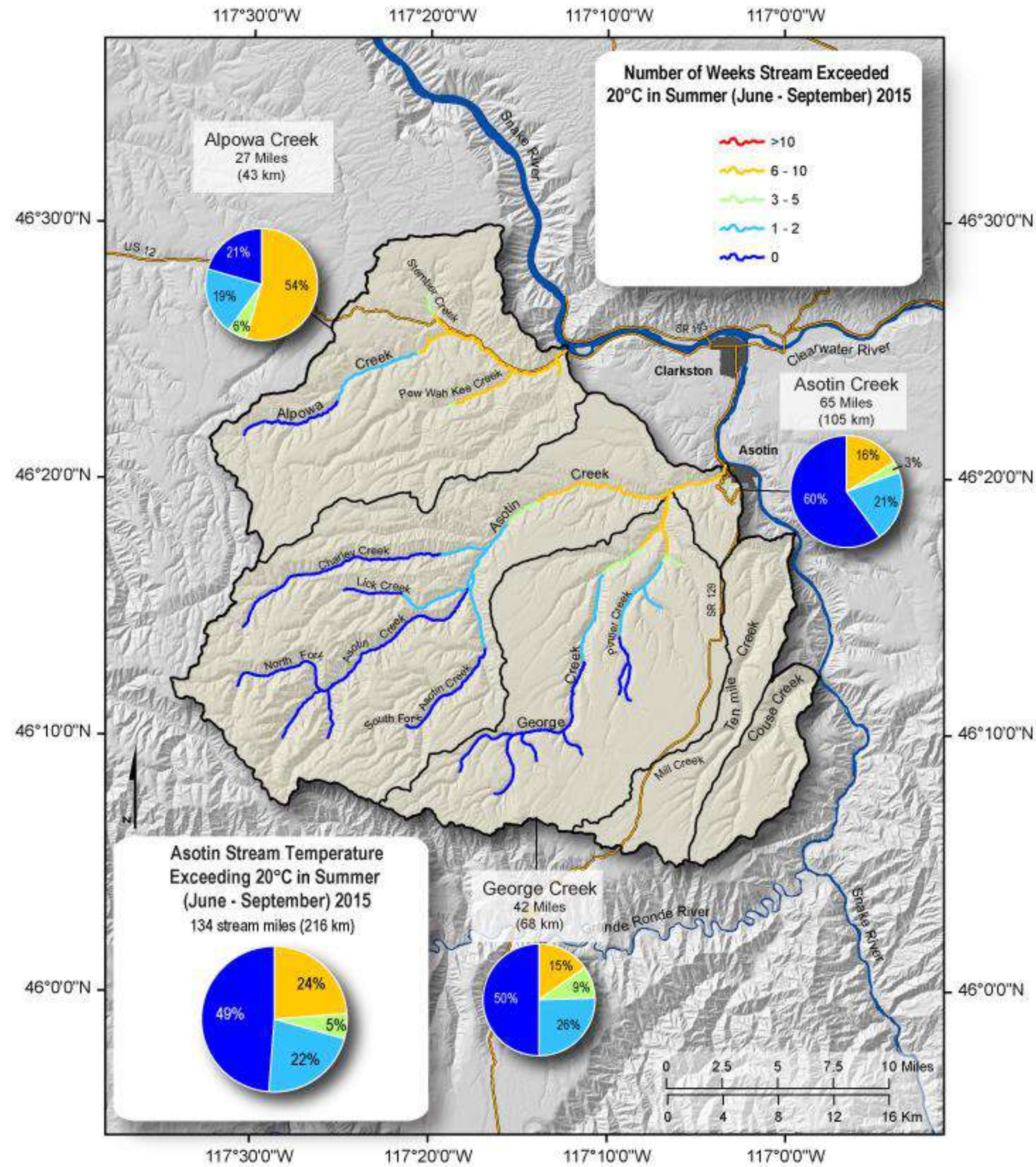
Appendix A. 20. Stream Temperature Model results for July 2011. Line segment colors represent the number of weeks a reach exceeds 64.4 °F (18 °C) during the summer (June – September – 15 weeks). Pie charts represent the percent of RMs that exceed 64.4 °F (McNyset et al. 2015).



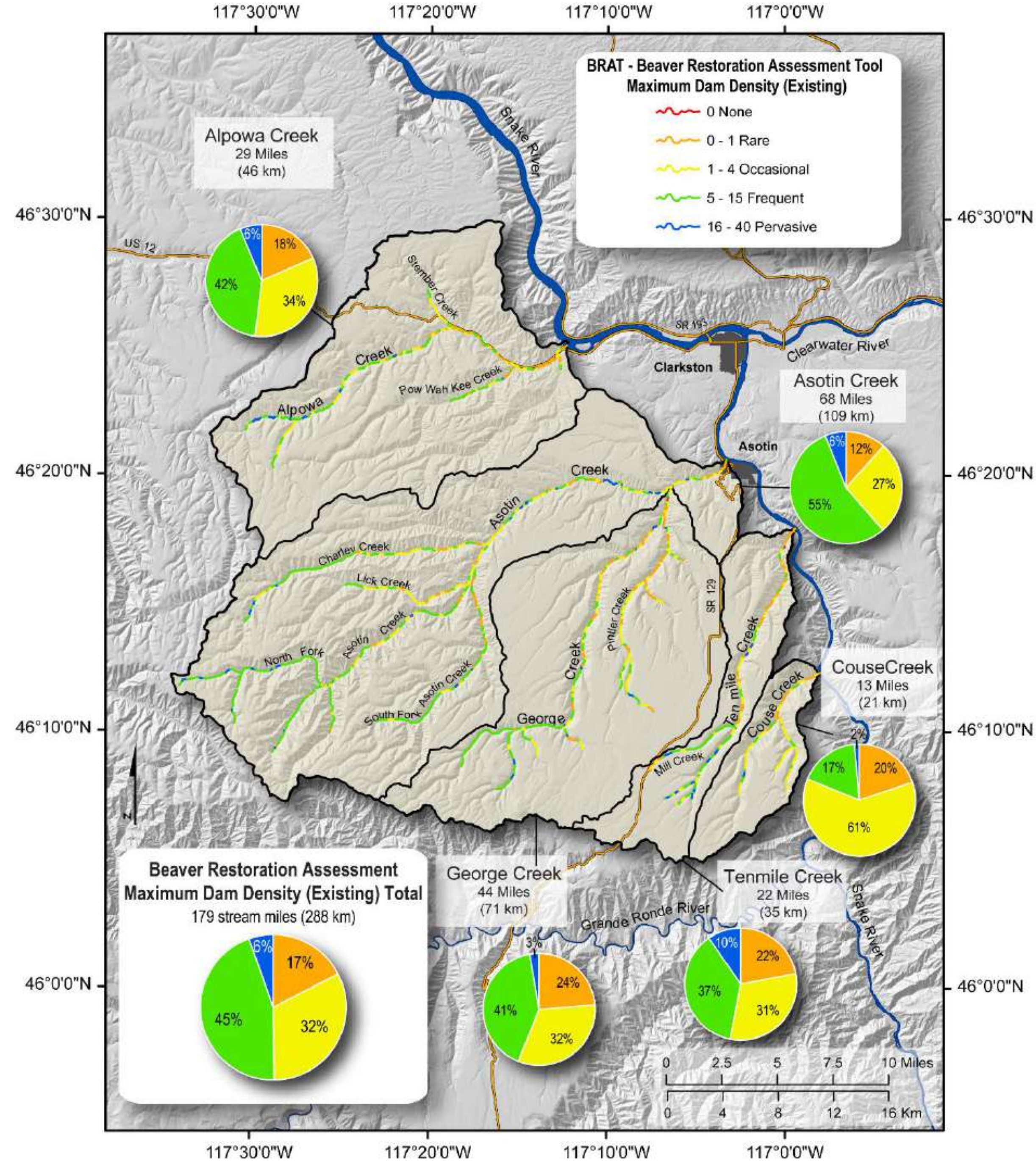
Appendix A. 21. Stream Temperature Model results for summer 2015 (June – September). Line segment colors represent the number of weeks a reach exceeds 64.4 °F (18 °C). Pie charts represent the percent of RMs that exceed 64.4 °F (McNyset et al. 2015).



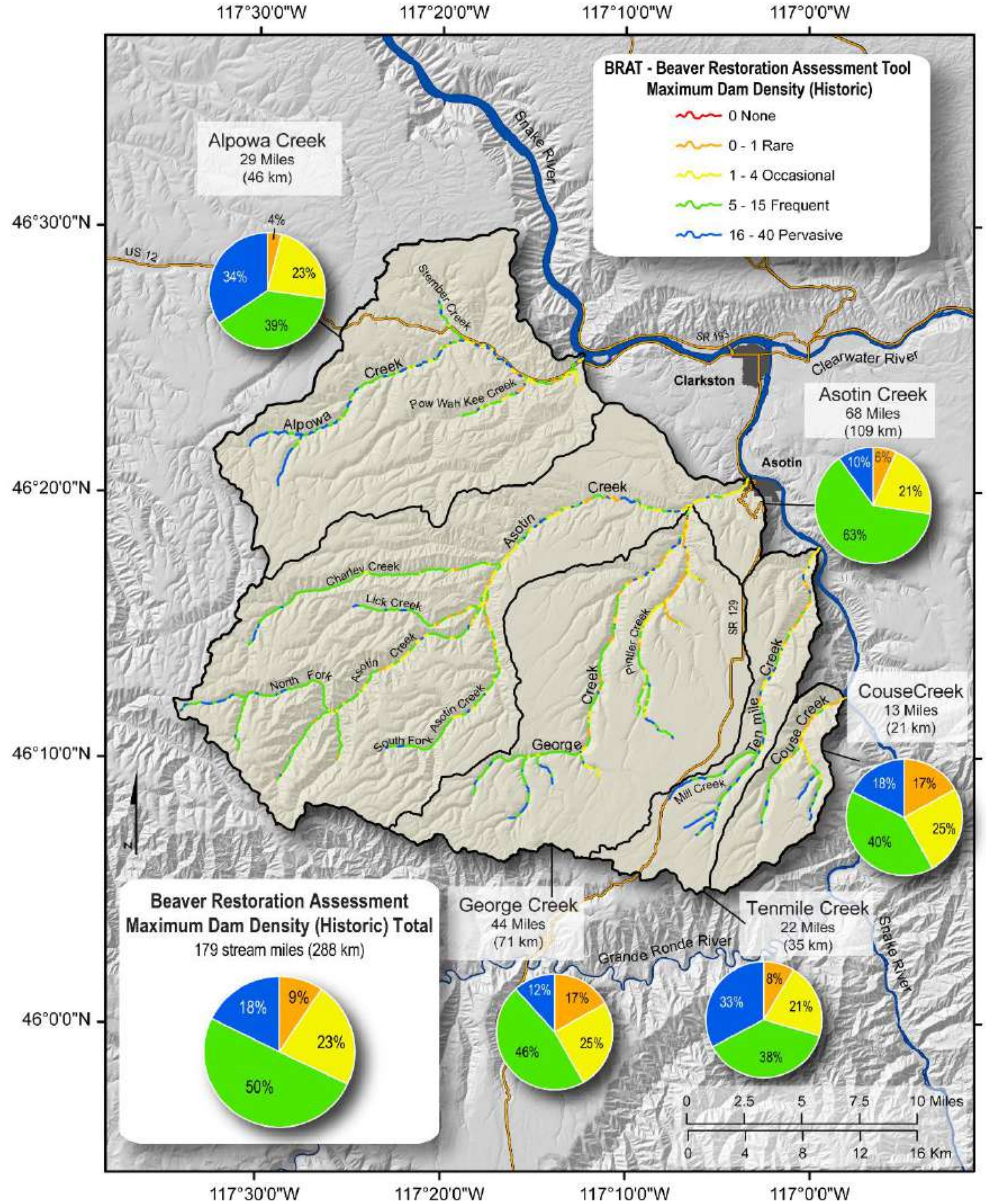
Appendix A. 22. Stream Temperature Model results for summer 2011 (June – September). Line segment colors represent the number of weeks a reach exceeds 68 °F (20 °C). Pie charts represent the percent of RMs that exceed 68 °F (McNyset et al. 2015).



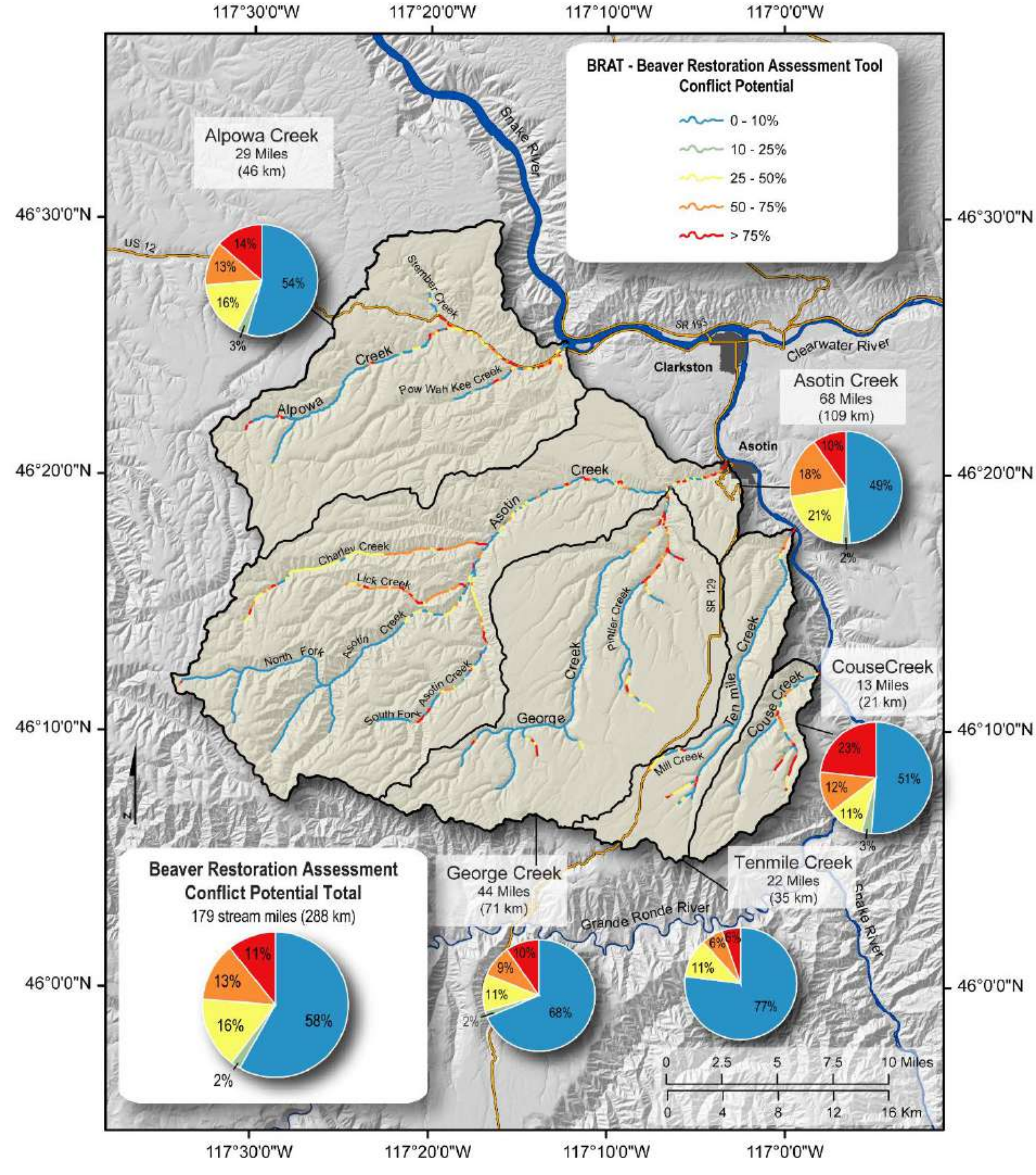
Appendix A. 23. Stream Temperature Model results for summer 2015 (June – September). Line segment colors represent the number of weeks a reach exceeds 68 °F (20 °C). Pie charts represent the percent of RMs that exceed 68 °F (McNyset et al. 2015).



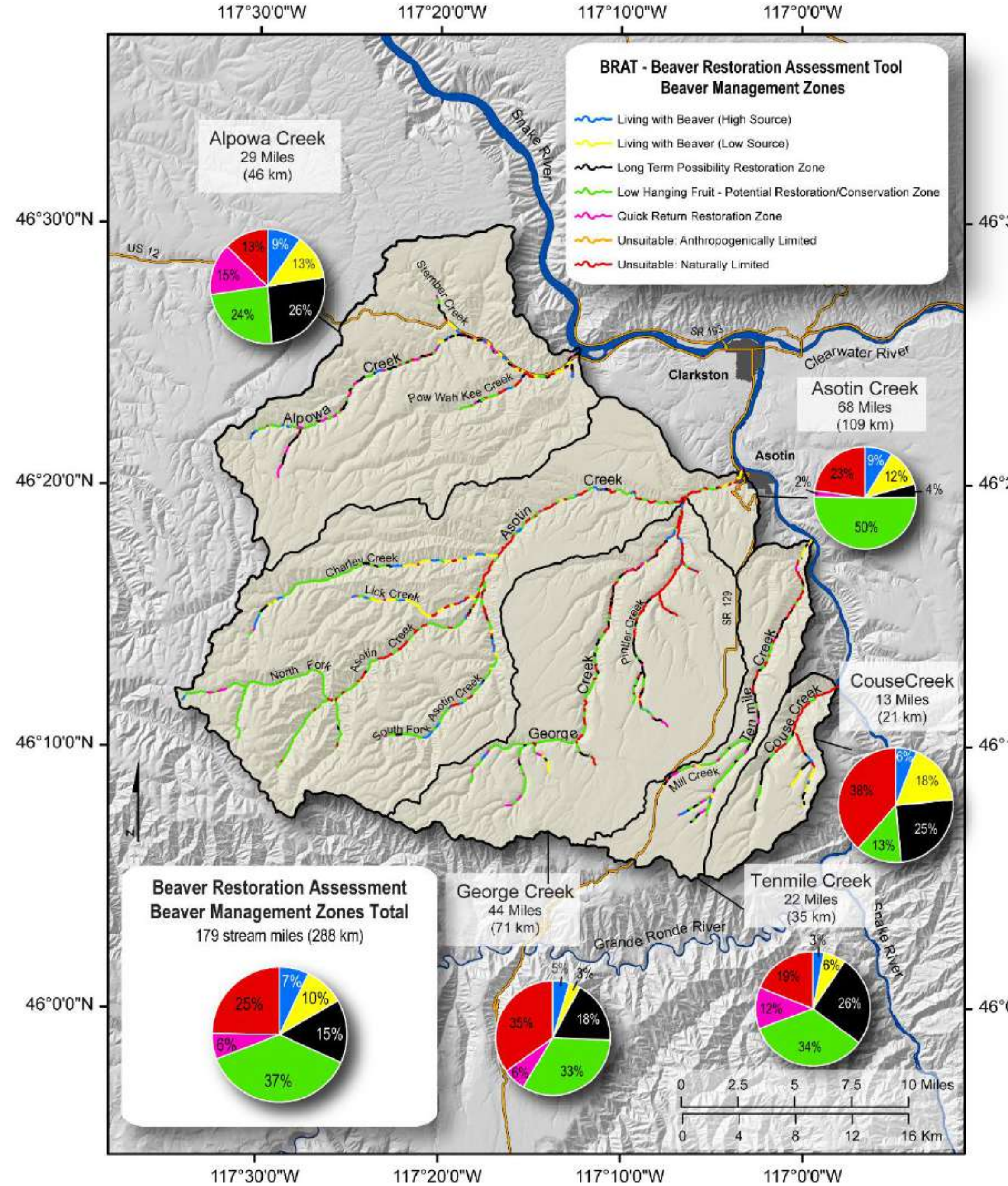
Appendix A. 24. Current capacity to support dam building beaver based on results of the Beaver Restoration Assessment Tool (Macfarlane et al. 2015).



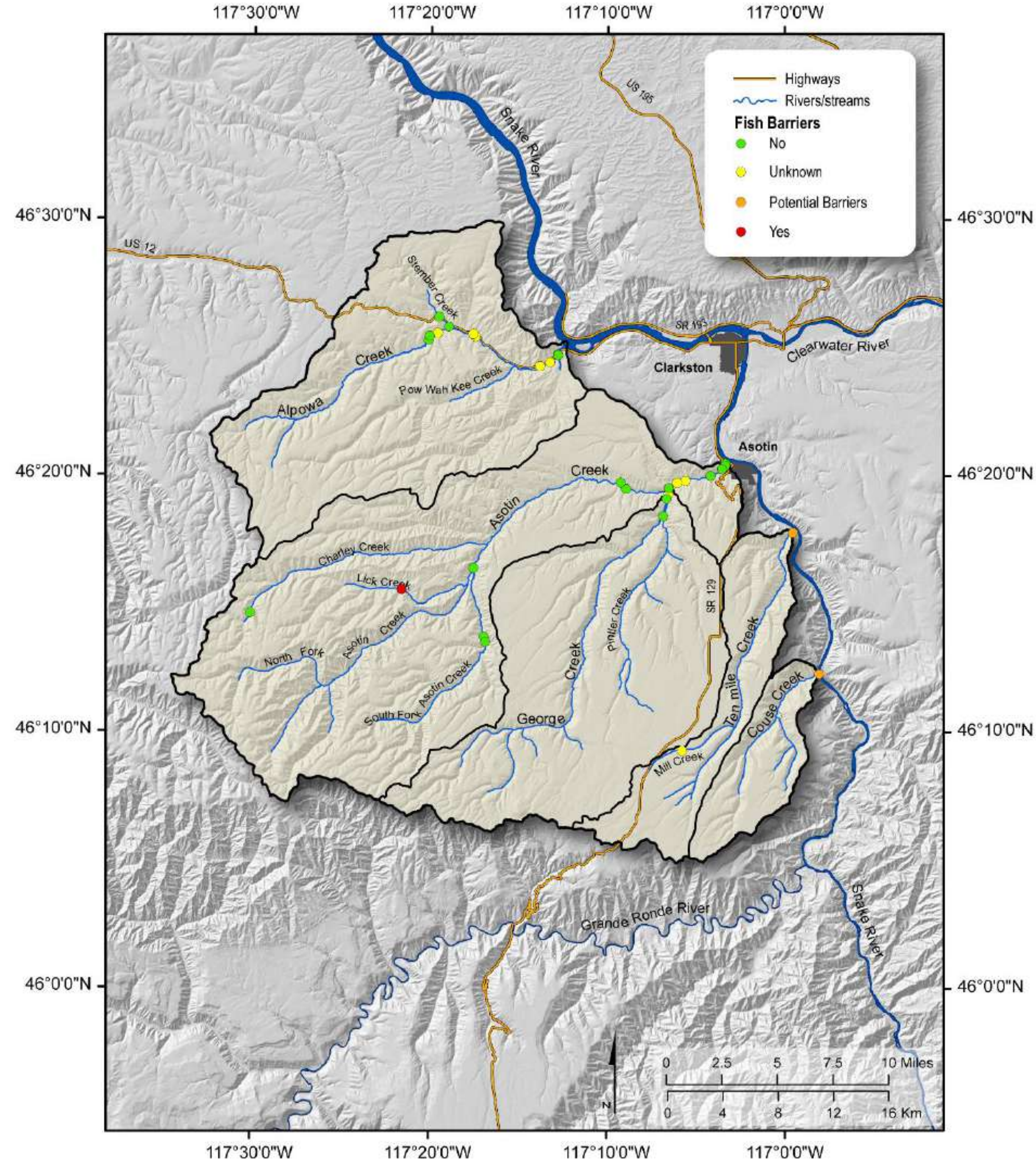
Appendix A. 25. Historic capacity to support dam building beaver based on results of the Beaver Restoration Assessment Tool (Macfarlane et al. 2015).



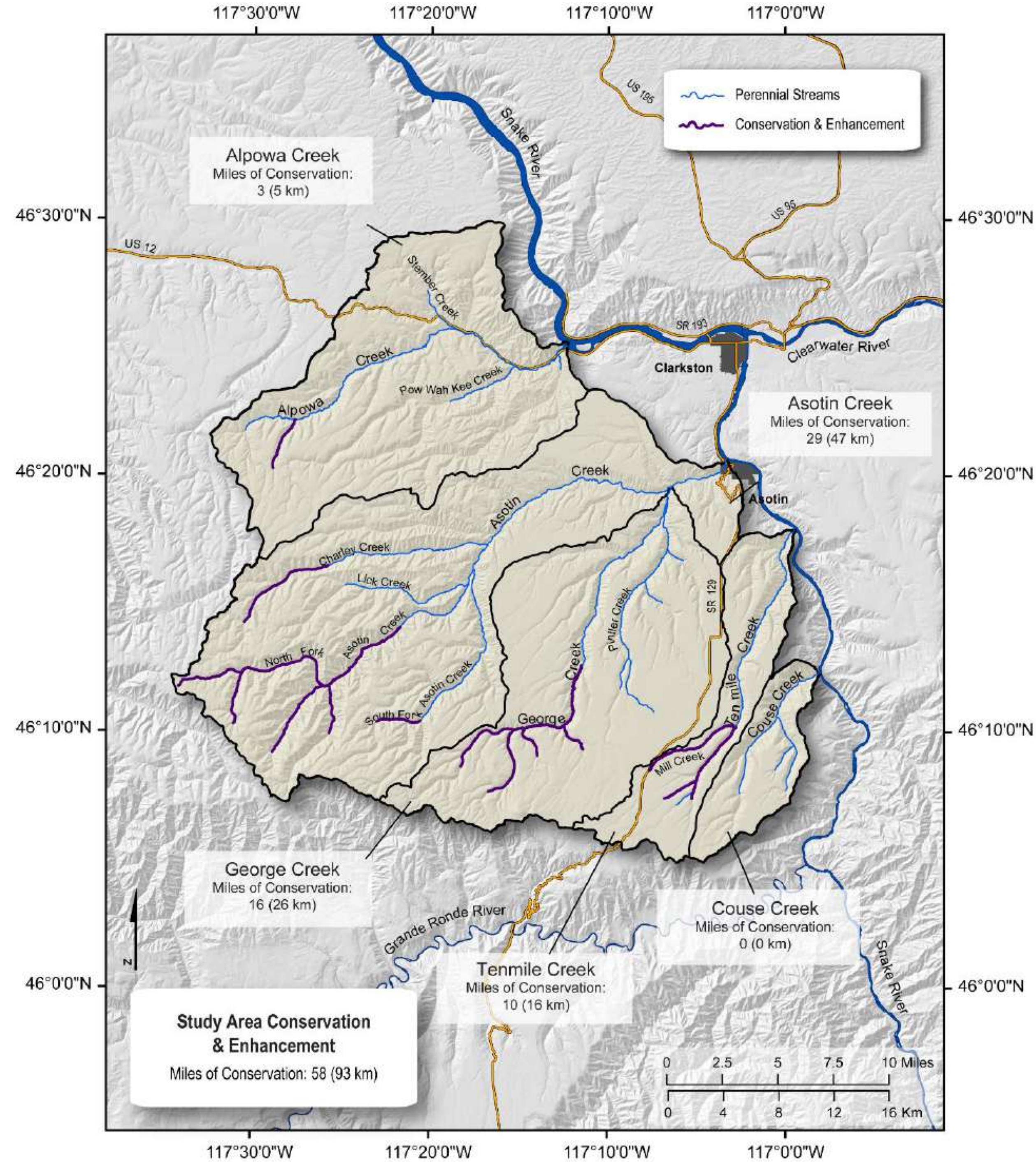
Appendix A. 26. Beaver conflict potential based on the results of the Beaver Restoration Assessment Tool (Macfarlane et al. 2015).



Appendix A. 27. Beaver management zones based on the results of the Beaver Restoration Assessment Tool (Macfarlane et al. 2015).



Appendix A. 28. Fish passage assessment conducted by Walla Walla Community College for the Snake River Salmon Recovery Board in 2008-2009 (WWCC 2009). Potential barriers are low flow or subsurface flow identified at the mouth of Couse and Tenmile Creeks.



Appendix A. 29. Conservation and enhancement reaches for maintenance of natural processes and potential trial beaver reintroduction locations.

APPENDIX B – TABLES

Appendix B. 1. Basic habitat requirements and limiting factors of steelhead, Chinook, and bull trout and links to how geomorphic and riparian functions affect these factors.

Life Stage	Habitat or Limiting Factor	General Salmonid Requirements	Link to Geomorphic and Riparian Condition
Egg and Alevin	Dissolved Oxygen	8-10 mg/L	excess of fines would indicate lower DO capacity
	Substrate	well-sorted, gravel and cobble (0.7 - 6 " diameter), < 10% fines	confined channels cause more scour; reduced floodplain connection limits dissipation of flow and can increase scour; reduced structural elements limit creation of well sorted bars and increase area of bed mobilization during high flows
	Temperature	most incubation occurs between 38-58 °F	NA
Fry and Juvenile	Food	energy inputs to salmonids come mainly from drifting invertebrates	limited riparian cover, poor riffle habitat would indicate lower terrestrial and aquatic invertebrate production
	Physical Habitat	multiple habitat types required for rearing including resting, foraging, predator avoidance, high flow refugia, thermal refugia	distribution and diversity of geomorphic units (bars, pools, undercuts, side-channels, runs, cascades, back-waters, etc.) is direct measure of fish habitat; presence of overstream cover, instream structural elements (LWD, boulders, vegetation, undercut banks, interstitial space in cobbles) is captured in geomorphic and riparian assessment
	Temperature	temperature affects all physiological processes including consumption rate and metabolism which in turn affect growth rates; preferred rearing 50-58° F (< 64° F 7 day average max)	limited riparian cover could cause increased or decreased growth depending on stream temperature, food and competition; lack of floodplain connection could reduce ground water inputs and affect temperature refugia
	Water Flow and Depth	stream flow has to be low enough velocity to feed and hold position and deep enough to provide holding and resting locations; rearing depths 2-60 inches	visual estimate
Adult Migration and Spawning	Cover	avoid predation from terrestrial and aquatic predators; cover such as boulders, large wood, undercut banks, and pools to help avoid predators.	presence of overstream cover, instream structural elements (LWD, boulders, vegetation, undercut banks, interstitial space in cobbles) is captured in geomorphic and riparian assessment
	Migration barriers	barriers include dams, culverts, waterfalls, diversions	
	Substrate	see egg and alevin above	
	Temperature	most migration and spawning temperatures take place between 38-58° F	NA

Appendix B. 2. Summary and key findings of numerous assessments, monitoring, and planning projects completed in Asotin County since 1995.

Assessment Title (Year)	**Scope (area and watersheds covered)**	**Key Findings/Actions**	**Key Recommendations/Actions**
ACCD Model Watershed (1995)	Asotin Creek watershed (including George and Pintler Creek)	i) high stream temperature, ii) lack of resting and rearing pools containing large woody debris (LWD), iii) fine sediment deposition in spawning gravels, and iv) high fecal coliform counts	581 restoration projects implemented since 1996 - riparian fencing (26,400 linear feet), riparian planting (36,000 linear feet), instream habitat structures (144), tree planting (30 acres), and changes to upland farming practices including over 1,400 ha reserved in permanent grass cover
NRCS Watershed Assessment (2001)	Asotin Creek and tributaries	Riparian function, channel, and bank conditions are still impaired in many areas, especially the lower reaches of Charley Creek on private land	Instream habitat restoration especially with LWD and riparian planting
DOE Water Quality Study (2015)	Mainstem Asotin Creek from George Creek Confluence down	i) Chloride and nitrate levels 3-5 times higher in George than Asotin ii) Fecal coliform highest in Asotin Creek, George contributes very small proportion iii) Fecal coliform and enterococci generally below WDOE standards, with unusual spike in August	Continued regular water quality monitoring on Asotin and George Creeks to identify the sources of excessive nutrient spikes and fecal coliform contamination
Subbasin Plan (2004); Snake River Salmon Recovery (2006; revised 2011)	All target watersheds	Key limiting factors: LWD, confinement, riparian function, sediment, key habitat loss, flow, bed scour, temperature	Instream habitat restoration, floodplain reconnection, riparian planting, upland management
Asotin Intensively Monitored Watershed (2008 to present)	Charley Creek, North Fork Asotin Creek, and South Fork Asotin Creek	- Lower 10 miles of each creek recovering riparian but low diversity instream habitat and infrequent floodplain inundation due to lack of LWD and channelization	- add LWD to promote instream habitat diversity and floodplain connection - focus LWD additions to promote side-channels reconnection, engauge

		- addition of LWD to treatment areas increased habitat complexity and fish abundance	floodplain, and promote bar and pool formation - continue to test effectiveness of LWD restoration and better understand fish capacity of Asotin tributaries
WDFW Asotin Assessment (2004 to present)	All target watersheds	- Asotin Creek (not including George Creek) adult steelhead returns average 650; average smolt outmigration 40,000 - Other target watersheds have adults returns and smolt production	- continue monitoring to better understand the productivity of target watersheds and better understand population trends and life history behavior
Hydrogeology (2009)	All target watersheds	Limited and discontinuous shallow ground water; Alpowa Creek heavily influenced by groundwater; ground water not contributing significantly to other watersheds	Limited impact from groundwater extraction likely (except for Alpowa)
USFWS Lamprey Assessment	Asotin Creek	Provides general assessment of Asotin Watershed and habitat characteristics important to different life stages of lamprey.	Determined George Creek likely not suitable for lamprey, Asotin Creek has suitable habitat, and recommended Headgate Dam be removed (which was completed in 2016)
WDFW Fish and Habitat Assessment for George, Tenmile, Couse (2000)	George, Tenmile, and Couse Creeks	i) First documented fish surveys in target streams ii) 63 redds identified, with highest densities in Tenmile iii) Majority of fish captured were age 0+ iv) Habitat described as fair to poor with pockets of good habitat	i) Resurvey streams with extended scope to include upper sections in the next 1-2 years ii) Repeat surveys every 3-5 years ii) Examine streams for potential restoration to stabilize banks and riparian, increase pool habitat and wood, reduce sediment loading, and decrease intensity of runoff events
ACCD Riparian Planting Projects in Asotin Watershed (2002)	Asotin Creek	i) 84,191 trees and shrubs planted ii) 9,100 feet of riparian fencing installed iii) installed 3 wells, 16 troughs, and 5 spring developments	ACCD Riparian Planting Projects in Asotin Watershed (2002)

Appendix B. 3. Indigenous and introduced fish species present in Asotin Creek Watershed and their approximate distribution (ACCD 2004).

Common Name	Genus Species	Indigenous	Distribution*
Bridgelip sucker	*Catostomas columbianus*	Yes	WS
Bull trout	*Salvelinus confluentus*	Yes	UW
Chinook salmon	*Oncorhynchus tshawytscha*	Yes	E
Largescale sucker	*Catostomas macrocheilus*	Yes	UNK
Longnose dace	*Rhinichthys cataractae*	Yes	UNK
Mountain whitefish	*Prosopium williamsoni*	Yes	UNK
Northern pikeminnow	*Ptychocheilus oregonensis*	Yes	UNK
Pacific lamprey	*Lampetra tridentata*	Yes	UNK
Paiute sculpin	*Cottus beldingi*	Yes	WS
Peamouth	*Mylocheilus caurinus*	Yes	NM
River lamprey	*Lampetra ayresi*	Yes	UNK
Speckled dace	*Rhinichthys osculus*	Yes	LW
Steelhead trout	*Oncorhynchus mykiss*	Yes	WS
Chiselmouth	*Acrocheilus alutaceus*	Yes	NM
Redside shiner	*Richardsonius balteatus*	Yes	UNK
Bluegill	*Lepomis macrochirus*	No	NM
Carp	*Cyprinus carpio*	No	LW
Channel catfish	*Ictaluris punctatus*	No	UNK
Crappie	*Pomoxis spp.*	No	NM
Smallmouth bass	*Micropterus dolomieui*	No	UNK

**** E = extirpated, LW = lower watershed, NM = near mouth of major drainages, UNK = unknown, UW = upper watershed, WS = wide spread (Adapted from ACCD 2004).***

Appendix B. 4. Geoindicators used to measure the geomorphic function of river styles in partly confined valley settings in the Asotin Creek watershed.

Geoindicator/River Style	Fan Controlled (DF)	Planform Controlled (DF)	Wandering Gravel Bed (DF)
Channel Attributes			
Size	Yes	Yes	Yes
Shape	Yes	No	Yes
Bank	Yes	Yes	Yes
Instream vegetation structure	Yes	Yes	Yes
Structural elements (e.g. woody debris loading)	Yes	Yes	Yes
Channel Planform			
Number of channels	Yes	Yes	Yes
Sinuosity of channels	Yes	Yes	Yes
Lateral stability	Yes	Yes	Yes
Geomorphic unit assemblage	Yes	Yes	Yes
Riparian vegetation	Yes	Yes	Yes
Bed Character			
Grain size and sorting	Yes	Yes	Yes
Bed stability	No	Yes	Yes
Sediment regime	Yes	Yes	Yes

Appendix B. 5. Geoindicators used to measure the geomorphic function of river styles in laterally unconfined valley settings in the Asotin Creek watershed.

Geoindicator/River Style	Upland Swale	Alluvial Fan
Channel Attributes		
Size	Yes	Yes
Shape	Yes	No
Bank	Yes	No
Instream vegetation structure	Yes	No
Structural elements (e.g. woody debris loading)	No	Yes
Channel Planform		
Number of channels	No	Yes
Sinuosity of channels	No	Yes
Lateral stability	No	No
Geomorphic unit assemblage	No	Yes
Riparian vegetation	Yes	Yes
Bed Character		
Grain size and sorting	No	Yes
Bed stability	No	No
Sediment regime	Yes	No

Appendix B. 6. Criteria and measures used to assess geomorphic function of variants of the Planform controlled discontinuous floodplain reach type in partly confined valley settings (adapted from Brierley and Fryirs 2005).

Degrees of freedom and their relevant geoindicators	**Questions used to assess geomorphic function of each reach**	North Fork of North Fork Asotin	South Fork Asotin	Alpowa Creek near Stember Creek confluence
Channel attributes	**3 out of 4 questions must be answered YES For stream to be assessed as HIGH function**			
Size	Is channel size appropriate given the catchment area, the prevailing sediment regime, and the vegetation character? Is the channel functionally connected to floodplain pockets? (i.e., is the channel over-widened, over-deepened, or does it have an appropriate width:depth ratio?)	Yes	Yes	No
Bank	Is the bank morphology consistent with caliber of sediment? Are banks eroding in the correct places?	Yes	No	No
Instream vegetation structure	Is the instream vegetation structure, composition, and density appropriate?	Yes	Yes	Yes
Structural elements (e.g woody debris loading)	Is there woody debris in the channel or potential for recruitment of woody debris? Is the density of other structural elements appropriate for the reach type and position in the catchment (e.g. boulders, bedrock)?	Yes	Yes	No
		✓	✓	**X**
Channel planform	**4 out of 5 questions must be answered YES**			
Number of channels	Is the channel appropriate for this river style? Are there signs of change such as avulsions or overbank channels forming on the floodplain?	Yes	Yes	No
Sinuosity of channels	Is the channel sinuosity consistent with the sediment load/transport regime and the slope of the channel?	Yes	Yes	Yes
Lateral stability	Is the lateral stability consistent with the sediment texture and channel slope? Are there signs of degradation such as local widening and atypical in-channel reworking of bed material?	Yes	No	No
Geomorphic unit assemblage	Are the number, type and pattern of instream geomorphic units appropriate for the sediment regime, slope, bed material and valley setting? Are key units of this river style present (planar riffles and runs, cutbanks, pools, point bars)?	Yes	Yes	No
Riparian vegetation	Are the appropriate types and density of riparian vegetation present on the banks and floodplain?	Yes	No	No
		✓	✓	**X**
Bed character	**3 out of 4 questions must be answered YES**			
Grain size and sorting	Is the range of sediment throughout the channel and floodplain organized and distributed appropriately?	Yes	No	No

Bed stability	Is the bed vertically stable such that it is not incising or aggrading inappropriately for the channel slope, sediment caliber, and sinuosity?	Yes	Yes	Yes
Sediment regime	Is the sediment storage and transport function of the reach appropriate for the catchment position (i.e., is it a sediment transfer or accumulation zone?)?	Yes	Yes	No
Hydraulic diversity	Are roughness characteristics and the pattern of hydraulic diversity appropriate for the catchment position?	Yes	No	No
		✓	X	X
	Total checks and crosses are added for each stream reach	**3**	**1**	**0**
Geomorphic function		**High**	**Moderate**	**Limited**

Appendix B. 7. Criteria and measures used to assess geomorphic function of variants of the Wandering gravel bed with discontinuous floodplain reach type in partly confined valley settings (Brierley and Fryirs 2005). See Table Appendix for other reach types.

Degrees of freedom and their relevant geoindicators	**Questions used to assess geomorphic function of each reach**	North Fork Asotin Creek ~RM 7	Asotin Creek below Charley Creek	Asotin Creek near mouth	George Creek near mouth
Channel attributes	**4 out of 5 questions must be answered YES For stream to be assessed as HIGH function**				
Size	Is channel size appropriate given the catchment area, the prevailing sediment regime, and the vegetation character? Is the channel functionally connected to floodplain? (i.e., is the channel over-widened, over-deepened, or does it have an appropriate width:depth ratio?)	Yes	No	Yes	Yes
Shape	Is the channel shape consistent with partly confined valley features (typically asymmetrical)?	Yes	Yes	Yes	No
Bank	Is the bank morphology consistent with caliber of sediment? Are banks eroding in the correct places?	Yes	No	No	No
Instream vegetation structure	Is the instream vegetation structure, composition, and density appropriate?	Yes	Yes	Yes	No
Structural elements (e.g. woody debris loading)	Is there woody debris in the channel or potential for recruitment of woody debris? Is the density of other structural elements appropriate for the reach type and position in the catchment (e.g. boulders, bedrock)?	Yes	Yes	No	No
		✓	X	X	X
Channel planform	**4 out of 5 questions must be answered YES**				

Number of channels	Is the channel appropriate for this river style? Are there secondary channels or accessible flood channels?	Yes	No	No	No
Sinuosity of channels	Is the channel sinuosity consistent with the sediment load/transport regime and the slope of the channel?	Yes	Yes	Yes	No
Lateral stability	Is lateral stability consistent with sediment texture and channel slope? Is there minimal degradation (e.g., local widening/atypical in-channel reworking of bed material?	Yes	No	No	No
Geomorphic unit assemblage	Are the number, type and pattern of instream geomorphic units appropriate for the sediment regime, slope, bed material and valley setting? Are key units of this river style present (secondary channels, pool-riffle, forced pools, gravel sheets)?	Yes	Yes	No	No
Riparian vegetation	Are the appropriate types and density of riparian vegetation present on the banks and floodplain?	Yes	No	No	No
		✓	X	X	X
Bed character	**3 out of 4 questions must be answered YES**				
Grain size and sorting	Is the range of sediment throughout the channel and floodplain organized and distributed appropriately?	Yes	Yes	No	No
Bed stability	Is the bed vertically stable such that it is not incising or aggrading inappropriately for the channel slope, sediment caliber, and sinuosity?	Yes	Yes	Yes	No
Sediment regime	Is the sediment storage and transport function of the reach appropriate for the catchment position (i.e., is it a sediment transfer or accumulation zone?)?	Yes	Yes	Yes	No
Hydraulic diversity	Are roughness characteristics and pattern of hydraulic diversity appropriate for the catchment position?	Yes	Yes	No	No
		✓	✓	X	X
	Total checks are added for each stream reach	**3**	**1**	**0**	**0**
Geomorphic function		**High**	**Moderate**	**Limited**	**Limited**

Appendix B. 8. Criteria and measures used to assess geomorphic function of variants of the Fan controlled with discontinuous floodplain reach type in partly confined valley settings (Brierley and Fryirs 2005).

Degrees of freedom and their relevant geoindicators	Questions used to assess geomorphic function of each reach	Couse Creek near mouth	Charley Creek ~RKM 8	Charley Creek ~RKM 6
Channel attributes	**4 out of 5 questions must be answered YES For stream to be assessed as HIGH function**			
Size	Is channel size appropriate given the catchment area, the prevailing sediment regime, and the vegetation character? Is the channel functionally connected to floodplain pockets? (i.e., is the channel over-widened, over-deepened, or does it have an appropriate width:depth ratio?)	Yes	Yes	Yes
Shape	Is the channel shape consistent with partly confined valley features (typically asymmetrical)?	Yes	Yes	Yes
Bank	Is the bank morphology consistent with caliber of sediment? Are banks eroding in the correct places?	Yes	Yes	No
Instream vegetation structure	Is the instream vegetation structure, composition, and density appropriate?	Yes	Yes	Yes
Structural elements (e.g woody debris loading)	Is there woody debris in the channel or potential for recruitment of woody debris? Is the density of other structural elements appropriate for the reach type and position in the catchment (e.g. boulders, bedrock)?	No	Yes	No
		✓	✓	**X**
Channel planform	**4 out of 5 questions must be answered YES**			
Number of channels	Is the channel appropriate for this river style? Is the channel mostly single thread?	Yes	Yes	Yes
Sinuosity of channels	Is the channel sinuosity consistent with the sediment load/transport regime and the slope of the channel?	Yes	Yes	No
Lateral stability	Is the lateral stability consistent with the sediment texture and channel slope? Is there a low amount of degradation such as local widening and atypical in-channel reworking of bed material?	No	No	No
Geomorphic unit assemblage	Are the number, type and pattern of instream geomorphic units appropriate for the sediment regime, slope, bed material and valley setting? Are key units of this river style present (runs, rapids, forced pools, forced bars)?	No	Yes	No
Riparian vegetation	Are the appropriate types and density of riparian vegetation present on the banks and floodplain?	Yes	Yes	No
		X	✓	**X**
Bed character	**3 out of 4 questions must be answered YES**			
Grain size and sorting	Is the range of sediment throughout the channel and floodplain organized and distributed appropriately?	No	No	No

Bed stability	Is the bed vertically stable such that it is not incising or aggrading inappropriately for the channel slope, sediment caliber, and sinuosity?	Yes	Yes	Yes
Sediment regime	Is the sediment storage and transport function of the reach appropriate for the catchment position (i.e., is it a sediment transfer or accumulation zone?)?	Yes	Yes	No
Hydraulic diversity	Are roughness characteristics and the pattern of hydraulic diversity appropriate for the catchment position?	Yes	No	No
		✓	X	X
	Total checks and crosses are added for each stream reach	**2**	**2**	**0**
Geomorphic function		**Moderate**	**Moderate**	**Limited**

Appendix B. 9. Criteria and measures used to assess geomorphic function of variants of the Wandering gravel bed with discontinuous floodplain reach type in partly confined valley settings (Brierley and Fryirs 2005).

Degrees of freedom and their relevant geoindicators	**Questions used to assess geomorphic function of each reach**	North Fork Asotin Creek ~RKM 12	Asotin Creek below Charley Creek	Asotin Creek near mouth	George Creek near mouth
Channel attributes	**4 out of 5 questions must be answered YES For stream to be assessed as HIGH function**				
Size	Is channel size appropriate given the catchment area, the prevailing sediment regime, and the vegetation character? Is the channel functionally connected to floodplain pockets? (i.e., is the channel over-widened, over-deepened, or does it have an appropriate width:depth ratio?)	Yes	No	Yes	Yes
Shape	Is the channel shape consistent with partly confined valley features (typically asymmetrical)?	Yes	Yes	Yes	No
Bank	Is the bank morphology consistent with caliber of sediment? Are banks eroding in the correct places?	Yes	No	No	No
Instream vegetation structure	Is the instream vegetation structure, composition, and density appropriate?	Yes	Yes	Yes	No
Structural elements (e.g woody debris loading)	Is there woody debris in the channel or potential for recruitment of woody debris? Is the density of other structural elements appropriate for the reach type and position in the catchment (e.g. boulders, bedrock)?	Yes	Yes	No	No
		✓	X	X	X
Channel planform	**4 out of 5 questions must be answered YES**				
Number of channels	Is the channel appropriate for this river style? Are there secondary channels or accessible flood channels?	Yes	No	No	No

Sinuosity of channels	Is the channel sinuosity consistent with the sediment load/transport regime and the slope of the channel?	Yes	Yes	Yes	No
Lateral stability	Is the lateral stability consistent with the sediment texture and channel slope? Is there a low amount of degradation such as local widening and atypical in-channel reworking of bed material?	Yes	No	No	No
Geomorphic unit assemblage	Are the number, type and pattern of instream geomorphic units appropriate for the sediment regime, slope, bed material and valley setting? Are key units of this river style present (secondary channels, pool-riffle, forced pools, gravel sheets)?	Yes	Yes	No	No
Riparian vegetation	Are the appropriate types and density of riparian vegetation present on the banks and floodplain?	Yes	No	No	No
		✓	X	X	X
Bed character	**3 out of 4 questions must be answered YES**				
Grain size and sorting	Is the range of sediment throughout the channel and floodplain organized and distributed appropriately?	Yes	Yes	No	No
Bed stability	Is the bed vertically stable such that it is not incising or aggrading inappropriately for the channel slope, sediment caliber, and sinuosity?	Yes	Yes	Yes	No
Sediment regime	Is the sediment storage and transport function of the reach appropriate for the catchment position (i.e., is it a sediment transfer or accumulation zone?)?	Yes	Yes	Yes	No
Hydraulic diversity	Are roughness characteristics and the pattern of hydraulic diversity appropriate for the catchment position?	Yes	Yes	No	No
		✓	✓	X	X
	Total checks and crosses are added for each stream reach	**3**	**1**	**0**	**0**
Geomorphic function		**High**	**Moderate**	**Limited**	**Limited**

Appendix B. 10. Criteria and measures used to assess geomorphic function of variants of the Bedrock canyon reach type in confined valley settings (Brierley and Fryirs 2005).

Degrees of freedom and their relevant geoindicators	Questions used to assess geomorphic function of each reach	Alpowa Creek tributary ~RKM 16	Mainstem Asotin Creek ~RKM 11	Stember Creek tributary HWY 12
Channel attributes	**3 out of 4 questions must be answered YES For stream to be assessed as HIGH function**			

Size	Is channel size appropriate given the catchment area, the prevailing sediment regime, and the vegetation character? Is the channel functionally connected to floodplain pockets? (i.e., is the channel over-widened, over-deepened, or does it have an appropriate width:depth ratio?)	Yes	Yes	Yes
Shape	Is the channel shape consistent with confined valley features (typically symmetrical)?	Yes	Yes	Yes
Bank	Is the bank morphology consistent with caliber of sediment? Are banks eroding in the correct places?	Yes	Yes	No
Structural elements (e.g woody debris loading)	Is there woody debris in the channel or potential for recruitment of woody debris? Is the density of other structural elements appropriate for the reach type and position in the catchment (e.g. boulders, bedrock)?	Yes	No	Yes
		✓	✓	✓
Channel planform	**4 out of 5 questions must be answered YES**			
Number of channels	Is the channel appropriate for this river style? Is the channel single thread?	Yes	Yes	Yes
Sinuosity of channels	Is the channel sinuosity consistent with the sediment load/transport regime and the slope of the channel? Is the channel valley aligned?	Yes	Yes	No
Lateral stability	Is the lateral stability consistent with the sediment texture and channel slope? Is there a low amount of degradation such as local widening and atypical in-channel reworking of bed material?	Yes	Yes	No
Geomorphic unit assemblage	Are the number, type and pattern of instream geomorphic units appropriate for the sediment regime, slope, bed material and valley setting? Are key units of this river style present (runs, rapids, plunge pools)?	Yes	Yes	Yes
Riparian vegetation	Are the appropriate types and density of riparian vegetation present on the banks and floodplain?	No	No	No
		✓	✓	X
Bed character	**3 out of 4 questions must be answered YES**			
Grain size and sorting	Is the range of sediment throughout the channel and floodplain organized and distributed appropriately?	Yes	No	No
Bed stability	Is the bed vertically stable such that it is not incising or aggrading inappropriately for the channel slope, sediment caliber, and sinuosity?	Yes	Yes	Yes
Sediment regime	Is the sediment storage and transport function of the reach appropriate for the catchment position (i.e., is it a sediment transfer or accumulation zone?)?	Yes	Yes	No
Hydraulic diversity	Are roughness characteristics and the pattern of hydraulic diversity appropriate for the catchment position?	No	No	No
		✓	X	X

	Total checks and crosses are added for each stream reach	**3**	**2**	**1**
Geomorphic function		**High**	**Moderate**	**Limited**

Appendix B. 11. Criteria and measures used to assess geomorphic function of variants of the Steep ephemeral hillslope reach type in confined valley settings (Brierley and Fryirs 2005).

Degrees of freedom and their relevant geoindicators	Questions used to assess geomorphic function of each reach	Alpowa Creek tributary ~RKM 16	Asotin Creek tributary ~RKM 1
Channel attributes	**1 out of 1 questions must be answered YES For stream to be assessed as HIGH function**		
Structural elements (e.g woody debris loading)	Is there woody debris in the channel or potential for recruitment of woody debris? Is the density of other structural elements appropriate for the reach type and position in the catchment (e.g. boulders, bedrock)?	Yes	Yes
		✓	✓
Channel planform	**1 out of 1 questions must be answered YES**		
Geomorphic unit assemblage	Are the number, type and pattern of instream geomorphic units appropriate for the sediment regime, slope, bed material and valley setting? Are key units of this river style present (steps, cascades)?	Yes	Yes
		✓	✓
Bed character	**2 out of 2 questions must be answered YES**		
Grain size and sorting	Is the range of sediment throughout the channel and floodplain organized and distributed appropriately?	Yes	No
Sediment regime	Is the sediment storage and transport function of the reach appropriate for the catchment position (i.e., is it a sediment transfer or accumulation zone?)?	Yes	No
		✓	**X**
	Total checks and crosses are added for each stream reach	**3**	**2**
Geomorphic function		**High**	**Moderate**

Appendix B. 12. Criteria and measures used to assess geomorphic function of variants of the Steep perennial headwater reach type in confined valley settings (Brierley and Fryirs 2005).

Degrees of freedom and their relevant geoindicators	Questions used to assess geomorphic function of each reach	South Fork Asotin Creek headwaters	Charley Creek headwaters
Channel attributes	**1 out of 1 questions must be answered YES For stream to be assessed as HIGH function**		
Structural elements (e.g woody debris loading)	Is there woody debris in the channel or potential for recruitment of woody debris? Is the density of other structural elements appropriate for the reach type and position in the catchment (e.g. boulders, bedrock)?	Yes	Yes
		✓	✓
Channel planform	**1 out of 1 questions must be answered YES**		
Geomorphic unit assemblage	Are the number, type and pattern of instream geomorphic units appropriate for the sediment regime, slope, bed material and valley setting? Are key units of this river style present (cascades, forced pools, plunge pools, rapids, runs)?	Yes ✓	Yes ✓
Bed character	**2 out of 3 questions must be answered YES**		
Grain size and sorting	Is the range of sediment throughout the channel and floodplain organized and distributed appropriately?	Yes	Yes
Sediment regime	Is the sediment storage and transport function of the reach appropriate for the catchment position (i.e., is it a sediment transfer or accumulation zone?)?	Yes	No
Hydraulic diversity	Are roughness characteristics and the pattern of hydraulic diversity appropriate for the catchment position?	Yes	Yes
		✓	✓
	Total checks and crosses are added for each stream reach	**3**	**3**
Geomorphic function		**High**	**High**

Appendix B. 13. Criteria and measures used to assess geomorphic function of variants of the Confined occasional floodplain pockets reach type in confined valley settings (Brierley and Fryirs 2005).

Degrees of freedom and their relevant geoindicators	Questions used to assess geomorphic function of each reach	Lower Mill Creek	Montgomery Gulch	Mainstem Asotin Creek ~RKM 9	Dry Gulch

Channel attributes	**4 out of 5 questions must be answered YES For stream to be assessed as HIGH function**				
Size	Is channel size appropriate given the catchment area, the prevailing sediment regime, and the vegetation character? Is the channel functionally connected to floodplain pockets? (i.e., is the channel over-widened, over-deepened, or does it have an appropriate width:depth ratio?)	Yes	Yes	Yes	No
Shape	Is the channel shape consistent with partly confined valley features (typically symmetrical)?	Yes	Yes	Yes	No
Bank	Is the bank morphology consistent with caliber of sediment? Are banks eroding in the correct places?	Yes	No	Yes	No
Instream vegetation structure	Is the instream vegetation structure, composition, and density appropriate?	Yes	Yes	Yes	No
Structural elements (e.g woody debris loading)	Is there woody debris in the channel or potential for recruitment of woody debris? Is the density of other structural elements appropriate for the reach type and position in the catchment (e.g. boulders, bedrock)?	Yes	No	No	Yes
		✓	X	✓	X
Channel planform	**2 out of 3 questions must be answered YES**				
Lateral stability	Is the lateral stability consistent with the sediment texture and channel slope? Is there a low amount of degradation such as local widening and atypical in-channel reworking of bed material?	Yes	Yes	Yes	Yes
Geomorphic unit assemblage	Are the number, type and pattern of instream geomorphic units appropriate for the sediment regime, slope, bed material and valley setting? Are key units of this river style present (forced pools, pool-riffle, forced bars, rapids, runs)?	Yes	Yes	No	No
Riparian vegetation	Are the appropriate types and density of riparian vegetation present on the banks and floodplain?	Yes	No	Yes	No
		✓	✓	✓	X
Bed character	**2 out of 3 questions must be answered YES**				
Grain size and sorting	Is the range of sediment throughout the channel and floodplain organized and distributed appropriately?	Yes	Yes	No	Yes
Sediment regime	Is the sediment storage and transport function of the reach appropriate for the catchment position (i.e., is it a sediment transfer or accumulation zone?)?	Yes	No	Yes	No
Hydraulic diversity	Are roughness characteristics and the pattern of hydraulic diversity appropriate for the catchment position?	Yes	Yes	No	No
		✓	✓	X	X
	Total checks and crosses are added for each stream reach	**3**	**2**	**2**	**0**

Geomorphic function	**High**	**Moderate**	**Moderate**	**Limited**

Appendix B. 14. Criteria and measures used to assess geomorphic function of variants of the Upland swale reach type in laterally unconfined valley settings (Brierley and Fryirs 2005).

Degrees of freedom and their relevant geoindicators	Questions used to assess geomorphic function of each reach	Lower Mill Creek	Montgomery Gulch	Mainstem Asotin Creek ~RKM 9
Channel attributes	**4 out of 5 questions must be answered YES For stream to be assessed as HIGH function**			
Size	Is channel size appropriate given the catchment area, the prevailing sediment regime, and the vegetation character? Is the channel functionally connected to floodplain pockets? (i.e., is the channel over-widened, over-deepened, or does it have an appropriate width:depth ratio?)	Yes	Yes	Yes
Shape	Is the channel shape consistent with partly confined valley features (typically symmetrical)?	Yes	Yes	Yes
Bank	Is the bank morphology consistent with caliber of sediment? Are banks eroding in the correct places?	Yes	No	Yes
Instream vegetation structure	Is the instream vegetation structure, composition, and density appropriate?	Yes	Yes	Yes
		✓	X	✓
Channel planform	**2 out of 3 questions must be answered YES**			
Riparian vegetation	Are the appropriate types and density of riparian vegetation present on the banks and floodplain?	Yes	No	Yes
		✓	✓	✓
Bed character	**2 out of 3 questions must be answered YES**			
Sediment regime	Is the sediment storage and transport function of the reach appropriate for the catchment position (i.e., is it a sediment transfer or accumulation zone?)?	Yes	No	Yes
		✓	✓	X
	Total checks and crosses are added for each stream reach	**3**	**2**	**2**
Geomorphic function		**High**	**Moderate**	**Moderate**

Appendix B. 15. Temperature requirements for cold water salmon, trout and char (DOE 2002).

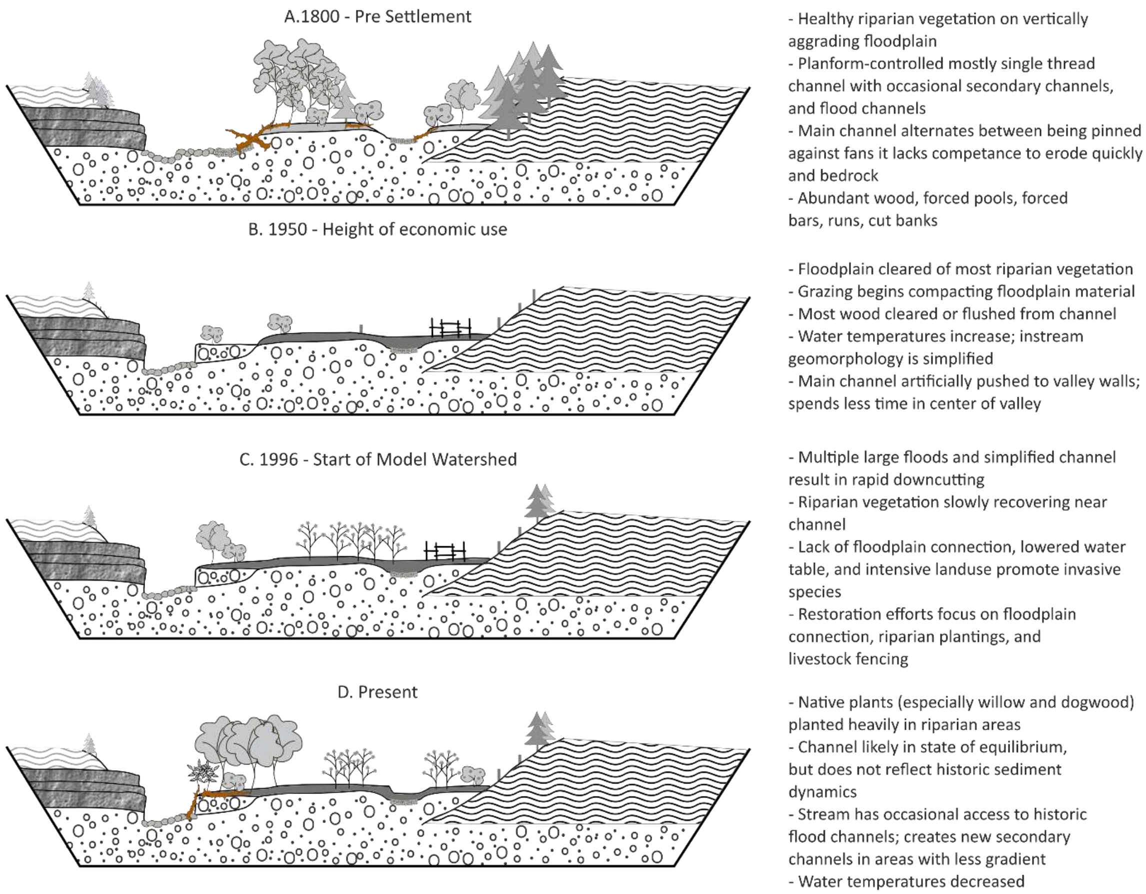
Species	**Life Stage**	**°F**
Bull trout	Spawning and incubation	46.1
	Juvenile rearing	55.9
	Disease viral	57.9
	Lethal	70.3
Macro-invertebrates	Headwaters	59.2
Salmon and trout	Spawning and incubation	55.8
	Juvenile rearing	61.9
	Smolt	60.2
	Disease viral	57.9
	Disease infection	63.3
	Lethal	72.0
	Migration	71.8
Macro-invertebrates	Headwaters	59.2
	Main streams	73.2

Appendix B. 16. Summary of water temperature data collected across the study area from 2009-2016 (data sources are DOE stream gauges and IMW temperature monitoring).

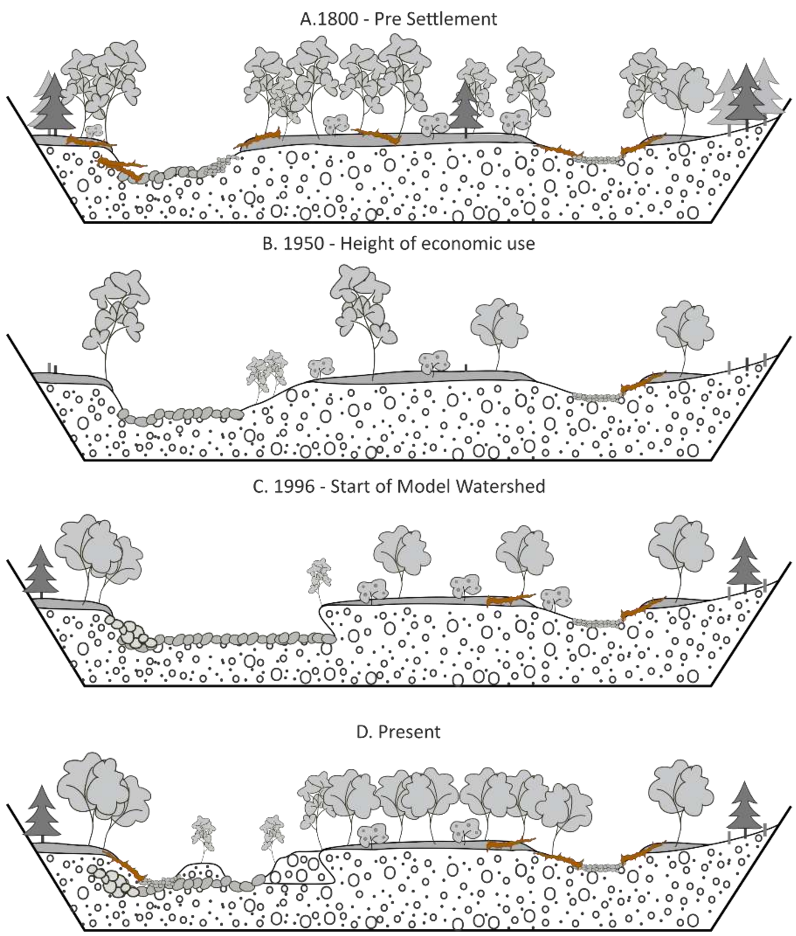
			Year									
Data Source	**Site**	**RM**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**Total**	**Days/ Year**
IMW	Asotin	0.5	13	7	0	6	8	-	-	4	38	7.6
DOE 35D100	Asotin	3.2	1	0	0	0	1	0	13	0	15	1.9
IMW	Asotin	14.0	0	0	0	0	0	0	-	0	0	0.0
IMW	Charley	1.9	0	0	1	0	0	0	0	0	1	0.1
IMW	Charley	3.1	0	0	0	0	0	0	0	0	0	0.0
IMW	Charley	5.6	0	0	0	0	0	0	0	0	0	0.0
IMW	Charley	10.6	0	0	0	0	0	0	0	0	0	0.0
IMW	South Fork	1.9	12	-	-	-	-	1	2	-	15	1.9
IMW	South Fork	3.1	-	-	-	-	1	-	-	-	1	0.1
IMW	South Fork	8.1	-	0	-	-	-	-	-	-	0	0.0
IMW	North Fork	0.6	0	0	0	0	0	0	0	0	0	0.0
IMW	North Fork	4.3	0	0	0	0	0	0	0	0	0	0.0
IMW	North Fork	6.8	0	0	0	0	0	0	0	0	0	0.0
IMW	George	0.5	-	6	-	-	-	-	-	-	6	0.8
DOE 35P050	George	0.5	-	-	0	0	-	-	-	-	0	0.0
DOE 35K050	Alpowa	0.5	3	1	0	4	3	2	10	0	23	2.9
DOE 35H050	Couse	0.5	-	-	0	0	1	-	-	-	1	0.1
DOE 35J050	Tenmile	0.5	-	-	0	0	0	-	-	-	0	0.0

APPENDIX C – FIGURES

Appendix C. 1. River evolution sequences for partly confined a) fan controlled, b) planform controlled, and c) wandering gravel bed reach types. These reach types encompass the majority of the steelhead distribution in the target watersheds. Evolution sequences allow us to look back to how reach form and function was prior to development and land use impacts.



A) Partly confined, Fan controlled with occasional floodplain



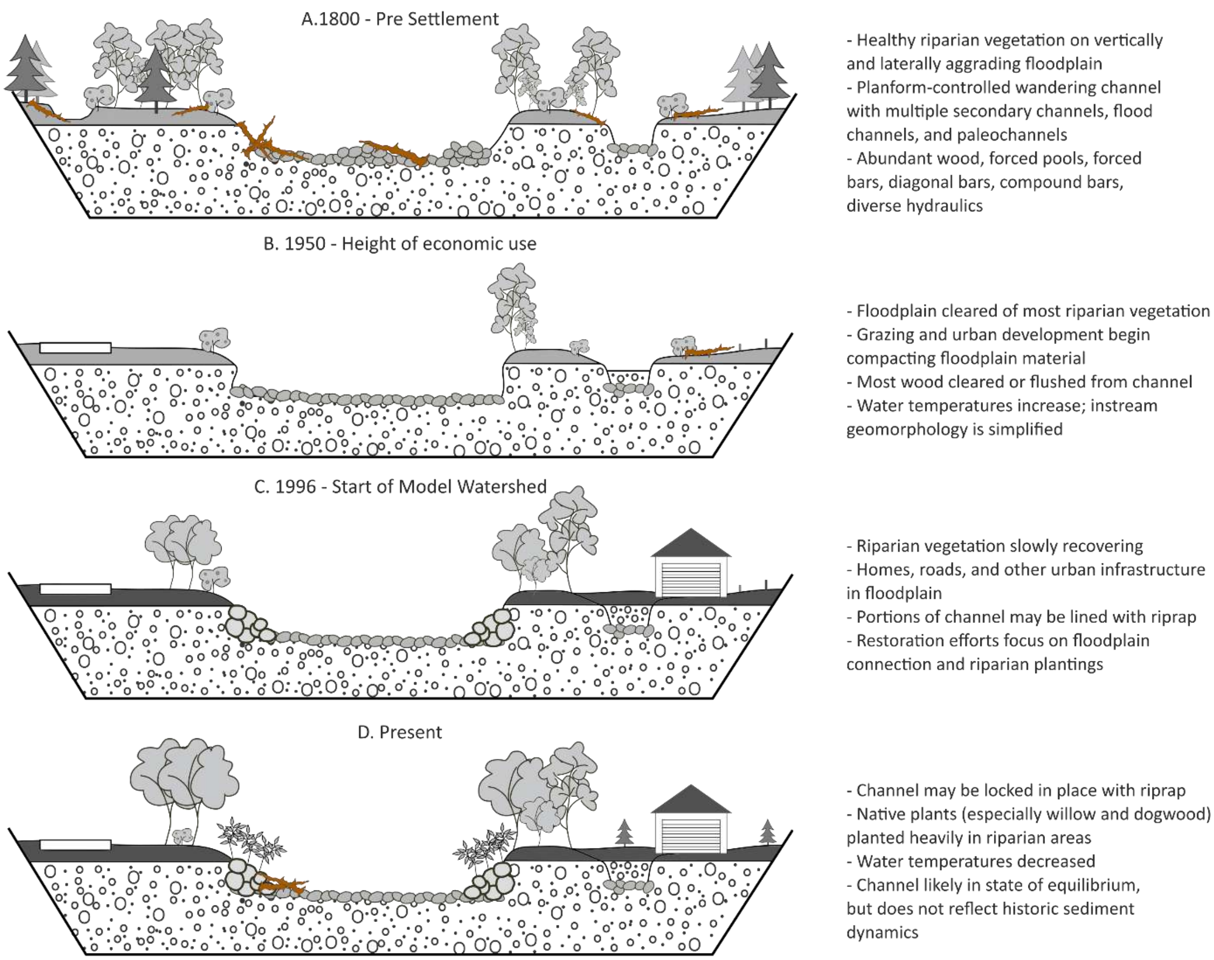
- Healthy riparian vegetation on vertically aggrading floodplain
- Planform-controlled mostly single thread channel with frequent secondary channels, and flood channels
- Main channel bounces between valley walls
- Abundant wood, pool-riffle, forced pools, forced bars, chutes

- Floodplain cleared of most riparian vegetation
- Most wood cleared or flushed from channel
- Water temperatures increase; instream geomorphology is simplified
- Channel often disconnected from floodplain

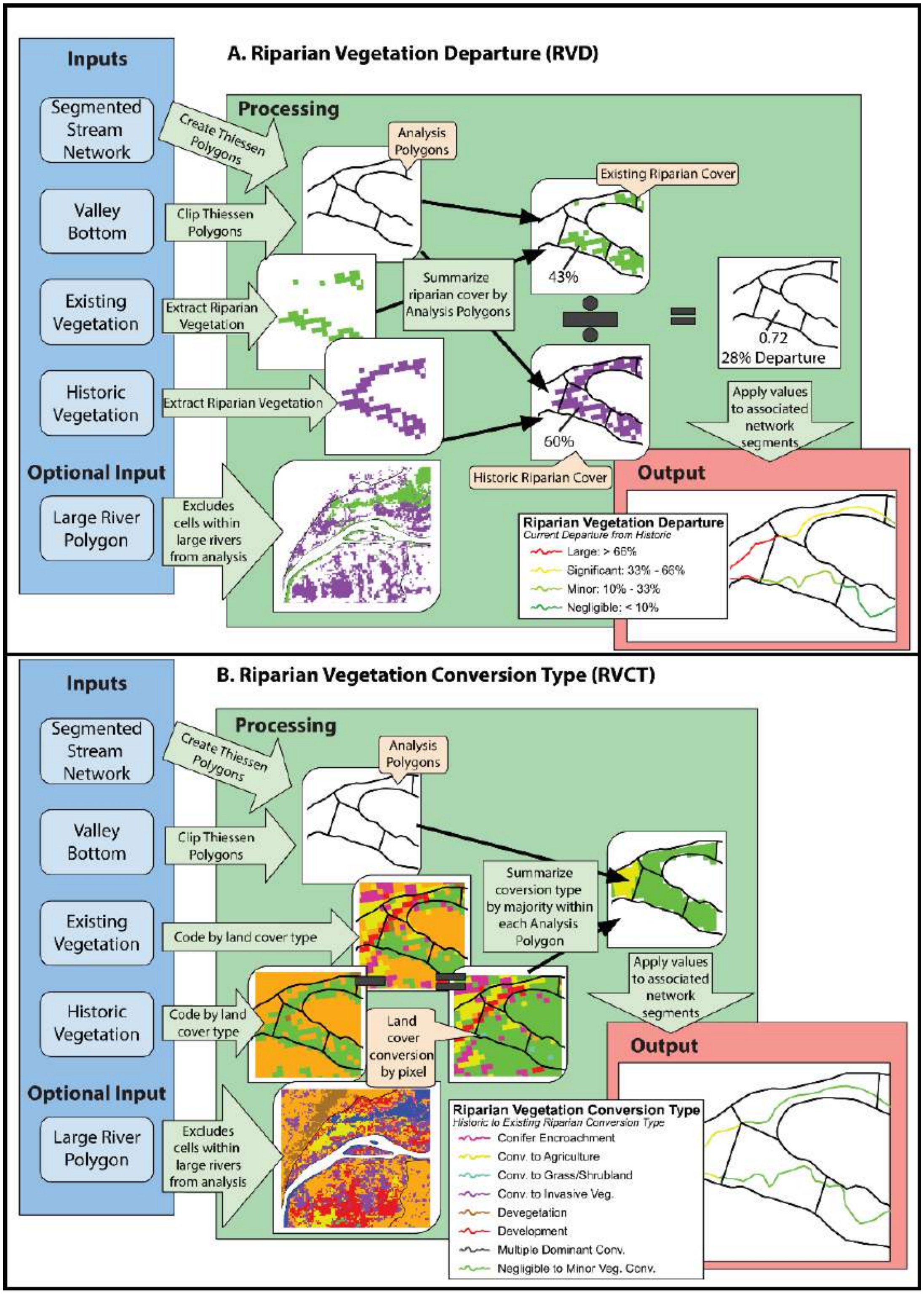
- Multiple large floods and simplified channel result in rapid downcutting and widening
- Riparian vegetation slowly recovering near channel; lack of floodplain structural elements inhibits establishment of riparian vegetation
- Prevalent cut banks and undercuts, boulder berms; boulder ribs become dominant structural element
- Restoration efforts focus on floodplain connection, riparian plantings, and instream habitat complexity

- Channel likely in state of equilibrium, but does not reflect historic sediment dynamics
- Stream has occasional access to historic flood channels; creates new secondary channels in areas with less gradient
- Water temperatures decreased
- Abundance of alder; cottonwood begins reestablishing where floodplain soils have been reworked

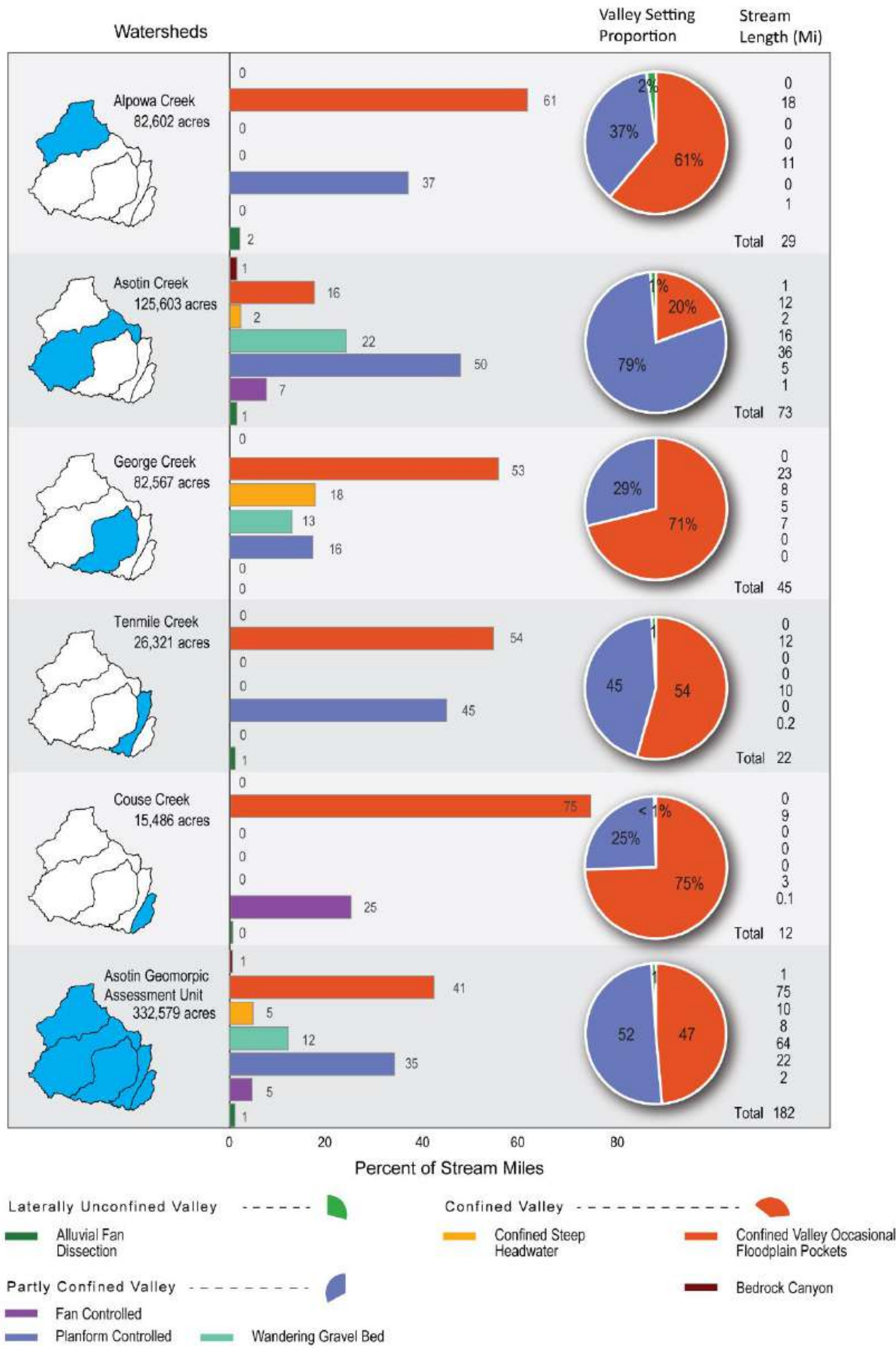
B) Partly confined, Planform controlled with occasional floodplain



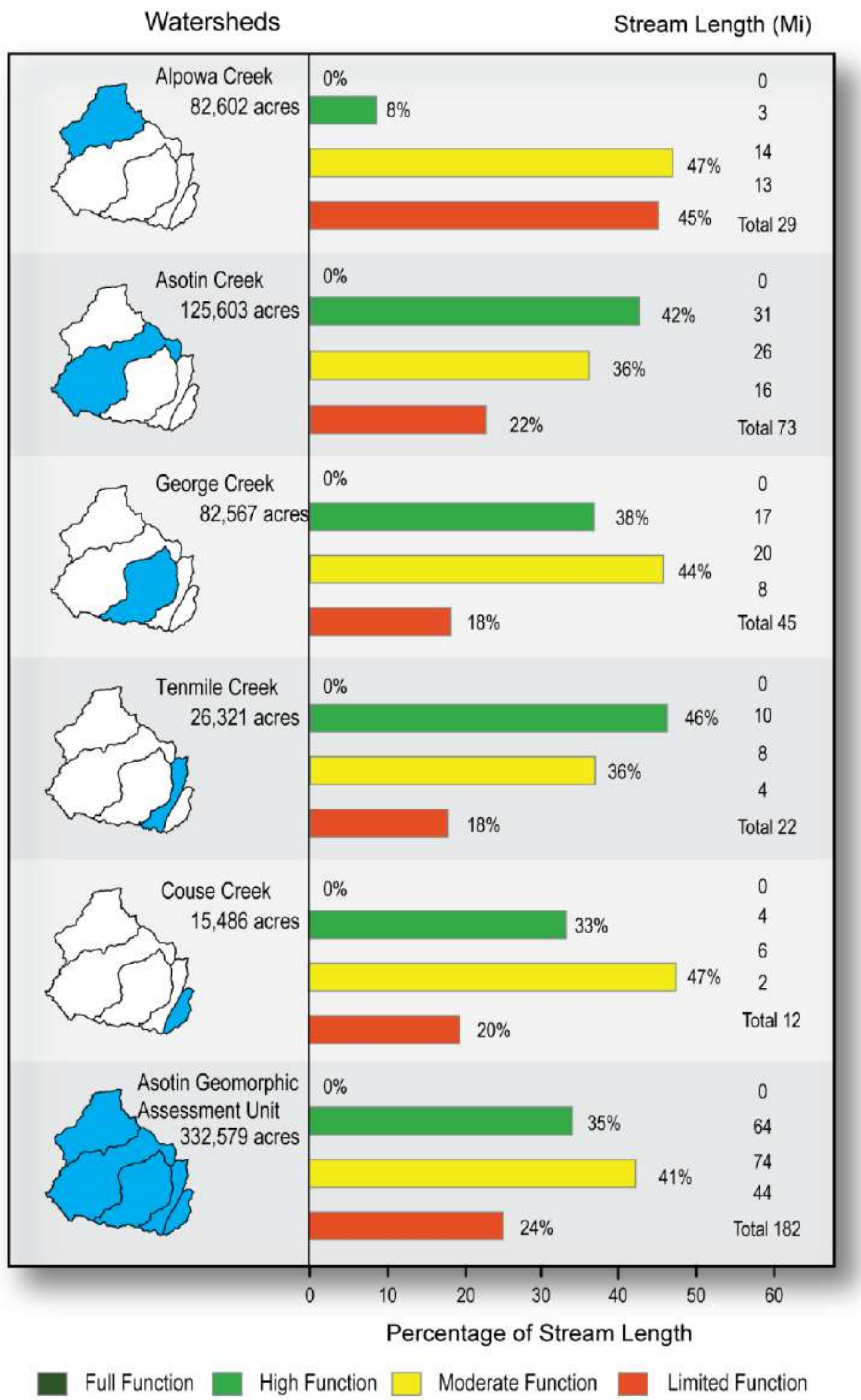
C) Partly confined, wandering gravel bed with discontinuous floodplain



Appendix C. 2. Flowchart showing the workflow of the a) Riparian Vegetation Departure index and b) Riparian Vegetation Conversion Type Classification (MacFarlane et al. 2017).

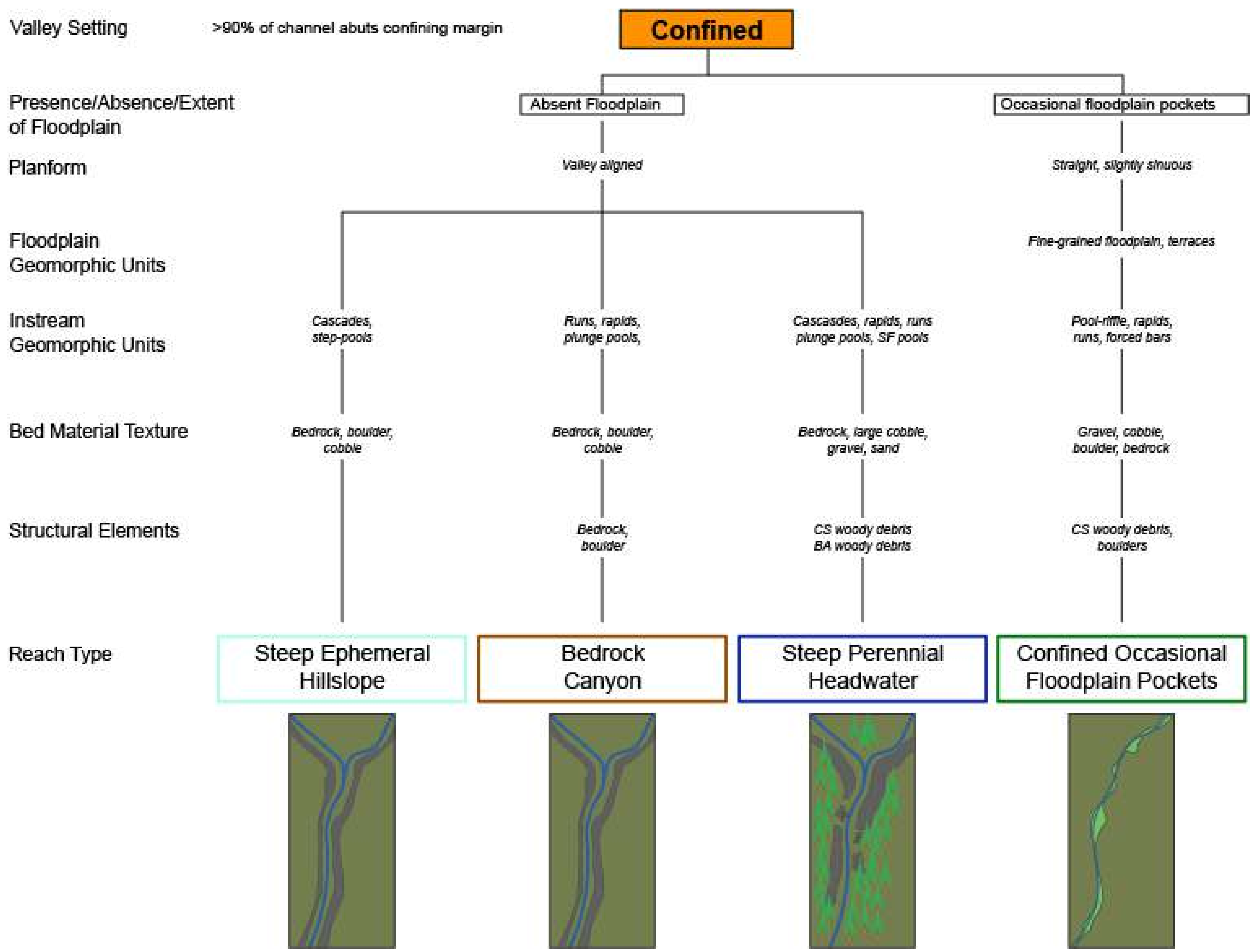


Appendix C. 3. Proportion and length (RMs) of valley setting and reach types by watershed for the perennial network.



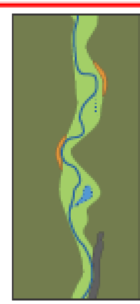
Appendix C. 4. Proportion and length (RMs) of the perennial stream network by geomorphic function type and target watershed.

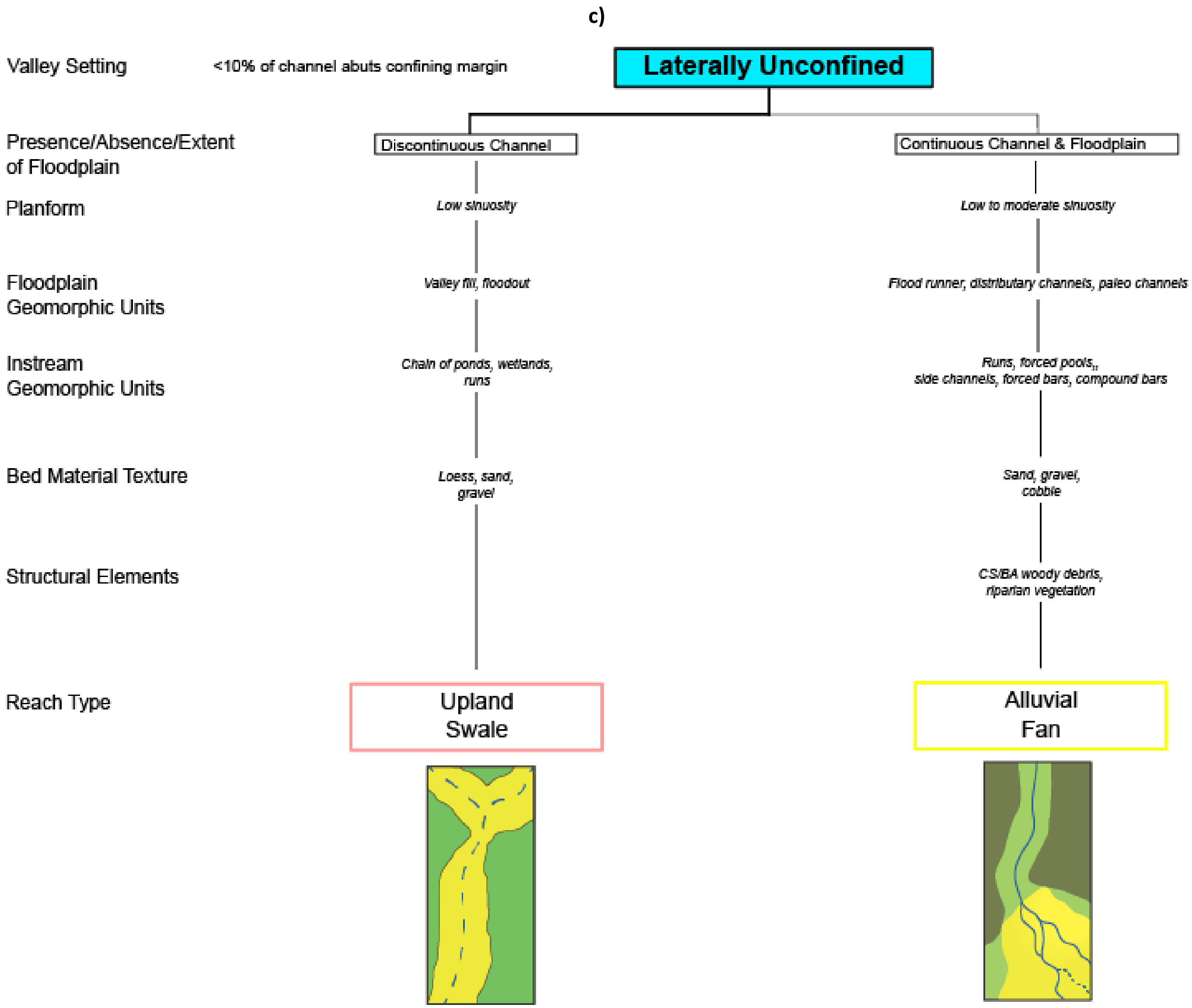
a)


Valley Setting
>90% of channel abuts confining margin
Confined
Presence/Absence/Extent of Floodplain
Absent Floodplain
Occasional floodplain pockets
Planform
Valley aligned
Straight, slightly sinuous
Floodplain Geomorphic Units
Fine-grained floodplain, terraces
Instream Geomorphic Units
Cascades, step-pools
Runs, rapids, plunge pools,
Cascasdes, rapids, runs plunge pools, SF pools
Pool-riffle, rapids, runs, forced bars
Bed Material Texture
Bedrock, boulder, cobble
Bedrock, boulder, cobble
Bedrock, large cobble, gravel, sand
Gravel, cobble, boulder, bedrock
Structural Elements
Bedrock, boulder
CS woody debris BA woody debris
CS woody debris, boulders
Reach Type
Steep Ephemeral Hillslope
Bedrock Canyon
Steep Perennial Headwater
Confined Occasional Floodplain Pockets

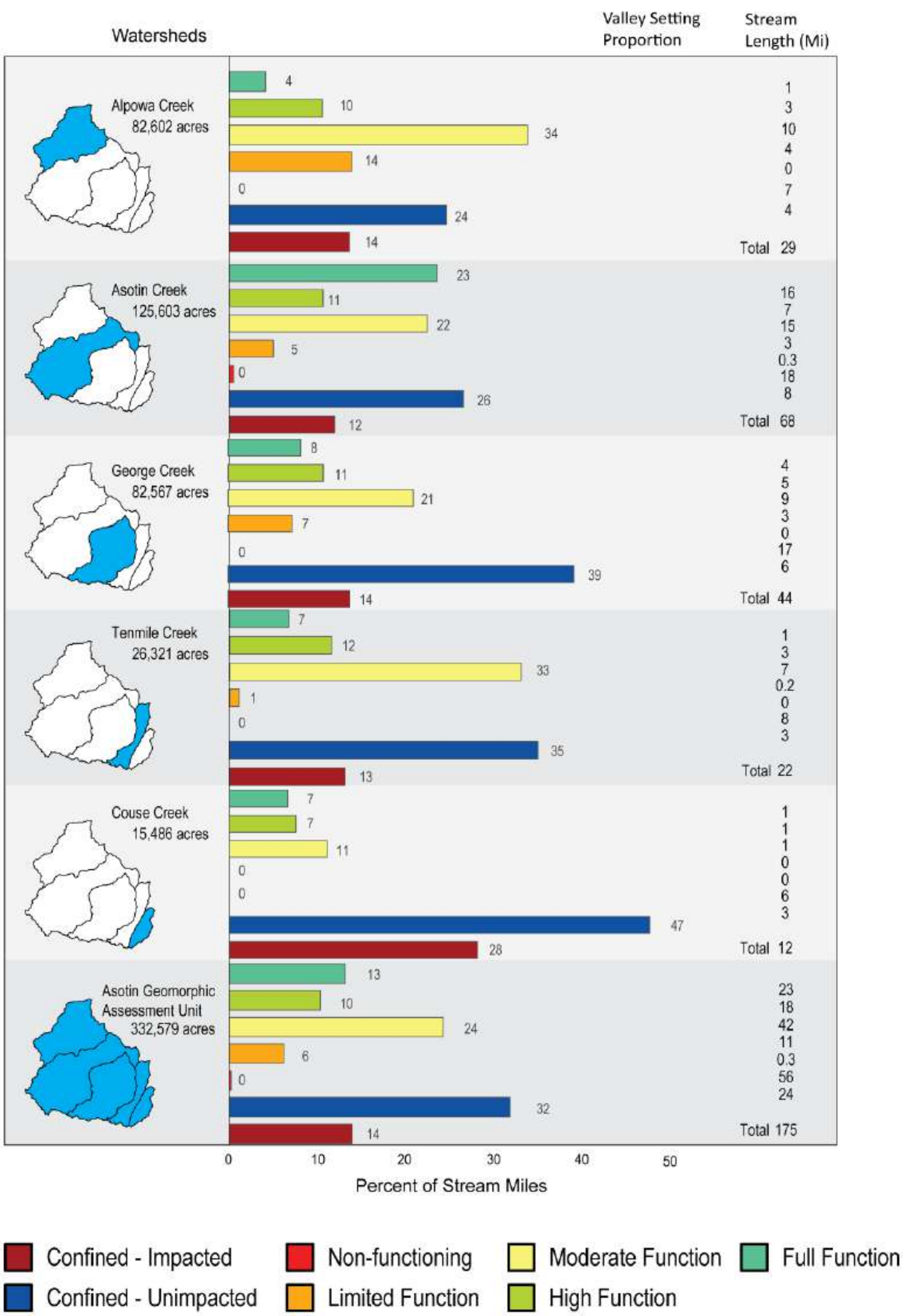
b)

Valley Setting	10-90% of channel abuts confining margin	**Partly Confined**	
Presence/Absence/Extent of Floodplain	Planform controlled, discontinuous floodplain		Fan controlled, discontinuous floodplain
Planform	*Moderate sinuosity, 10-50% confined*	*Low to moderate sinuosity, alvusive, jump channel changes, 10-50% confined*	*Low to moderate sinuosity, often abuts fans, 60-90% confined*
Floodplain Geomorphic Units	*Secondary channels, terraces, paleo channels, chute cutoffs flood runners, backwaters, islands*	*Fine-grained uniform floodplain, secondary channels, anabranches paleo channels, flood channels, chute cutoffs, sheets, islands*	*Flood runners, backwater, debris fans, alluvial fans*
Instream Geomorphic Units	*Pool-riffle, runs, rapids, cutbanks, forced pools, forced bars*	*Pool-riffle, runs, rapids, forced pools, compound bars chutes, gravel/cobble sheets, diagonal bars*	*Runs, rapids, cutbanks, forced pools, forced bars*
Bed Material Texture	*Cobble, gravel, boulder*	*Cobble, gravel, boulder*	*Cobble, gravel, sand*
Structural Elements	*LWD, boulder ribs, riparian vegetation, beaver dams*	*LWD, riparian vegetation, debris jams, boulder ribs, beaver dams*	*LWD, roots, boulder ribs*
Reach Type	Planform Controlled with Discontinuous Floodplain	Wandering Gravel Bed with Discontinuous Floodplain	Fan Controlled with Discontinuous Floodplain





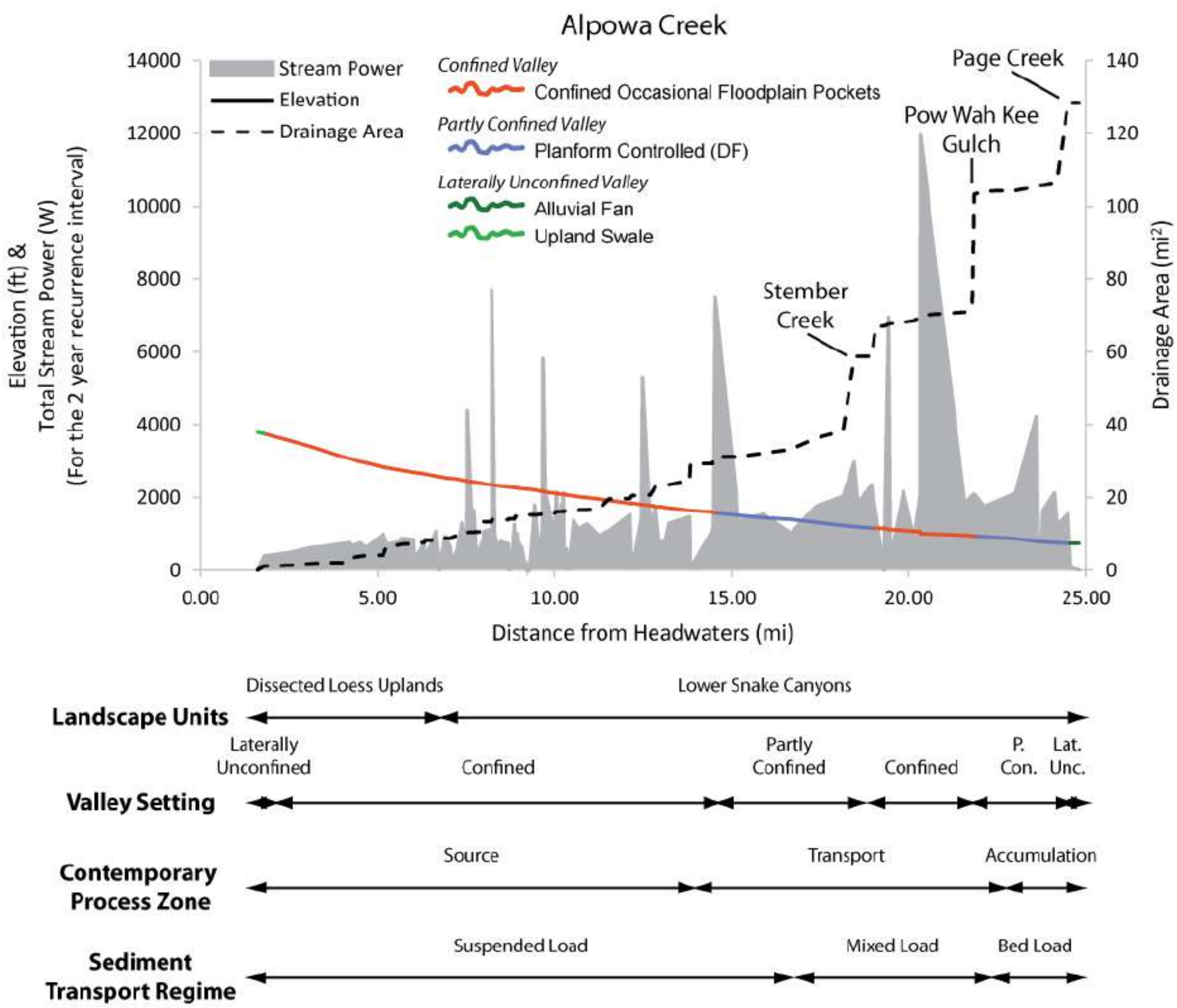
Appendix C. 5. Reach type decision tree describing the character of each reach type and how it is differentiated from other reach types within three valley setting: a) confined, b) partly confined, and c) laterally unconfined.



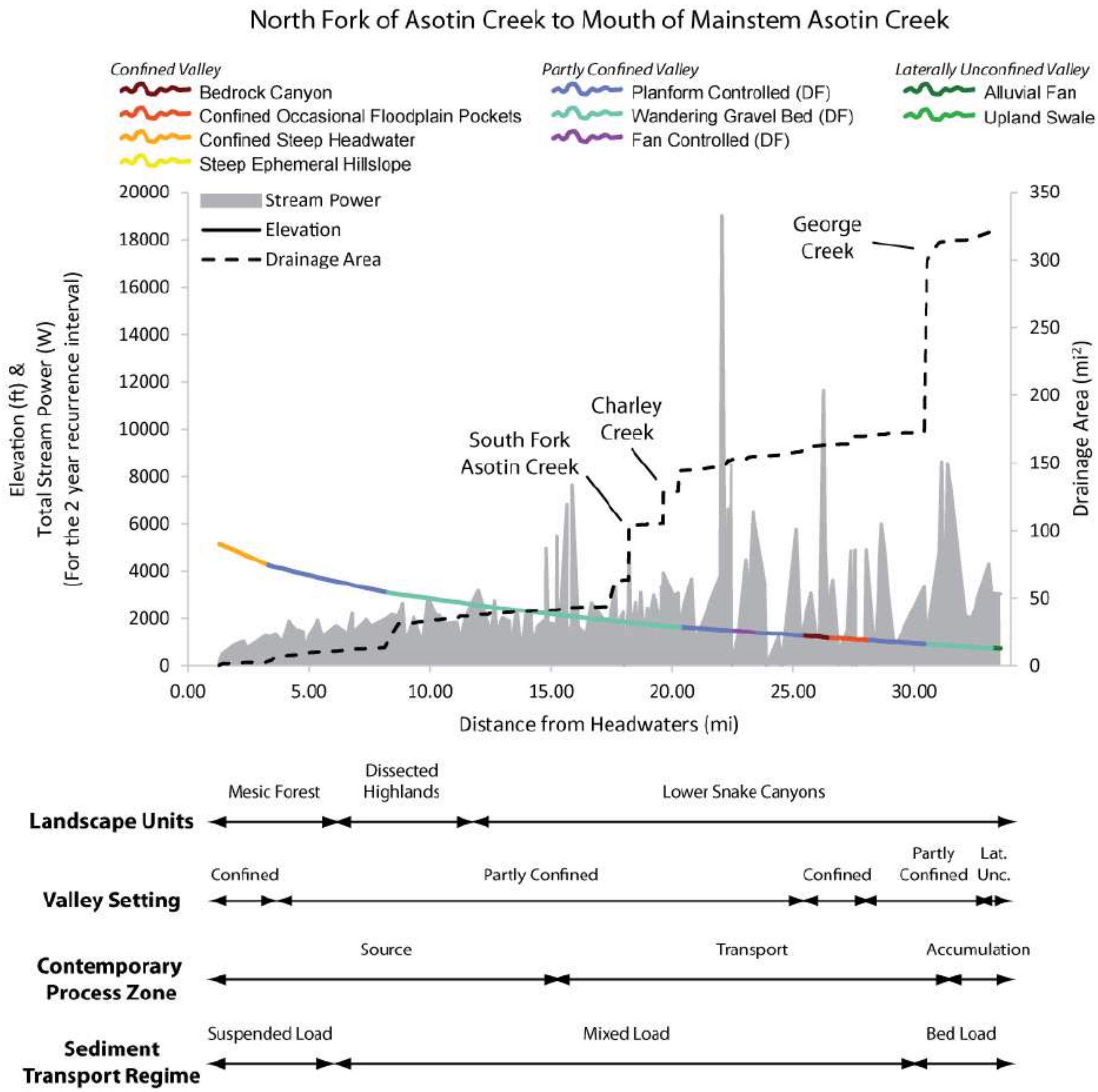
Appendix C. 6. Proportion and length (RMs) of the perennial stream network by riparian function and target watershed.

Appendix C. 7. Long profiles of a) Alpowa Creek, b) Asotin Creek (including North Fork Asotin Creek), c) Couse Creek, and d) Tenmile Creek.

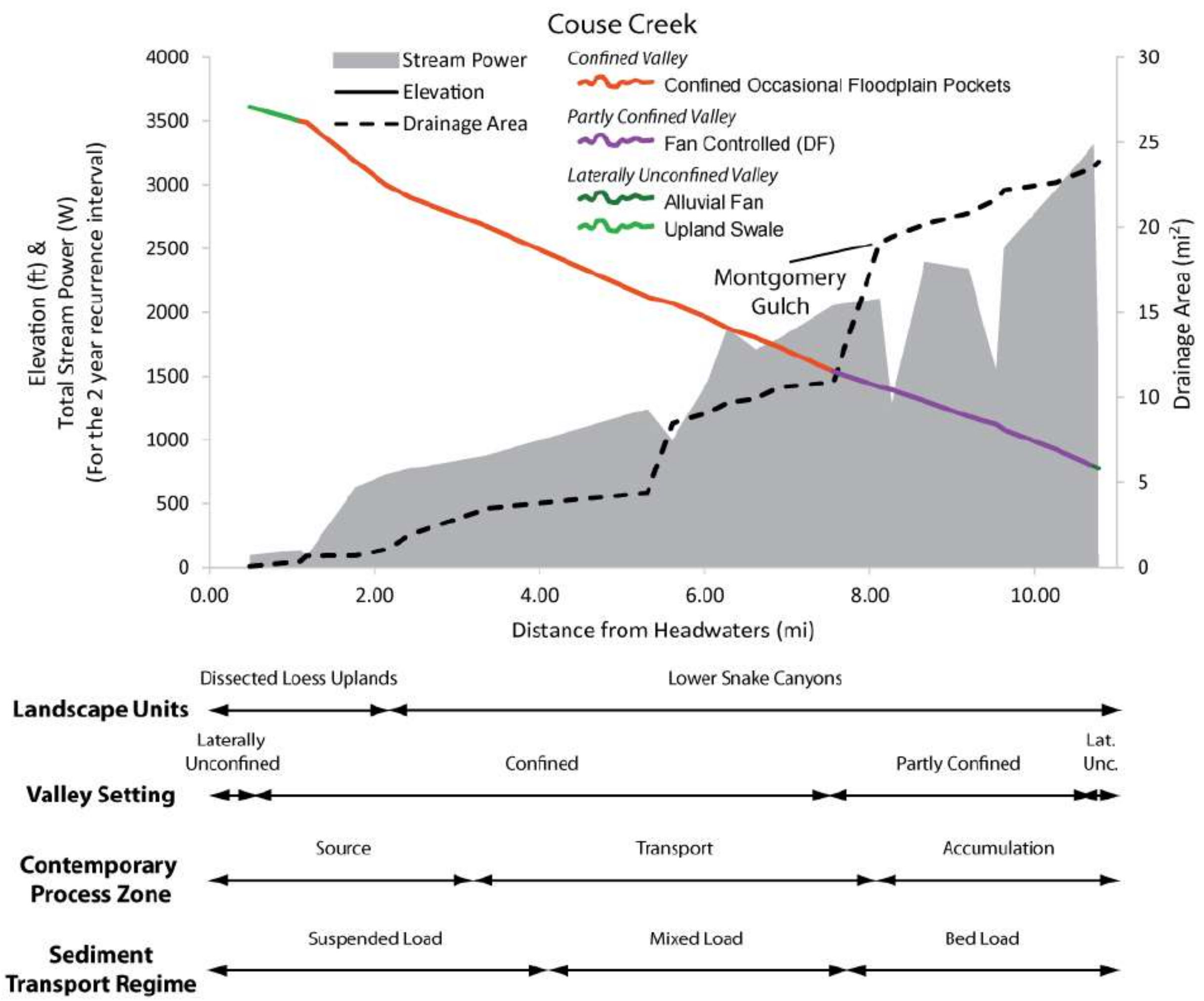
a) Alpowa Creek begins in an unconfined valley in the dissected loess uplands. After passing over the first exposed basalt layer (Grande Ronde member), stream gradient increases, and valley confinement increases. The stream quickly dissects the through the basalt, entering the lower snake canyons and works through its own alluvium, primarily consisting of fines, sands, and some small gravels. The valley becomes partly confined and begins transporting a mixed sediment load as drainage are and stream power increase. Pulses in stream power are caused by pinch points in the valley bottom and result in an alternative net positive and net negative sediment flux. Bed load contribution to the sediment regime is low until near the confluence with Pow Wah Kee Gulch.



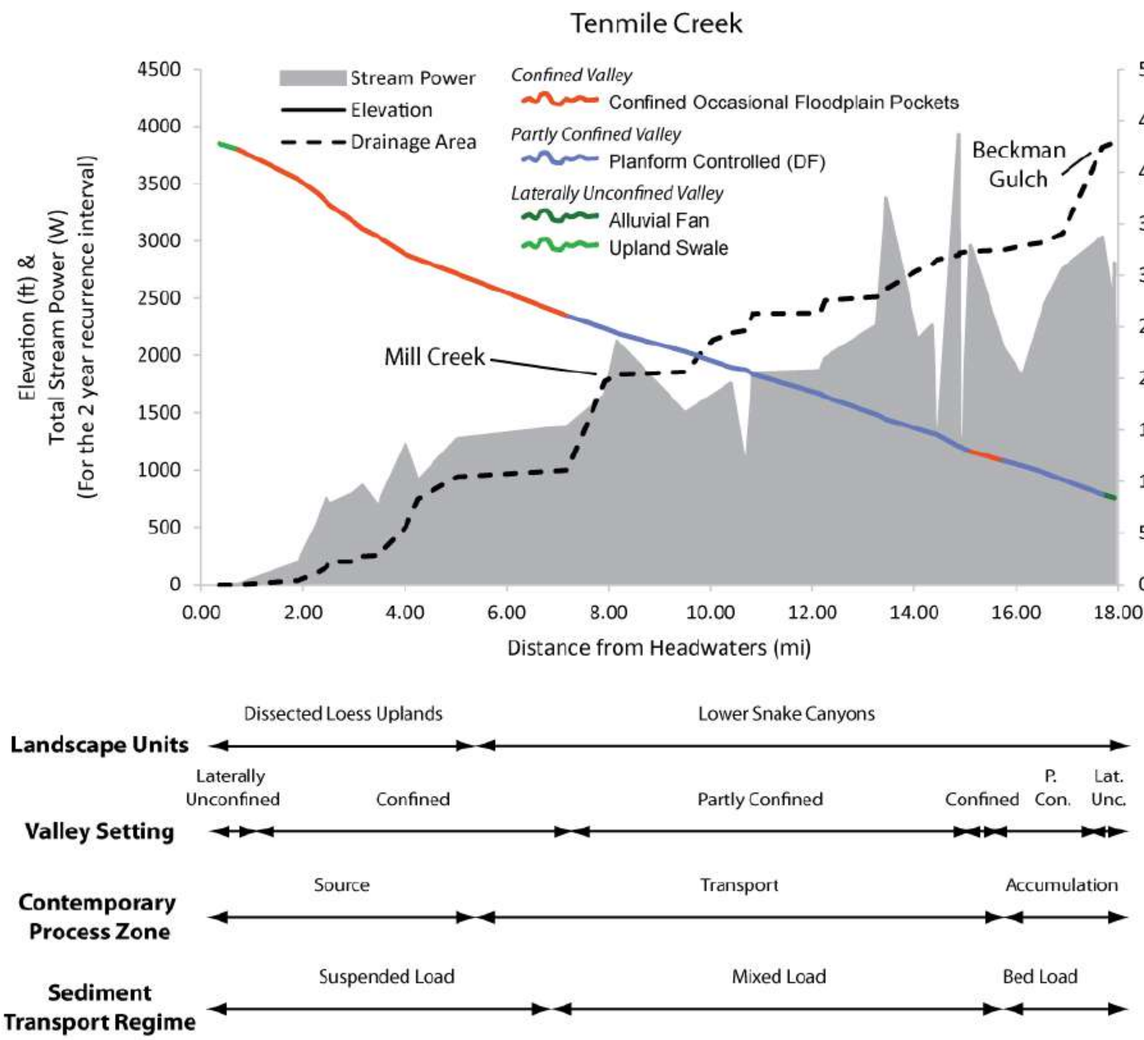
b) Asotin Creek begins as confined steep headwaters in the mesic forest of the Blue Mountains. The three forks of the North Fork all merge within 0.2 miles of each other, increasing drainage area, bed load sediment, and valley width. After entering the lower Snake Canyons, stream gradient decreases as the stream works the alluvial valley and transports a relatively even mix of bed load and suspended load. Bed load contributions to the sediment regime increase at the confluence with the South Fork of Asotin Creek, while Charley Creek contributes higher proportions of suspended load. Valley confinement increases slightly after the confluence with Charley Creek and the stream dissects older basalt flow members. The Wanapum basalt member is exposed in the bedrock canyon, creating a high valley constriction and greatly increasing stream power for a short section. Bed load transport and accumulation increases after the confluence with George Creek.

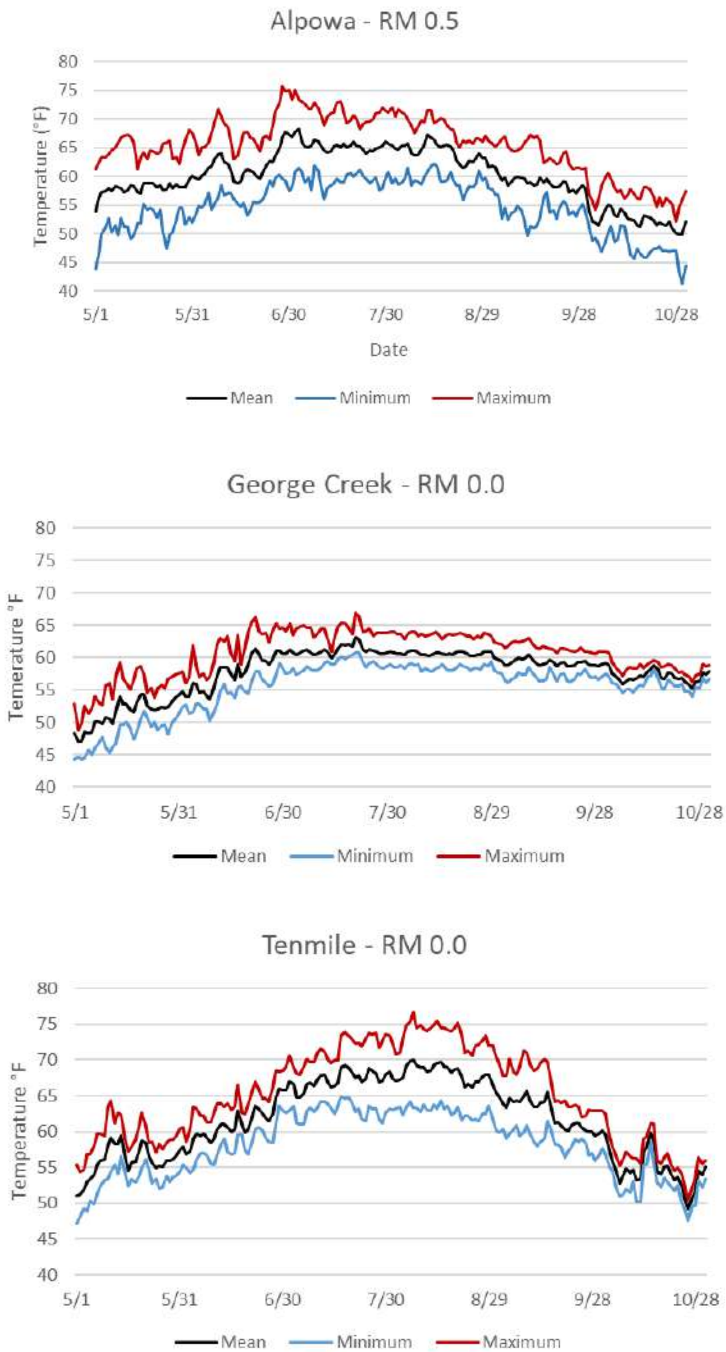


c) The Couse Creek drainage begins unconfined in the dissected loess uplands with a relatively shallow slope, contributing primarily fine sediments. Stream gradient greatly increases as the stream passes over the first exposed basalt layer (Saddle Mountain member) and enters a confined valley. Stream power gradually increases through the confined section and transports a mixed sediment load until the confluence with Montgomery Gulch. As the valley widens and drainage area increases, sediment accumulates in the valley bottom and bed load transport becomes the primary sediment regime.

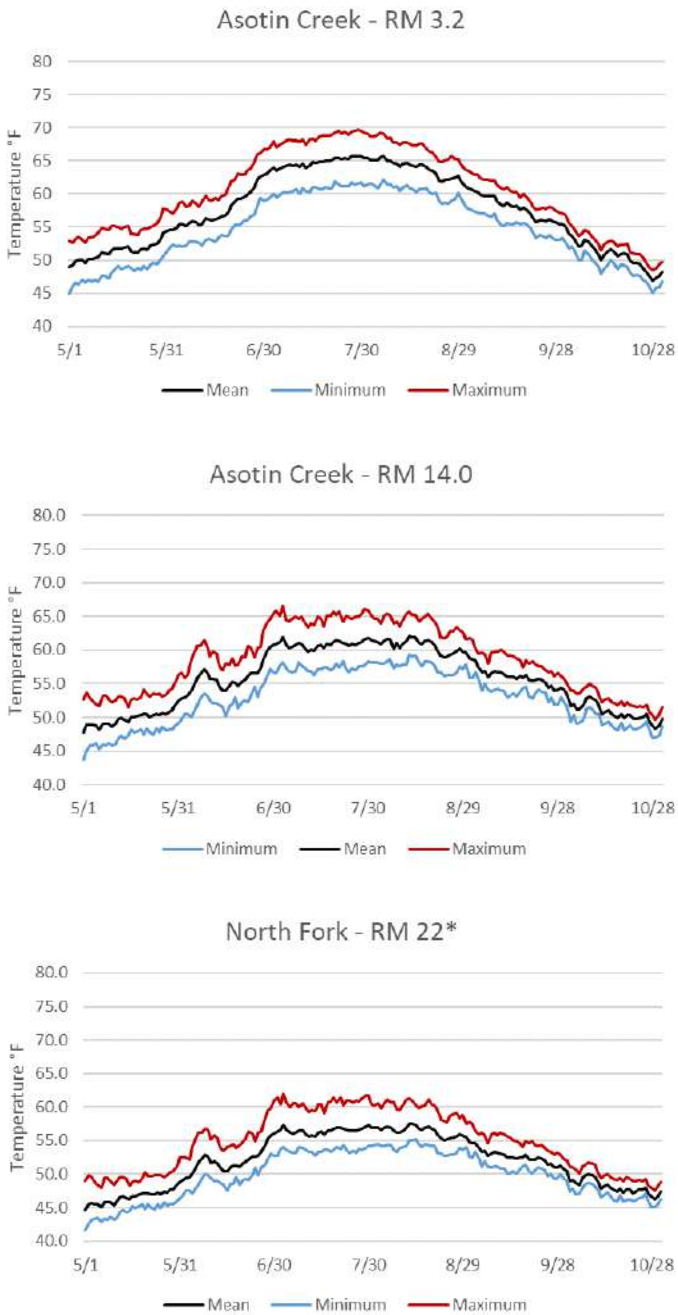


d) Tenmile Creek begins unconfined in the dissected loess uplands. After the stream flows over the first exposed basalt layer (Saddle Mountain member), valley confinement, stream gradient, and stream power increase until the confluence with Mill Creek. The valley widens, but the width is variable until the mouth of the creek causing pulses of increased stream power. The pinch points caused by valley width variability creates alternating sections of sediment erosion and deposition with a negative net sediment flux until the confluence with the Snake River.





Appendix C. 8. Average mean, minimum, and maximum stream temperature from May 1 to October 30 for Alpowa, George, and Tenmile Creeks: 2011-2016. Date represent the lower river mile (RM) of each stream. All data are from DOE stream gauges. See Table 4 for site names.



Appendix C. 9. Average mean, minimum, and maximum stream temperature from May 1 to October 30: 2013-2016. Asotin Creek mainstem just above George Creek at river mile (RM) 3.2, Asotin Creek below the confluence of South Fork and Asotin Creeks (RM 14), and North Fork Asotin Creek (RM 22*). North Fork RM 22* represents the distance from the mouth of Asotin Creek to 6.8 miles upstream on North Fork Creek. Data are from the DOE stream gauge above George Creek and IMW temperature surveys.

APPENDIX D – NETWORK TOOLS BACKGROUND INFORMATION

We used a variety of network analysis tools to support the geomorphic assessment and better describe the watershed condition as it relates to fish habitat and stream function. The following provide more detail on how the network tools were used and where to access free GIS code and tool kits.

RIPARIAN PRODUCTS

Riparian Vegetation Departure (RVD) index

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Planning & Restoration

DESCRIPTION

Riparian vegetation condition controls the delivery of sediment, water, nutrients, and structure (e.g. wood). Much of the ability to conserve and restore streams is also dependent on riparian condition. Therefore, a watershed network assessment of riparian vegetation condition is essential for the development of stream management options. The Riparian Vegetation Departure index (RVD) characterizes riparian vegetation departure from pre-European settlement condition (Macfarlane et al. In Press).

To estimate this departure at the reach-level, the Valley Bottom Extraction Tool (V-BET; Gilbert et al. 2016) is used to delineate the valley bottom, which is then separated into analysis polygons that act as the boundaries for characterizing vegetation departure (Figure 1). The proportion of each area that contains native riparian vegetation (existing and historic) is calculated (Figure 1). An estimate of riparian condition is then made by dividing the historic proportion by the existing proportion (Figure 1). The quality of this ratio depends on the accuracy of the vegetation coverage datasets, and whether the resolution of the data inputs is suitable for calculations at the reach scale. For outputs, the closer a value is to 0, the larger the departure from historic riparian coverage. High values (i.e., near or beyond 1.0) indicate that riparian communities are relatively intact (or even increasing). Each reach then is shown in terms of percent departure from historic cover (Figure 1).

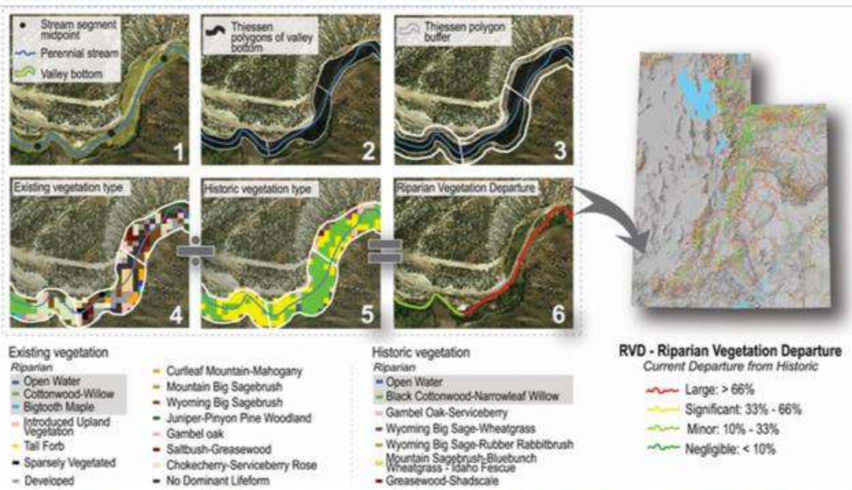

Figure 1. RVD index diagram showing how mid points of the stream network (1) are used to generate Thiessen polygons (2) and how these are buffered by the resolution of the vegetation data to ensure that all of the data lie within the valley bottom (3). The ratio of existing area of native riparian vegetation (4) to historic area of native riparian vegetation (5) is used to calculate departure from historic condition scores and map the reaches (6).

Citations: Gilbert, J. T., W. W. Macfarlane, and J. M. Wheaton. 2016. The Valley Bottom Extraction Tool (V-BET): A GIS tool for delineating valley bottoms across entire drainage networks. Computers & Geosciences 97:1-14.

Macfarlane, W. W., J. T. Gilbert, M. L. Jensen, J. D. Gilbert, N. Hough-Snee, P. A. McHugh, J. M. Wheaton, and S. N. Bennett. In Press. Riparian vegetation as an indicator of riparian condition: Detecting departures from historic condition across the North American West. Journal of Environmental Management.

FINDINGS AND USES

The Riparian Vegetation Departure (RVD) index is able to describe and depict current vs. historic riparian cover conditions at the reach-scale.

RVD output can help managers i.d. and prioritize potential actions (e.g., conserve intact areas, restore areas that have been most altered from historic condition).

QUICK FACTS

Contact: Wally Macfarlane, wally.macfarlane@usu.edu, (435) 512-1839

Development Team: Joe Wheaton, Jordan Gilbert, Josh Gilbert, Martha Jensen, Peter McHugh, Nate Hough-Snee, Steve Bennett, Chalese Hafen, Justin Jimenez

Current Status: Operational; Published

Funding source: BLM, State of Utah, ISEMP

URL: http://etal.joewheaton.org/rcat

3

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Appendix D. 1 Description of the riparian vegetation departure tool (RVD) and source of GIS code (Macfarlane et al. 2016, Macfarlane et al. 2018).

RIPARIAN PRODUCTS

Riparian Condition Assessment (RCA) tool

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Planning & Restoration

DESCRIPTION

The Riparian Condition Assessment (RCA) tool was developed to assess impacts on reach-scale (500-m) riparian condition across watersheds caused by three dominant stressors:

(1) riparian vegetation departure from historical condition,

(2) land use intensity within the valley bottom, and

(3) floodplain fragmentation due to infrastructure within valley bottoms.

A fuzzy inference system, which explicitly accounts for model uncertainty, was used with freely, nationally-available data to combine the three stressors and estimate reach-scale riparian floodplain condition for perennial streams and rivers, in Utah and twelve watersheds of the interior Columbia River Basin (CRB), USA (Figure 1). A comparison of modeled reaches with field observations yielded 87% agreement, indicating that modeled riparian conditions reflect actual conditions. Model outputs showed that, of the streams and rivers with floodplains, roughly 49% have at least moderately impaired riparian condition.

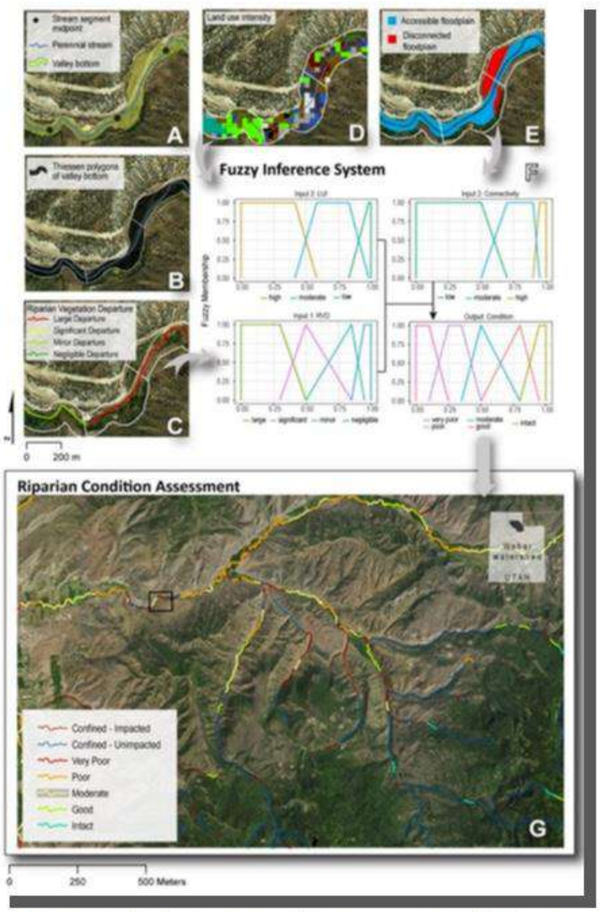

Figure 1. Within the Riparian Condition Assessment Tool, mid-points of the drainage network (A) are used to generate Thiessen polygons (B). The riparian vegetation departure index outputs (C) are combined with land use intensity (D) and floodplain accessibility outputs (E) within a Fuzzy Inference System (F) to produce a segmented drainage network containing riparian condition assessment scores (G).

FINDINGS AND USES

The maps and data RCA produces can be used to help identify which watersheds and portions thereof should be targeted for conservation and restoration.

RCA is capable of supporting regional planning and decisions about sustainable river and watershed management across Utah and the Columbia River Basin.

QUICK FACTS

Contact: Wally Macfarlane, wally.macfarlane@usu.edu, (435) 512-1839

Development Team: Joe Wheaton, Jordan Gilbert, Josh Gilbert, Carl Saunders, Nate Hough-Snee, Chalese Hafen, Justin Jimenez

Current Status: Operational, in review (as of 4/19/17)

Funding source: BLM, State of Utah, ISEMP

URL

http://etal.joewheaton.org/rcat

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Appendix D. 2 Description of the riparian vegetation condition assessment tool (RCA) and source of GIS code (Macfarlane et al. 2016, Macfarlane et al. 2018).

RIPARIAN PRODUCTS

Beaver Restoration Assessment Tool (BRAT)

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Planning & Restoration

DESCRIPTION

Beaver are becoming more broadly appreciated for their utility as an ecosystem engineer capable of restoring streams, rivers, and wetlands to the benefit of numerous flora and fauna, including salmon and steelhead (Bouwes et al. 2016). Recently, Utah State University develop a spatially explicit network model called the Beaver Restoration Assessment Tool (BRAT) to help assess the potential for using beaver as a stream conservation and restoration agent at the watershed scale.

BRAT models the capacity of the landscape to support dam-building activity by beaver (Macfarlane et al. 2017). Capacity estimates come from five main lines of evidence: (1) a reliable water source; (2) stream bank vegetation conducive to foraging and dam building; (3) vegetation within 100 m of edge of stream to support large beaver colonies; (4) likelihood that dams could be built across the channel during low flows; and (5) the likelihood that a dam is capable of withstanding typical floods. For assessment, BRAT combines information on: A) existing and historic capacity, B) riparian habitat condition and recovery potential, and C) probabilities of potential conflict with humans, and then assigns stream segments into different beaver conservation and restoration categories (Figure 1). BRAT has been run with existing GIS datasets across Utah and the interior Columbia River Basin (http://brat.joewheaton.org/).

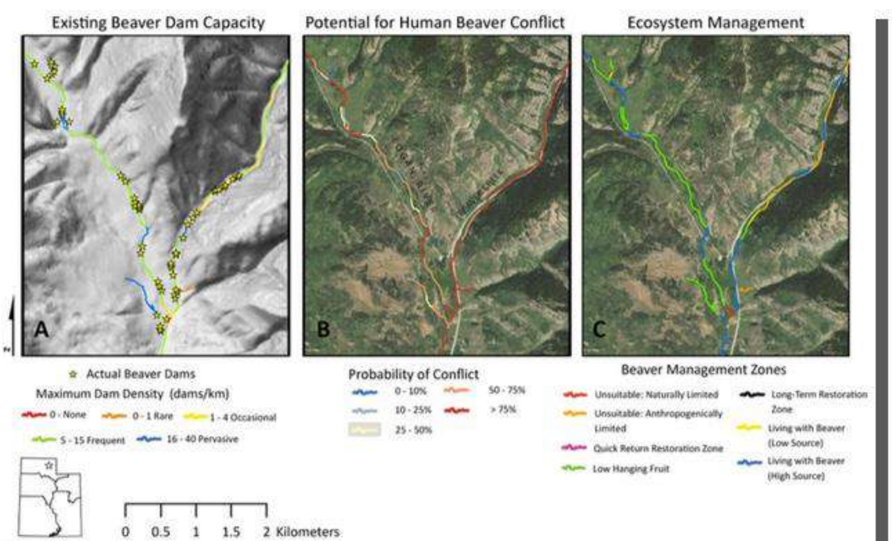

Figure 1. Example of BRAT outputs: A) existing beaver dam capacity, B) potential for human-beaver conflict and C) beaver management zones.

FINDINGS AND USES

BRAT's beaver dam density and total maximum dam capacity estimates compare favorably to actual distributions, even across a large, climatically and physiographically diverse landscapes where water and/or wood may be locally limiting.

BRAT helps assess where beaver may be a viable restoration tool or where they may be seen as a nuisance requiring mitigation or relocation.

QUICK FACTS

Contact: Wally Macfarlane,

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Development Team: Joe Wheaton, Nick Bouwes, Martha Jensen, Jordan Gilbert, Josh Gilbert, Nate Hough-Snee, John Shivik, Chalese Hafen

Current Status: Operational, published

Funding source: State of Utah, ISEMP, CHaMP

URL: http://brat.joewheaton.org/

Citations: Bouwes, N., N. Weber, C. E. Jordan, W. C. Saunders, I. A. Ta am, C. Volk, J. M. Wheaton, and M. M. Pollock. 2016. Ecosystem experiment reveals benefits of natural and simulated beaver dams to a threatened population of steelhead (*Oncorhynchus mykiss*). Scientific Reports 6:28581.

Macfarlane, W. W., J. M. Wheaton, N. Bouwes, M. L. Jensen, J. T. Gilbert, N. Hough-Snee, and J. A. Shivik. 2017. Modeling the capacity of riverscapes to support beaver dams. Geomorphology 277:72-99.

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Appendix D. 3. Description of the beaver restoration assessment tool (BRAT) and source of GIS code (Macfarlane et al. 2016, Macfarlane et al. 2018).

APPENDIX E – MAPS WITH VALLEY EXTENT AND CONFINING FEATRUES FOR EACH RIVER MILE FOR THE EXTENT OF 1 M LIDAR.

Appendix E. 1. See separate attachment (100 + maps)

APPENDIX F. SUMMARY OF ASSESSMENT FINDINGS AND RECOMMENDATIONS FOR RESTORATION STRATEGIES

Appendix F. 1. Summary of the Asotin County Assessment results by restoration reach and recommended restoration strategies for Alpowa and Asotin Creeks and their tributaries. Map number refers to the stream and section number of Appendix E of the complete assessment report. Appendix E provides 1 m LIDAR imagery, and delineation of valley extent and anthropogenic confining features by river mile (RM) for the mainstem of each study creek. See figures and appendix in the report for definitions of the color codes.

Map	Watershed	Subwatershed	Tributary	Reach ID	RM Start	RM End	Reach Length	Valley Setting *Appendix A.10* (Unconfined, Partly Confined, Confined)	Dominant Reach Type *Appendix A.10* (Alluvial Fan, Canyon, Confined, Fan Controlled, Headwater, Planform, Wandering)	Hydrologic Regime *Appendix A.5* (Groundwater, Snow-rain, Snowmelt)	Geomorphic Function *Appendix A.12-13* (Limited, Moderate, High)	Disconnected Floodplain *Appendix E* (Low, High)	Riparian Function *Appendix A.15-18* (Impacted, Unimpacted, Limited, Moderate, High, Full)	Recovery Potential *Appendix A.14* (Low, Moderate, High)	Dominant Species *Appendix A.8* (Steelhead, Chinook, Lamprey, Bull Trout)	Fish Use *Figure 9-10* (Spawning, Rearing, Migration)	Recommendation
E.1.	**Alpowa**	mainstem	-	AP_01	0.0	0.6	0.6										assess predation, riparian mgt, increase complexity
E.1.	**Alpowa**	mainstem	-	AP_02	0.6	13.9	13.3										reconnect habitats, promote overbank flow, habitats, riparian mgt, increase complexity
n/a	**Alpowa**	mainstem	-	AP_03	13.9	19.6	5.7										promote overbank flow, habitats, riparian mgt, increase complexity, beaver mgt
n/a	**Alpowa**	Pow Wah Kee	-	PW_01	0.0	3.9	3.9										reconnect habitats floodplain, riparian mgt, increase complexity, beaver mgt
E.2.1	**Asotin**	mainstem	-	AC_01	0.0	0.4	0.4										reconnect habitats, promote overbank flow, riparian mgt, increase complexity
E.2.1	**Asotin**	mainstem	-	AC_02	0.4	7.3	6.9										reconnect habitats, promote overbank flow, riparian mgt, increase complexity
E.2.1	**Asotin**	mainstem	-	AC_03	7.3	8.3	1.0										increase complexity
E.2.1	**Asotin**	mainstem	-	AC_04	8.3	15.4	7.1										reconnect habitats, promote overbank flow, increase complexity
E.2.2	**Asotin**	Charley	-	CC_01	0.0	2.0	2.0										reconnect habitats, promote overbank flow, riparian mgt, increase complexity
E.2.2	**Asotin**	Charley	-	CC_02	2.0	7.9	5.9										assess old dams, promote overbank flow, riparian mgt, increase complexity, beaver mgt
E.2.2	**Asotin**	Charley	-	CC_03	7.9	13.0	5.1										increase complexity, beaver mgt
E.2.3	**Asotin**	North Fork	-	NF_01	0.0	0.8	0.8										reconnect habitats, promote overbank flow, increase complexity
E.2.3	**Asotin**	North Fork	-	NF_02	0.8	10.1	9.3										increase complexity, beaver mgt
n/a	**Asotin**	North Fork	South Fork	NF_03	0.0	2.3	2.3										increase complexity, beaver mgt
n/a	**Asotin**	North Fork	Middle Fork	NF_04	0.0	3.8	3.8										increase complexity, beaver mgt
n/a	**Asotin**	North Fork	North Fork	NF_05	10.1	17.4	7.3										increase complexity, beaver mgt
n/a	**Asotin**	North Fork	Cougar Creek	CG-01	0.0	3.2	3.2										increase complexity, beaver mgt
n/a	**Asotin**	North Fork	Lick	LC_01	0.0	0.2	0.2										reconnect habitats, promote overbank flow, increase complexity
n/a	**Asotin**	North Fork	Lick	LC_02	0.2	2.0	1.8								outside fish distribution	- - -	promote overbank flow, increase complexity, beaver mgt
n/a	**Asotin**	North Fork	Lick	LC_03	2.0	6.4	4.4									- - -	promote overbank flow, increase complexity, beaver mgt
E.2.4	**Asotin**	South Fork	-	SF_01	0.0	10.9	10.9										increase complexity, beaver mgt

Appendix F. 2. Summary of the Asotin County Assessment results by restoration reach and recommended restoration strategies for George, Couse, Tenmile Creeks, and their tributaries. Map number refers to the stream and section number of Appendix E of the complete assessment report. Appendix E provides 1 m LIDAR imagery, and delineation of valley extent and anthropogenic confining features by river mile (RM) for the mainstem of each study creek. See figures and appendix in the report for definitions of the color codes.

Column sub-categories (colour-coded): Valley Setting: *Unconfined, Partly Confined, Confined*; Dominant Reach Type: *Alluvial Fan, Canyon, Confined, Fan Controlled, Headwater, Planform, Wandering*; Hydrologic Regime: *Groundwater, Snow-rain, Snowmelt*; Geomorphic Function: *Limited, Moderate, High*; Disconnected Floodplain: *Low, High*; Riparian Function: *Impacted, Unimpacted, Limited, Moderate, High, Full*; Recovery Potential: *Low, Moderate, High*; Dominant Species: *Steelhead, Chinook, Lamprey, Bull Trout*; Fish Use: *Spawning, Rearing, Migration*

Map	Watershed	Subwatershed	Tributary	Reach ID	RM Start	RM End	Reach Length	Valley Setting *Appendix A.10*	Dominant Reach Type *Appendix A.10*	Hydrologic Regime *Appendix A.5*	Geomorphic Function *Appendix A.12-13*	Disconnected Floodplain *Appendix E*	Riparian Function *Appendix A.15-18*	Recovery Potential *Appendix A.14*	Dominant Species *Appendix A.8*	Fish Use *Figure 9-10*	Recommendation
E.3.1	**George**	mainstem	-	GC_01	0.0	9.2	9.2										reconnect habitats, promote overbank flow, riparian mgt, increase complexity,
E.3.1	**George**	mainstem	-	GC_02	9.2	10.3	1.1										promote overbank flow, riparian mgt, increase complexity, beaver mgt
E.3.1	**George**	mainstem	-	GC_03	10.3	20.1	9.8										increase complexity, beaver mgt
n/a	**George**	-	-	GC_04	0.0	1.6	1.6										increase complexity, beaver mgt
n/a	**George**	-	-	GC_05	0.0	1.6	1.6										increase complexity, beaver mgt
n/a	**George**	-	-	GC_06	0.0	4.7	4.7										increase complexity, beaver mgt
n/a	**George**	Pintler	-	PC_01	0.0	3.6	3.6										promote overbank flow, riparian mgt, increase complexity, beaver mgt
n/a	**George**	Pintler	-	PC_02	3.6	8.7	5.1										promote overbank flow, riparian mgt, increase complexity, beaver mgt
n/a	**George**	Pintler	-	PC_03	8.7	11.2	2.5										promote overbank flow, riparian mgt, increase complexity, beaver mgt
n/a	**George**	Pintler	Ayers	AY_01	0.0	0.9	0.9										promote overbank flow, riparian mgt, increase complexity
n/a	**George**	Pintler	Kelly	KC_01	0.0	1.4	1.4										promote overbank flow, riparian mgt, increase complexity
n/a	**George**	Pintler	unnamed	PC_04	0.0	1.6	1.6										promote overbank flow, riparian mgt, increase complexity
n/a	**George**	Pintler	-	PC_05	0.0	1.6	1.6								outside fish distribution	- - -	increase complexity, beaver mgt
E.4	**Couse**	Couse	-	CO_01	0.0	3.2	3.2										reconnect habitats (assess barrier), promote overbank flow, riparian mgt, increase complexity
E.4	**Couse**	Couse	-	CO_02	3.2	7.4	4.2										increase complexity, beaver mgt
n/a	**Couse**	Couse	-	CO_03	0.0	1.5	1.5								outside fish distribution	- - -	increase complexity
n/a	**Couse**	Couse	-	CO_04	3.2	6.9	3.7								outside fish distribution	- - -	increase complexity
E.5	**Tenmile**	Tenmile	-	TM_01	0.0	4.5	4.5										reconnect habitats (assess barrier), promote overbank flow, riparian mgt, increase complexity
E.5	**Tenmile**	Tenmile	-	TM_02	4.5	10.7	6.2										promote overbank flow, increase complexity, beaver mgt
E.5	**Tenmile**	Tenmile	-	TM_03	10.7	14.8	4.1										increase complexity, beaver mgt
n/a	**Tenmile**	Unnamed	-	TM_04	0.0	1.7	1.7										increase complexity, beaver mgt
n/a	**Tenmile**	Unnamed	-	TM_05	0.0	1.0	1.0										increase complexity, beaver mgt
n/a	**Tenmile**	Mill	-	MC-01	0.0	4.7	4.7										increase complexity, beaver mgt