January 2021
Tucannon Basin Habitat Restoration

Geomorphic Assessment and Restoration Prioritization

Prepared for Columbia Conservation District

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Habitat Restoration Prioritization and Conceptual Restoration Plans

Prepared for
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ABBREVIATIONS

1D	one-dimensional
2D	two-dimensional
CCD	Columbia Conservation District
cfs	cubic foot per second
CHM	Canopy Height Model
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
CWT	Coded-Wire Tag
DEM	digital elevation model
Ecology	Washington State Department of Ecology
ELJ	engineered log jam
ESA	Endangered Species Act
ESU	evolutionarily significant unit
FCRPS	Federal Columbia River Power System
ICTRT	Interior Columbia River Technical Recovery Team
LFH	Lyons Ferry Hatchery
LiDAR	Light Detection and Ranging
LSRCP	Lower Snake River Compensation Plan
LWM	large woody material
MaSA	major spawning area
MPG	major population group
NMFS	National Marine Fisheries Service
PA	project area
PIT	Passive Integrated Transponder
RM	river mile
SRSRB	Snake River Salmon Recovery Board
USGS	U.S. Geological Survey
USFWS	U.S. Fish and Wildlife Service
WDFW	Washington Department of Fish and Wildlife

1 Introduction

The Tucannon River is a tributary to the lower Snake River and supports Endangered Species Act (ESA)-listed summer steelhead, spring Chinook salmon, fall Chinook salmon, and bull trout, which have all been identified as aquatic focal species in the *Tucannon Subbasin Plan* (CCD 2004). Intensive restoration efforts in the Tucannon Basin in the last decade have been aimed at restoring salmonid populations and beneficial geomorphic processes. Sponsors of restoration in the basin include the Columbia Conservation District (CCD), the Snake River Salmon Recovery Board (SRSRB), and the Confederated Tribes of the Umatilla Indian Reservation (CTUIR). This Geomorphic Assessment and Restoration Prioritization report is the sequel to the *Tucannon River Geomorphic Assessment and Habitat Restoration Study* (Anchor QEA 2011a) and provides an assessment of current geomorphic conditions and restoration opportunities in the basin as well as an analysis of implemented restoration projects.

The restoration opportunities identified through this assessment represent the most effective restoration actions, based on current scientific data, to restore the geomorphic and ecological processes to the Tucannon River and floodplain to the highest extent possible. There are other interests and needs in the basin that represent constraints on the opportunities identified, but documents, such as the Wooten Wildlife Floodplain Management Plan (WDFW 2014), exist to express additional goals and interests. Therefore, this assessment does not make a specific attempt to identify those outside interests or the constraints they may have on restoration actions. Any restoration project that is pursued further will need to consider the constraints of individual interests in the basin and factor them in through collaboration and discussion with stakeholders.

The goals and objectives for this report were designed to address the goals and objectives for restoration within the Tucannon Basin. The limiting factors to salmonid survival in the Tucannon Basin were established in the *Tucannon Subbasin Plan* and include fine sediment, lack of woody debris, lack of key pool habitats, compromised riparian habitat, anthropogenic confinement of the floodplain, high summer water temperatures, and inadequate summer stream flow (CCD 2004). In response to these limiting factors in the Tucannon Basin, Anchor QEA developed the following basin goals and restoration objectives, shown in Table 1-1 and referenced throughout the report. Some of these goals address the limiting factors directly, while others, such as increasing storage of in-channel bedload sediment, are meant to help restore the impaired fluvial processes that are impacting the limiting factors. How these goals affect the limiting factors is discussed more in Sections 6, 7, and 8.

Table 1-1
Basin Goals and Restoration Objectives

Programmatic Goal	Restoration Goals and Objectives	Reference Section
Improve floodplain connectivity	The available 5-year recurrence floodplain is connected at the 2-year event	Appendix F and Section 10
Develop a high-functioning riparian corridor	The available riparian zone, as defined in Section 10 and Appendix K, will be vigorously growing with native deciduous species	Appendix K and Section 10
Increase channel complexity at low-winter flows	Low-winter flow complexity to levels of current 90th percentile of basin	Appendix G and Section 10
Increase channel complexity during spring and winter peaks	Mean-winter and 1-year flow complexity to levels of current 90th percentile of basin	Appendix G and Section 10
Increase quantity of pools	Increased pool frequency	Not included in this document due to incomplete data
Improve quality of pools	Large, deep, channel-spanning pools	Not included in this document due to incomplete data
Increase temporary storage of in-channel bedload sediments	No river segments significantly above the excess transport capacity regression line	Appendix H and Section 10

Note: Table 8-1 of this assessment provides more details on specific targets and assessment methods for each of these goals.

The analyses of this assessment were created to provide the information needed to meet the habitat targets and goals of the objectives. To that end, analyses were developed with the following goals:

1. Use the available data to measure the key components of the habitat targets and basin goals including:
    a. Floodplain Connectivity: measure the existing connected floodplain and potential floodplain targets and determine floodplain potential.
    b. Channel Complexity: Measure channel complexity at a variety of flow conditions and determine which reaches are complex and which are not.
    c. Transport Capacity: Determine where the rivers of the Tucannon Basin have too much stream power for the maintenance of natural geomorphic processes of sediment transport.
    d. Gravel Augmentation Plan: Determine and target reaches and project areas that would receive most geomorphic benefit from additional gravel supply.
2. Prioritize areas for restoration and identify restoration opportunities that can provide the most benefit and uplift to habitat for the focal species through restoration of natural geomorphic processes.
3. Provide the data on key components of habitat targets for future evaluation, target setting, and accomplishment tracking for each of these key metrics.

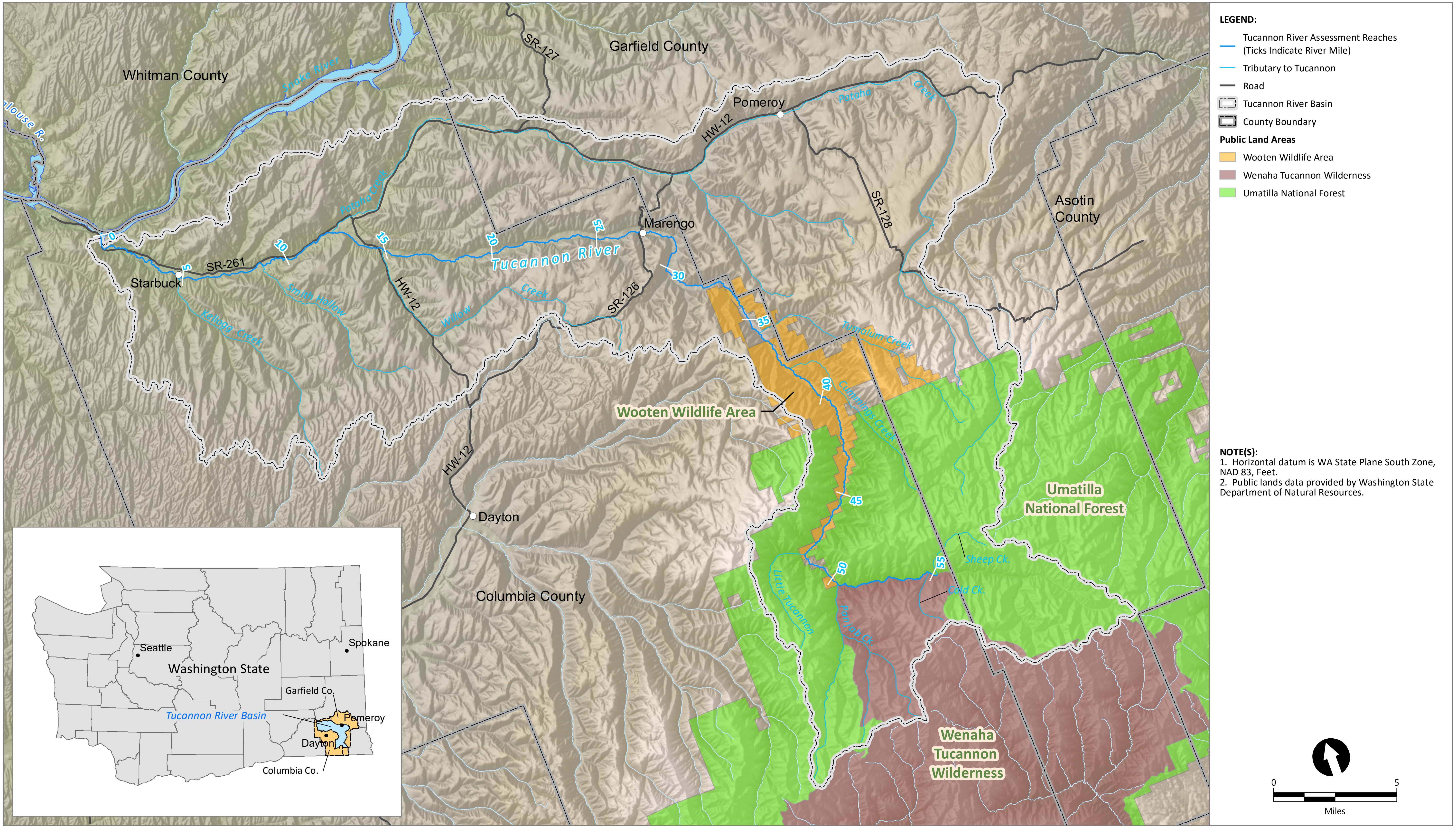
2 Basin Overview

The Tucannon Basin is located in Columbia and Garfield counties in the southeast corner of Washington State (Figure 2-1). The main channel is approximately 58 miles long and drains approximately 503 square miles from its headwaters in the Blue Mountains and Umatilla National Forest, to the mouth of the Snake River approximately 20 miles upstream of the Lower Monumental Dam. Several major tributaries drain into the main channel, the largest (by basin area) being Pataha Creek, which enters the main channel at river mile (RM) 12.3. Pataha Creek is approximately 56 miles in length with a long, narrow watershed draining 185 square miles. The second and third largest tributaries (by basin area) are Kellogg Creek (35 square miles) and Willow Creek (30 square miles). A full list of the Tucannon tributaries and their known fish use is shown in Table 2-1.

The river's headwaters are within the Umatilla National Forest and Wenaha-Tucannon Wilderness, and the upper watershed drains densely forested valleys with minimal anthropogenic impacts outside of historical logging and recreation. Downstream of its confluence with the Little Tucannon River, the Tucannon River has been anthropogenically confined by roads and levees. Habitat quality in this reach has been limited by channel confinements, which have reduced complexity, and by man-made floodplain lakes that limit channel migration and divert water. Restoration activities in this reach in the last decade have prioritized restoring large wood, promoting pool formation, and increasing floodplain connectivity.

Continuing downstream to the confluence with Pataha Creek, agricultural impacts become the dominant impact on habitat quality. Fields and their associated levees have encroached on much of the floodplain and confined the channel, causing incision and reducing complexity and connectivity. Removal of riparian forests has resulted in decreased shading, high summer temperatures, sedimentation, and loss of woody debris. The combination of reduced riparian forests and water withdrawals has altered the hydrologic regime to cause increased peak flows and reduced summer baseflows. Successful restoration efforts in this reach along with landowner outreach and cooperation have reformed agricultural practices to reduce sediment runoff and reduce irrigation withdrawals while restoring riparian forests (SRSRB 2011).

The lower Tucannon reach and the Pataha watershed are heavily influenced by agriculture as well as the towns of Starbuck and Pomeroy. Pataha Creek is highly incised and has an undeveloped road network that confines the channel and contributes fine sediment. High temperatures caused by a lack of riparian trees and irrigation withdrawals are a primary concern in the lower basin. The Tucannon River confluence with the Snake River is not included in the prioritization of this assessment, but concerns about predation and temperature are also major concerns here. More information about habitat and attraction flows in this area could also be useful for future assessments.



LEGEND:

- Tucannon River Assessment Reaches (Ticks Indicate River Mile)
- Tributary to Tucannon
- Road
- Tucannon River Basin
- County Boundary

Public Land Areas

- 🟧 Wooten Wildlife Area
- 🟫 Wenaha Tucannon Wilderness
- 🟩 Umatilla National Forest

NOTE(S):
1. Horizontal datum is WA State Plane South Zone, NAD 83, Feet.
2. Public lands data provided by Washington State Department of Natural Resources.

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Figure 2-1
Basin Vicinity and Site Map

Geomorphic Assessment and Restoration Prioritization
Tucannon Basin Habitat Restoration

Two dams that blocked fish passage were historically present in this reach, the De Ruwe Dam at RM 16 and the Starbuck Dam at RM 5.5. Only the Starbuck Dam remains, and a fish ladder was constructed in 1992 to provide fish passage (SRSRB 2011). Restoration actions to reduce grazing, limit sediment runoff, and restore riparian forests have improved conditions in this reach, but high sediment loads, lack of key habitat, and high temperatures remain limiting factors.

2.1 Perennial Waterways in the Tucannon Basin

In 2018, the Tucannon Technical Work Group summarized perennial tributaries of the Tucannon River for the purpose of assimilating available information into the 2019 Conceptual Restoration Plan. Although the majority of habitat restoration has occurred in the Tucannon River mainstem, some work has also occurred in the tributaries. Much of this work has been focused on forest and land management and includes: the Forest Management Plan (Pomeroy District), Conceptual Restoration Plan (Natural Resources Conservation Service), and forest management (Washington Department of Natural Resources and Washington Department of Fish and Wildlife). Many of the tributaries have been the target of fish passage restoration work.

While the focus of this restoration plan is on the mainstem Tucannon River, the tributaries in the basin do provide valuable habitat that should not be ignored. Although current fish use within the tributaries of the Tucannon River are not available, local experience and field biologists have identified stream reach extents where salmon and steelhead have been noted over the past 20 years, which is reflected in Table 2-1, although these extents are estimates and future evaluation of fish presence in the tributaries may be warranted. Habitat restoration actions within the tributaries will develop a more robust population structure for aquatic species and aid in building resiliency within the population particularly for steelhead and bull trout within the basin. Tributary improvements also add to the increased resilience of the basin as a whole by slowing flows within the upper basin, increasing floodwater retention, changing peak flow timings, and reducing flood power. Table 2-1 provides basic flow and known fish presence extents for the tributaries in the Tucannon Basin for spring Chinook salmon and steelhead. This information can be used to help identify where tributary restoration will be most valuable as opportunities arise. More detailed information on the state of the tributaries to the Tucannon River can be obtained from the SRSRB.

Table 2-1
Tucannon Tributaries and Fish Presence[1]

Stream Name	Chinook Presence (miles)	Steelhead Presence (miles)	Perennial Flow Extent (miles)	Primary Land Ownership
Kellogg Creek	None	1.94	1.94	Private
Smith Creek	None	0.42	0.42	Private
Pataha Creek	None	52.3	56.3	Private/Public
Hartsock Creek	Unknown	Unknown	0.52	Public
Tumalum Creek	None	6.2	1	Private/Public
Cummings Creek	None	11.03	11.03	Public
Blue Lake Creek	Unknown	Unknown	0.61	Public
Waterman Canyon Creek	Unknown	Unknown	1.08	Public
Big 4 Canyon Creek	0.74	0.74	1.89	Public
Grub Canyon Creek	Unknown	Unknown	0.89	Public
Hixon Creek	0.8	0.8	1.82	Public
Little Tucannon River	None	4.03	6.03	Public
Cow Canyon Spring	Unknown	Unknown	0.2	Public
Panjab Creek	2.52	8.38	8.38	Public
Meadow Creek	None	5.59	5.59	Public
Meadow Creek Tributary	Unknown	Unknown	2.23	Public
Turkey Creek	None	2.19	2.19	Public
Panjab Creek Tributary	Unknown	Unknown	1.49	Public
Tucannon Above Panjab[2]	5.06	9.53	11.78	Public
Cold Creek	Unknown	Unknown	1.93	Public
Sheep Creek	None	None	0.7	Public
Bear Creek	Unknown	Unknown	2.66	Public

Note:

1. The fish presence miles listed here are rough estimates based on field observations; further evaluation of fish use in the tributaries may be warranted.
2. The upstream boundary of this assessment is at Tucannon RM 50.17 and the Panjab Creek Confluence is at RM 50.34. The distances listed above begin at RM 50.17 and include the 0.17-mile section of the Tucannon River between the end of the assessment and the confluence with Panjab Creek.

Bull trout migrate throughout the mainstem, but their critical habitat is located in the mid- to upper-river cold-water tributaries including Cummings Creek, Hixon Creek, the Little Tucannon River, Panjab Creek, Cold Creek, Sheep Creek, and Bear Creek (USFWS 2010). Relative to the other species, the tributary habitat is more important to steelhead and bull trout, which can spawn and rear in smaller tributaries than the spring Chinook salmon. Of the four salmonid species in the basin, fall Chinook salmon use the tributaries the least and their spawning and brief rearing activities are mainly relegated to the lower mainstem Tucannon River (USFWS 2002).

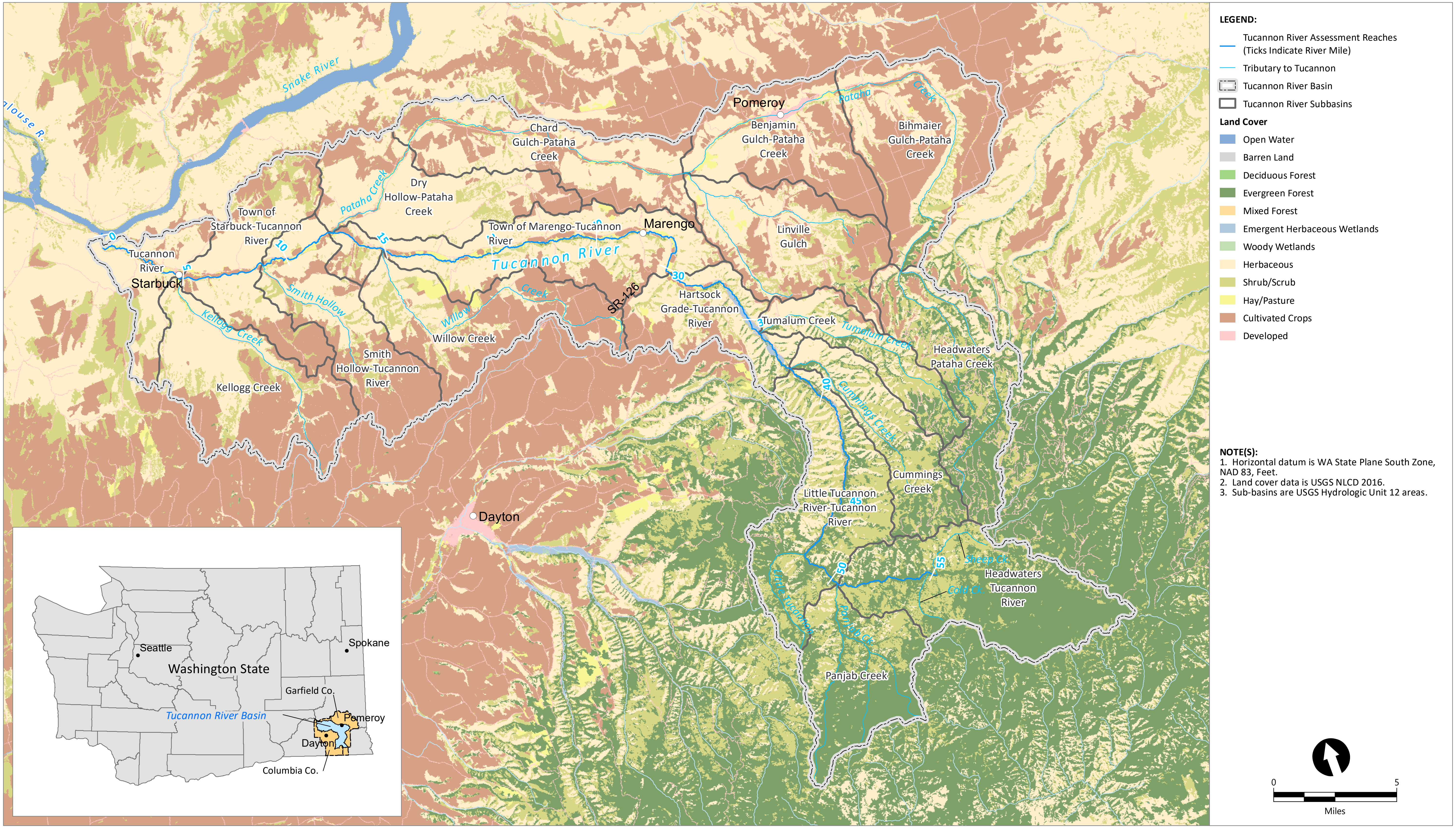
2.2 Land Cover and Vegetation

A majority of the watershed downstream of Tumalum Creek (RM 35.5) is under cultivation, primarily consisting of grain crops (Figure 2-2). The valley floor is occupied primarily by livestock pastures and some cultivated crops downstream of the National Forest boundary at RM 41, except for a vegetated riparian buffer along the margins of the channel. The watershed upstream of Tumalum Creek is typically covered in evergreen forest, with scrub/shrub on the steeper, southwest-facing slopes. The valley floor is forested, with sparse undergrowth in the floodplain until upstream of Panjab Creek (RM 50.2), where tree and undergrowth density increase significantly (USDA 1984). The riparian corridor typically contains interspersed evergreen and deciduous trees with dense undergrowth.

As is true throughout the western Rocky Mountains, the Tucannon Basin is a wildfire-maintained ecosystem and was managed to minimize wild fire, which had the effect of increasing fuel loads and potentially leading to a more significant burn cycle over the past 60 years. Large forest fires in 2005 (School Fire), 2006 (Columbia Complex Fire), 2010 (Hubbard Fire), 2014 (Grizzley Fire), and 2015 (Hartsock Fire) impacted the upper basin, including the floodplain and riparian corridor (USFS 2008).

2.3 Regional Geology

The Tucannon Basin consists primarily of Miocene-aged Columbia River Basalt flows of the Grande Ronde, Wanapum, and Frenchman Springs members with recent Quaternary river alluvium along the valley floor (Figure 2-3). Basalt is exposed at the surface upstream of Tumalum Creek (RM 35.5) and along the valley walls and gullies down from Tumalum Creek to RM 18. Downstream of RM 18, including within the Pataha and Willow Creek subbasins, the basalt is overlain by loess deposits (fine sand and silt) of the Palouse Formation. In these areas, bedrock is only exposed in gullies and along valley slopes. The valley walls in much of the lower basin downstream of RM 18 are composed of Quaternary flood outburst deposits consisting of stratified sand, gravel, and cobble. Alluvial fans line the valley floor at the mouths of tributaries; the fans tend to be large and wide in locations where tributaries drain loess-dominated subbasins, and small and narrow in basins where mainly bedrock is exposed.



NOTE(S):
1. Horizontal datum is WA State Plane South Zone, NAD 83, Feet.
2. Land cover data is USGS NLCD 2016.
3. Sub-basins are USGS Hydrologic Unit 12 areas.

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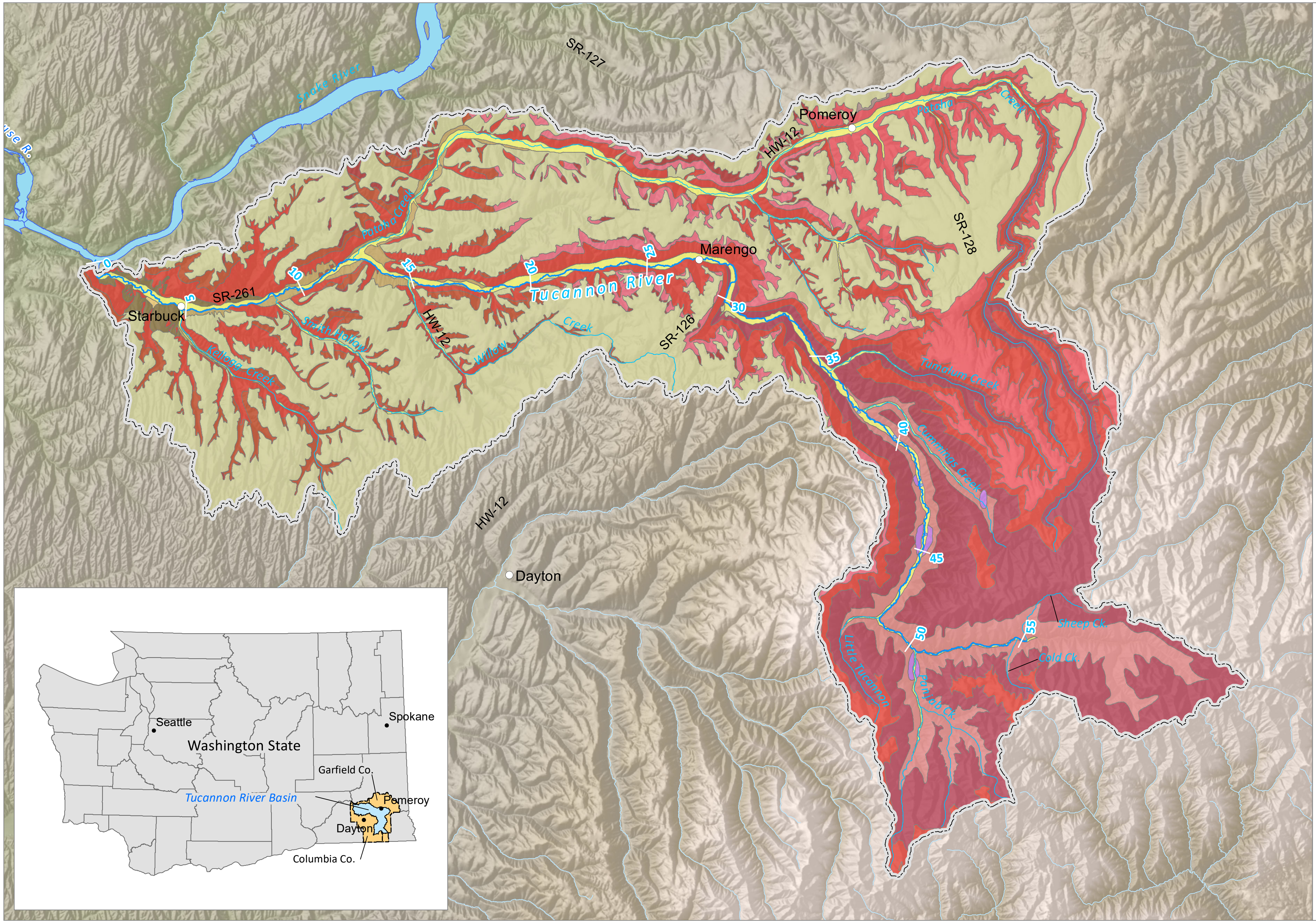
Figure 2-2
Landcover Units and Subbasins
Geomorphic Assessment and Restoration Prioritization
Tucannon Basin Habitat Restoration



LEGEND:

— Tucannon River Assessment Reaches (Ticks Indicate River Mile)
— Tributary to Tucannon
▭ Tucannon River Basin

Tucannon Basin Geologic Units

▨ Mv(gN1) - basalt flows (Grande Ronde, lower norm.)
▨ Mv(gN2) - basalt flows (Grande Ronde, upper norm.)
▨ Mv(gR2) - basalt flows (Grande Ronde, upper rev.)
▨ Mv(slm) - basalt flows (lower Saddle Mtn.)
▨ Mv(sp) - basalt flows (Pomona Member)
▨ Mv(su) - basalt flows (Umatilla Member)
▨ Mv(w) - basalt flows (Wanapum undiv.)
▨ Mv(wem) - basalt flows (Eckler Mtn.)
▨ Mv(wfe) - basalt flows - (Frenchman Spr. and Eckler Mtn.)
▨ Mv(wfs) - basalt flows (Frenchman Spr.)
▨ Mv(wr) - basalt flows (Roza)
▨ Qa - alluvium
▨ Qaf - alluvial fan deposits
▨ Qf(bg) - Bonneville flood deposits
▨ Qfs(t) - outburst flood deposits, sand and silt
▨ Ql - loess
▨ Qls - mass wasting deposits
▨ pTmt - metasedimentary and metavolcanic rocks
▨ Water

NOTE(S):
1. Horizontal datum is WA State Plane South Zone, NAD 83, Feet.
2. Geologic unit data provided by Washington State Department of Natural Resources.

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Miles

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Figure 2-3
Basin Geology
Geomorphic Assessment and Restoration Prioritization
Tucannon Basin Habitat Restoration

2.4 Overview of Basin-Scale Geomorphic Processes

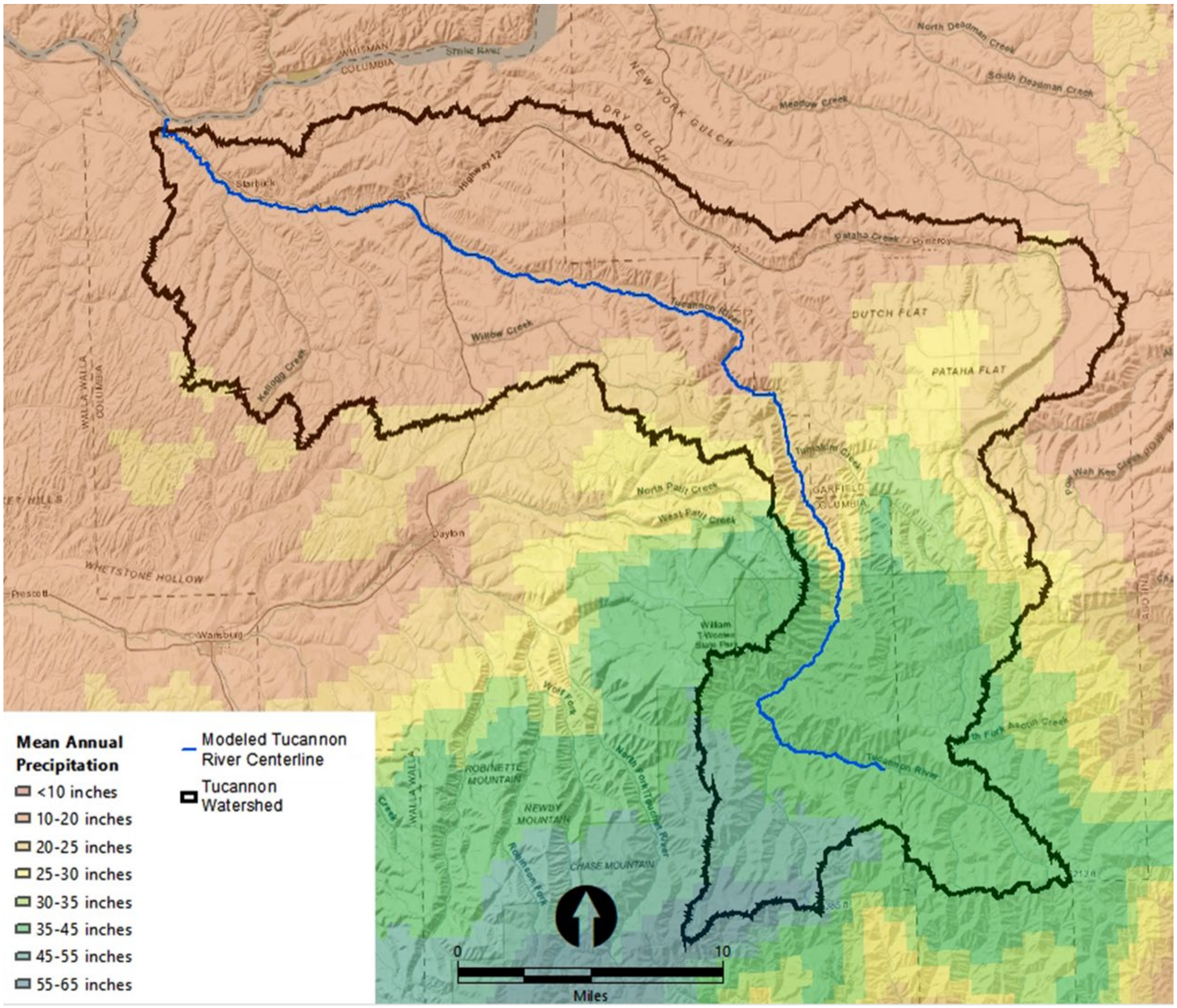
The Tucannon River and its tributaries comprise a steep mountain system in an arid setting. The surrounding peaks at the headwaters in the Blue Mountains reach 6,300 feet, and the mouth at its confluence with the Snake River (63 miles downstream) lies at 540 feet. The geometry of the basin appears to be geologically controlled, paralleling a northwest-southeast trending feature for the first 10 miles, before turning north and exiting the mountains another 10 miles downstream. The river loses about half of its elevation in its upper portion where it is likely actively incising the terrain. Downstream of the turn, the gradient slackens, and the valley floor widens. There are abundant relic channels in this reach that show a history of avulsion, deposition, and channel reorganization. Upland sediment sources in the mountain reaches include sheet and rill erosion on non-forested slopes, shallow landslides from steep valley walls, and debris flows (USDA 2002). As the river transitions into the loess-dominated landscape of the Columbia Basin downstream of its confluence with Tumalum Creek (RM 35), the valley floor becomes wider still where the river has had more room to migrate and more sediment to deposit. Anthropogenic influence in this reach and the lower portion of the mountain reaches has disconnected much of the river from its floodplain, halting geomorphic and hydrologic processes like deposition, channel migration, and groundwater recharge.

2.5 Precipitation and Runoff Overview

The basin climate is primarily continental, with some marine influences. Precipitation occurs primarily in the winter months as frontal storms pass over the basin. Frontal and convective storms occur in late spring through early summer. In the dry, late summer months, precipitation is primarily from convective events (Hecht 1982).

Mean annual precipitation data for the basin were summarized in the *Tucannon Subbasin Plan* (CCD 2004) and updated data were available geospatially from Oregon State University through the PRISM climate model (OSU 2019), as shown in Figure 2-4. Precipitation data remained largely unchanged from the precipitation data calculated in the previous assessments (Anchor QEA 2011a, 2011b, 2012a, 2012b). The distribution of precipitation in the Tucannon Basin is highly dependent on elevation. Mean annual precipitation ranges from 10 inches at lower elevations to more than 40 inches at higher elevations. Runoff from precipitation events varies distinctly with antecedent moisture conditions and the extent and type of ground freezing. At higher elevations, much of the mean annual precipitation falls in the form of snow, with a basin mean annual snowfall of 65 inches (CCD 2004). The snow pack typically melts during the months of March, April, May, and June, with occasional rain on snow events in December through February causing rapid snowmelt below the freezing elevation.

Figure 2-4
Mean Annual Precipitation Distribution, Tucannon Basin



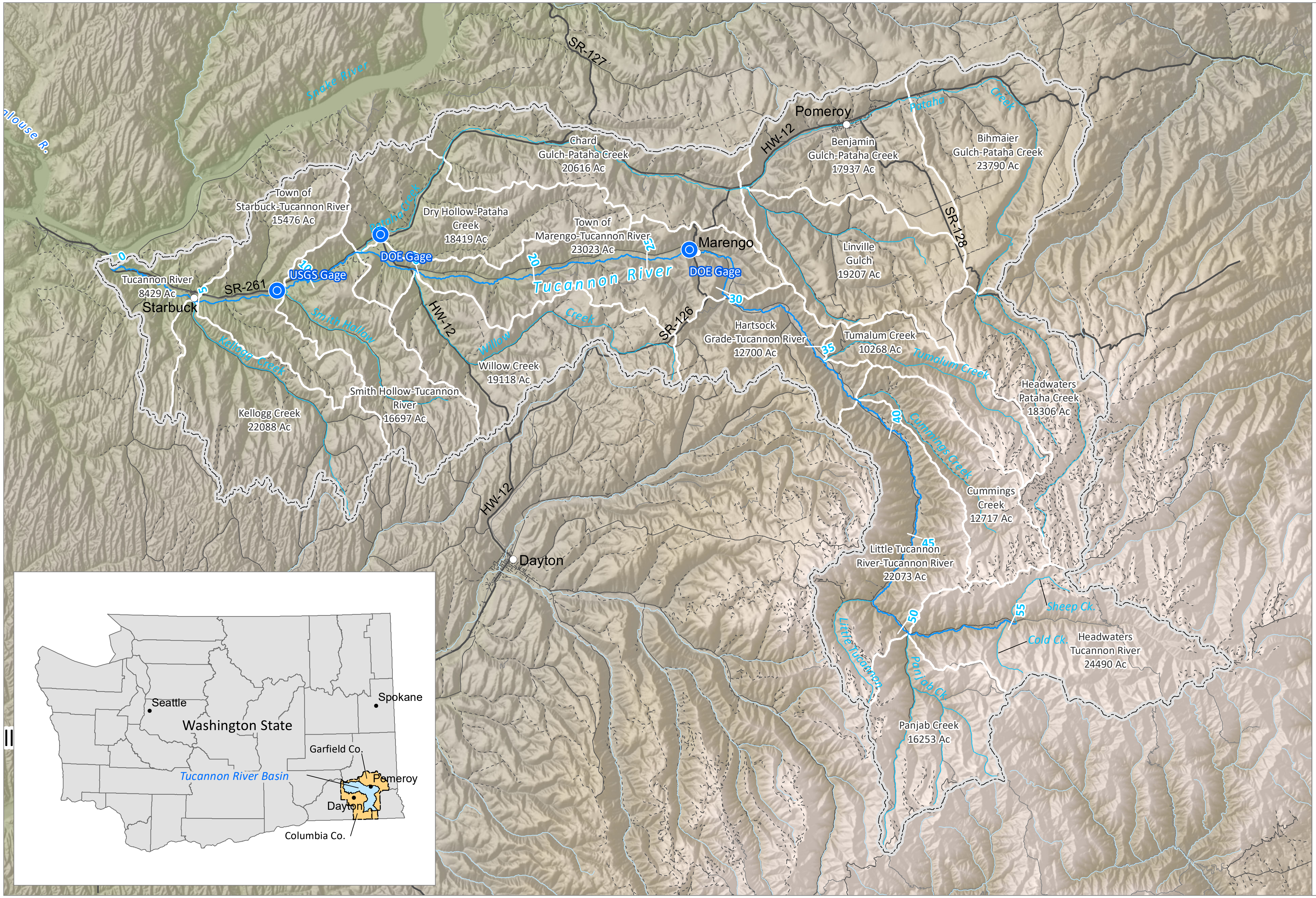
Note: Precipitation data were drawn from the Oregon State University PRISM climate model (OSU 2019) and represent the 30-year (1981 to 2010) annual average.

This precipitation pattern often means that the basin experiences multiple unique discharge peaks in a water year—one peak typically occurs as the result of a winter storm and the other as the result of spring snowmelt. For the period of record, 32 of the maximum annual discharges occurred in December, January, or February, while only 18 maximum annual discharges occurred in March, April, or May. The spring peak discharge is often similar in magnitude to the winter storm peak discharge, although with a much longer duration driven by the length of the spring snowmelt. Additionally, because the hydrologic regime in the basin is primarily driven by snow melting events, the majority of the basins flow and most perennial tributaries originate from the upper basin. So even though some tributary catchments that are larger in area are located in the lower basin, they are often intermittent because they do not extend up to elevations were precipitation is enough to support perennial flow. Although there is not much information on the potential to modify or increase flow duration in some of the ephemeral catchments, holding back and slowing flow through channel and floodplain restoration could be a way to increase the amount of time surface flow occurs in these basins.

Peak flow basin hydrology for the Tucannon River was developed for input to the basin-scale hydraulic model and for use in reach delineation. Information on hydrology in the Tucannon Basin included discharge gages on the Tucannon River (U.S. Geological Survey [USGS] 13344500) and Pataha Creek (Washington State Department of Ecology [Ecology] 35F050) and spatially distributed rainfall data. Figure 2-5 shows major tributaries, gage locations, and subbasin areas in the Tucannon Basin. Distributing hydrologic inputs throughout the basin required the use of some standard flood frequency analysis methods along with basin scaling techniques and gage discharge correlations (USGS 2018; Thomas et al. 1994). A thorough description of the methodology and hydrologic results are discussed in Appendix C.

The lack of hydrologic gage sites in the upper basin, limited historical record, and local climate conditions (e.g., wet and drought year regime) created uncertainties in the flood magnitude and frequency analysis. Therefore, this assessment used a range of discharge values along the main channel that employ different methodologies for flow estimation and proportioning (USGS 2001). The values used for this study are provided in Table 2-2.

Notable flood events recorded at the Starbuck gage include those in water years 1916 (February 10, 1916) at 5,740 cubic feet per second (cfs); 1930 (February 2, 1930) at 6,000 cfs; 1963 (February 3, 1963) at 4,700 cfs; 1965 (December 22, 1964) at 7,890 cfs; 1996 (February 9, 1996) at 5,580 cfs; and 2020 (February 7, 2020) at 3,410 cfs. These events are all approximately at or larger than the 10-year return period event. The flood of record (7,890 cfs) is slightly less than the 50-year return period event. Both the 1965 and 1996 water year floods had documented channel changes and floodplain inundations associated with them. During the 1965 flood, the levee in the town of Starbuck was overtopped and flooded the town with approximately 2 feet of water (USACE 2010). Several major channel avulsions were documented, and, in some cases, post-flood “restoration” was performed to re-establish a desirable channel configuration.



LEGEND:

- Tucannon River Assessment Reaches (Ticks Indicate River Mile)
- Tributary to Tucannon
- Tucannon River Basin
- Tucannon River Subbasins (Drainage Area in Acres)
- ○ Stream Gage

Roads

- Highway
- Light-Duty Improved Road
- Unimproved Road
- Unknown

NOTE(S):

1. Horizontal datum is WA State Plane South Zone, NAD 83, Feet.
2. Road data provided by Washington State Department of Natural Resources.
3. Subbasins are USGS Hydrologic Unit 12 areas.

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Figure 2-5
Subbasin Areas and Stream Gages
Geomorphic Assessment and Restoration Prioritization
Tucannon Basin Habitat Restoration

Table 2-2
Flood Discharges Values (cfs)

Flow Change (RM)	Tributary/ Location Name	Return Period (years)							Maximum Avg. Winter Flow[2]
		1	2	5	10	25	50	100	
4.9	Kellogg Creek	595	1,548	2,728	3,869	5,861	7,850	10,379	323
8.8	Smith Hollow[1]	552	1,435	2,528	3,585	5,431	7,275	9,619	300
12.4	Pataha Creek	532	1,383	2,437	3,457	5,237	7,014	9,275	289
14.9	Willow Creek	367	956	1,683	2,388	3,617	4,845	6,406	200
35.8	Tumalum Creek	367	954	1,573	2,231	3,327	4,418	5,799	199
38.1	Cummings Creek	348	906	1,474	2,090	3,106	4,117	5,411	189
48.3	Little Tucannon River	284	738	1,192	1,691	2,512	3332	4,367	154
50.4	Panjab Creek	267	694	1,109	1,574	2,334	3,094	4,058	152
55.14	Above Panjab	168	436	723	1,026	1,545	2,072	2,745	145

Notes:

1. For the purposes of modeling, the discharge downstream of Smith Hollow was assumed to be equivalent to the discharge at the Starbuck gage.
2. The highest monthly average flow during the months of January to May at the Starbuck gage.

2.6 Anthropogenic Impacts

Primary anthropogenic impacts in the basin include agriculture and forestry, infrastructure including roads, levees, bridges, and dams, and biological impacts such as hatcheries and invasive plants. Land use in the basin including irrigated agriculture and forestry have impacted hydrology by removing riparian forests, increasing runoff, and reducing groundwater storage. Agriculture and infrastructure within the floodplain have reduced habitat complexity and connectivity by confining the channel and disconnecting the river from its floodplain. Historical removal of riparian forests and wood have also simplified the channel. Anthropogenic confinements including levees and riprap have caused increased transport capacity, reducing gravel storage and limiting pool formation. Dams within the basin have reduced fish passage and changed sediment transport regimes. Anadromous salmon in the Tucannon River also have to pass the four lower Columbia River dams and two of the lower Snake River dams, causing a multitude of threats including fish passage barriers, thermal stress, and predation during both legs of the journey. Finally, biological impacts of hatcheries have affected salmonid life cycles and survival, and proliferation of invasive plants has reduced the ability of riparian forests to provide sufficient shade and woody debris. Altogether, the salmonids of the Tucannon and Snake River basins are further threatened by the effects of climate change including increased water temperatures, increased peak flows, and reduced summer low flows.

The basin was settled in the mid-19th century and has since been heavily influenced by agriculture, forestry practices, and other developments that have typically increased fine sediment loading, degraded riparian areas, and limited natural geomorphic processes such as large woody material (LWM) recruitment and floodplain connectivity. Native bunchgrass in the lower part of the basin that once minimized soil erosion has been replaced by grain crops, and some native floodplain and riparian areas were cleared and replaced with pastures (Beckham 1995).

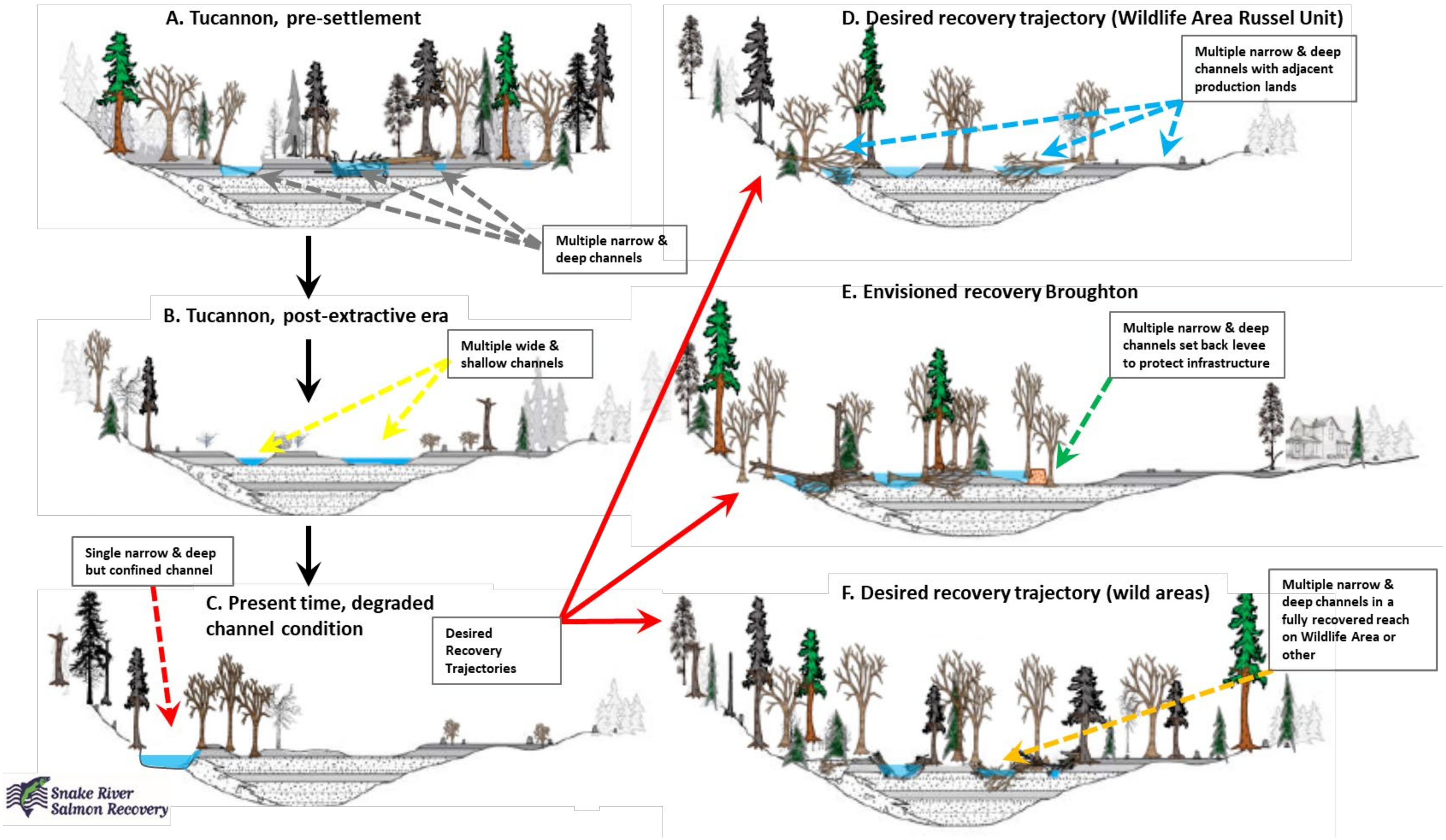
LWM volume and riparian cover have been significantly reduced from past conditions, through the lower 50 miles of the basin. Channel wood-clearing and straightening practices were common in the Pacific Northwest in the early 19th century and have been known to occur in the Tucannon Basin from the mouth upstream to Camp Wooten (RM 46.5) and beyond. Removal of mature trees from both main channel and tributary riparian zones has decreased the average size and density of riparian trees. This clearing of mature vegetation has contributed to a reduction in the volume of key wood pieces (more than 6 meters long and 0.3 meter in diameter) available for recruitment to the system. Riparian tree removal has also reduced shading and increased water temperatures. Although a riparian buffer exists throughout a majority of the valley, historical accounts and photography indicate that the density of mature trees and undergrowth was much heavier before extensive settling occurred; riparian trees were likely cut down for firewood and the undergrowth was grazed upon by livestock (Beckham 1995). Logging in the upper basin also likely contributed to reduction of the riparian zone; logging practices may have involved channel clearing, straightening, and otherwise reducing channel complexity for easier transport of materials. Timber harvesting of the Tucannon River valley in the upper watershed continued to occur until the 1980s (SRSRB 2006). Following the floods of 1964 and further in 1996, the channel was carved out and shaped in many reaches to increase flood conveyance. Channel modification and straightening have reduced channel length and increased stream power over time, further diminishing the channels ability to recruit and maintain key wood pieces within the channel. These channel modifications have also led to an increase in stream power and armoring of larger bed material, limiting geomorphic change.

Starbuck Dam, Tucannon Falls, and the Hatchery Dam are all passable by adult salmonids, but may act as partial barriers to some individuals and specifically out-migrating juveniles (SRSRB 2006). Fish ladders have been installed at both dams, but long-term removal of the Starbuck Dam presents a long-term opportunity to fully remove this barrier and its impacts on fish passage and sediment transport. Historically, the Starbuck and De Ruwe dams were barriers to fish passage and major causes of the decline of salmonid populations throughout the 20th century.

Figure 2-6 illustrates the effects of anthropogenic actions on an idealized cross section of the Tucannon River floodplain and riparian forests. Section A depicts the pre-settlement, undisturbed condition, with multiple low-volume channels and mature riparian forest dispersed across the majority of the valley bottom. Section B illustrates changes that had occurred through the period of degradation with wide, shallow river channels and severely reduced riparian vegetation. Section C illustrates the existing condition of the majority of the Tucannon River, with a single, over-widened channel and excessive conveyance capacity, man-made confinement features, and minimal recovery of riparian habitat. Sections D, E, and F illustrate desired recovery trajectories for three different land types that all benefit salmon and steelhead. Section D illustrates working lands where occasional flooding is possible. Section E illustrates working lands with setback levees to protect infrastructure. Section F illustrates a full wild land restoration.

Historical irrigation and water use practices in the Tucannon Basin have created major impacts to aquatic habitat. Diversion of water for irrigation leads to a base flow that is lower than natural conditions, which greatly increases water temperatures during the dry season. However, present water conservation efforts have contributed over 10 cfs to base flow conditions.

Construction of dams in the lower basin adversely affected salmonid populations by creating fish passage barriers, reducing mainstem base flow in the summer, and by entrainment of juveniles. The De Ruwe Dam, which washed out in the 1964 flood, and the Starbuck Dam (RM 6.4) upstream of the town of Starbuck did not have sufficient fish passage features and thus blocked passage of adults into the upper watershed. The Starbuck Dam is still in place and it is believed that the dam does not currently act as a barrier for upstream migration of focal aquatic species (SRSRB 2006). The hatchery weir and bedrock falls partially formed through anthropogenic influences have both been partially addressed to restore some fish passage.



This model illustrates an idealized cross section of the Tucannon River floodplain and riparian forests over time since pre-settlement. Sections A and B illustrate changes that had occurred through the period of degradation with wide, shallow river channels, and Section C illustrates a modified condition with a single, narrow channel that has confinement and recovering riparian habitat. Sections D and E illustrate desired recovery trajectories for three different land types that all benefit salmon and steelhead. Section D illustrates working lands where occasional flooding is possible, Section E illustrates working lands with infrastructure protection setback levee, and Section F illustrates a full wild land restoration. Source: Kris Buelow, Snake River Salmon Recovery Board, via email communication.

Figure 2-6
Tucannon Conceptual Stream Model

Restoration for salmon and other aquatic and riparian species has been occurring in the basin for several decades. In the floodplain, programs that work to establish native vegetation on private and public lands have made strides towards reestablishing a portion of the historical riparian cover. This assessment is focused on the in-channel processes and does not make an attempt to directly assess the state of the riparian vegetation, although some inferences may be made as riparian vegetation and wood availability plays a large role in channel complexity. Additionally, many in-channel restoration projects have occurred in the river; those that have taken place since the previous assessments are examined in more detail in this assessment. Other in-channel restoration projects are typical for the time period including large rock and boulder vanes and barbs, as shown in Figure 2-7, as well as some anchored large wood. While not directly addressed in this assessment, these projects have had an undeniable effect on the habitat conditions and geomorphic processes of the basin.

Figure 2-7
Rock Weir Restoration in Project Area 5

3 Tucannon Fish Recovery Targets and Pressures

The Snake River Salmon Recovery Plan for Southeast Washington (SRSRB 2011) identifies recovery targets and actions that need to occur to meet recovery goals and future broad sense goals. Although the restoration partners have been working on recovery efforts since the ESA listings of spring Chinook salmon, fall Chinook salmon, summer steelhead, and bull trout in the basin, there are still many data gaps even given the best available science and information we have learned from additional efforts and experience (discussed further in Section 11). For additional details, please refer to the Recovery Plan and associated efforts.

3.1 Goals for Spring/Summer Chinook Salmon

According to the Recovery Plan, spring/summer Chinook in the Tucannon Basin are considered to be an intermediate population within the Lower Snake River major population group (MPG). The minimum abundance threshold is 750 and the productivity threshold is 2.10. The Interior Columbia River Technical Recovery Team (ICTRT) recommends that the Tucannon population be at a "very low risk" level of abundance and productivity (<1%) for the MPG to meet delisting criteria. To meet spatial structure and diversity criteria, natural rates and levels of spatially mediated processes must be maintained to minimize the likelihood that populations will be lost due to local catastrophe, to maintain natural rates of recolonization within the population and between populations, and to maintain other population functions that depend on the spatial arrangement of the population. Natural patterns of variation must also be maintained to ensure that populations can withstand environmental variation in the short and long terms (ICTRT 2007). Restoration goals were also established in the Recovery Plan for natural-origin returning adults; that goal for was 2,400. Comparatively, although historical abundances are not available, the Nez Perce Tribe ecological goal, established in phase 1 of the Columbia Basin Partnership Task Force of the Marine Fisheries Advisory Committee, is 22,000.

3.2 Goals for Steelhead

According to the Recovery Plan, summer steelhead in the Tucannon Basin are considered to be an intermediate population within the Lower Snake River MPG. The minimum abundance threshold is 1,000 and the productivity threshold is 1.20. To meet spatial structure and diversity criteria, natural rates and levels of spatially mediated processes must be maintained to minimize the likelihood that populations will be lost due to local catastrophe, to maintain natural rates of recolonization within the population and between populations, and to maintain other population functions that depend on the spatial arrangement of the population. Natural patterns of variation must also be maintained to ensure that populations can withstand environmental variation in the short and long terms (ICTRT 2007). Restoration goals were also established in the Recovery Plan for natural-origin returning adults; that goal for was 1,823 to 3,400. Comparatively, the Columbia Basin Partnership Task Force of the Marine Fisheries Advisory estimated 1960s abundance for steelhead at 3,400 and the Nez Perce Tribe ecological goal is set at 15,000.

3.3 Goals for Bull Trout

Recovery goals and metrics for bull trout are similar to, but not the same as, goals for steelhead and Chinook salmon. The U.S. Fish and Wildlife Service (USFWS), which has regulatory authority for bull trout, developed a goal and objectives for bull trout recovery throughout its range (USFWS 2002). The goal for all populations is:

> . . . ensure the long-term persistence of self-sustaining, complex interacting groups (or multiple local populations that may have overlapping spawning and rearing areas) of bull trout distributed across the species' native range.

The USFWS recognized that recovery of bull trout will also require reducing threats to the long-term persistence of populations, maintaining multiple interconnected populations of bull trout across the diverse habitats of their native range, and preserving the diversity of bull trout life history strategies (e.g., resident or migratory forms, emigration age, spawning frequency, local habitat adaptations).

To recover bull trout, the USFWS identified four objectives:

- Maintain current distribution of bull trout within core areas as described in recovery unit chapters and restore distribution where recommended in recovery unit chapters.
- Maintain stable or increasing trend in abundance of bull trout.
- Restore and maintain suitable habitat conditions for all bull trout life history stages and strategies.
- Conserve genetic diversity and provide opportunity for genetic exchange.

3.4 Goals for Fall Chinook Salmon

According to the ESA Recovery Plan for Snake River fall Chinook salmon (NMFS 2017), all fall Chinook salmon in the Snake River Basin are defined as a single MPG within the evolutionarily significant unit (ESU). The Tucannon River was identified as one of five major spawning areas (MaSAs) within the entire population, and was defined as the area downstream of Tucannon Falls and the adjacent inundated mainstem Snake River section associated with Little Goose and Lower Monumental Dams. The minimum abundance threshold for the entire MPG is 3,000 natural-origin fish. There is no minimum abundance threshold specific for the Tucannon River run of fall Chinook salmon. Limiting factors for fall Chinook salmon in the Tucannon River include excess sediment (from Pataha Creed), loss of habitat, and reduced habitat diversity and channel stability. Currently, productivity estimates determined by NOAA Fisheries is 1.53 for the entire MPG, of which the Tucannon River MaSA contributes. The Lower Snake River fall Chinook salmon population is currently rated as viable, at low (1% to 5%) risk of extinction with 100 years based on current abundance and productivity. The spatial structure and diversity are considered moderate risk (NMFS 2017), which is reflective of the widespread distribution of hatchery origin returns across the MaSAs. To meet spatial structure and diversity criteria, natural rates and levels of spatially mediated processes must be maintained to minimize the likelihood that populations will be lost due to local catastrophe, to maintain natural rates of recolonization within the population and between populations, and to maintain other population functions that depend on the spatial arrangement of the population. Natural patterns of variation must also be maintained to ensure that populations can withstand environmental variation in the short and long terms (ICTRT 2007). Currently, the Tucannon MaSA natural-spawning population is difficult to determine due to a lack of evidence supporting natural-origin spawners. Natural-origin fish are likely present in the Tucannon River, but because approximately 50% of the hatchery-origin fall Chinook salmon produced within the Snake River Basin are unmarked/untagged, the only way to precisely determine origin requires genetic analysis. Lack of funding prevents this from occurring.

3.5 Summary of Tucannon Salmonid Fish Pressures

3.5.1 Habitat

In general, habitat pressures occur both within the Tucannon Basin, as identified in Section 6 of this report, as well as outside the basin. Collectively, this assessment identifies the Tucannon Basin habitat shortcomings and restoration. Habitat factors such as Snake and Columbia fish passage and environmental conditions are the focus of the Federal Agencies through the Federal Columbia River Power System (FCRPS) Biological Opinion (NOAA 2008), and although the impacts of the hydropower system are acknowledged in this effort they are not directly addressed within this report. This approach has been taken in relation to habitat as one of the "4 Hs" (habitat, harvest, hatchery, and hydropower)to allow the stakeholders to focus their available resources and local expertise on improving habitat conditions for the most vulnerable life stages.

3.5.2 Harvest

In general, out-of-basin harvest pressures on Tucannon natural-origin salmonids varies by species and there are data available to support this. However, there are unknowns and data gaps related to harvest, and harvest conservation measures could be bolstered to potentially provide future success.

To demonstrate this, using Tucannon hatchery spring Chinook salmon harvest—as reported on the Coded-Wire Tag (CWT) database (Regional Mark Information System)—data have been summarized to two time periods when hatchery fish were clipped or unclipped. Out-of-basin harvest used to be about 10% per year, but since marking ceased harvest is about 2% to 3%. It is believed that the decrease observed is due to the lack of marking due to the fact that the Columbia River is mark selective for spring Chinook salmon. However, not all fisheries in the Columbia River may be adequately sampled (either not sampled or not sampled at a high enough rate to appropriately expand the CWTs). For example, in Zone 6 (Bonneville Dam to McNary Dam, fishery harvest appears to be less than 1%. However, based on Passive Integrated Transponder (PIT) tag conversions of Tucannon spring Chinook salmon through this area, approximately 15% are lost annually (includes all sources of mortality such as harvest, natural mortality, predation). These discrepancies in apparent fish loss in this area need to be further explored.

It is also known that the Columbia River spring Chinook fisheries can have high harvest levels, and that upriver fish (Snake Basin) are present in higher percentages earlier in the run (Sorel 2018; Sorel 2020). When so few fish return, any harvest impact is important. The only conservation measures that are taken in the Columbia River fishery are to comply with ESA take permits (Columbia River Policy C-3620). If fish abundance gains are made, there are no conservation mechanisms in place for recovery success if those gains are lost through harvest.

3.5.3 Hatchery Considerations

As stated in the Recovery Plan, it is important to understand that management of adult returning hatchery-origin fish in the Tucannon River (spring Chinook salmon and steelhead) is complicated and co-managers are not necessarily in agreement on all hatchery management actions listed within the Recovery Plan. Some studies have shown that excess hatchery-origin adults spawning in the wild may reduce natural population productivity (e.g., Araki et al. 2008). However, this issue is still considered a critical uncertainty and, as such, proper management actions are still in development until additional information is obtained.

For steelhead, in the Tucannon, the co-managers have shifted to an endemic stock. It is important to understand this management change as it relates to Tucannon steelhead abundance (for details, see Section 4.1).

To date, the hatchery program for spring Chinook salmon has been deemed critical for maintaining population viability at this point in time because the natural population has generally been below the replacement level. As such, managers have made drastic stop-gap decisions to collect all returning adults that reach the Tucannon hatchery intake weir to Lyons Ferry for holding. This was done to mitigate for high pre-spawn mortality of adults left in the river during the summer prior to the onset of spawning. Fish collected and not needed for broodstock have been returned to the upper basin above the hatchery trap each year. It is important to note that approximately 30% of the annual return remains below the adult trap to spawn.

3.5.4 Hydroelectric Installations

Tucannon salmon and steelhead populations are directly impacted by at least six hydroelectric dams (and up to eight, considering fish that overshoot the Tucannon River). As noted in the Recovery Plan, these efforts are being worked on by the Federal Agencies through the FCRPS Biological Opinion (NOAA 2008). Some of the key impacts from hydropower, as identified in the Recovery Plan, include the following:

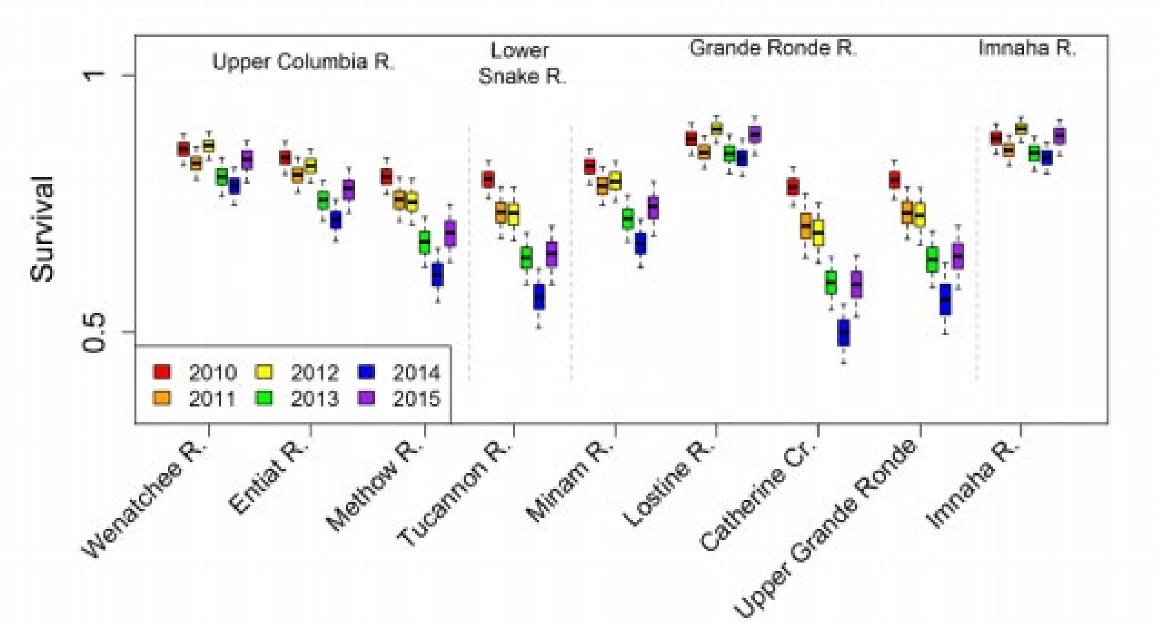
- Stocks are negatively impacted by flow regulation from dams in the upper Columbia and Snake rivers. Spring flows are lower and summer flows are generally higher.
- There is major loss of spawning and rearing habitat above Hells Canyon Dam, and loss or alteration of habitat for spawning and rearing in the lower Snake River (for Snake River fall Chinook primarily).
- Flow impacts are attributable to Dworshak and Hells Canyon dams.
- Some of the mainstem dams prevent fish that have overshot their natal tributary from returning to that tributary, as adequate adult passage is generally lacking and limited to going through the turbines, back down the fish ladders, or through the juvenile bypass facilities. For Tucannon steelhead, from PIT tags the overall impact may be as high as 40% to 50% of the overall annual return, while for spring Chinook salmon the impact, while once thought high as well, appears to be in the 5% to 10% range. In the 2020 FCRPS Biological Opinion (NOAA 2020), to reduce the effect of steelhead overshooting, the dams have begun periods of surface spilling during months when no spill for juveniles is already planned, allowing adult steelhead to migrate back downstream.

3.5.5 Predation

Extensive research on predation and efforts at predator control, including piscivorous fish, avian predators, and marine mammals, have been undertaken in the Columbia Basin for decades, and will continue. Population year specific survival declined between 2010 and 2015 by more than 18% (shown in Figure 3-1) while marine mammal population increased in the mouth of the Columbia River over the same time likely impacting early migrating Chinook salmon population the greatest (Chasco et al. 2017). Tucannon spring Chinook salmon were found to have the highest associated mortality due to increased sea lion predation of all populations evaluated (Sorel 2020). The FCRPS Biological Opinion (NOAA 2008) and the Estuary Module (73 FR 161, January 2, 2008), both of which are part of the Recovery Plan, provide extensive evaluations of these issues as threats and limiting factors as well as specific strategies and actions for both monitoring and addressing them. Of note are the recent anthropogenically increased levels of avian and marine mammal predation. Also of concern is the potential of northern pike invasion from the upper Columbia River.

Recently, however, the Washington Department of Fish and Wildlife (WDFW) has liberalized fishing regulations around non-native predatory fish in the anadromous water of the Columbia Basin, including the Snake and Tucannon rivers, with the hope of reducing predation through recreational fishing (WDFW 2020b).

Figure 3-1
Predation of Columbia River Spring Chinook



Source: Sorel et al. 2017

3.5.6 *Estuary, Ocean, and Climate Change*

The combined influence of diking and filling tidal wetlands and hydrosystem flow management have reduced habitat capacity in the Columbia River estuary, and hatchery genetic effects have reduced salmonid life history variation that helped temporally maximize utility of the productive estuarine habitat. The quantity of tidal wetlands critical for juvenile outmigrants in the lower Columbia River has been halved due to levees and filling combined with reduced inundation resulting from flow management at dams (Bottom et al. 2011). Hatchery simplification of life histories and selection for early out-migration timing has shifted peak estuary occupancy to the spring and removed much of the summer and fall estuary usage. This shortened use of the estuarine habitat is also exacerbated by estuarine habitat loss and diminished inland and upper Columbia salmonid populations, including the Tucannon population, that would arrive later in the year (Bottom et al. 2011).

Research also suggests that recent warm and unfavorable ocean conditions are an increasing threat to Columbia River salmonid populations. Extremely warm marine water temperatures initiating in 2014 and 2015 associated with a strong El Niño event reduced upwelling and primary productivity and favored less nutritious plankton populations (NWFSC 2015). Trends of warm coastal waters and reduced productivity associated with El Niño conditions and warm Pacific Decadal Oscillation periods are expected to increase in frequency and strength with climate change (NWFSC 2015). However, the effects of marine conditions will not be uniform among species with regard to Tucannon populations. Columbia River spring Chinook salmon typically migrate to Alaska while fall Chinook salmon remain on the Washington/Oregon coast, and steelhead migrate directly west in the North Pacific, all experiencing different marine conditions (NWFSC 2015).

Projected climate change effects include reduced spring snow cover and glaciation, sea surface temperature rise, increased ocean acidification, and increased marine thermal stratification and hypoxia. Climate change will affect salmon directly via mortality from heat stress during rearing and adult phases. Altered flow regimes will influence migration timing and energetics and increased flooding will reduce egg survival (NWFSC 2015). Altogether, predicted warming ocean and river conditions will continue to threaten Snake and Tucannon River salmonid populations.

4 Fish Management

4.1 Steelhead

Historical wild-origin steelhead abundance in the Tucannon River is relatively unknown but thought to have been as high as 2,000 to 3,000 adults in the 1950s. By the mid-1970s, sport harvest in the Tucannon River (which was solely supported by wild-origin steelhead) was rapidly declining (Figure 4-1), and steelhead fishing in the Tucannon River was limited or closed altogether. The Lower Snake River Compensation Plan (LSRCP) hatchery program started releasing hatchery-origin steelhead in the Tucannon River in 1983. The LSRCP hatchery program was initiated in the early 1980s to compensate for fish losses from the construction and operation of the four lower Snake River dams. The hatchery stock(s) originally used were from out-of-basin hatchery programs (Wells and Wallowa) and were later termed the Lyons Ferry Hatchery (LFH) stock once they started returning to the hatchery for broodstock. Shortly after hatchery releases started, steelhead sport harvest in the Tucannon River was quickly re-established (Figure 4-1). In addition, estimating the number of steelhead spawning in the Tucannon River started in the mid-1980s as part of the monitoring and evaluation program funded by the LSRCP hatchery program. The average number of wild and LFH hatchery-origin spawners from 1987 to 1999 was estimated at 238 and 404, respectively, with wild-origin steelhead continuing to decline over that period.

In 1997, all Snake River Basin steelhead populations were listed under the ESA as threatened. Following the ESA listing, and due to the apparent low or declining number of wild-origin steelhead in the Tucannon River, the National Marine Fisheries Service (NMFS) questioned WDFW about the continued use of the LFH stock in the Tucannon River. From that, WDFW was requested to develop a new stock from “localized” adult steelhead (i.e., wild-origin returns that could have either wild or LFH stock parents), with the eventual goal of replacing the LFH stock from the basin. In 2000, with agreement from co-managers, WDFW began a 5-year “test” program to: 1) collect broodstock; 2) rear successfully at the hatchery; 3) return adults to support sport harvest; and 4) assist in the recovery of wild-origin steelhead.

The new “test” program produced 50,000 smolts, but because they were derived from wild-origin fish they could not be marked for harvest. Concurrently, the LFH stock releases were reduced by 60,000 (down to 100,000 total smolt release) to offset the additional hatchery production in the river. Some drop-off in sport harvest was expected but was deemed acceptable by the co-managers because returns to the Tucannon River were exceeding the hatchery return goals. By 2005, there still was not enough information to determine if the “test” program was successful. As such, WDFW and the co-managers agreed to continue testing the program for another 5 years.

In 2009, NMFS requested updates to the Hatchery and Genetic Management Plans (a required ESA document that allows hatchery programs where listed species are involved) for both the LFH and

Tucannon River steelhead stocks. Prior to re-submittal of these two plans, NMFS indicated they would not issue an ESA Permit for the continued propagation/release of any LFH stock steelhead into the Tucannon River. However, by 2010, enough information was available to determine that the "test" program was successful in returning adults to support not only the sport fishery, but also to maintain a conservation component of the program to help support the depressed wild-origin population (Figure 4-1). Concurrent with the decision to implement the Tucannon River stock program, releases of LFH stock steelhead in the Tucannon River were ceased (last release in 2010).

A key component of the Tucannon River stock implementation plan (50,000 smolts for conservation, 100,000 smolts for sport harvest) was the need for additional rearing space at the LFH. The LFH was designed for production of a few separate stocks of fish, with large rearing vessels that can hold multiple release locations. As such, elimination of the LFH stock releases did not free up additional rearing space for the Tucannon River stock. When the initial decision was reached to proceed with the Tucannon River stock, WDFW and the co-managers were promised that additional rearing space in the form of 20-foot circular tanks would be in place within a year (ready for rearing in 2011), with no gap in overall smolts released.

Due to a variety of factors, the additional rearing space at the LFH has yet to be realized. Because of that, there was no harvestable steelhead (adipose fin clipped) released into the Tucannon River from 2011 to 2013, which is reflected in the lower harvest estimates since then (Figure 4-1). Other program changes have occurred in the meantime, and currently WDFW has attempted to fulfill full production of this stock (Figure 4-2), although efforts have been hampered by low adult returns and disease outbreaks in the hatchery, which has limited overall smolt production. The LSRCP hatchery program is currently funding engineers to design additional rearing capabilities at the LFH, which will benefit Tucannon River steelhead and other stocks reared at the LFH.

Current Status: Determining the status of steelhead returning to the Tucannon River is difficult because fish return over many months, and spawn during periods of higher stream flows with poor visibility, so operation of adult traps or conducting redd surveys are often ineffective. Recently, instream PIT tag arrays have been deployed throughout the basin, and these have been used to estimate total escapement to the Tucannon River (Figure 4-3). Wild-origin steelhead continue to remain at relatively depressed levels, yet a large number of out-of-basin steelhead (both hatchery- and wild-origin) are present in fairly large numbers, which has complicated management of the population. Furthermore, the overshoot of Tucannon River steelhead to areas above Lower Granite Dam is hampering overall efforts to recover this stock or make the hatchery program successful. Overall impacts to the Tucannon River steelhead population from overshooting is difficult to quantify, but generally only 40% to 50% of the Tucannon River stock that cross Ice Harbor Dam make it back to the Tucannon River.

Figure 4-1
Estimated Harvest of Wild- and Hatchery-Origin Summer Steelhead in the Tucannon River (1967 to 2017)

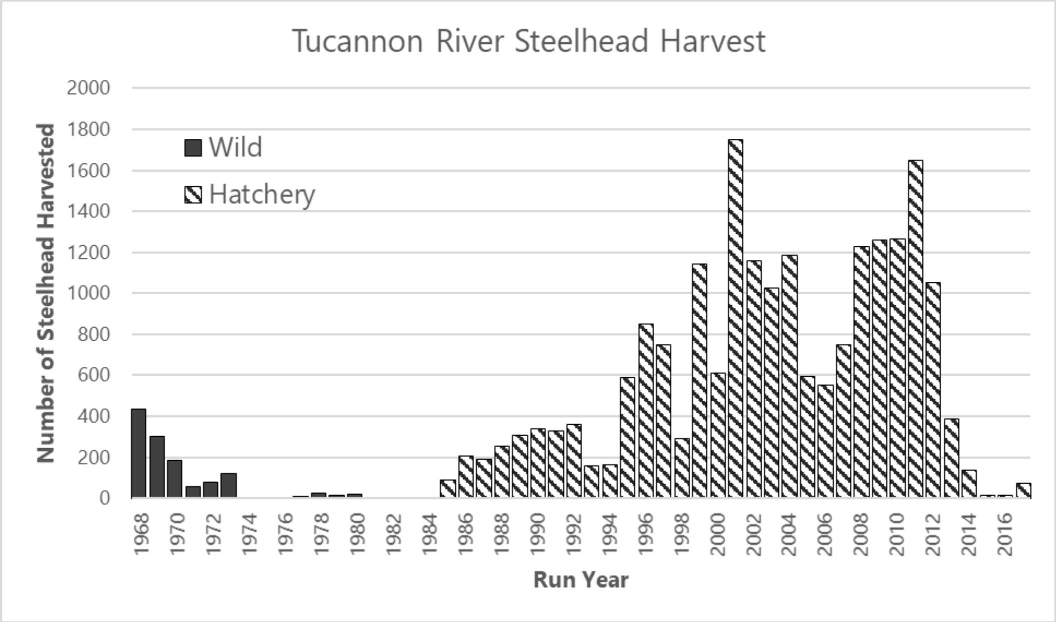


Figure 4-2
Number of Hatchery-Origin Steelhead from Either LFH or Tucannon River Stocks Released into the Tucannon River (1983 to 2019)

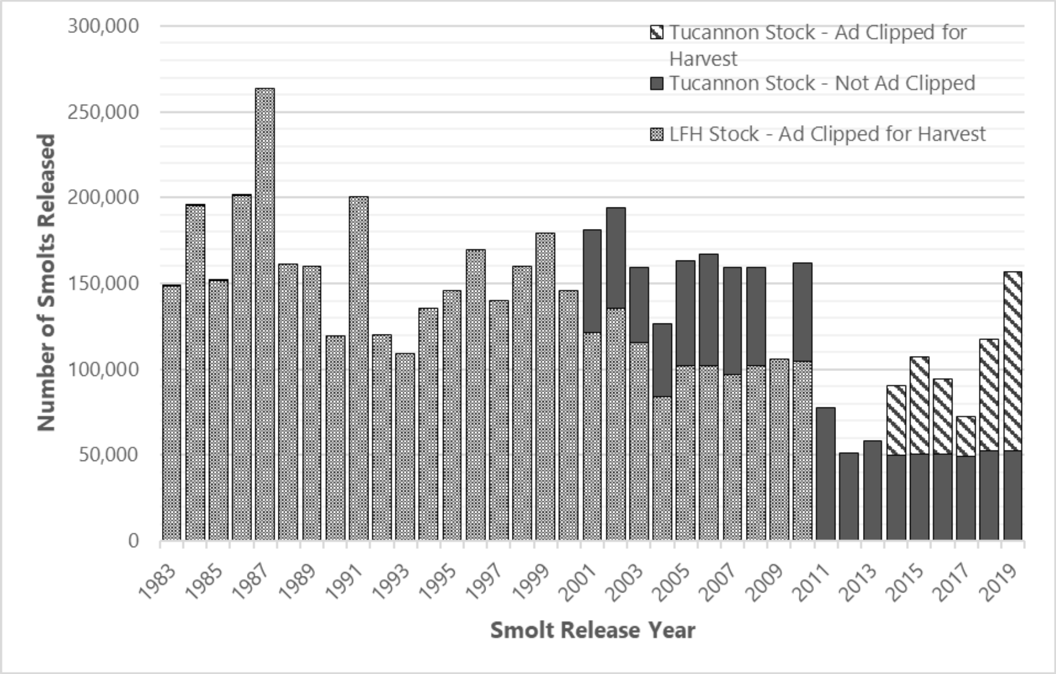
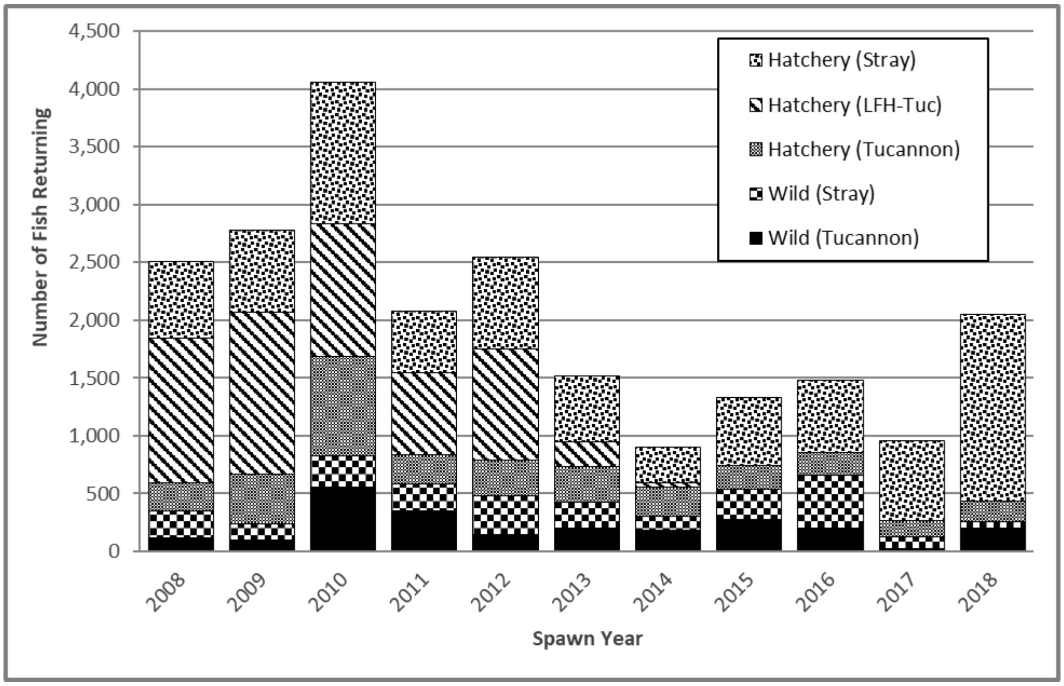


Figure 4-3
Estimated Number of Wild- and Hatchery-Origin Steelhead (Multiple Stocks) that Escape to the Tucannon River (2007 to 2018 Spawn Years)



4.2 Spring Chinook Salmon

Historical spring Chinook salmon abundance in the Tucannon River is relatively unknown; some rough estimates suggest the river could have supported as many as 30,000 adults, but by the 1950s estimates suggest this was less than 5,000 (Johnson 1995; CBPTF 2019). Based on expanded index redd surveys from 1958 to 1984, the natural population was in a slow decline (Figure 4-5). With completion of the four lower Snake River dams, the LSRCP hatchery program started releasing hatchery-origin spring Chinook salmon in the Tucannon River in 1987; the first broodstock collections began in 1985. The spring Chinook salmon hatchery program was initiated with natural-origin returns, and then both hatchery- and natural-origin fish have been used for broodstock annually since 1989. While originally meant for harvest mitigation, there has yet to be a spring Chinook salmon sport fishery in the Tucannon River since the LSRCP hatchery program began. The original goals of the program were to produce 132,000 smolts annually, released at 15 fish per pound, with an assumed 0.87% smolt to adult survival rate, which would return approximately 1,152 adults to the Tucannon River.

Monitoring of the first hatchery returns in the late 1980s suggested that smolt to adult survival of hatchery fish was only about one-quarter of what was expected. In addition, it was determined that the natural population (those juveniles that rear in the Tucannon River) were below replacement levels, and the population would continue to decline (see Appendix B for more information). In 1992, all spring/summer Chinook salmon in the Snake River basin were ESA-listed as “endangered,” including the Tucannon spring Chinook salmon stock. The listing status was downgraded in 1995 to “threatened.” The Tucannon salmonid survival assessment report (Crawford et al. 2019) identified survival and normalized-for-time survival in different reaches of the Tucannon River (both for spring Chinook salmon and steelhead). The information on survival from this effort has provided support for working on habitat related to over-winter survival and work in the lower Tucannon River.

Hatchery returns up to ESA listings, while not as high as expected, were at least above replacement levels and would help slow or stabilize the overall decline of spring Chinook salmon in the Tucannon River. A few different rearing strategies were tried to increase survival, but before results could be obtained, record low returns of both hatchery- and natural-origin fish occurred in 1994 (140 fish) and 1995 (54 fish), as shown in Figure 4-5. In addition, major floods in 1996 and 1997 destroyed most of the natural production from those 2 years. Moreover, an 80% loss of the hatchery egg take occurred in 1997 due to a malfunction of a water chiller that cold shocked the eggs. Because of the lower than expected adult returns in 1996 and 1997, the losses to both natural and hatchery production, and the natural population being below replacement levels, WDFW initiated a captive broodstock program with 1997 brood year fish to prevent the potential extirpation of the population. The captive broodstock program duration was planned for 5 brood years, with the intent to provide a demographic boost to the population (in adult returns) in coming years, but to lessen the overall effect of this extreme hatchery intervention. The captive program generally went as planned, yet due to some unknown factors following the release of juveniles from the program, they never returned as many adults as expected (Figure 4-5).

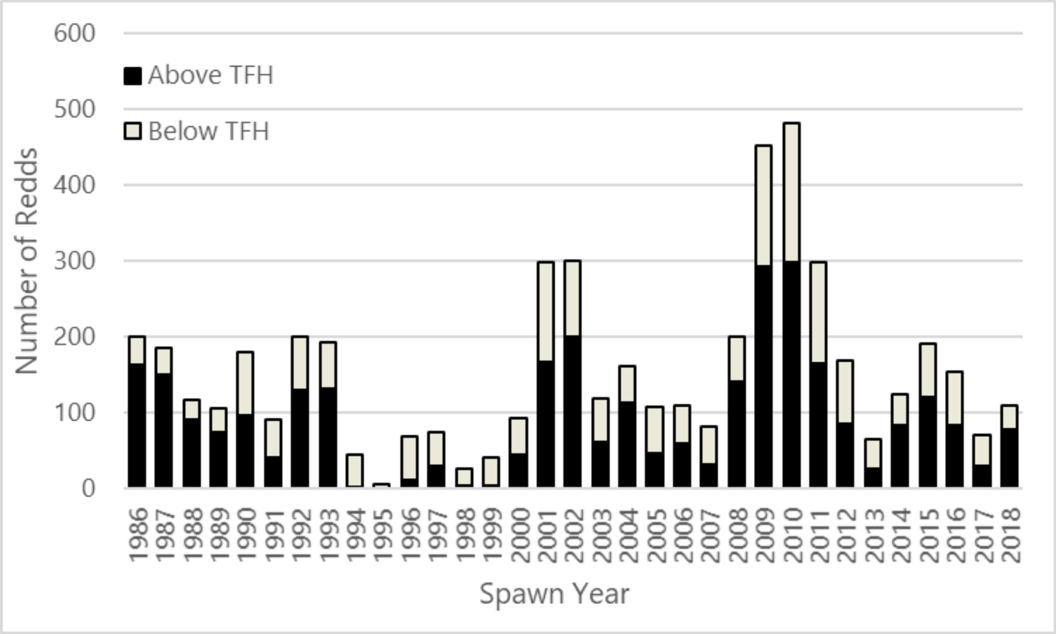
Over this time period, natural-origin fish generally remained below replacement, and hatchery-origin fish helped to maintain the population at somewhat decent returns. Hatchery smolt releases were moved to Curl Lake in 1998 to: 1) potentially increase smolt to adult survival; and 2) shift the spawning distribution of hatchery fish in the river to areas where spawning densities for spring Chinook salmon were historically the highest prior to hatchery intervention. In addition, in 2002, none of the hatchery fish were adipose fin clipped anymore so they would not be harvested in downriver mark selective fisheries, allowing for a greater escapement of adults to the spawning grounds. However, hatchery fish overall continued to perform poorly (in spite of these and a few other alternative rearing strategies), and survival was still well below the assumed smolt to adult survival goal that was used to size the hatchery program in 1985. As a result, in 2006, the managers (state, tribal, and federal) agreed to increase the program size to 225,000 smolts (Figure 4-6). They also began a size at release study (15 fish per pound vs. 9 fish per pound) to see if that would help increase the survival of hatchery fish.

For a short period in the mid-2000s, smolt to adult survivals increased for both hatchery- and natural-origin fish, but this was mainly attributed to favorable ocean and out-migration conditions (Figure 4-5). In 2013 and continuing over the next few years, WDFW documented high pre-spawn mortality over the summer; the direct cause has yet to be determined. Due to the high pre-spawn mortality, WDFW and the co-managers made the decision to hold all, or a portion of, the fish that would normally be passed upstream of the adult trap be transported and held at the LFH. These fish would then be outplanted to the river just prior to spawning (late August). To date, holding and outplanting of adults occurred in 2015, 2016, 2018, 2019, and 2020.

In 2016, WDFW initiated nutrient enhancement in the upper Tucannon Basin by putting out salmon carcasses from the Snake River fall Chinook salmon program at the LFH. It is anticipated the approximately 1,200 carcasses will be returned to the stream annually for the foreseeable future. The added nutrients over time are expected to increase the overall productivity of the ecosystem, which may increase survival of the juvenile spring Chinook salmon in the river.

Current Status: Overall returns have dropped from the levels observed in the mid-2000s but have been around 500 total fish the last few years (Figure 4-5). Hatchery fish, while released at a larger size and in greater numbers than the original program, continue to perform poorly, and discussions are underway to try alternative release strategies in the future. Natural-origin fish remain below the replacement level in most years and continue to be assisted by the hatchery program to ensure some natural production occurs. Historical redd distribution of spring Chinook salmon throughout the Tucannon River is shown in Figure 4-4. It is still unknown if the high pre-spawn mortality over the summer months experienced a few years ago is still occurring. Because of this uncertainty, and the expected low returns in the next few years due to poor ocean conditions, the holding and outplanting strategy used recently will likely continue until it can be determined that the high pre-spawn morality is not an issue. Monitoring activities on this population include pre-spawning and spawning ground surveys; adult trapping (broodstock and other needs); smolt monitoring and PIT tagging wild spring Chinook salmon at the smolt trap; adult trap passage/delay; and, depending on funding, juvenile parr PIT tagging to determine over-winter survival, movements, and habitat use.

Figure 4-4
Historical Redd Distribution in the Tucannon River Above and Below the TFH Adult Trap on the Tucannon River



Source: WDFW 2020a, Table 8

Figure 4-5
Estimated Number of Wild- and Hatchery-Origin Spring Chinook Salmon that Returned to the Tucannon River (1958 to 2018 Spawn Years)

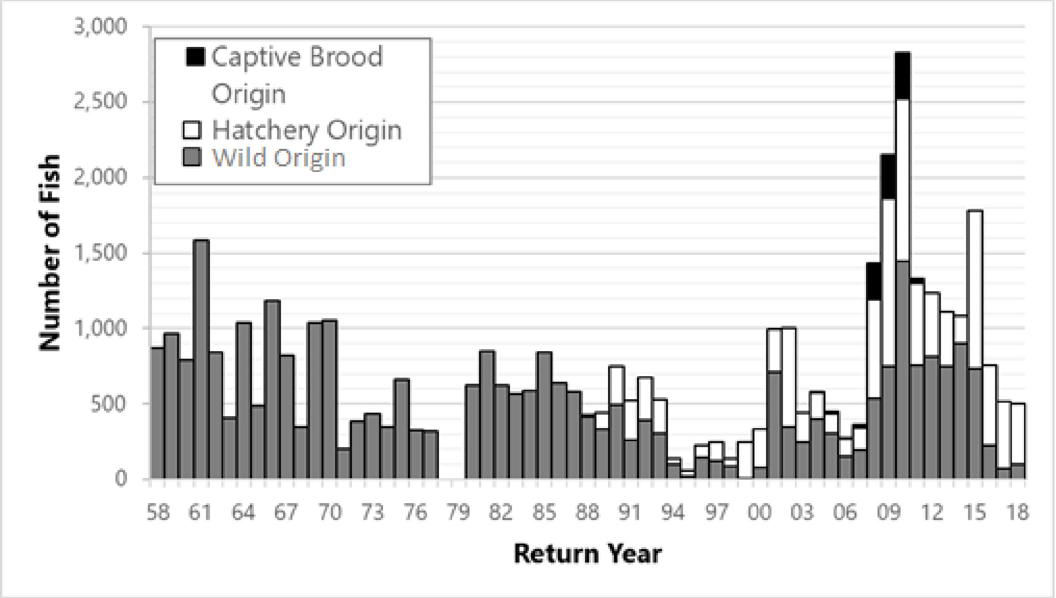
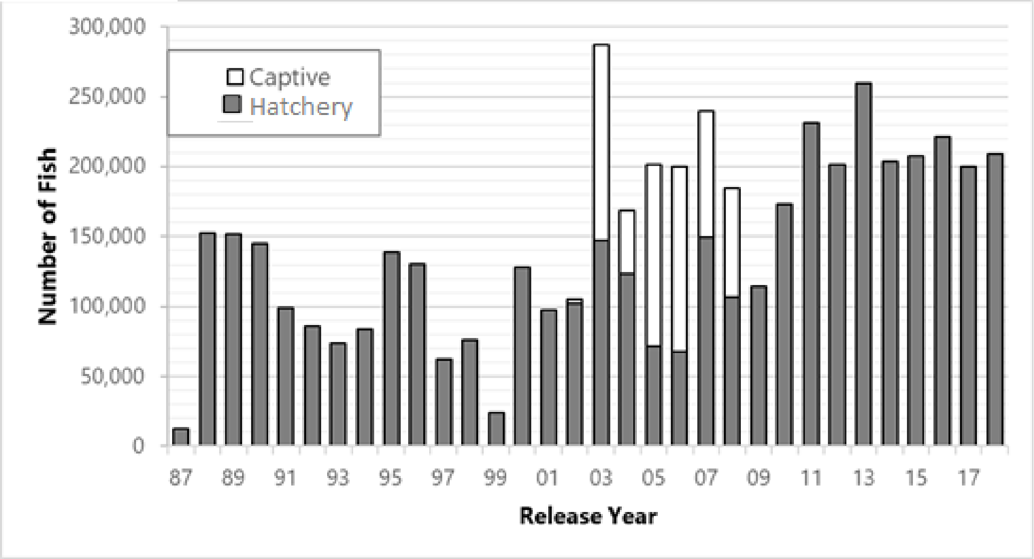


Figure 4-6
Number of Hatchery-Origin Spring Chinook Smolts Released into the Tucannon River (1985 to 2018)



4.3 Fall Chinook Salmon

Historical fall Chinook salmon abundance in the lower Tucannon River was relatively unknown until redd counts began in the late 1980s under the LSRCP hatchery program. Fall Chinook salmon in the Tucannon River are part of the much larger Snake River fall Chinook salmon population, all of which were ESA-listed as "threatened" in early 1990s. With completion of the four lower Snake River dams, the LSRCP hatchery program at the LFH started releasing hatchery-reared fall Chinook salmon in the Snake River, but no releases have ever been programed for the Tucannon River. Currently, 80% of the total fall Chinook salmon hatchery production in the Snake River basin is released upstream of Lower Granite Dam. Based on redd surveys and carcass recoveries, the majority of fall Chinook salmon spawning in the Tucannon River are hatchery-origin, with most originating from the on-station releases of fall Chinook salmon at the LFH, although some strays from the Umatilla River hatchery program have also been found. About 95% of the fall Chinook salmon spawning in the Tucannon River takes place from the Highway 12 bridge downstream to the mouth. Redd counts are highly correlated with the overall return of fall Chinook salmon to the Snake River basin (Figure 4-7). Besides redd and carcass surveys, the only other monitoring of fall Chinook salmon occurs at the smolt trap just upstream of the Highway 261 bridge. Natural smolt production (Figure 4-8) of fall Chinook salmon from the Tucannon River has been shown to be highly variable, with the largest factors in determining production being high stream flows that can scour redds and sediment input (Pataha Creek) that can smother the redds. No additional population monitoring or management actions are planned for fall Chinook salmon in the Tucannon River at this time.

Figure 4-7
Estimated Number of Fall Chinook Salmon (Hatchery- and Natural-Origin) Returning to the Snake River Basin (1938 to 2017) and the Number of Fall Chinook Redds Estimated in the Tucannon River (1986 to 2017)

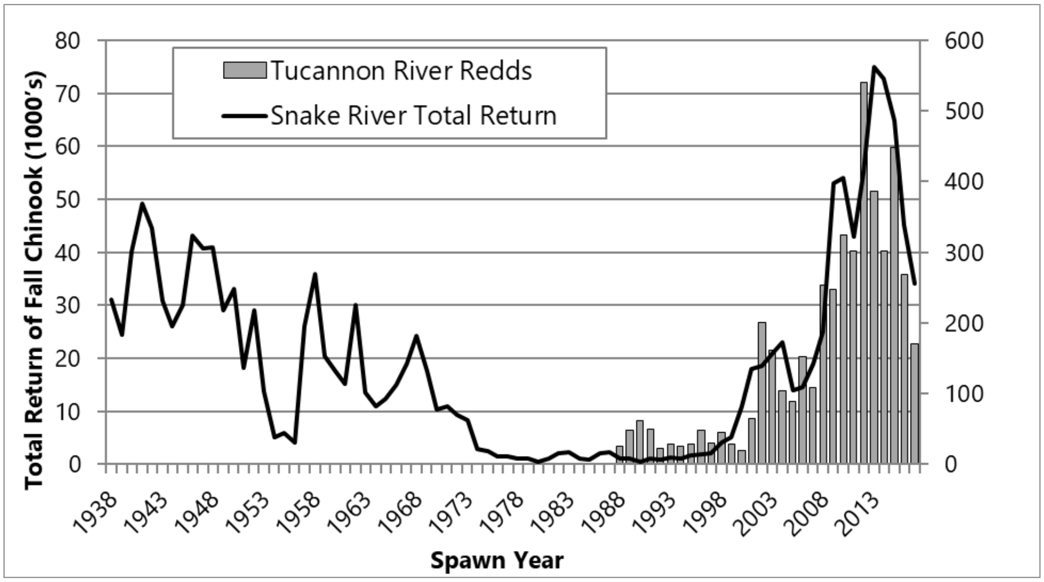
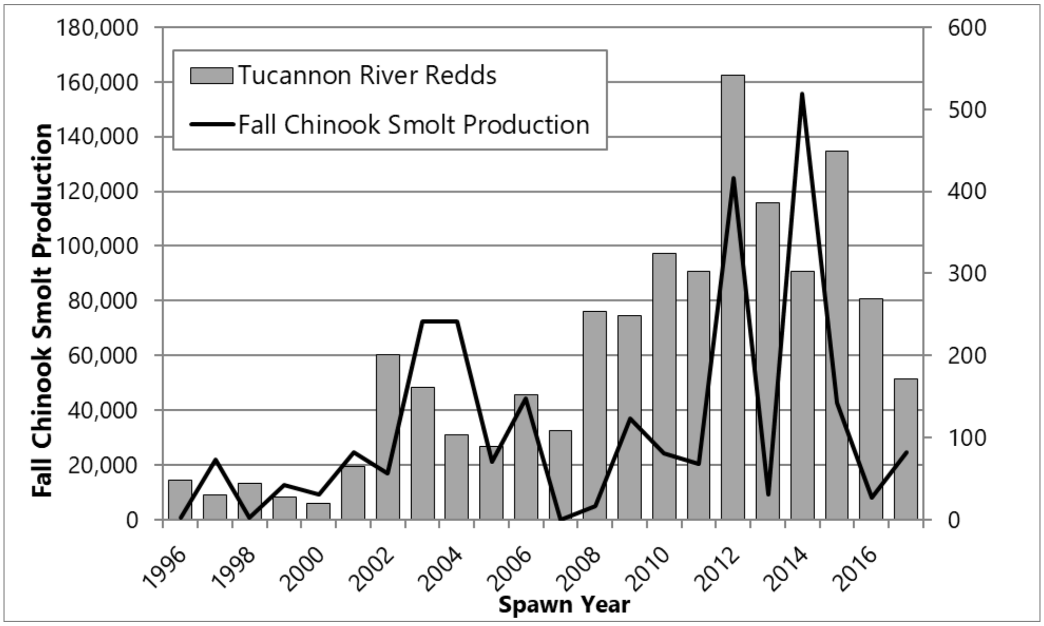


Figure 4-8
Estimated Number of Fall Chinook Redds and Subsequent Smolts Migrating from the Tucannon River the Following Spring (1996 to 2017 Spawn Years)



4.4 Bull Trout

Bull trout in the Columbia Basin were ESA-listed as threatened in 1998. The Tucannon River bull trout population is part of the Lower Snake River geographic area of the Mid-Columbia Recovery Unit (USFWS 2015). Bull trout life histories present in the Tucannon River include resident, fluvial, and adfluvial forms. Migratory bull trout move upstream from the lower Tucannon and Snake rivers into the upper Tucannon River in the spring and early summer, with nearly identical run timing at the Tucannon Fish Hatchery adult trap to that of spring Chinook salmon. Critical habitat in the Tucannon Critical Habitat Subunit, as designated by the USFWS, includes the mainstem Tucannon River, Little Tucannon River, and Cummings, Hixon, Panjab, Cold, Sheep, and Bear creeks (USFWS 2010). Juvenile rearing is primarily thought to occur in the mainstem Tucannon River upstream of Tumalum Creek to the headwaters and the tributaries listed above. The lower and middle Tucannon River provide over-wintering habitat and a migratory corridor for adults and sub-adults to the spawning and rearing areas upstream in the watershed.

Historically, the bull trout population in the Tucannon River was considered healthy based on redd surveys; however, redd survey data, and adult trap data (Figures 4-9 and 4-10) from the mid-2000s suggested a population decline (USFWS 2010). However, since that time, redd numbers and bull trout captures at the Tucannon Fish Hatchery adult trap increased to previous levels. Due to lack of available funding, redd surveys following 2014 have been discontinued. WDFW continues to trap bull trout at the Tucannon Fish Hatchery trap. Currently, the only monitoring is to conduct PIT tagging of all bull trout captured annually at the Tucannon Fish Hatchery adult trap. Re-detection of bull trout with PIT tags is being used to monitor: 1) the proportion, arrival, and departure of spawners at the Tucannon/Panjab fork; 2) the upstream and downstream movement and travel time of bull trout in the Tucannon and Snake rivers at other PIT tag array locations; and 3) passage and passage delay at the Tucannon Fish Hatchery adult trap.

Figure 4-9
Total Number of Redds during Bull Trout Spawning Survey in the Tucannon Basin (1994 to 2014)

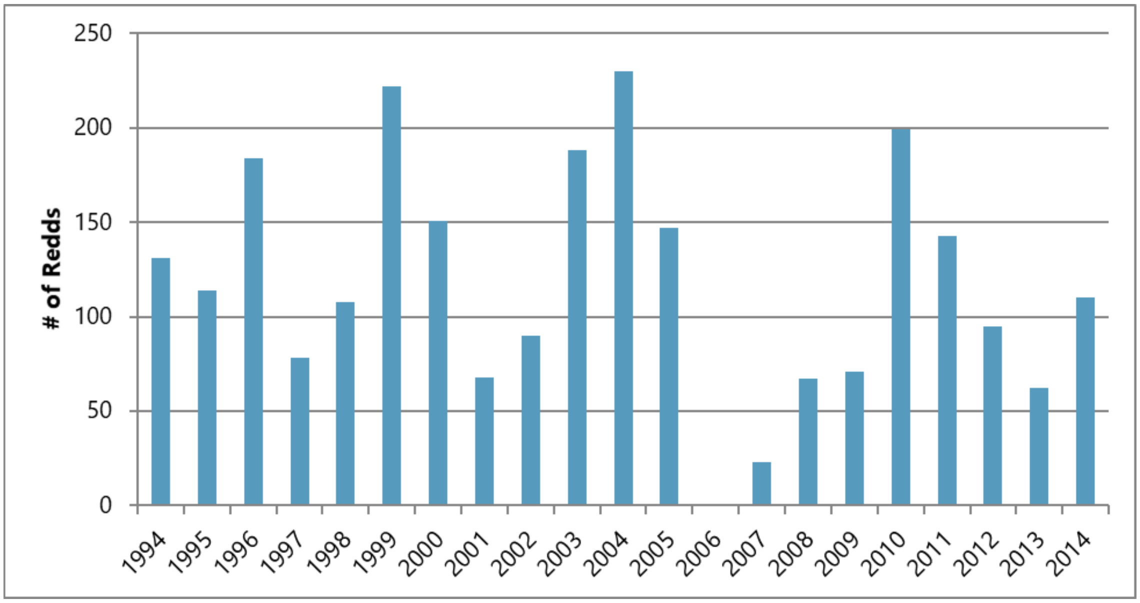
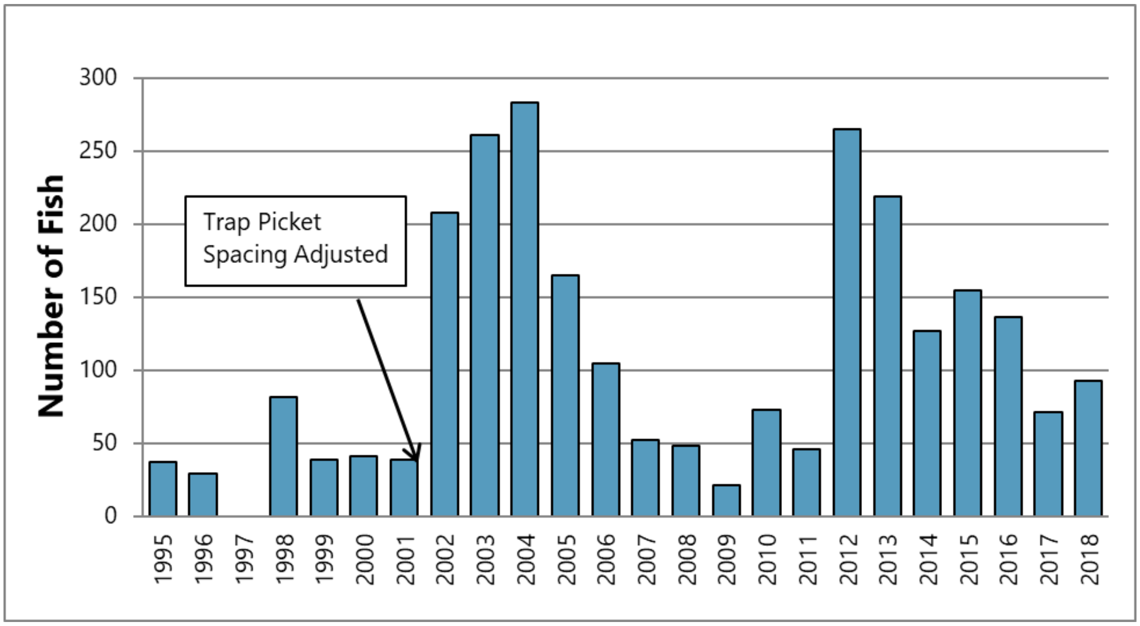


Figure 4-10
Bull Trout Captured at the Tucannon Fish Hatchery Adult Trap (1995 to 2018)



Note: Years prior to 2002 do not represent all fish that likely passed through the trap/weir due to larger picked spacing between the panels.

5 Fish Habitat, Life Cycle, and Distribution

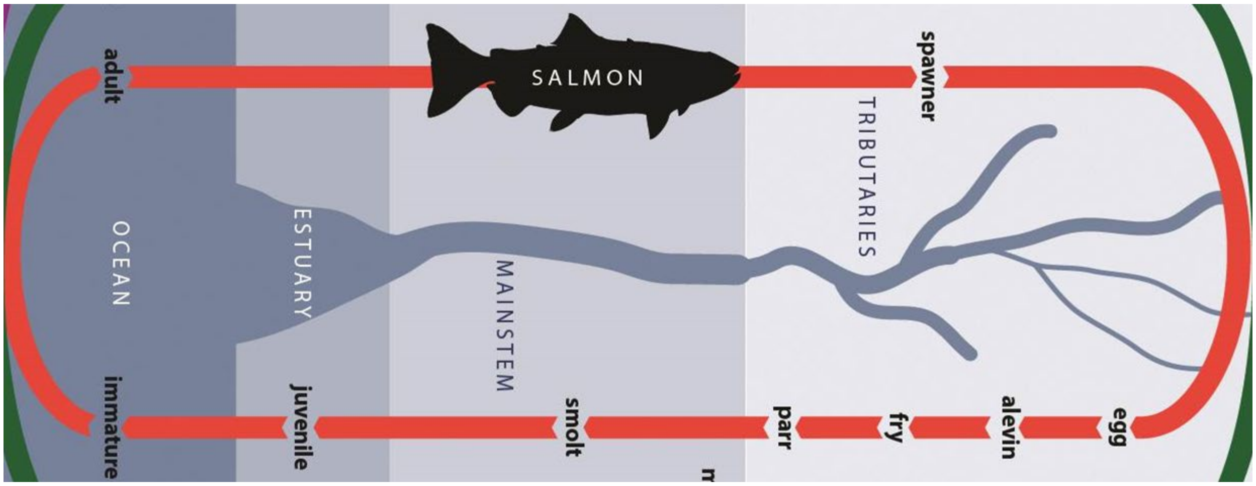
The Tucannon River supports four ESA-listed Snake River Basin salmonid populations throughout all or a portion of their life stages. Summer steelhead, spring Chinook salmon, fall Chinook salmon, and bull trout were identified in the Tucannon Subbasin Plan as aquatic focal species (CCD 2004). Collectively, these species use the main channel from the mouth to the headwaters, as well as major tributaries including Pataha Creek. The following information is summarized from the Tucannon Subbasin Plan (CCD 2004) and the Snake River Salmon Recovery Plan (SRSRB 2006), and revised to include new information from recent data being collected by WDFW and others in the basin (SRSRB 2011; Gallinat and Ross 2010; Crawford et al. 2019). This information has been updated to reflect the current status as of 2018, through email communication with WDFW (WDFW 2019). Table 5-1 shows the spatial distribution of steelhead and Chinook salmon in the mainstem of the Tucannon River, with darker shades of gray indicating higher densities of fish present during their respective life stages. Information on bull trout was not sufficient to provide distribution data as reported for the other focal species.

Natural Tucannon River summer steelhead, spring Chinook salmon, and fall Chinook salmon all express anadromous life cycles, where they spend at least a portion of their life span in fresh water (the Tucannon, Snake, and Columbia rivers for this group) followed by a part in the brackish Columbia River estuary and the Pacific Ocean. The time spent in each ecosystem varies by each species and within species depending on environmental conditions (e.g., stream temperature, ocean productivity). Bull trout within the Tucannon River are potamodromous, meaning they are migratory without going to the ocean, spending their life in fresh water.

This is simplified life cycle for salmon indicating the life stages of Chinook salmon for the Tucannon River. Figure 5-1 tracks a typical life cycle of Tucannon salmon beginning with adults spawning in 2019. Starting with the adult life stage, salmon enter the Columbia River from March to April 2019, enter the Tucannon River in May to June 2019, and finally spawn in the Tucannon River in September 2019. The eggs remain in the gravel from September 2019 to February 2020, hatching into alevins, and leaving the gravel in April to May 2020 as fry. Salmon fry live in the Tucannon River and become parr between June and July 2020. Parr will remain in the Tucannon River until the spring freshet between April and June 2021 when they migrate down the Columbia River to its estuary to undergo smoltification, preparing themselves for the ocean environment. They feed in the productive, brackish estuarine environment prior to entering the marine environment. The smolts will spend some time acclimating to saltwater conditions in the mild, brackish estuary environment, while feeding on the bountiful food production of the Columbia River estuary. The Tucannon River spring Chinook salmon eventually enter the Pacific Ocean and will remain in the ocean ranging as far as the Gulf of Alaska before returning to the Tucannon in 2022 (as jacks) or in 2023 to 2024 (as adults).

Figure 5-1
Tucannon River Salmon Life Cycle

Spawn 2019



Ocean 2022–2024 **Smolt 2021** **Rear 2020**

Table 5-1
Distribution of Steelhead, Chinook Salmon, and Bull Trout in the Mainstem Tucannon River

Geographic Area	From (RM)	To (RM)	Summer Steelhead				Spring Chinook				Fall Chinook			Bull Trout			
			Spawning	Summer Juvenile Rearing	Winter Juvenile Rearing	Adult Holding	Spawning	Summer Juvenile Rearing	Winter Juvenile Rearing	Adult Holding	Spawning	Juvenile Rearing	Adult Holding	Spawning	Summer Juvenile Rearing	Winter Juvenile Rearing	Adult Holding
Mouth	0	0.7				░					█	░	░			░	░
Lower Tucannon	0.7	4.8	░	░	░	░					█	░	░	Note: Migratory and resident fish. Distribution data are limited.		░	░
	4.8	5.5	░	░	░	░			░		█	░	░			░	░
	5.5	8.7	░	▓	░	░			░		▓	░	░			░	░
	8.7	12.3	░	▓	░	░			▓		▓	░	░			░	░
Pataha-Marengo	12.3	16.5	▓	█	░	░			▓		░	░	░			░	░
	16.5	18.6	▓	█	░	░		░	▓		░	░				░	░
	18.6	22.8	▓	█	░	░		░	▓			Note: Juveniles out-migrate as subyearlings				░	░
	22.8	26.6	▓	█	░	░	▒	▓	▓	░						░	░
Marengo-Tumalum	26.6	35.6	▓	█	░	░	▓	█	▓	░						░	░
Tumalum-Hatchery	35.6	37.8	▓	█	░	░	▓	█	▓	░					░	░	░
	37.8	41.9	▓	█	░	░	█	█	▓	░					░	░	░
Hatchery-Little Tucannon	41.9	44.6	▓	█	░		█	█	▓	░					░	░	░
	44.6	45.6	▓	▓	░		█	█	▓	░					░	░	░
	45.6	48.1	▓	▓	░		█	█	░	░					▓	░	░
Mountain	48.1	50.2	▓	░	░		▓	▓	░	░				▒	▓	░	░
Wilderness (Panjab to Sheep Creek)	50.2	56.0	░	░	░		▓	▒	░	░				█	▓	░	░
	53.0	56.0	░	░	░		▒			░				█	▓	░	░
Wilderness (Sheep Creek to Headwaters)	56.0	59.0					▒							█	▓	░	░
	59.0	62.0												▒	▒	░	░

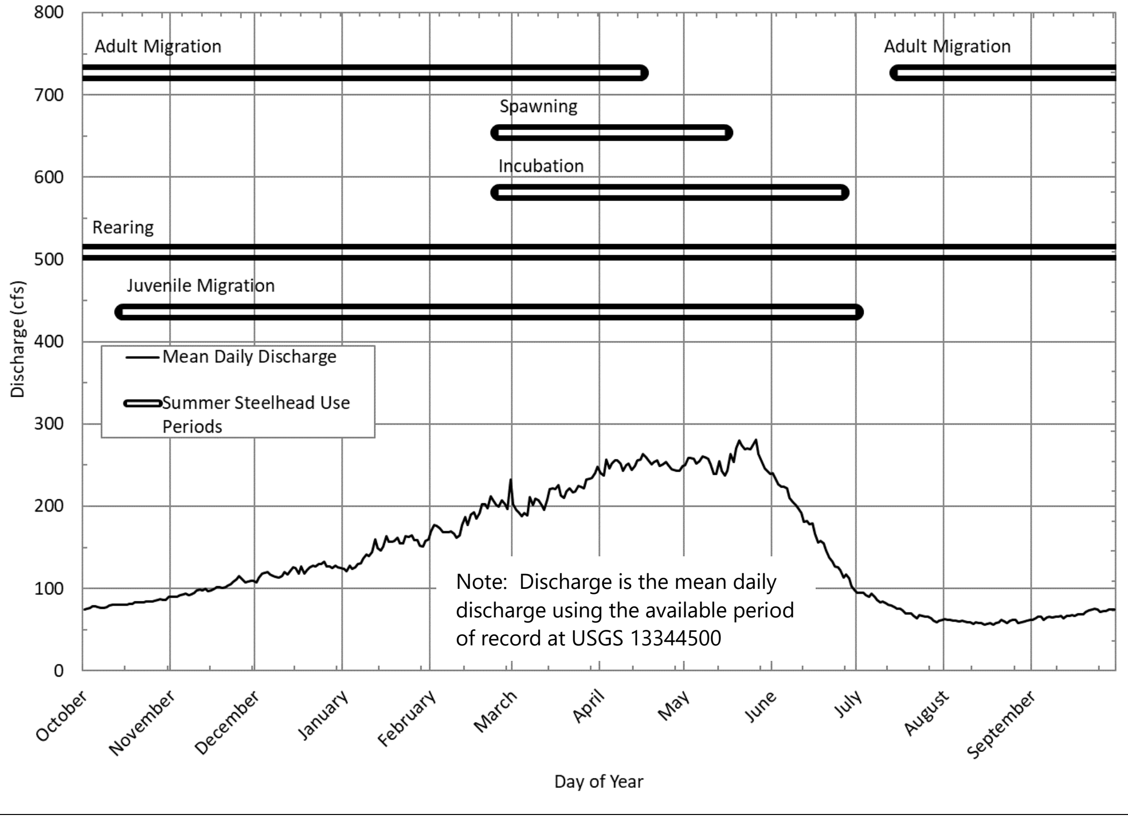
Notes:

1. Distribution data have been collected by WDFW, updated in 2018, and conveyed via email communications for this report.
2. Darker shades of gray indicate higher densities of fish present during their respective life stages.

5.1 Summer Steelhead

Summer steelhead in the Tucannon River are part of the Snake River Basin steelhead ESU, which was listed as threatened in 1997. Summer steelhead enter the Tucannon River as early as July and begin spawning in late February to early March with spawning continuing to late May (Figure 5-2). Spawning occurs in the mainstem Tucannon River from the mouth (RM 0.0) upstream to the Tucannon River headwaters, as well as within Cummings Creek and in the lower portions of Panjab, Sheep, Little Tucannon, and, in some years Tumulum Creek; the greatest concentration of steelhead spawning is typically found in the mainstem river between Tucannon Falls (RM 16.5) and Beaver/Watson Lake at approximately RM 42. Juveniles also rear throughout the mainstem river but are typically found in the greatest numbers between approximately RM 18 and School Canyon (approximately RM 45).

Figure 5-2
Mean Annual Hydrograph and Typical Timing of Life History Stages for Summer Steelhead in the Tucannon Basin



Note: Discharge is the mean daily discharge using the available period of record at USGS 13344500

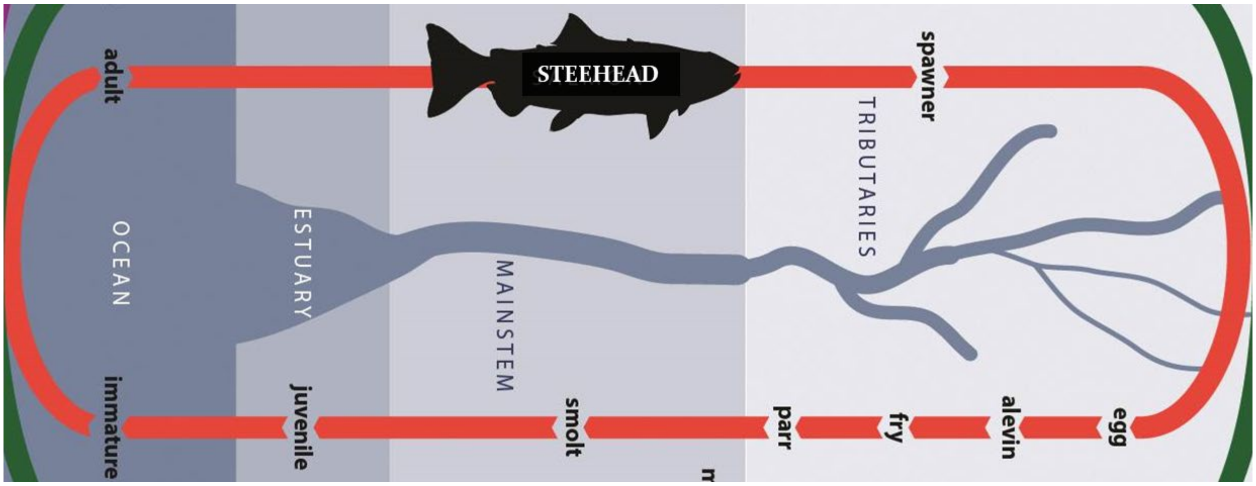
In the Tucannon River, it is believed that the steelhead exhibit both anadromous and resident life histories where some steelhead progeny remain in the Tucannon River and complete their life cycle without leaving the river. The number and proportion of these fish is not known; however, and a recent study looking into spring Chinook salmon and summer steelhead survival and distribution (Crawford et al. 2019) indicates that the number of residual fish may be limited. Although not directly investigating juvenile steelhead age structure within the basin, the random sampling method included developing an age structure model indicating the vast majority of aged steelhead to be age 0 to age 1 (98.66%), with few fish being age 2 (1.33%) or older. The study found steelhead emigration from spawning and rearing, varied with juvenile parr spending between 1 and 3 years within the Tucannon River before smolting (Crawford et al. 2019). Tucannon steelhead complete their anadromous life cycle on average in 3 to 6 years following the egg stage, spending 1 to 3 years in the ocean.

The WDFW study investigated juvenile steelhead survival within the Tucannon River downstream to Monumental Dam on the Snake River in 2016 and 2017 using both brood years (Crawford et al. 2019). Fish movement was completed using PIT tags and modeled survival based on instream detections at four in-basin tag receives during the seaward migration through 2018. Tagged fish have been observed leaving the upper basin in the mid to late fall using the middle and lower river basin to over-winter before entering the Snake River in the spring.

The Tucannon River steelhead exhibit an anadromous life cycle that for some individuals can take up to 7 years to complete. Figure 5-3 portrays the Tucannon steelhead anadromous life cycle, beginning with adult spawning in the Tucannon River between March and May of 2019. Alevins emerge from the gravel and become fry between June and July 2019. Fry grow to become parr, remaining for one to two winters or from August 2019 to April 2021, and then smolt and emigrate into the Snake River and then the Columbia River. The smolts can remain in the Columbia River estuary or directly enter the Pacific Ocean where they mature from sub-adults into adults. As adults they will spend between 1 and 3 years in the ocean before reentering the Columbia River between June and September of 2021 to 2025. The longer steelhead adults remain in the ocean, the larger they will be at spawning. The wild steelhead population remains in the Columbia River and Snake River from late summer until winter and early spring before arriving in the Tucannon River and spawning in the late winter or early spring.

Figure 5-3
Tucannon River Steelhead Life Cycle

Spawn 2019

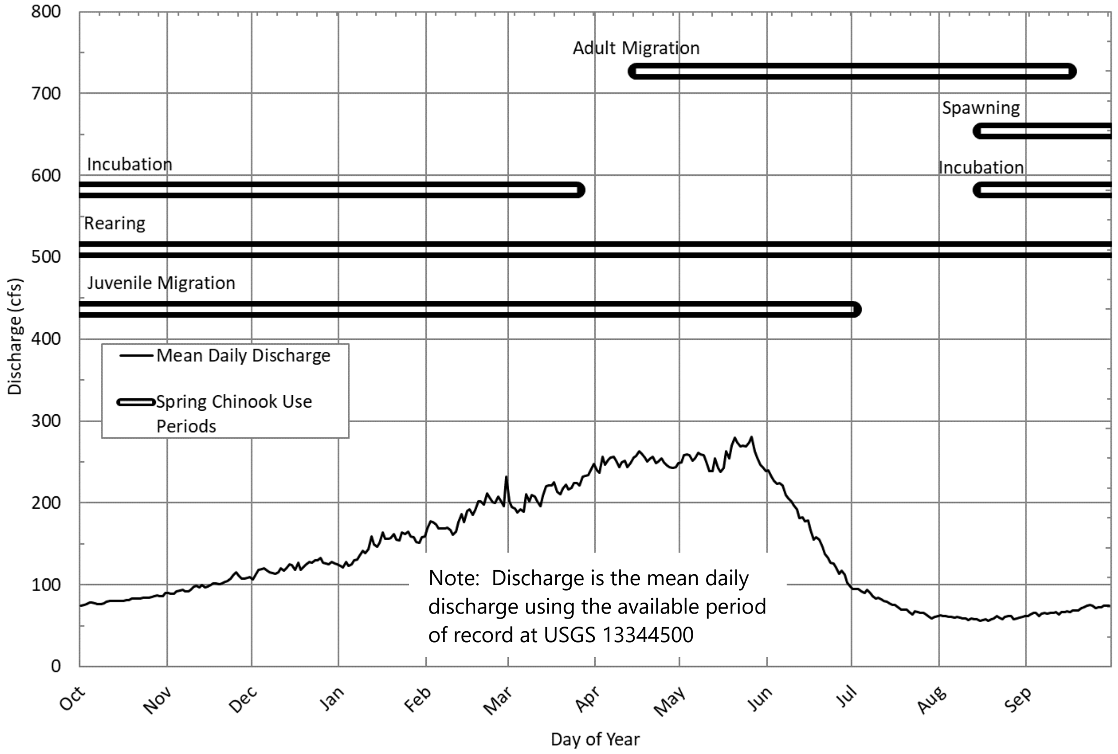


Ocean 2021–2025 **Smolt Spring** **Rear 2020–2022**

5.2 Spring Chinook Salmon

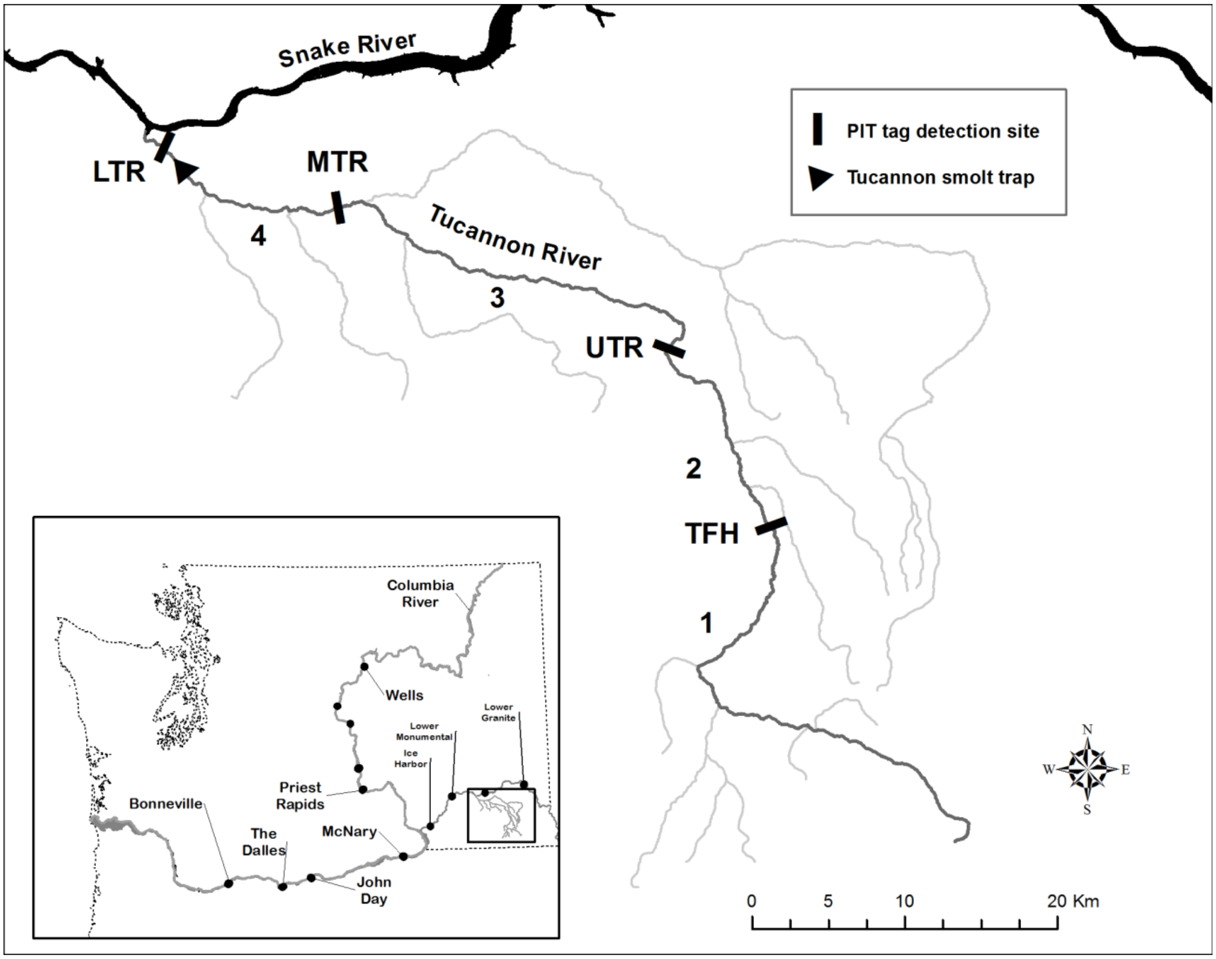
Spring Chinook salmon in the Tucannon River are part of the Snake River spring/summer Chinook salmon ESU that was ESA-listed as endangered in 1992 but downgraded to threatened in 1995. Spring Chinook salmon enter the Tucannon River beginning as early as mid-April and can enter as late as mid-September, although generally 90% of the run enters the lower river between May 1 and June 30 (Figure 5-4). Spawning occurs from mid-August to the end of September, almost exclusively in the main channel from approximately King Grade (RM 22.9) to the mouth of Sheep Creek near RM 55 (Gallinat and Ross 2017). The greatest densities of spawners are between Cummings Creek (RM 38) and the Little Tucannon River (approximately RM 48.1). Summer rearing of juveniles occurs from approximately Tucannon Falls (RM 16.5) to the headwaters, with the highest densities located between Marengo and School Canyon (approximately RM 45).

Figure 5-4
Mean Annual Hydrograph and Typical Timing of Life History Stages for Spring Chinook Salmon in the Tucannon Basin



In 2016 and 2017, WDFW investigated juvenile spring Chinook salmon migration behavior and survival within the Tucannon River downstream to Monumental Dam on the Snake River (Crawford et al. 2019). Fish observations were completed using PIT tags and instream detections at four receivers within the basin to determine emigration behavior spatially/temporally and modeled survival to the Snake River. The study found that across the two year classes that were tagged, a large proportion of parr tagged in the two upper-most river strata (labeled as TFR and UTR in Figure 5-5) emigrate seaward from the upper basin in the mid to late fall using the middle and lower river basin to over-winter before entering the Snake River. Based on outcomes from Crawford et al. (2019), the upper river (TFH, UTR) is used as over-winter habitat but is proportionally used less than the middle river (MTR) by over-wintering Chinook parr. Additionally, the study indicated reduced survival over winter in the third strata located in the middle river (between UTR and MTR, as shown in Figure 5-5).

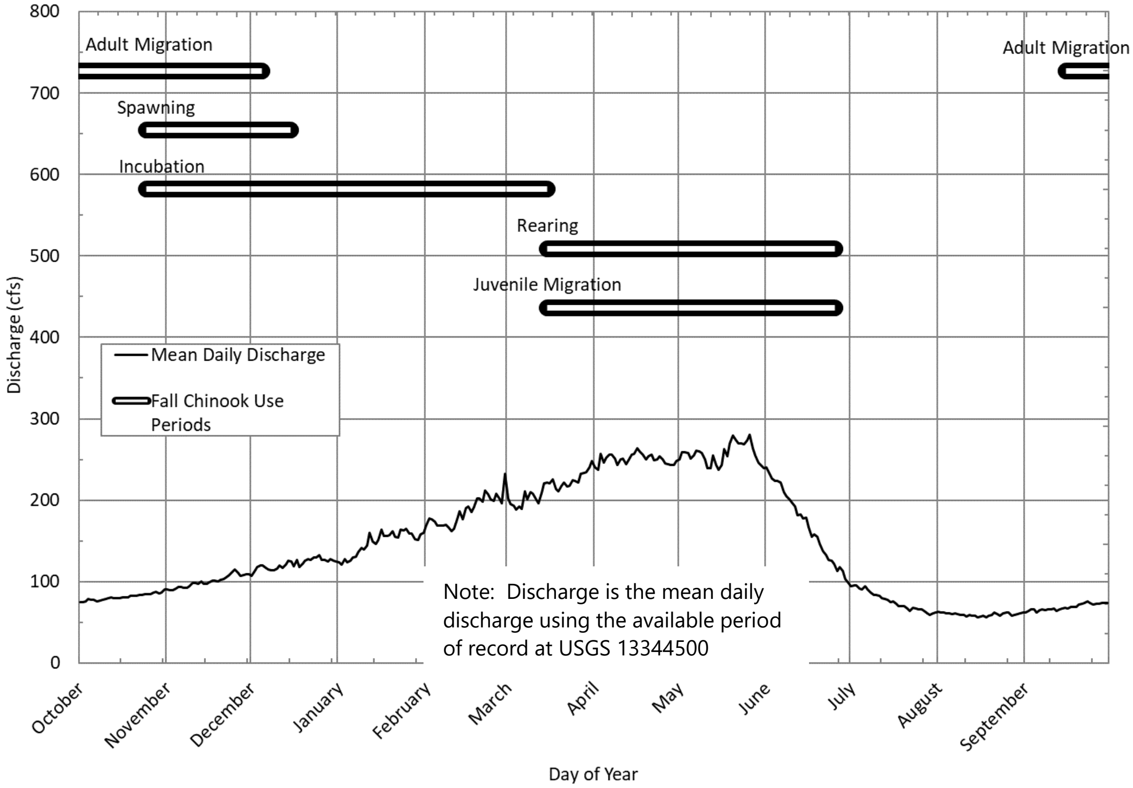
Figure 5-5
Tucannon PIT Tag Locations



5.3 Fall Chinook Salmon

Fall Chinook salmon are part of the Snake River fall Chinook salmon ESU, also listed as threatened in 1992. Fall Chinook salmon enter the lower Tucannon River beginning as early as mid-September and can continue to enter the river through early December. Spawning typically begins in late October and continues into mid-December (Figure 5-6). Fall Chinook salmon use the main channel of the river from the mouth, and have been occasionally observed spawning as high as King Grade Road (RM 22.9), but the highest concentration of spawning is generally from the mouth to around the Starbuck Dam near RM 5.5. Juvenile fall Chinook salmon do not over-winter in the Tucannon River and out-migrate shortly after emergence during early spring to early summer.

Figure 5-6
Mean Annual Hydrograph and Typical Timing of Life History Stages for Fall Chinook Salmon in the Tucannon Basin



Note: Discharge is the mean daily discharge using the available period of record at USGS 13344500

5.4 Bull Trout

Bull trout in the Columbia Basin were ESA-listed as threatened in 1998. The Tucannon River bull trout population is part of the Lower Snake River Critical Habitat Unit (USFWS 2010). Bull trout life histories present in the Tucannon River include resident, fluvial, and adfluvial forms. Migratory bull trout move upstream from the Snake River into the upper Tucannon River in the spring and early summer, with nearly identical timing to that of spring Chinook salmon. Critical habitat in the Tucannon Critical Habitat Subunit, as designated by the USFWS, includes the mainstem Tucannon River, Cummings Creek, Hixon Creek, the Little Tucannon River, Panjab Creek, Cold Creek, Sheep Creek, and Bear Creek (2010). Juvenile rearing occurs upstream of Tumalum Creek to the headwaters. The lower and middle Tucannon River are important migratory corridors to spawning and rearing areas upstream in the watershed, including the headwaters and tributary streams noted here.

Historically, the bull trout population in the Tucannon River has been considered healthy; however, data from the mid-2000s suggested some population declines (USFWS 2010). As cited by USFWS, WDFW surveys indicated the number of redds in the upper Tucannon River dropped from more than 100 in 2002 and 2003 to less than 20 in 2007. This correlated with a decline in the number of adult migratory bull trout captured at the Tucannon Fish Hatchery trap as they were moving upstream. However, since that time redd numbers increased, with an average redd count from 2008 to 2014 of 83 redds, with a high of 161 redds. Due to lack of funding, redd surveys following 2014 have been discontinued. WDFW continues to trap bull trout at the Tucannon Fish Hatchery trap, and following 2007 also rebounded and appear fairly stable, with the average number of bull trout trapped between 2008 and 2018 equaling 114, with a high of 265 and low of 21.

5.5 Other Species of Concern

Besides the four ESA-listed species, many other native aquatic species are present in the Tucannon River. Unfortunately, most of these have little to no biological information on their current status and health. Based on previous surveys by WDFW, species such as sculpins (multiple species), dace (long-nose or speckled), and red-sided shiners are plentiful throughout the basin. Other species such as whitefish, suckers, Pacific lamprey, and freshwater mussels were also once abundant within the basin, but are now thought to be critically depressed from historical levels. Previous actions within and outside the basin likely contributed to their decline, and it is hoped that habitat prescriptions described within this assessment will assist in their recovery. Although some species are currently abundant in the Snake pool between Lower Monumental Dam and Little Goose Dam including mountain whitefish (*Prosopium williamsoni*) or suckers (Catostomidae sp.), they do not seem to be migrating upriver and initiating/supporting populations. It is possible these riverine potamodromous species are unable to navigate the fish ladder at Starbuck Dam or the Tucannon Falls. Snorkel surveys conducted between 2014 and 2018 by the Action Effectiveness Monitoring project, sponsored by both the Bonneville Power Administration and Snake River Funding Board recorded observations of all fish species observed during surveys and found that both whitefish and sucker species decreased moving upstream and were absent above RM 37 and nearly absent above RM 26 (Roni 2019).

6 Limiting Factors Progression

Many efforts have been made to understand the factors negatively affecting salmon and steelhead growth and survival across varying life history stages throughout the Pacific Northwest. The priority habitat factors limiting survival and production within a given river segment, tributary, or basin change over time as conditions continue to degrade or improve. Early watershed assessments often focused on limiting factors that were directly killing fish (called imminent threats), such as dewater streams, migratory blockages, or unscreened diversions. As the imminent threats were addressed across the watershed, restoration efforts transitioned toward limiting factors that indirectly killed fish or limited their growth or survival over several life cycles or part of their life cycle. Simplified instream conditions and lack of deep pools, degraded riparian conditions, and fine sediment input from logging, farming, and other land use activities are primary factors affecting fish. In the Tucannon Basin, fine sediments and elevated summer water temperatures impacted returning adult spring Chinook survival, which led to widespread use of minimum till agriculture, riparian planting, and bank stabilization projects. These early assessments were often focused on the adult life history stage and looking at the ability of adult fish to traverse, hold, and successfully spawn in river systems.

Protection of riparian areas, improved irrigation and tilling practices, levee setbacks, and instream channel improvements, that began in the 1990s, have greatly reduced land use practices that were negatively impacting the river. This has led to significantly improved ecological conditions such that temperature and fine sediment inputs are no longer considered limiting factors. Summer water temperatures in the mid-1980s typically would reach 26°C below RM 20, making the river migratory seasonal habitat; however, since 1997 it has been recognized that steelhead spawning and rearing habitat exists to the mouth of the Tucannon River. This was based on catches of newly emerged steelhead fry captured in the rotary screw trap in May/June, and subsequent catches of parr/fingerling-sized juveniles during late summer electrofishing surveys. Riparian corridors now provide significant shading and nutrient contributions through much of the river, as well as providing floodplain stability and flood resiliency.

The following studies have evaluated limiting factors in the Tucannon River:

- The Tucannon Subbasin Plan (CCD 2004)
- Snake River Salmon Recovery Plan for SE Washington (SRSRB 2006)
- Response to ISRP comments on BiOp proposal, Tucannon River Programmatic Habitat Project (SRSRB 2011)

Table 6-1 summarizes the limiting factors considered for each of these efforts and displays how these limiting factors changed as conditions in the basin have improved and additional information has been collected.

Table 6-1
Summary of Life History Stages and Limiting Factors

Salmon Life History Stage	EDT Limiting Factors [1]	Key Limiting Factor [2]	Cause of Problem	2011 Salmon Recovery Plan Obj. [3]	2011 Programmatic Objectives [4]	2020 Prioritization Goals [5]	2020 Prioritization Objectives [5]	Expected Ecological Response [5]	Assessment Method [8]
Spring Chinook Egg-Fry	Sediment Load [A, a] Temperature [b] Channel Stability [C] Habitat Diversity [D]	Large Wood Log Jams Confinement [F] Riparian Function Key Habitat (pools) Temperature	Channelization, loss of floodplain and riparian, loss of channel complexity and function	Riparian: > 40-70% max LWM: > 1 key piece/channel width Confinement: < 20-50% of Length Temperature < 4 day > 72°F Embeddedness: < 20% [G]	OBJ-1 OBJ-2 OBJ-3 OBJ-4 OBJ-6 [H]	Increase complexity at low-winter flows, during spring and winter peaks Reconnect abandoned floodplains Increase retention and storage of bed load gravel	Flow Complexity to levels of current 90th percentile of basin for low-winter and mean spring/winter peaks 75% of the available floodplain is connected at the 2-year event > 15% pool area	Improved habitat conditions for summer and fall juvenile rearing and winter refugia Improved extreme event refugia, riparian growth, wood material availability, bedload material availability juvenile rearing	Channel complexity at low-winter, mean-winter, and 1-year flow Channel aggradation floodplain potential, encroachment removal, and total floodplain potential Excess transport capacity, connectivity, and complexity analysis
Spring Chinook Fry-Smolt	Temperature [B] Channel Stability [C] Habitat Diversity [D] Key Habitat [E]	Large Wood Log Jams Confinement Riparian Function Key Habitat (pools) Temperature	Channelization, loss of floodplain and riparian, loss of channel complexity and function		OBJ-1 OBJ-2 OBJ-3 OBJ-4 OBJ-5				
Spring Chinook Adult	Temperature [B] Habitat Diversity [D] Key Habitat [E]	Large Wood Log Jams Riparian Function Key Habitat (pools) Temperature	Loss of channel process and complexity		OBJ-1, OBJ-3, OBJ-4, OBJ-5	Improve quantity and quality of pools	> 15% pool area	Improved adult holding and cover	Pool frequency analysis and excess transport capacity analysis
Steelhead Egg-Fry	Sediment Load [A, a] Temperature [b] Channel Stability [C] Habitat Diversity [D] Key Habitat [E]	Large Wood Log Jams Confinement Riparian Function Key Habitat (pools) Temperature Sediment [A]	Channelization, loss of floodplain and riparian, loss of channel complexity and function	Riparian: > 40-70% max LWM: > 1 key piece/channel width Confinement: < 20-50% of Length Temperature < 4 day > 72°F Embeddedness: < 20% [G]	OBJ-1 OBJ-2 OBJ-3 OBJ-4 OBJ-6 [H]	Increase complexity at low-winter flows, during spring and winter peaks Reconnect abandoned floodplains Increase retention and storage of bed load gravel	Flow Complexity to levels of current 90th percentile of basin for low-winter and mean spring/winter peaks 75% of the available floodplain is connected at the 2-year event > 15% pool area	Improved habitat conditions for summer and fall juvenile rearing and winter refugia Improved extreme event refugia, riparian growth, wood material availability, bedload material availability juvenile rearing	Channel complexity at low-winter, mean-winter, and 1-year flow Channel aggradation floodplain potential, encroachment removal, and total floodplain potential Excess transport capacity, connectivity, and complexity analysis
Steelhead Fry-Smolt	Temperature [B] Channel Stability [C] Habitat Diversity [D] Key Habitat [E]	Large Wood Log Jams Confinement Riparian Function Key Habitat (pools) Temperature	Channelization, loss of floodplain and riparian, loss of channel complexity and function		OBJ-1 OBJ-2 OBJ-3 OBJ-4 OBJ-5				
Steelhead Adult	Habitat Diversity [D] Key Habitat [E]	Large Wood Log Jams Riparian Function Key Habitat (pools) Temperature	Loss of channel process and complexity		OBJ-1, OBJ-3, OBJ-4, OBJ-5	Improve quantity and quality of pools	> 15% pool area	Improved adult holding and cover	Pool frequency analysis and excess transport capacity analysis
Fall Chinook Egg-Fry	Sediment Load [A] Temperature [B] Habitat Diversity [D] Key Habitat [E]	Large Wood Log Jams Confinement Riparian Function Key Habitat (pools) Temperature Sediment [A]	Channelization, loss of floodplain and riparian, loss of channel complexity and function	Riparian: > 40-70% max LWM: > 1 key piece/channel width Confinement: < 20-50% of Length Temperature < 4 day > 72°F Embeddedness: < 20% [G] Note: The Recovery Plan identifies these objectives as habitat recovery for the Tucannon downstream of Pataha Creek but not directly for fall Chinook.	OBJ-1 OBJ-2 OBJ-3 OBJ-4 OBJ-6	Increase complexity at low-winter flows, during spring and winter peaks Reconnect abandoned floodplains Increase retention and storage of bed load gravel	Flow Complexity to levels of current 90th percentile of basin for low-winter and mean spring/winter peaks 75% of the available floodplain is connected at the 2-year event > 15% pool area	Improved habitat conditions for summer and fall juvenile rearing and winter refugia Improved extreme event refugia, riparian growth, wood material availability, bedload material availability juvenile rearing	Channel complexity at low-winter, mean-winter, and 1-year flow Channel aggradation floodplain potential, encroachment removal, and total floodplain potential Excess transport capacity, connectivity, and complexity analysis
Fall Chinook Fry-Smolt	Temperature [B] Habitat Diversity [D] Key Habitat [E]	Large Wood Log Jams Confinement Riparian Function Key Habitat (pools) Temperature	Channelization, loss of floodplain and riparian, loss of channel complexity and function		OBJ-1 OBJ-2 OBJ-3 OBJ-4 OBJ-5				
Fall Chinook Adult	Temperature [B] Habitat Diversity [D] Key Habitat [E]	Large Wood Log Jams Riparian Function Key Habitat (pools, spawning riffles)	Loss of channel process and complexity		OBJ-1, OBJ-2, OBJ-3, OBJ-4, OBJ-5, OBJ-6	Improve quantity and quality of pools	> 15% pool area	Improved adult holding and cover	Pool frequency analysis and excess transport capacity analysis

Notes:

[A] – Fine sediment on redds is no longer an impact to salmonid redds upstream from Patah Creek and is identified as being only an active limiting factor downstream of Patah Creek.

[a] – Diminished or disrupted bed load in some reaches has led to insufficient gravel to support riffle and pool development.

[B] – Water temperature that is too cold or too warm can reduce the survival of all salmonids in the Tucannon River and is the result of poor river channel shape and loss of connection to the floodplain, leading to reduced hyporheic flow in channel and return flow from floodplain storage.

[b] – Egg-to-Fry stage are primarily impacted by low water temperature in the Tucannon River; for example, ice impacts to redds and larvae.

[bb] – Warm temperatures increasing moving downstream below the Tucannon Fish Hatchery Weir and more so below Marengo, WA.

[C] – Channel stability in the Tucannon River is best described as the plane bed channel with bed armor and entrenchment, which has led to increased stream power and bed scour and loss of floodplain connectivity and confinement.

[D] – Habitat diversity in the Tucannon River is the extent of habitat complexity within a river segment, including side channels at base flow up to ~ 5-year return flow, pools, riffles, and off-channel habitats on the floodplain.

[E] – Key habitat is referring directly to the number of pools, spawning riffles, and off-channel rearing habitats including large wood log jams.

[F] – Floodplain and river meander confinement.

[G] – Embeddedness is a restoration objective for the lower Tucannon River below Pataha Creek and is not currently limiting above Pataha Creek.

[H] – The programmatic objective for embeddedness < 20% for all reaches above Pataha Creek is currently being met.

[1] – The limiting factors used in this table were taken from the Salmon Recovery Plan for SE WA (2011) Chapter 5 (Table 5-1).

[2] – The key limiting factors for the Tucannon River are listed in full detail in the Salmon Recovery Plan for SE WA (2011) Chapter 5 (Table 5-2).

[3] – A summary table of restoration objectives is provided in the Salmon Recovery Plan for SE WA (2011) Chapter 6 (Table 6-2).

[4] – For a full description of the Programmatic Restoration objectives, see Table 1-1 in this report.

[5] – A list and full description is provided in Table 1-2 in this report.

Working in concert with these efforts is addressing the longer term processes that the current strategies target. Addressing impaired processes such as floodplain connectivity will contribute to reversing negative trends in longer term processes, for example establishing and maturing riparian forests increasing resiliency and the natural long-term recovery of the basin. Table 6-2 summarizes the impaired processes and limiting factors as understood by the SRSRB and its restoration partners at the time of this assessment.

Table 6-2
Summary of Impaired Processes and Limiting Factors

Impaired Processes	Causes	Limiting Factors for Fish and Wildlife
Reduced in-channel structure (e.g., wood)	Past removal of wood from channel	• Low diversity of in-channel habitats • Lack of deep pools for holding or rearing • Limited quantity of off-channel habitat • Lack of cover
	Lack of large trees in the riparian zone	
	Historical channel straightening and levee building	
	Much of the existing wood is highly mobile	
Modified sediment delivery and transport	Loss of in-channel structure increases transport and bed incision	• Low diversity of substrates and potential for coarsening over time • Reduced quality of spawning gravel
	Levees reduce floodplain storage and exchange	
	Reduced riparian density increases bank erosion potential (i.e., fine sediment delivery)	
	Bank armoring reduces channel migration (i.e., coarse sediment delivery)	
Reduced floodplain connectivity and function	Channel incision from reduced in-channel structure	• Limited quantity of off-channel habitats • Low diversity of off-channel habitats • Lack of high-flow refugia • Reduced groundwater recharge and discharge
	Bank armoring and other geomorphic impediments	
Reduced riparian condition and function	Past removal or harvest of riparian vegetation	• Limited cover • Low diversity of in-channel or off-channel habitats • Reduced nesting and foraging habitats • Reduced productivity of food webs • High water temperatures (primarily downstream)
	Widespread colonization by invasive species	
	Rapid bank erosion and human/animal trampling prevents maturation of riparian plantings (some locations)	

7 Restoration Strategies

The restoration opportunities presented in this report are focused on promoting natural geomorphic and ecological processes to restore ecosystem functions. Developing restoration strategies that take advantage of those opportunities and promote natural processes is vital to providing the greatest benefit to salmonid abundance and productivity in the near term, as well as long-term sustainability of project actions. In order to adequately understand how process-based restoration strategies can be used to promote the goals and objectives of this assessment, this section examines the driving geomorphic processes and the expected geomorphic response of each prioritization goal. Through understanding the driving geomorphic processes of the prioritization goals, process-based restoration strategies have been developed that are expected to induce the desired geomorphic processes to achieve the prioritization goals and objectives and promote the desired ecological response. Section 7.2 describes the general restoration strategies that may be identified as an opportunity in any given project area, along with the physical and biological benefits of each opportunity, and which analysis results were used to inform each restoration opportunity.

7.1 Consistency with Natural Geomorphic Process

In order to develop process-based restoration strategies to meet the goals of the prioritization, it is necessary to first understand the physical and ecological processes that support those goals. There are specific physical and ecological processes that support the prioritization goals and proposed restoration strategies. These restoration strategies focus on the following geomorphic processes: bedload sediment transport, floodplain connection and inundation, wood material recruitment, and channel confinement and incision. Table 7-1 shows how the goals of this prioritization are related to these geomorphic processes, which are discussed in more detail in the following section. Additionally, Table 7-1 provides a description of the type of response that can be expected from the advancement of the prioritization goals and how this response relates to maintaining the natural fluvial processes in the basin. Because these goals and the geomorphic processes behind them are all connected at some level, Table 7-1 lists what other goals will be affected by the driving geomorphic processes and the expected responses.

Table 7-1
Prioritization Goals and Their Driving Geomorphic Processes

Goal	Driving Geomorphic Processes	Expected Geomorphic Response
Increase complexity at low-winter flows	• Bedload sediment transport and availability • Floodplain connection and inundation • Wood material recruitment	Channel systems that change primary low-winter flow paths year to year and are resilient to catastrophic change, and incision via maintenance of multiple low-winter flow pathways.
Increase complexity during spring and mean-winter peaks	• Bedload sediment transport • Floodplain connection and inundation • Wood material recruitment	Channel systems maintain low velocity alternative channels during high-flow events by causing yearly geomorphic change to the banks and floodplain. Dynamic channels mobilize sediment stored in the floodplain and recruit wood material from riparian areas.
Reconnect disconnected and abandoned floodplains	• Bedload sediment transport and availability • Floodplain connection and inundation	Floodplains that are inundated every few years allow for greater riparian growth of native species, and therefore allow for an increase of wood material on the floodplain. Low-lying connected floodplains allow for more frequent channel avulsions and increased complexity.
Improve quantity and quality of pools	• Bedload sediment transport and availability • Wood material recruitment	Pools store water, increase hyporheic exchange, and recharge groundwater, allowing for healthy riparian areas and wood material rejuvenation in the floodplain.
Increase retention and storage of in-channel bedload sediments	• Bedload sediment transport and availability • Wood material recruitment	Bedload sediment material that is mobilized on a yearly basis allows for complex dynamic channels, changing bedforms, formation of pools with instream wood, and connection to riparian floodplains.

The most encompassing process listed in Table 7-1 is bedload sediment transport, including mobilization and availability. This process influences the availability of gravel and cobble material that is necessary for geomorphic change in the Tucannon River. It has been noted through experiential knowledge that lack of these materials often causes restoration projects to respond slowly or not at all, preventing geomorphic change from occurring. In functioning reaches of the Tucannon River, alluvium that can be mobilized with a 1- to 2-year flow event is continuously stored in and released from the floodplain and channel as channel migrations and avulsions occur through the floodplain. These migrations and avulsions are in turn caused by the deposition of similarly sized material from upstream reaches in a process that drives the complexity and geomorphic change in the Tucannon River. The availability and deposition of this material directly in the channel also raises the overall water surface in a reach and allows for more frequent floodplain inundation. Therefore, the transport and availability of this material through either upstream channel dynamics or gravel augmentation is essential to all of the goals of this prioritization.

The process of floodplain connection and inundation is similarly essential in that it allows for connection and recharge of groundwater and healthy riparian growth. Many native riparian species depend on this semi-annual source of water in the Tucannon River ecosystem, and therefore this process drives wood material rejuvenation and eventual recruitment. Regular access to the floodplain allows for geomorphic change such as bank erosion, meander bar building, and channel migration. Because of this, the goal of reconnecting disconnected and abandoned floodplains is also tied indirectly to the goals of increasing low-winter flow, mean-winter flow, and 1-year flow complexity.

Closely tied to the processes of floodplain connection and bedload transport is the process of wood material rejuvenation and recruitment. Shallow groundwater in connected floodplains (supplemented by the Tucannon River) supports the growth of floodplain forests which are the source of large wood recruitment into the Tucannon River. As geomorphic changes occur, this wood is recruited into the active channel along with easily transportable gravel material, eventually causing more geomorphic change, and complexity. When adequate sediment is available, large wood also aids in the creation of pools. In this way the process of wood material rejuvenation and recruitment is a crucial step in the long-term maintenance of the goals of complexity for low-winter, mean-winter, and yearly flows, as well as the formation of pools and in-channel complexity.

7.2 Habitat Restoration Actions

The fundamental tenet of the strategies for restoration opportunities identified in this assessment is that promoting geomorphic change and channel mobility allows for the natural creation and maintenance of beneficial habitat conditions, both in channel and in the larger riparian area. Enhancing habitat may be accomplished by undertaking a variety of treatment actions within the main channel, along the banks, and within the riparian zone and floodplain. In the previous sections, driving geomorphic processes and expected responses were related to the goals and objectives of this prioritization. Restoration strategies presented here have been conceptualized and developed to directly influence those driving geomorphic processes and bring about the expected geomorphic change for each prioritization goal. Table 7-2 presents the restoration strategies that will be identified for each goal based on the driving geomorphic processes. For each of the project area cut sheets in Appendix J, these restoration strategies will be discussed for use in the specific circumstances of the project area, using the assessment results in Table 7-2 as key indicators for when these restoration strategies should be employed. Each project area presents its own unique set of circumstances, limitations, and requirements, so not every one of the restoration strategies indicated by the assessment results may be used for the individual project area. However, the strategies listed in this table present a range of conceptual strategies that could be used to address the driving geomorphic processes. These strategies and how they will influence the driving geomorphic processes are discussed in greater detail in the following sections.

Table 7-2
Restoration Strategies for Geomorphic Processes and Goals

Goal	Driving Geomorphic Processes	Assessment Result Indicators	Restoration Strategies
Increase complexity at low-winter flows (~130 cfs)	• Bedload sediment transport and availability • Floodplain connection and inundation • Wood material recruitment	• Standardized Complexity Evaluation at Low-Winter Flow	• Gravel augmentation for channel dynamics • Address encroaching features • Reconnect/develop side channels • Develop instream structure (wood) • Riparian zone enhancement for wood recruitment
Increase complexity during spring and winter peaks (~1,000 cfs ??)	• Bedload sediment transport • Floodplain connection and inundation • Wood material recruitment	• Standardized Complexity Evaluation at Mean-Winter Flow • Standardized Complexity Evaluation at 1-year Flows • Excess Transport Capacity	• Gravel augmentation for channel dynamics • Address encroaching features • Reconnect/develop side channels • Develop instream structure (wood) • Riparian zone enhancement for wood recruitment
Reconnect disconnected and abandoned floodplains	• Bedload sediment transport • Floodplain connection and inundation • Channel confinement and incision	• Channel Aggradation • Encroachment Removal • Excess Transport Capacity	• Channel aggradation to reverse incision • Address encroaching features • Reconnect/develop side channels
Improve quantity and quality of pools	• Bedload sediment transport • Wood material recruitment	• Pool Frequency Analysis • Excess Transport Capacity	• Gravel augmentation for channel dynamics • Address encroaching features • Develop instream structure (wood) • Riparian zone enhancement
Increase retention and storage of in-channel bedload sediments	• Bedload sediment transport • Channel confinement and incision • Wood material recruitment	• Excess Transport Capacity • Channel Aggradation	• Gravel augmentation • Address encroaching features • Develop instream structure (wood) • Riparian zone enhancement for wood recruitment • Modify or remove obstructions

7.2.1 Project-Specific Gravel Augmentation

The availability of bedload material that can be mobilized on a 1- to 2-year basis in the Tucannon River has been identified as a primary factor in the success of restoration projects in the Tucannon Basin. Restoration actions and natural LWM that do not have access to a supply of bedload material mobilized on a 1- to 2-year basis are often associated with slow or delayed geomorphic change based on local observations. Oftentimes channels that do not have access to this material are, therefore, plane-bed, homogenous, and incised. Incised and plane-bed channels in turn transport material extremely effectively further limiting in-channel structural complexity. Minimizing structural complexity exacerbates the problem in a feedback loop where there is not enough transportable material to cause complexity and not enough complexity to retain transportable material in the channel. As discussed previously, this feedback loop has drastic effects on every one of the goals for this prioritization: complex channel systems cannot occur, channels become incised and floodplains become disconnected, pools do not form, and sediment is not retained in the system.

Within the Tucannon Basin, it is now recognized that the solution to this problem cannot only be found in any one restoration strategy. In the past, adding woody material to force geomorphic change has been attempted as a restoration strategy for reaches experiencing this feedback loop. However, some of these restoration strategies have not performed on the desired time frame, possibly due to the lack of mobile gravel/cobble material. Instead, it is now believed by local experts and restoration practitioners that both the addition of LWM and the addition of mobile gravel bedload material is necessary to promote geomorphic change and "jumpstart" natural processes. To provide a reliable source of this gravel bedload material and accelerate improvements, gravel augmentation is identified as a restoration opportunity for suitable areas within the basin. Gravel augmentation has historically been used to supplement salmonid spawning habitat (Merz et al. 2004; Zeug et al. 2013) but has increasingly been recognized as having a positive effect on juvenile rearing habitat associated with floodplain connectivity and complexity (Sellheim et al. 2016). However, just as adding wood structure alone did not always produce desired results, gravel augmentation is a restoration strategy that should always be performed in tandem with the development of instream structure and addition of LWM. Without instream structure to trap and retain some of this sediment and promote geomorphic change, gravel augmentation will, at best, be a temporary boost to complexity and connectivity. At worst, augmented gravel could be washed through the targeted restoration area without causing any change. By supplementing gravel material and developing instream structure, the physical processes of sediment deposition and mobilization can jumpstart geomorphic change and help maintain functional geomorphic process over time.

While all of the restoration strategies affect the natural processes occurring in the river, and therefore can and often do affect project areas outside of the immediate target, gravel augmentation in particular has far-reaching effects that exceed the bounds of one or two project areas. Section 9 develops an overarching plan for strategically implementing gravel augmentation in the Tucannon Basin, based on the metrics and analysis results developed for this prioritization. It describes how to consider gravel augmentation as one element in a larger restoration strategy for a site, and how to integrate it into a basin-wide strategy. Appendix L lays out a comprehensive plan for long-term gravel augmentation at specific sites.

7.2.2 Reconnect Side Channels and Disconnected Habitat

Off-channel habitat provides critical holding and rearing habitat for juvenile salmonids during moderate to high flows and often provides preferred habitat conditions at lower flows. Several disconnected features are present in the Tucannon River floodplain, including off-channel wetlands that are wetted during part of the year and become disconnected at lower flow periods, disconnected side channels, and floodplain areas.

Encouraging reconnection of these features will increase habitat complexity by providing off-channel habitat and increased connectivity with the channel where disconnected features become cut off or create stagnant conditions during the dry season. Reconnecting these areas will allow fish to move in and out of these features for longer periods of time and enhance water quality conditions, particularly during low flows.

Actions for reactivating disconnected habitat may include earthwork to establish hydraulic connections with the main channel, aggradation of the main channel to provide more consistent connection or installation of LWM to backwater flows in the main channel or assist in keeping pathways to the main channel accessible.

Side channels often provide preferred rearing habitat during low flows and provide hydraulic refuge and cover during high flows (see Appendix J for specific locations). Encouraging multiple flow paths will increase habitat complexity by diversifying the planform, dissipating stream energy, distributing sediment load, and providing hydraulic complexity. Diverse floodplain and side channel networks often have multiple flow paths at various elevations across the valley bottom. Therefore, different channels are accessed at different water surface elevations. In this manner, off-channel habitat is accessed in different areas of the channel network under changing flow regimes providing a multitude of habitat during a large range of flow conditions.

7.2.3 Address Encroaching Features

Tens of thousands of linear feet of levees confine the mainstem Tucannon River and prevent or limit a surface water connection to the adjacent floodplain (see Appendix J for specific locations). In these areas, levee removal and/or setback may be used to increase the active floodplain area, thereby promoting floodplain and side channel connectivity and more natural channel migration processes. In a majority of the locations identified, working outside the limits of existing irrigation areas will allow widening of the floodplain corridor without significant changes to agricultural practices by working outside the limits of existing irrigation areas as much as possible.

Removing levees and promoting floodplain connectivity encourages geomorphic processes while dissipating velocities during high flows as floodwaters are distributed onto the floodplain. This also allows fine sediment to deposit on the floodplain, promoting ecological processes. Decreased channel velocities may also lessen erosive energy along the banks in areas of concern for landowners. Allowing the channel to migrate throughout a wider corridor will encourage development of complex channel and planform geometry, distributing energy and sediment load. It will be important to consider the reach-scale effects of widening the floodplain, particularly at the downstream end of confined reaches. For example, creating an unconfined floodplain below a tightly confined section will likely result in a large amount of sediment deposition and channel migration.

7.2.4 Develop Instream Structure – Wood Placement

Instream habitat complexity is correlated to hydraulic complexity created by the channel geometry, bedforms such as gravel bars and pools, hardpoints such as bedrock, and perhaps most importantly to the presence of LWM. The primary biological function of LWM in rivers and streams is to provide complexity that creates hydraulic refuge and cover for adult and juvenile salmonids.

In natural systems, riparian trees often enter a watercourse as the result of erosion, windfall, disease, beaver activity, or natural mortality. However, in most Pacific Northwest river systems, including the Tucannon River, LWM has been removed from the river channels and cleared from riparian areas. In addition, a significant quantity of natural LWM that would otherwise be recruited from riparian areas has been removed by logging and agricultural practices. Anthropogenic activities in the basin have decreased the number, size, and volume of LWM being introduced to the river through natural processes. Therefore, installing LWM is necessary to supplement existing conditions, recognizing that it will take decades of riparian planting and development to begin to provide natural replenishment rates. In the long term, the added channel and bank roughness created by wood structures will help retain additional mobile wood and sediment, diversifying hydraulic and bedform complexity and contributing to increased floodplain connectivity and functionality of floodplain processes over time. For the Upper Tucannon River Major Spawning Area, the Snake River Salmon Recovery Plan recommended at least two pieces of LWM per channel width (SRSRB 2006). Installation of rock structures is also considered as an option to add instream complexity, particularly in areas where bedrock already interfaces with the channel.

7.2.4.1 LWM Placements

LWM placements that are suitable for placement in the Tucannon River include single-log placements or multiple-log assemblies with rootwads that are installed in the channel bed or bank to create beneficial fish habitat and desired geomorphic effects. These features emulate natural tree fall of mature riparian trees and provide a base for mobile wood to accumulate. The different types of LWM placements have varying levels of engineering and construction effort and range in magnitude of physical and biological benefit. LWM is generally considered more mobile than the engineered log jams described in the next section. However, after the 2020 flow events, much of the placed wood is believed to have traveled less than a few hundred meters from placement and often the wood was found to be stable in the placed location.

7.2.4.2 Engineered Log Jams

Engineered log jams (ELJs) are large wood structures that can be placed in the main channel that emulate naturally occurring, stable log jams. Historically, several log jams per mile were likely present in the main channel, but they have either been cleared or are no longer able to become established due to a lack of mature riparian trees being recruited to the river, particularly in reaches where the local riparian conditions are poor. ELJs are typically placed along the bank or in the channel with the bottom of the structure at the anticipated scour depth and the top built to the approximate height of the 100-year flood water surface elevation. The structure is backfilled with streambed materials for stability, and a gravel bar deposit may be placed in the lee of the structure that emulates the natural sediment deposit that would occur. ELJs are generally designed to be more stable and less mobile during flow events compared to placed LWM with light or simple anchoring.

ELJs can create large flow stagnation areas upstream and downstream of the structure and contain a substantial amount of void space within the logs and root masses, providing considerable area for fish refuge. During high flows, the rootwads interact with hydraulic forces from the river and scour large, deep pools that provide holding areas for adults while the void space within the face of the structure is used by juveniles. In addition, these structures are able to retain mobile wood debris. Because of the hydraulic conditions and hard points created by ELJs, they may also be used as "deflectors" to influence flow direction to promote channel expansion or to activate side channels.

On a reach scale, installation of multiple ELJs can influence gravel movement and deposition to create localized pool-riffle sequences, increased hydraulic complexity, and a more stable channel profile. Sediment storage and deposition adjacent to the ELJs can create large gravel bars in the active channel allowing for colonization of riparian vegetation and eventually the development of forested islands. The overall roughening of the active channel and aggrading of the riverbed promotes rehabilitation of natural processes, which increases floodplain connectivity and promotes channel migration.

7.2.5 Riparian Zone Enhancement

Riparian habitat enhancement will involve protection of healthy riparian areas, removal of undesirable vegetation, and planting of native riparian communities on the channel banks, on higher elevation gravel bars, and in the floodplain. However, establishment of the ideal riparian buffer width may be limited by the location of agricultural fields, infrastructure, and the feasibility of irrigating and maintaining plantings. Riparian planting may also be conducted in conjunction with LWM structure placement, including ELJs.

The riparian zone provides several habitat and physical process benefits including increased bank and floodplain roughness, cover, and nutrients for instream species and wildlife. Increased roughness encourages sediment deposition and decreased channel and overbank velocities during floods. Additionally, fully developed mature riparian areas are a source of LWM to the river over time. Riparian restoration should begin with protection of existing healthy riparian areas through programs such as the Conservation Reserve Enhancement Program. Where riparian habitat has been degraded, removing invasive plants and vegetation and replacing with native species in appropriate environments should be performed. For example, cottonwoods or willows may be planted in wetter areas such as along the banks, as opposed to drier floodplain terraces. Monitoring and maintenance of plantings for at least the first few years after planting, which will greatly contribute to the success of the restoration effort, may be required for permitting approval. Eradication of invasive species such as will likely require a longer and more involved maintenance and monitoring effort. Additional monitoring of project sites and areas targeting increased floodplain connectivity may be necessary as new planting areas may be necessary as new areas of the floodplain become connected.

7.2.6 Modify or Remove Obstructions

Three primary obstructions to fish passage were identified in the mainstem Tucannon River: Starbuck Dam, Tucannon Falls, and the Hatchery Dam. Although adult fish are able to pass these features, there may be impacts to juvenile salmonids and non-game native fishes (SRSRB 2006). These features may have led the lesser density of non-game native fish in the Tucannon Basin. In addition, the hydraulic conditions created by flow obstructions can adversely affect habitat quality. Extensive sections of upstream backwater often lead to deposition of sands and gravels on the upstream side, potentially starving the channel downstream of easily transportable material and LWM. Removal of obstructions would allow for more natural sediment and woody debris transport and better allow natural evolution of the channel grade and planform. Hence, a consequence of obstruction removal would likely be some adjusting of the channel bed elevation; removal must consider the future evolution associated with this action as additional bank stabilization actions may be required.

7.2.7 Long-Term Opportunity: Road Relocation

Throughout the Tucannon Basin, multiple roads, including Highway 261 in the lower basin, exist in the riparian and active floodplain of the Tucannon River. For nearly the entire river length in this assessment, Tucannon Road and Highway 12 run parallel to the river. Other county, local, and private roads often run parallel to the river as well. Roads running parallel to the river can effectively act as well-established levees, preventing channel migration and inundation in the floodplain. Many other roads run perpendicular to the river and many bridges have been identified throughout the basin. Perpendicular roads and bridges often limit channel migration, restrict the width of the floodplain, and frequently need to be protected with riprap or other hard engineering solutions. Sometimes roads being located in the floodplain is an unavoidable situation with no reasonable alternative.

However, there are several instances in the Tucannon Basin where there are reasonable alternative locations for both parallel roads and perpendicular roads and bridges, and moving these out of the floodplain could have major benefits to the natural geomorphic processes and habitat in the river. Road relocation is not a typically funded restoration project and likely would require the right set of circumstances to be considered a viable project. However, the enormous benefit that road relocation projects could provide is too valuable not to consider. Therefore, road relocations have been identified as "long-term" opportunities, in that they may not be part of the regular set of restoration work, but should be considered if the right set of regulatory, landowner agreement, and funding circumstances arises.

Long-term opportunities to relocate roads occupying the floodplain were developed using input from the previous Conceptual Restoration Plans from 2011 and 2012 (Anchor QEA 2011a, 2011b, 2012a, 2012b) Specific opportunities for road relocation can be found in the Project Area Cut Sheets in Appendix J and in the Conceptual Restoration Maps. Roads highlighted for relocation separate the channel from substantial floodplain area and act as levees that limit channel migration. Along with the road relocation opportunities, some bridges were suggested for relocation from areas where they act as floodplain bottlenecks to areas with floodplains already confined by levees. In other cases, road relocations were suggested that would enable bridges to be removed entirely, limiting the effects of bridges on channel confinement and sediment transport continuity. In all instances where road relocation was suggested, moving the road out of the floodplain will improve floodplain connectivity, reduce channel confinement and sediment transport capacity, and help restore beneficial riparian vegetation. All these actions are projected to be costly and thus are earmarked for long-term restoration potential.

7.2.8 Other Long-Term Opportunities

In addition to the removal of in-channel barriers and road relocations, the project area specific cut sheets (Appendix J) also highlight other long-term opportunities that could have major impacts on floodplain connectivity. The Floodplain Management Plan includes conceptual reconfigurations of many of the Tucannon Lakes, which could help minimize the impacts the lakes have on the floodplain and fluvial processes. Decommissioning some of the lake, while not discussed or recommended in the Floodplain Management Plan, may in some circumstances provide the highest benefit to fish and wildlife and should be evaluated but would require a specific and unique set of circumstances to maintain fishing opportunity while wild populations recover in the basin. Projects should be considered that strike a balance between these two factors, such as the Rainbow Lake project, which moved the lake impoundment partially out of the floodplain while maintaining fishing opportunities, as well as those outlined in the Floodplain Management Plan.

Large levees associated with Camp Wooten and the town of Starbuck represent areas of significant confinement and lack of floodplain. Any opportunity to alleviate the confinement due to these levees should be considered and evaluated for feasibility if the circumstances ever allow for it. The former railroad prism also acts as a confining feature in multiple project areas including Project Area (PA) 45 where a removal of the railroad grade was proposed.

8 Tucannon Programmatic Restoration Targets and Adaptive Management

Clear restoration targets and an efficient, concise adaptive management plan are important for the tracking of restoration progress, understand what treatment are most effective, and informing future decision making that will maximize the success of restoration activities in the Tucannon Basin. This document identifies restoration targets for evaluation metrics and adaptive management decision-making protocols that will promote successful long-term river and floodplain restoration implementation. This protocol will help track restoration success and make informed decisions on achievement of restoration goals and when necessary actions are needed to help achieve goals. In addition, it includes a process to identify and mitigate potential hazards that may arise as an outcome from habitat restoration actions.

In order to evaluate the success of the Tucannon Programmatic, restoration targets must be set and an adaptive management plan needs to be implemented. Table 8-1 provides a summary of restoration targets related to each of the Programmatic' s restoration goals. Post-implementation monitoring will compare site conditions to these targets when evaluating project performance.

Table 8-1
Habitat Targets Related to Programmatic Goals

Programmatic Goal	Restoration Goals and Objectives	Target Value	Basis of Target Values	Reference Section
Improve floodplain connectivity	The available 5-year recurrence floodplain is connected at the 2-year event	2-year connected inundation = 5-year available in 2017	5-year available floodplain defined by the 2017 1D model results. 2-year connected to be updated as projects are completed.	Appendix F and Section 10
Develop a high-functioning riparian corridor	The available riparian zone, as defined in Section 10 and Appendix K, will be vigorously growing with native deciduous species	25% of riparian area at 15–40-foot height class 40% of riparian area at 40–80-foot height class	2017 LiDAR dataset analysis comparison of first returns to bare earth	Appendix K and Section 10
Increase channel complexity at low-winter flows	Low-winter flow complexity to levels of current 90th percentile of basin	Low-winter flow complexity = 0.32	2017 complexity values from LiDAR water surface elevation raster as developed for this analysis. New complexity values will be compared against only 2017 complexity values. [1]	Appendix G and Section 10

Programmatic Goal	Restoration Goals and Objectives	Target Value	Basis of Target Values	Reference Section
Increase channel complexity during spring and winter peaks	Mean-winter and 1-year flow complexity to levels of current 90th percentile of basin	Mean-winter flow complexity = 0.5 1-year flow complexity = 0.645	2017 complexity values from 2D model inundation results as developed for the analysis. New complexity values will be compared against only 2017 complexity values. [1]	Appendix G and Section 10
Increase quantity of pools	Increased pool frequency	1 pool per 7 channel widths	Channel width is based on the inundated area at 300 cfs defined by the 2017 2D model results for mean-winter flow.	Not included in this document due to incomplete data
Improve quality of pools	Large, deep, channel-spanning pools	15% of wetted channel area is pool habitat	Channel area is based on the inundated area at 130 cfs defined by the 2017 2D model results for mean-winter flow.	Not included in this document due to incomplete data
Increase temporary storage of in-channel bedload sediments	No river segments significantly above the excess transport capacity regression line	Variation of 10% or less from transport capacity regression line	Based on the regression line defined in Appendix H.	Appendix H and Section 10

Note:

1. When calculating new complexity values for a project area it is important to use only the 2017 complexity values for the other project areas in the calculation process and not an updated database of current complexity. Complexity values are "standardized" in the calculation against other values, so if an updated database is used in the calculations, target values will increase as complexity increases.

Adaptive management should be considered if project areas are not achieving restoration goals after treatments have been implemented. Guiding principles for adaptive management in the Tucannon Basin are to: 1) work within the existing streamlined data collection and monitoring activities, rapid habitat assessments, and photograph documentation, such that it is repeatable and can be reproduced in the era of retreat from programmatic monitoring programs; and 2) use a combination of on-the-ground data collection and remote sensing to conduct implementation, effectiveness, and change detection monitoring. The general adaptive management process would be as follows:

1. Project area treatment
2. Performance monitoring (minimum 5 years, or after a 5-year return event)*
3. Assessment of habitat trends and goal attainment after 5 years
4. If new site-specific fish use data are available, consider those trends along with habitat trends
5. Determination of restoration action/no action
6. Adaptive management treatment design
7. Adaptive management treatment construction
8. Performance monitoring (start the cycle over)

* If no 2-year return period event occurs during this 5-year time period, it is possible that the lower flows have not produced desired geomorphic change or process and more time may be required for monitoring and adaptive management process.

Project Area Treatment

Within this framework, treatment should be considered a comprehensive effort that has the potential to result in reach-scale geomorphic change. If a project area has only been lightly or partially treated, then additional activities could occur prior to the 5-year monitoring period. Once those additional treatments occurred, the 5-year monitoring period would begin.

Performance Monitoring

During the 5-year monitoring period, the site would be evaluated periodically using rapid habitat surveys and other visual observations. These evaluations would be streamlined and there would likely be three or more surveys conducted within the monitoring period to help understand trends in recovery. In addition, these site surveys will be mindful of and record any potential risk that may have resulted from restoration activities. It is not expected that any detailed, data-intensive monitoring activities would occur specific to individual project, but more likely that data-intensive analyses would be completed in conjunction with future Light Detection and Ranging (LiDAR) data collection.

Assessment of Habitat Trends and Goal Attainment

After the 5-year (minimum) monitoring period, a detailed evaluation would occur that would include a qualitative/quantitative assessment and comparison of site conditions to restoration targets described in Table 8-1. While the intent of this assessment would be as quantitative as possible, it is understood that some attributes may be estimated based on available data. This assessment would include the direct data comparison, present difference value, as well as a trend attribute stating whether each element was trending toward the restoration target. This assessment would also include assessment of risk and risk tolerances.

Determination of Restoration Action/No Action

Determining the need for adaptive management action would be based on the assessment and consideration of the trends in the project area. For example, a given project area may not be meeting all targets, but recent progress has been observed and it is likely that the project area will meet goals within a few years. One key habitat element that could be used as an indicator that adaptive actions should be taken would be pools. If pools are not present or are not of sufficient size and depth, it is unlikely that other habitat metrics are trending toward recovery. Not meeting pool targets 5 years after implementation would trigger adaptive management actions. Another metric evaluation that would likely trigger a need for adaptive management would be if more than half of the habitat metrics are more than 20% off target conditions and trending even or negative. In addition, risks as a result of restoration activities would be evaluated and a determination of potential actions to reduce these risks would be made.

Adaptive Management Treatment Design

Once adaptive management actions have been determined to be necessary, design for treatments should be targeted toward specific habitat conditions that are lacking while also taking a process-based geomorphic approach to design.

Adaptive Management Treatment Construction

Plan for and implement the adaptive management action. This becomes the new treatment date.

Performance Monitoring

Start the cycle over at Step 2.

Existing Monitoring Protocols to be Augmented by this Protocol

LiDAR and aerial photography surveys:

- The Tucannon Programmatic uses LiDAR to collect basin-wide datasets on a reoccurring interval of approximately 8 years or immediately following flood flow events with a greater than 25-year return interval to conduct geomorphic change analysis of floodplain and channel complexity.
- A baseline data sample was collected in 2010 prior to the majority of restoration actions being implemented in the basin.
- A follow-up data collection event occurred in 2017/2018 to support an update to the Tucannon conceptual restoration strategy.
- In February 2020 the basin experienced an approximately 25-year flood event, which triggered the collection of LiDAR in late fall 2020 for the purpose of watershed evaluation and adaptive management and learning opportunities.

Rapid Habitat Survey

The habitat Programmatic also collects habitat data and maintains a dataset on restoration projects for the purpose of implementation and effectiveness monitoring. Restoration project areas are surveyed identifying channel complexity, LWM, floodplain connectivity, and pool presence and quality, in a before/after monitoring protocol with follow-up surveys beginning following significant flows or within 3 years of project completion.

9 Gravel Augmentation Basin Plan

9.1 Introduction

Investment in restoring salmonid habitat in the Tucannon River has been extensive, and results have been immediate in some cases. In other areas, the results were less than expected. Some of this has been attributed to the lack of large, bed-moving hydrologic events. Where results have been immediate, sediment supply has been high. Where sediment supply has been lower, habitat development has been slower to evolve or has not trended in the direction desired.

Gravel augmentation has been implemented in rivers for a variety of reasons, including feeding sediment-starved reaches, providing spawning-sized materials in degraded systems, and resetting the bed elevation of a stream (Merz et al. 2004; Sellheim et al. 2016). Gravel augmentation is proposed in the Tucannon River to support and accelerate the benefits of current restoration efforts in the basin by accomplishing the following:

- Mitigate for past dredging, straightening, and channelizing of the river.
- Reintroduce materials that have been used to levee off the floodplain, or lost into the floodplain through channel incision.
- Feed materials into degraded habitats.
- Feed materials into reaches treated with wood placement to accelerate habitat benefits.
- Improve floodplain connectivity.
- Promote channel complexity.
- Promote more natural transport and temporary storage of sediments throughout the basin.
- Promote more natural patterns of channel migration and natural creation and maintenance of riverine and floodplain habitat.
- Address concerns about starving river segments below heavily treated reaches.

Gravel augmentation should be thought of as one element of the overall restoration plan for the system, and planning should consider other restoration actions in the basin. Maximizing the benefits of gravel augmentation requires integration with and consideration of other restoration activities and the integration of these efforts. The following general thoughts have helped guide the development of the conceptual restoration plan:

- Consider the needs of the entire basin.
- Effort should be most intense in the upstream areas of the restoration plan to promote the achievement of goals progressing from upstream to downstream. This could be thought of as ground zero development from upstream to downstream. With the concept of jumpstarting geomorphic processes, gravel augmentation in the upper basin should supplement the need for gravel augmentation in the mid-lower basin through reactivation of natural geomorphic processes.

- Identify locations where placement can be efficient, effective, and routine.
- Feed areas where intense wood placement has been completed.
- Be mindful of sediment needs in locations downstream from intense wood placement.
- Integrate elements of gravel augmentation into other restoration implementation and management actions.
- Treat high-energy areas.
- Consider some sites that are purely feeding material.
- Consider some sites where gravel augmentation leads to large-scale restoration by lowering the floodplain or adjacent banks, creating large off-channel areas, and resulting in a high groundwater table from valley wall to valley wall.

9.2 Purpose and Need

The purpose of augmenting the gravel supply in the Tucannon River is to maximize the immediate benefits of restoration actions on a project scale and promote natural evolution toward more historical reach-scale river conditions. Since large-scale restoration in the Tucannon River began there have been concerns about how storing sediments in treatment areas may affect downstream reaches. Specifically, will this result in channel degradation and incision downstream of treated areas. Where gravel augmentation has been a project component, immediate floodplain connectivity and channel complexity has been realized. However, some locations downstream of wood placements have remained sediment starved and at risk to headcutting through treated locations upstream. Initial reports from the high-flow event in 2020 suggest that this may have occurred in a couple locations where floodplain connectivity and complexity gains may have lapsed.

Under more historical river conditions, the Tucannon River would have abundant sediment supply, regular bar forming and channel migration, and extensive sediment sorting and temporary storage. Augmenting the gravel supply is necessary to help reduce the “hungry river” effect that coarsens the riverbed and prevents sediment sorting and temporary storage. These supplemental materials will help jumpstart restoration treatments and promote increased floodplain connectivity and channel complexity, while helping reduce excess channel capacity. Where multiple flood flow paths are available to the river and groundwater elevations are sufficient to promote vibrant vegetative growth throughout the valley bottom, food web productivity will increase, and ecosystems will thrive.

9.3 Goals and Objectives

The overall goals of the gravel augmentation plan are as follows:

- Promote and accelerate the benefits of wood placement throughout the river through temporary storage local to log jams and feeding locations downstream of wood placement sites.
- Reconnect floodplain channels and upland to flood flows.
- Promote increased groundwater table throughout the valley floor.

- Promote vegetation growth throughout the valley floor.
- Feed high-energy/sediment starved river segments.
- Provide additional spawning opportunities throughout the basin.

9.4 Materials Sourcing

Sourcing of materials for use in augmentation will come from both local and import sources depending upon the placement location and available material. We expect sources to include the following:

- Floodplain benching
- Floodplain channel creation
- Existing stockpile areas in and adjacent to the floodplain
- Maintenance or emergency management activities

9.4.1 Materials Sizing

Before using material from any floodplain sourcing site, the existing material should be evaluated for gradation and content of fines. Gravel-sized material (4 to 64 mm) is generally preferable, although some content of small cobbles could also be used. Specific limitation will likely be determined by permitting, but locations with significant fines will likely need to be sorted before use. Excess fine material can be used on the floodplain where sourcing or placement is not recommended. Similarly, source locations with an excess of large cobbles and boulders will need to have those sorted out and not placed as part of gravel augmentation. The specifics of gravel sizing and sorting will likely need to be determined on a site-by-site basis during implementation.

9.4.2 Floodplain Benching

Floodplain benching involves cutting down the existing floodplain to allow for flood inundation much more frequently than under existing conditions. This will occur in locations directly adjacent to the river as well as in locations in the floodplain that are not near the existing river but will become inundated through benching. Benching will only occur in areas that are barren and not suitable for natural regeneration of valued deciduous vegetation. The target elevation for floodplain benching is the elevation of the 2-year recurrence flow with the reach. Providing the river access to the floodplain under 2-year recurrence flows will reduce hydraulic energy, increase nutrient exchange, and diversify flow conditions.

9.4.3 Floodplain Channel Creation

Within the floodplain benching areas, side channels will be excavated to help convey flows and distribute surface water throughout the valley floor. These channels will be excavated to the approximate 300 cfs water surface elevation.

9.4.4 Existing Stockpile Areas

Several stockpile areas exist within and adjacent to the floodplain. Sourcing from the floodplain areas also enhances floodplain connectivity. These sources are ideal for augmentation areas that are essentially feeding areas. Examples of these sources include PA 15 side channel materials and remnants in the PA 14 floodplain.

9.4.5 Maintenance and Emergency Materials

Maintenance dredge materials, such as at the Hatchery Dam, should be repurposed into the river as a routine practice. In addition, materials collected through road maintenance, drainage clearing, and other activities that produce suitable riverbed materials should be reintroduced to the river within this program.

9.5 Sequencing of Material Sourcing

Sequencing the sourcing of materials is an important consideration and should be focused on achieving the maximum immediate habitat benefits and reduction in hydraulic energy. Floodplain benching should begin with the areas directly adjacent to the river to maximize the area connected as early in the process as possible. Subsequent sourcing will work progressively across the floodplain connecting additional area. Side channels should begin excavation at the upstream and downstream extents. Excavating the upstream extents will help get flood flows out onto the floodplain during much lower flow rates and disperse these flows. Excavating the lower extents creates immediate alcove habitat for use by juveniles during spring runoff.

9.6 Monitoring for Success

Successful implementation will be evaluated through visual observation of several key evaluation criteria. This will include, but may not be limited to the following:

- Complete coverage of the mainstem channel with reduced grain size allowing for suitable spawning for multiple species
- Observed flood inundation area under 2-year and lessor recurrence flows
- Emergent deciduous vegetation growth, primarily cottonwood and willow, throughout the floodplain
- Presence of wetted side channels through most or all flow regimes

It should be noted that in order for many of these changes to occur and gravel augmentation to be successful, it is likely that LWM will be necessary as well. Amounts of LWM in an evaluation reach should be considered when monitoring for the success of gravel augmentation, and evaluated for supplementation along with corrective actions to the gravel augmentation program.

9.6.1 Mainstem Channel Grain Size

Much of the current bed material in the placement locations is coarse and not suitable for spawning for steelhead and other target and non-target species. One expected outcome of this program is a reduction in grain size of the bed material in the mainstem. Placement locations will be monitored for the following:

1. Did placed materials move? This evaluation will visually estimate and record the percentage of placed materials that were mobilized during higher flows.
2. Where did the materials go? This evaluation will track the movement of material to determine the distance of downstream movement and the approximate location of the river where finer bed materials are blanketing the riverbed after higher flows.

Once material from a placement site is blanketing the riverbed downstream to the location of the next placement site, monitoring will evaluate the downstream extent of movement collectively for the sites. This approach will be used for all sites such that the extent of success can be evaluated for the gravel augmentation program as a whole.

9.6.2 Flood Inundation at the 2-year Recurrence Flow and Below

Floodplain benching will target the 2-year recurrence flow elevation from the basin-scale model developed from the 2017 LiDAR data. As benching and gravel augmentation progresses, water surface elevations for a given flow will increase and benches should have flowing water at the 2-year event and get inundated at progressively lower recurrence flows. This progression will be monitored and the approximate extent of the inundated floodplain will be documented.

9.6.3 Emergent Deciduous Vegetation Growth

Emergent vegetation throughout the floodplain is an indicator of groundwater table and will be used to evaluate the success of the program. The extent of emergent growth will be monitored and documented as progress is realized. Once emergent vegetation growth is spread throughout the valley floor, gravel augmentation through this area will be considered successful and discontinuing augmentation will be considered.

9.6.4 Presence of Wetted Side Channels

Wetted side channels will be documented and used to evaluate complexity and program success. Ideal conditions would be multiple side channels through common winter flows and some perennial side channels through much of the river during summer low flow.

10 Geomorphic Analysis Summary and Evaluation

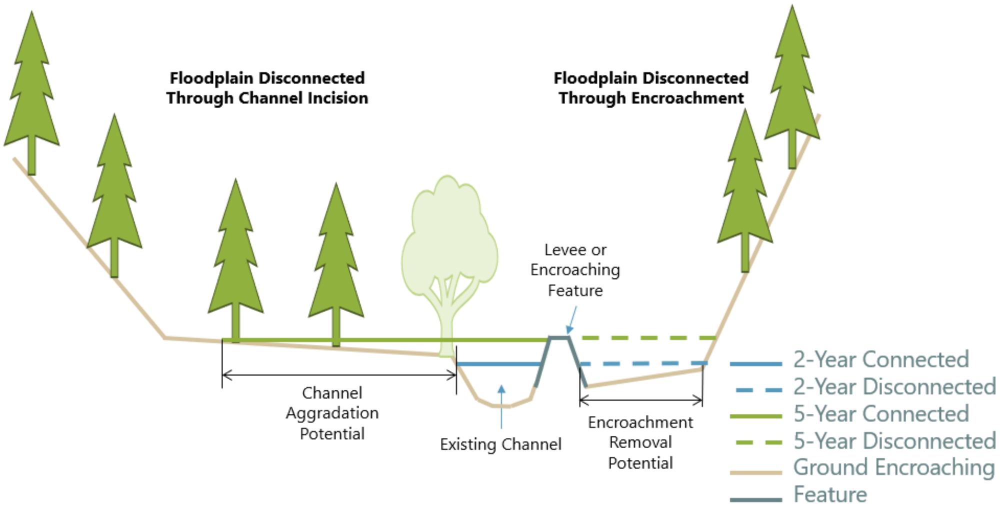
The analyses of this assessment were created to provide the information needed to meet the habitat targets and goals of the objectives. To that end the analyses were developed to use the updated data available to measure the key components of the habitat targets and programmatic objectives including Floodplain Connectivity, Channel Complexity, and Transport Capacity. The Floodplain Connectivity analysis measures the existing connected floodplain and potential floodplain targets and determines floodplain potential. The Channel Complexity analysis measures channel complexity at a variety of flow conditions and compares each project area against the range of complexity across the basin. Finally, the Transport Capacity analysis determines where the Tucannon River has too much sediment transport capacity for maintenance of natural geomorphic processes. All of these analyses were then looked at through the lens of measuring success and gaging direction. To that end these analyses provide the data for future evaluation, target setting and accomplishment tracking for each of these key metrics. The following summaries describe in more detail what these analyses are, and why they are important to the Tucannon River system and salmon recovery. Detailed instructions for performing these analyses as well as results for each project area can be found in the respective appendices.

10.1 Connectivity Analysis Summary

Increased floodplain connectivity comes with geomorphic, societal, and biologic benefits for a watershed. It can lead to increased channel complexity, reduce flood damage downstream, and improve riparian and instream habitat. With new access to floodplain area, a river is likely to establish additional channels on the floodplain that can provide flood refuge for aquatic species or that can incise and remain wetted at lower flows, increasing channel complexity and thus both riparian and instream habitat. Furthermore, greater storage capacity on the floodplain can reduce flood damage to communities downstream by flattening the curve of a flood’s hydrograph. Flood peaks farther down in the basin can be reduced by allowing more water on the floodplain in upstream areas of the basin, including the Wooten Wildlife Area, during higher flows such as 5-year return or greater. Connected floodplains provide benefit for nearly all riverine aquatic species in the form of hyporheic and riparian habitat, high-flow refugia, nutrient influx, and woody material supply. Additionally, connected floodplains, and the resilient ecosystems they support provide the material for instream wood, which in turn are key pieces of geomorphic processes associated with the functioning and resilient river system. In this analysis floodplain connectivity refers to floodplains that are connected hydraulically to the river through periodic inundation at 1- to 5-year return intervals, hyporheic flows, and groundwater connectivity. In other words, it looks only at the hydraulic connection of the floodplain to the river channel, but as described above, hydraulic connections in the floodplain are the building blocks for riparian ecosystems and geomorphic processes that provide multiple habitat benefits.

Confining features along the banks of the Tucannon River and on the floodplain have influenced hydraulic conditions during large floods, affecting local and reach-scale geomorphic processes such as sediment mobility and channel migration. Confining features may be both natural and influenced by anthropogenic activities. Inspections of aerial photography, LiDAR, and field reconnaissance were used to identify confining features within the study area. These features include bedrock along the valley wall, alluvial fan deposits, bank armoring (e.g., riprap), levees and pond berms, and road prisms. Additionally, the Tucannon River can be disconnected from the floodplain through channel incision and downcutting. Channel incision is often associated with encroaching features such as levees or bedrock valley walls because straightened channels provide more stream power for sediment transport. Channel incision is often the beginning of a cycle of sediment starvation. Appendix F of this report discusses channel incision in more detail, as well as a possible root cause and where it might be happening. The following connectivity analysis discusses the potential benefits of reversing this trend of channel incision, as well as the benefit of removing encroaching features and increasing the total area of connected floodplain.

Figure 10-1
Conceptual Cross Section of Floodplain and Floodplain Potential



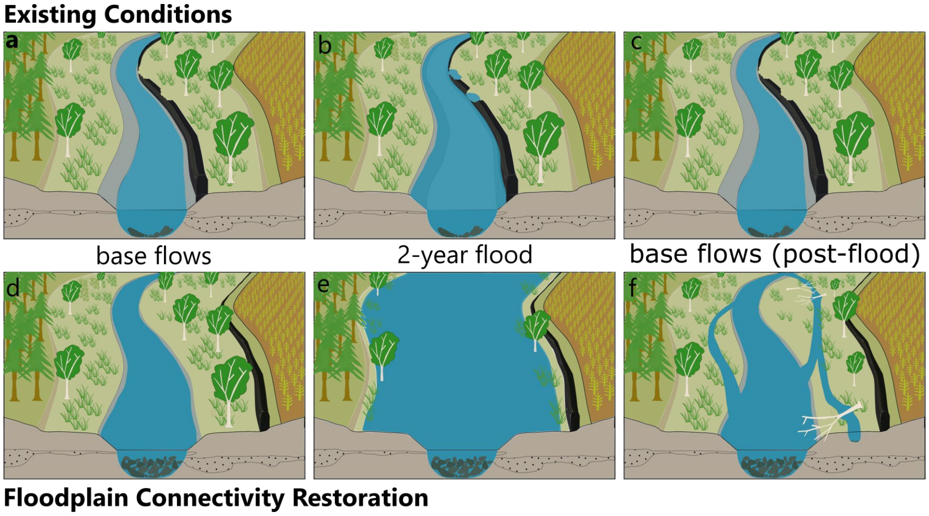
The purpose of this analysis is to describe the floodplain connectivity of a reach in a way that can be compared to the other reaches in the system and help inform potential restoration actions. The analysis focused on three characteristics of the floodplain:

1. The area of floodplain currently accessed and connected at a given flow event
2. The area that could potentially be accessed given the removal of encroaching features
3. The area that could be accessed given sediment deposition and reversal of channel incision

Figure 10-1 provides a conceptual valley cross section showing these three floodplain characteristics. The existing floodplain and potential floodplains are represented as lengths in this cross section but will be discussed as 2D (areas) for this assessment as the concept in Figure 10-1 is applied along the length of the valley for each assessment reach.

Removal of encroaching features and channel bed aggradation (or reversing channel incision) were identified as restoration actions that have the potential to provide the most benefit to floodplain connection. Figure 10-2 demonstrates how they can accomplish this goal. Panels a-c illustrate how encroaching features and channel incision can limit the river's connectivity with the floodplain by constraining the river to a narrower, deeper channel. Panels d-f illustrate the potential geomorphic response to the restoration efforts. Since these two metrics are directly related to floodplain connectivity, representations of them are easy to compute using the available data and analysis. It should be noted that these restoration actions, particularly channel bed aggradation, may be treating symptoms of other underlying problems with the geomorphic processes of the reach. When performing any restoration action, it is essential to consider the underlying drivers behind the current state of the reach in question, and address those as well. The restoration opportunities discussed here are identified simply as a measure of potential in the floodplain only. Section 7 explores additional restoration actions, measures, or considerations that may need to be taken to ensure the success of either of the above restoration actions.

Figure 10-2
Geomorphic Response to Removal of Encroaching Features and Bed Aggradation

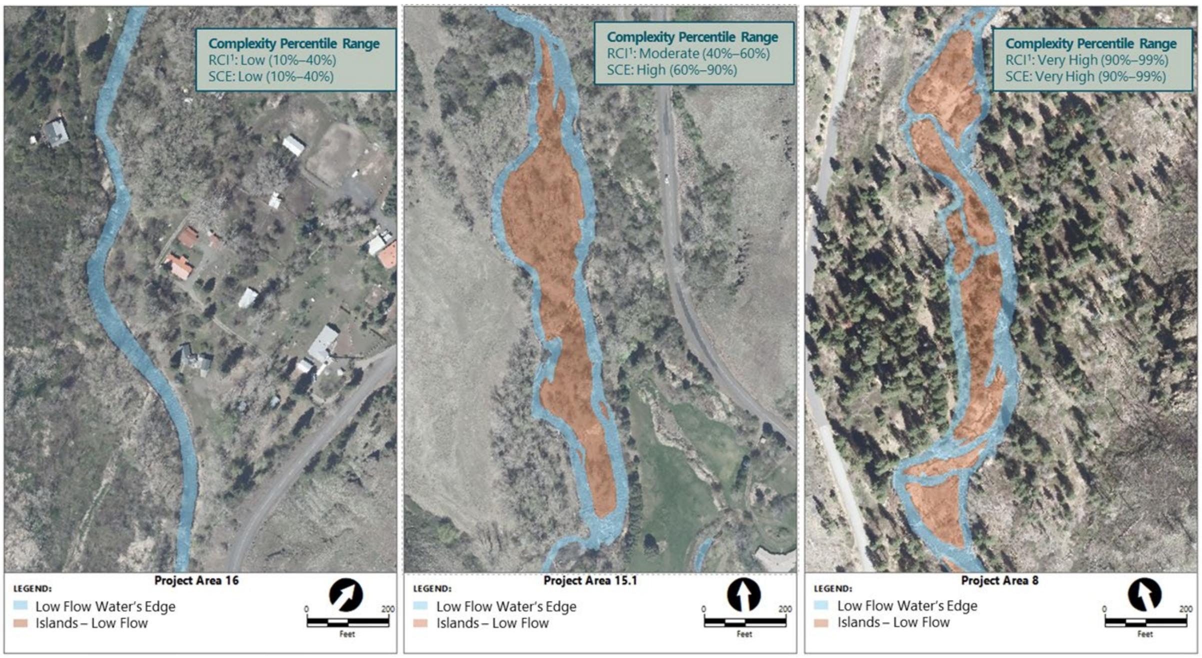


For this analysis, floodplain connectivity is a measure of the potential floodplain that could be gained with the restoration actions listed above. Each of the three above types of potential floodplain gain are weighted and combined for one connectivity score per project area. For more details on how this analysis calculates floodplain connectivity see Appendix F.

10.2 Complexity Analysis Summary

Complexity has taken on many meanings in the realm of fluvial sciences in multiple contexts, including ecologically and geomorphically. For this assessment, complexity primarily refers to the geomorphic concept of spatial heterogeneity of plan forms and channel types within the fluvial corridor. River reaches with multiple side channel, split flows or high sinuosity are thought of here as complex. Historically the Tucannon River was likely an anabranching river, which is defined as a multiple channel system characterized by forested and stable alluvial islands that divide flows up to bankfull, as shown in Figure 10-3. Much of the Tucannon River has diverged from the natural condition to a single planar bed, which is straighter, steeper, and wider than would be expected given valley characteristics.

Figure 10-3
Example of Complexity, From Uniform and Confined on the Left to Most Complex on the Right



Complexity is an important factor for both the geomorphic and ecological processes in a river corridor and the benefits of complexity have been discussed thoroughly in the literature of fluvial sciences (Amoros 2001; Carson 2007; Harrison 2009; Sheldon 2006; Wohl 2016). However, the geomorphic significance of complexity to river corridors has been well summarized into key points in Wohl 2016, of which four are directly relevant here:

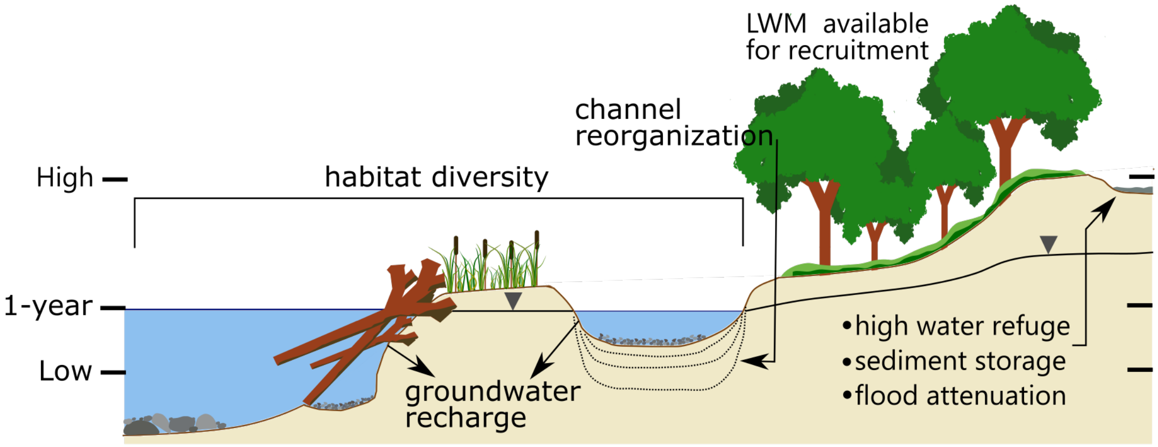
1. Provides habitat and biodiversity to the river system.
2. Attenuates downstream fluxes – of water (floods), sediment, and instream wood.
3. Provides resistance and resilience to catastrophic change.

4. Influences River Processes – sediment and wood transport, groundwater recharge, floodplain connectivity.

   Note: Adapted from Wohl, 2016, Part II

Specific to the Tucannon Basin, channel and floodplain complexity have been identified as major objectives as complexity has increasingly been associated with juvenile salmonid rearing and over-wintering, as well as benefits for many other aquatic species of relevance based on local expertise and observations. In other basins throughout Washington and the Pacific Northwest, complexity is being recognized as an important factor for habitat and salmonid recovery at multiple life stages (Quinn and Peterson 1996; Collins and Montgomery 2002). Because of this multi-species and multi-lifestage benefit, it is important to examine a reach's complexity at several different flow levels—typically at lower, sustained flows (see Table 10-1).

Figure 10-4
Complexity at Multiple Flow Stages



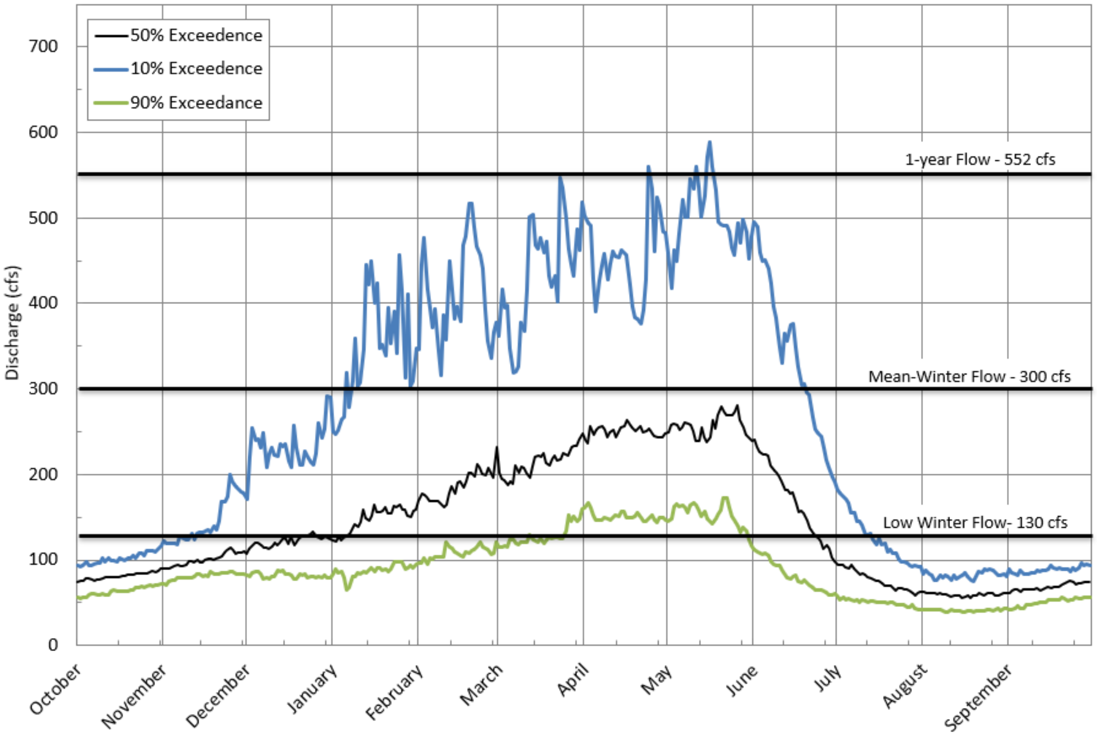
When complexity is maintained during summer low flows and winter flows, it indicates that side channels, backwaters, and other off-channel areas that are important for a variety of ecological process are sustained for longer periods of time and will therefore provide these ecological benefits including juvenile salmonid rearing for a large portion of the hydrograph. While the 1-year flow is episodic in nature, maintaining complexity at this flow level is important for both the geomorphic and ecological processes of the system. Channel systems that maintain and reoccupy alternative channels during high-flow events create geomorphically resilient systems that mobilize sediment stored in the floodplain and recruit wood material from riparian areas, both key aspects of the natural processes of a riverine system. Furthermore, the lower velocity channel alternatives, and backwaters indicated by complexity, provide essential hydraulic refugia for fish during these high-flow events. These three flows should represent the normal range of river conditions where habitat benefits from complexity are most relevant for juvenile salmonids. Figure 10-4 illustrates what complexity at these three flow stages might look like in the Tucannon River and highlights some of the geomorphological and ecological benefits described by Wohl (2016), and listed previously.

Table 10-1
Flow Used for Examining Complexity

Flow Description	Data Source	Flow Rate at Starbuck
Low-Winter Flow	Water Surface DEM	130 cfs
Mean-Winter Flow	2D Hydraulic Model	300 cfs
1-year Flood Event	2D Hydraulic Model	552 cfs

DEM: digital elevation model

Figure 10-5
Complexity Flows and Hydrograph at the Starbuck Gage, 10% 50% and 90% Flows from 1971 to 2019



This assessment uses three separate geomorphic indicators to determine the complexity of a reach:

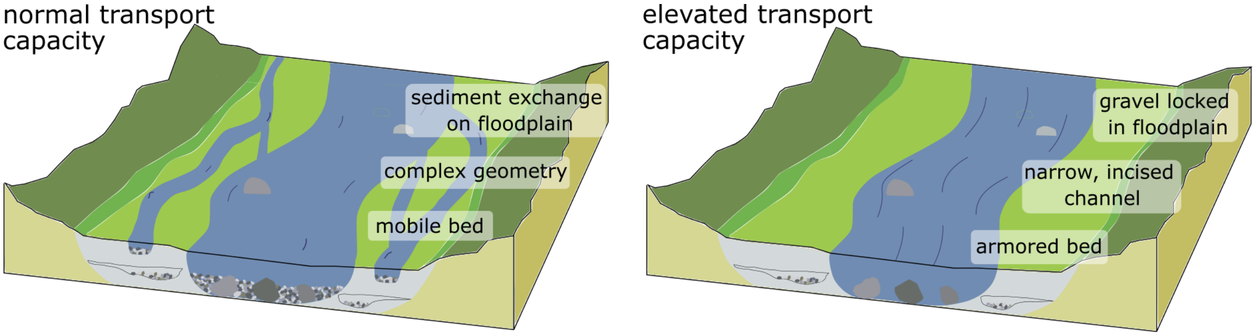
- Number of islands in the channel (and therefore number of side channels/split flows)
- Total size of the islands in the reach (perimeter length)
- Reach length sinuosity of the main channel

These three characteristics were chosen as they provide insight into how complex, and how close to the original anastomosing channel state the Tucannon River is in a given reach at a given flow. However, as discussed above, complexity is important for many different parts of the hydrograph such as habitat for salmonids at low flow, over-wintering and refugia during higher flows and attenuation of downstream fluxes at flood flows. For this reason, this analysis examines complexity at three flows shown in Table 10-1. These three flows are plotted on the mean hydrograph shown in Figure 10-5, and are a good representation of flows that would be experienced in a normal year. The complexity value used to assess reaches in this analysis is a combination of the previously listed geomorphic indicators (island count, island perimeter, and sinuosity) at the flows listed in Table 10-1. For more information about how complexity is calculated for this assessment see Appendix G.

10.3 Transport Capacity

The availability and abundance of gravel or small cobble-sized material in the plays a large role in the geomorphic processes that force bedforms, complexity, and connectivity. Figure 10-6 illustrates how these variables can vary in a reach based on the presence of gravel as determined by transport capacity. Through on-site assessment, it is clear that reaches with ample gravel to small cobble-sized material, available throughout the reach, form pools at instream wood locations more easily, access the floodplain more frequently, and develop complex side channels and split flows. The individual project area assessments show that many of these areas are associated with river avulsions or migrations shortly upstream, providing a potential source of these gravel-sized materials. However, for other reaches, as is often the case with confined and incised systems, the supply of material can become “locked” in the floodplain and is no longer accessed on a regular basis. The materials remaining in the channel bottom often represent lag deposits and collectively form an armor layer that resists pool formation and temporary sediment storage and facilitates high-energy flows through the reach. When this happens, a feedback loop of confinement and incision propagates and can extend downstream over time. Without human intervention or a large natural change, such as a large tree falling into the river and capturing additional wood and sediment, the dominant channel bed material becomes resistant to regularly occurring geomorphic change. With less frequent geomorphic change, the floodplain and the smaller material stored therein are accessed and mobilized less frequently, contributing to this feedback loop. The process of confinement often continues until a threshold and possibly catastrophic flow breaks the cycle.

Figure 10-6
Geomorphic Response to Elevated Transport Capacity



Note: both depictions have the same valley slope.

One solution to this cycle is to provide another source of material that is sized to be frequently mobilized. This material can quickly cause localized geomorphic change, which in turn will release material "locked" in the floodplain and jumpstart the process of sediment transport and minor avulsions or migrations. For this reason, gravel augmentation is one of the restoration opportunities identified in this assessment. However, to make decisions on the placement and amount of this restoration action, it is important to understand how the transport capacity of a reach might be different from other reaches in the basin.

The Excess Transport Capacity analysis described in Appendix H establishes a basin-wide trend in transport capacity based on the modeled shear stress and uses this trend to identify reaches of the basin where shear stress and transport capacity differ from the expectations for the basin. While this method does not determine what the transport capacity of a reach is, it can tell us something about how the reach is different from other similar reaches in this basin, and provide enough clues for better identification of opportunities for gravel augmentation and sediment transport continuity in general.

10.4 Riparian Vegetation Assessment

Riparian vegetation and geomorphic processes of the channel and floodplain are closely linked and exhibit multiple feedbacks. Vibrant floodplains provide immediate habitat for both aquatic and terrestrial species, but also influence geomorphic processes that lead to more beneficial habitat down the line. Channel complexity is important for providing rich and resilient habitat, and is largely influenced by patterns of vegetation. Vegetation amplifies complexity by diverting streamflow onto the floodplain when large pieces fall in the main channel and encouraging channel formation on the floodplain by routing streamflow and focusing stream power. Vegetation also increases roughness on the floodplain, which both reduces flood risk downstream, and increases deposition and temporary storage of sediment on the floodplain—the root benefits of floodplain connectivity.

Phreatophytes living adjacent to or in the active channel, such as reeds, sedges, or willows, can also trap sediment along the banks, building natural levees, and collecting nutrient-rich detritus, in even low-magnitude floods.

The Tucannon Basin has a long history of logging and land-clearing. The logging industry has removed much of the old-growth vegetation in the upper basin, drastically reducing the size and density of riparian trees. In the lower basin, land-clearing for agriculture and development has had similar effects and narrowed the riparian corridor. Further degradation of the riparian corridor was caused by the introduction of invasive species, which have outcompeted endemic vegetation. Historical accounts and photography indicate that before significant development in the basin, the riparian corridor of the Tucannon River was much denser than it is today.

Human development of the basin has also modified and halted geomorphic processes that have implications for riparian vegetation. Flood prevention and channel straightening measures reduce floodplain connectivity, which has a suite of implications for riparian vegetation, including lowering of the groundwater table and reduction of nutrient flux.

The riparian area has been further degraded by the halting of geomorphic processes like flooding and avulsion. Flood prevention and channel straightening measures have disconnected the river from its natural floodplain. This lowers the groundwater table and reduces nutrient flux, limiting plant growth. In addition, dams have reduced native migratory fish populations which bring nutrients from the ocean and lower basin into the upper basin.

The purpose of this analysis on the Tucannon River is to detect change in riparian vegetation since 2010 (the previous date of data collection) and to set a new baseline for comparison with detailed, repeatable steps (available in Appendix K). It allows for assessment of the current state of riparian vegetation and reveals trends in riparian conditions over time. Repeated scans of high resolution LiDAR data allow for the assessment of the overall coverage of riparian vegetation within the riparian corridor, and investigation in to the breakdown of vegetation heights, which can be used as a proxy for vegetation type and also show patterns in growth over time. Comparing the results to target values based on ideal conditions shows which project areas are lacking riparian vegetation and showing their trends over time reveals which project areas are in decline or moving towards a more robust riparian corridor.

The riparian vegetation analysis for this report uses a Canopy Height Model (CHM) to quantify the extent of riparian vegetation in each project area, and classifies the vegetation based on height as shown in Table 10-2. The CHMs were calculated as the difference between the first returns and the bare earth results from LiDAR datasets and sorted into vegetation size classes. Additionally, two CHMs were created using LiDAR data collected in 2010 and 2017 (QSI 2018). Comparing CHMs from different years allows for the quantification of change in the riparian vegetation. Interpretation of these results provides a way to assess the condition of riparian vegetation in each project area and to understand the trends of coverage and vegetation type over time. It also provides a baseline for future riparian vegetation analyses which will help inform restoration efforts.

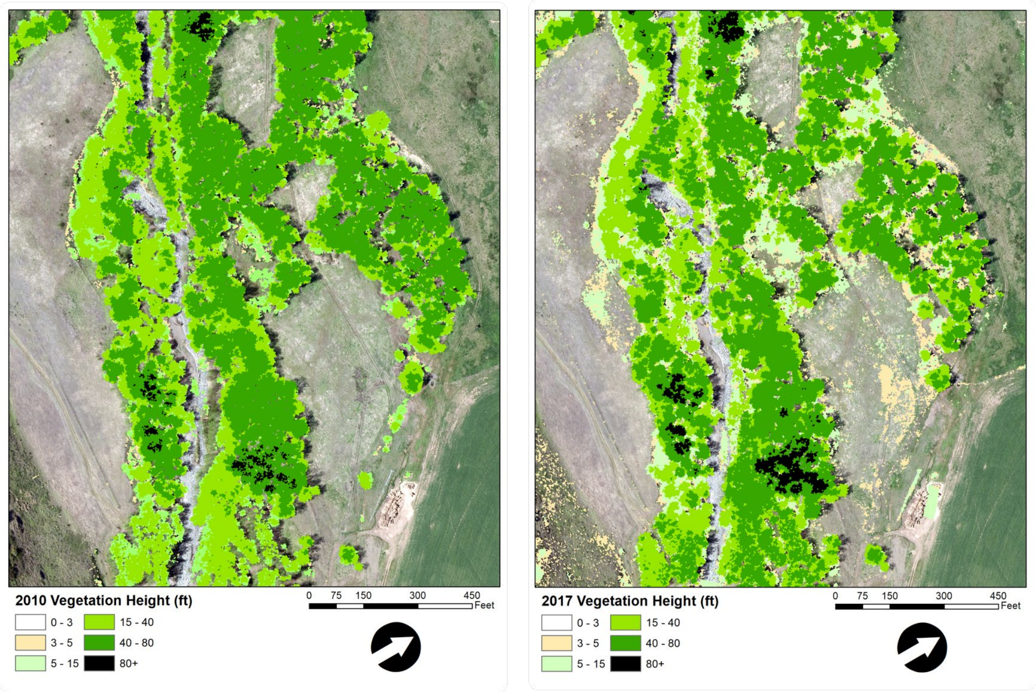
Table 10-2
Breakdown of Vegetation Classes

Size Range (ft)	Designed to Capture
0-3	Crops; grasses; wildflowers
3-5	Emergent or establishing woody vegetation like willows
5-15	Small deciduous trees like alders or elms
15-40	Intermediate range of large alders, or smaller cottonwoods
40-80	Large, deciduous trees like cottonwoods
80+	Very old cottonwoods and large conifers in upper basin

The canopy height models were only examined within the riparian area, which was determined based on a combination of a thalweg buffer, historical migration paths and the 5-year floodplain. This area is described in more detail in Appendix K. Further filtering of the data was deemed not necessary because of the lack of man-made structures within the boundaries of the study area. Once calculated, the vegetation heights were separated into classes (listed in Table 10-2) that are based on experiential knowledge of vegetation in the basin and isolate vegetation types that hold different roles in the riparian corridor. A portion of the results are displayed in Figure 10-7. The extent of coverage, the distributions of vegetation type, and the change in each vegetation type between the two years were investigated for each project area.

Having this information will benefit restoration efforts in the basin by highlighting project areas that are lacking robust riparian vegetation in the short term and revealing trends in vegetation growth in the long-term. Vegetation growth (both vertical and total area) over time can be used to track the efficacy of restoration efforts and also to identify any project areas that may have appeared in good condition at the time of initial assessment but are actually in gradual decline. Results of the vegetation analysis will be considered together with the results of connectivity analyses to quantify how connectivity is related to vegetative cover in the Tucannon Basin and used to inform future restoration strategies.

Figure 10-7
Results from Vegetation Analysis



Target values of 25% and 40% were set for the percentage of riparian area in each project area covered by the 15- to 40-foot and 40- to 80-foot vegetation classes, respectively, as summarized in Table 10-3. These two vegetation classes are especially important for health of the riparian corridor because they provide the most shade and shelter to the river and are the most commonly recruited as LWM. The target values were chosen based on experiential knowledge of healthy riparian corridors and the Tucannon Basin. Secondary, 5% lower, targets and a 7-year trend of riparian coverage were also evaluated to highlight project areas that are close to the target values or trending towards target value. These results are shown and discussed further for each project area in Appendix K.

Table 10-3
2017 Riparian Vegetation Targets

Size Class (feet)	Target	Near Target Level
15–40	25%	20%
40–80	40%	35%

11 Prioritization Summary

This section will give an overview of the evaluation and prioritization methods and describe how the goals and objectives of this report were used to develop the project area prioritization methods. Additionally, this section breaks down in detail the methods used for prioritization and how the analysis results were used to develop the prioritization metrics.

11.1 Prioritization Methods

The prioritization methods attempt to combine the raw assessment results from the Geomorphic Assessment in such a way that prioritized projects will be the most effective at reaching the objectives described in Section 8. A total of eight analysis results (shown in the first row of Figure 11-1) were produced directly from the methods described in the Geomorphic Assessment. The first step in the prioritization is to weight similar analysis results into the primary geomorphic metrics shown in the second row of Figure 11-1: Complexity, Connectivity, and Excess Transport Capacity. It should be noted that two analysis results were removed as factors in the prioritization. The Existing Connected Floodplain analysis was discounted because it is numerically the inverse of Total Floodplain Potential, and any factoring with both would be counterproductive. See Appendix F on Connectivity for a more detailed explanation of why these analysis results cancel each other out.

In order to combine similar analysis results into the three geomorphic metrics used in this prioritization, weights were assigned to each analysis result, which were then summed to produce the final metric value. Table 11-1 and Figure 11-1 show the weights for both complexity and connectivity. It should be noted that the analysis result for Excess Transport Capacity is the only result that factors into the Excess Transport Capacity metric and therefore does not need to be weighted at this step of the prioritization.

Figure 11-1
Prioritization Flow Chart From Analysis Result to Final Prioritization

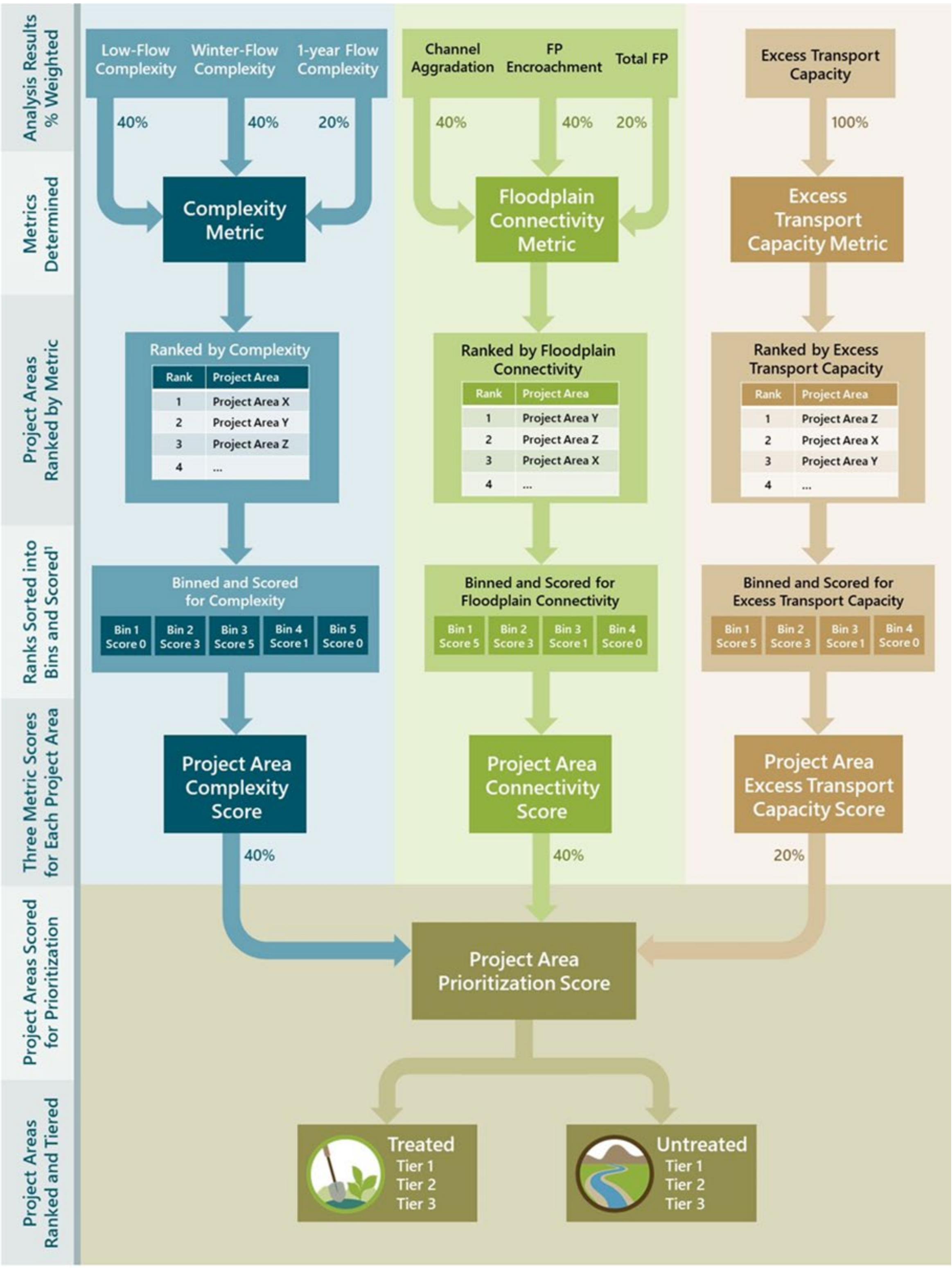


Table 11-1
Complexity and Connectivity Weighting

Complexity Weighting		Connectivity Weighting	
Analysis Result	**Percent Weight**	**Analysis Result**	**Percent Weight**
Low-Winter Flow Complexity	40%	Channel Aggradation Floodplain Potential	40%
Mean-Winter Flow Complexity	40%	Encroachment Removal Floodplain Potential	40%
1-year Flow Complexity	20%	Total Floodplain Potential	20%

The complexity weighting in Table 11-1 favors the Low-Winter Flow and Mean-Winter Flow Complexity values over the 1-year Flow Complexity results due primarily to the fact that the mean-winter and low-winter flows represent a significant portion of the hydrograph compared to the 1-year flow. While the high-flow refugia provided by the complexity at the 1-year flow is important, the mean-winter and low-winter flows better indicate habitat conditions as well as overall geomorphic processes. Similarly, for connectivity, the Channel Aggradation Floodplain Potential and Encroachment Removal Floodplain Potential are favored in the weighting over the Total Floodplain Potential. The Total Floodplain Potential represents the areas where benefit can be gained only by performing both floodplain connection restoration actions; while these areas still have value, they would require more restoration effort for similar benefits and therefore are weighted lower. For a complete explanation of why the Total Floodplain Potential is different than the simple sum of the other two metrics, see the Geomorphic Assessment (Anchor QEA 2019).

The next step in the prioritization process is to rank, classify, and score each project area in each of the three metrics (Complexity, Connectivity, and Excess Transport Capacity). Project areas are ranked from best to worst by the scores determined in the previous step. Each project area then has a rank for each metric and can be classified and scored according to the classification and scoring systems outlined in the individual appendices. Scoring is done differently for each metric as the three analyses measure different things. Floodplain connectivity measures the potential for restoration actions to improve the floodplain, and thus are score on a simple highest to lowest basis as shown in the in the fourth row of Figure 11-1. Similarly, the Excess Transport Capacity produces results where the highest scores need restoration the most and are also score on a simple high to low basis as shown in the in the fourth row of Figure 11-1. The complexity scores, however, rank Project Areas that are already very complex and may not need additional restoration work the highest and so Project Areas that rank near the middle are scored higher than those that rank very higher or very low as shown in the fourth row of Figure 11-1. A full explanation of these scores can be found in the respective appendices for these analyses.

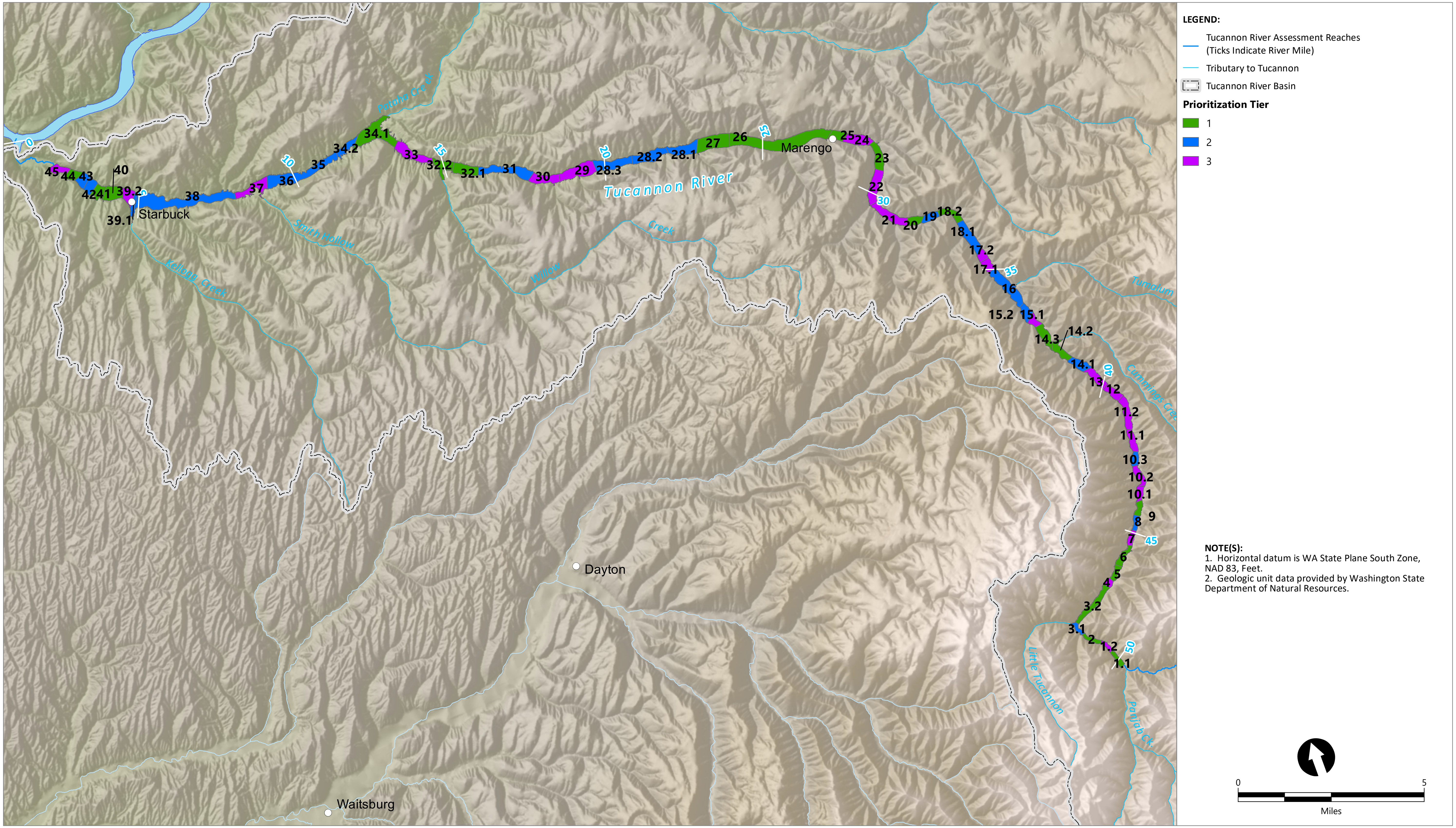
The final step in the prioritization method is to take the scores for each project area based on the above rankings and classifications and weight them towards total importance for restoration. As shown in Table 11-2, the Complexity and Floodplain Connectivity Potential metrics each provide 40% of the final score towards the prioritization ranking and Excess Transport Capacity was valued less at 20%. Over the period of restoration activities since the last assessment, complexity and connectivity have become recognized as the primary indicators of restored geomorphic processes in a reach. The specific restoration actions and strategies used to restore complexity and connectivity are all major influences on the larger geomorphic processes ongoing in the reach and will drive the achievement of the goals and objectives described in Sections 1 and 8 of this report. However, it has been increasingly recognized that some reaches simply do not have the easily transportable sediment supply within the active channel to induce the geomorphic processes that bring about both complexity and connectivity. For this reason, the Excess Transport Capacity metric is a valuable tool in identifying why geomorphic processes have not been restored in some areas where restoration actions targeted complexity and connectivity objectives.

Table 11-2
Prioritization Weighting of Classified Metrics

Metric	Percent Weight
Complexity	40%
Floodplain Connectivity Potential	40%
Excess Transport Capacity	20%

11.2 Prioritization Results

Once the final prioritization scores are calculated, projects areas are sorted into those that have had restoration work since the last assessment (called treated reaches) and those that have not had restoration work (called untreated reaches). These two categories were prioritized into three tiers for restoration, as shown in Figure 11-1. A full list of the treated and untreated tiers can be found in Appendix J. Figure 11-2 shows an overview map of the project areas color-coded by tier.



NOTE(S):
1. Horizontal datum is WA State Plane South Zone, NAD 83, Feet.
2. Geologic unit data provided by Washington State Department of Natural Resources.

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ANCHOR QEA

Figure 11-2
Project Area Prioritization
Geomorphic Assessment and Restoration Prioritization
Tucannon Basin Habitat Restoration

12 Limitations

This report has been prepared for use by the CCD to evaluate project areas and suggest a priority system for implementing project areas, along with identified opportunities for restoration strategies. Within the limitations of scope, schedule, and budget, Anchor QEA's services have been executed in accordance with generally accepted scientific and engineering practices in this area at the time this report was prepared. The information presented in this report is based on available data and limited site reconnaissance at the time of report development. Conditions within the study reach will change both spatially and with time.

It is understood that this report is in part meant to provide a baseline for future evaluations and prioritization, and as a guide for processing data as they become available. No dataset is perfect, and a complex river system cannot be perfectly modeled. There are several gaps in the currently available data that, if addressed, could greatly increase the accuracy and usefulness of this prioritization and evaluation of project areas, including and perhaps most importantly the repeated collection of LiDAR data over time. The repetition of the analyses within the Geomorphic Assessment as they pertain to the available digital elevation model would provide a temporal picture of the geomorphic processes in each reach. This would allow for a prioritization that reflects not only the state of the basin at the time, but also the direction in which the basin and individual project areas are headed. With the increased availability and affordability of collecting LiDAR data, it may be possible to conduct basin-wide surveys on a regular basis. More data on fish use and survivability could also better direct habitat actions and increase survival across life stages and rivers. Specifically, more information on egg-to-fry survival would be useful for determining habitat benefits at this life stage.

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Appendix A

Project Areas Overview

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