APPENDIX D

Reach-Based Ecosystem Indicators (REI)

1. INTRODUCTION

This Reach-based Ecosystem Indicator (REI) assessment provides a well-established and consistent means of evaluating biological and physical conditions in relation to criteria that represent known habitat requirements for aquatic biota. The REI assessment characterizes the state of geomorphic and ecological processes within the Wenatchee River watershed and within each of the 10 project area reaches. The REI criteria used in this assessment are based on the Matrix of Diagnostics/Pathways and Indicators (USFWS 1998), the National Oceanic and Atmospheric Administration National Marine Fisheries Service (NMFS) Matrix of Pathways and Indicators (1996), as well as more recent work conducted within the region by the Bureau of Reclamation and their adaptation of these indicators (USBR 2012).

Data collected during the habitat survey, geomorphic assessment, and hydraulic analysis informed this REI assessment. Specific analysis results are presented and discussed for each indicator, and are used to assign a condition rating of "adequate," "at risk," or "unacceptable." The criteria for rating categories are explained in detail for each indicator below.

2. PATHWAY: WATERSHED CONDITION

GENERAL INDICATOR: WATERSHED ROAD DENSITY AND EFFECTIVE DRAINAGE NETWORK

Metric Overview

Road density can be a good indicator of watershed condition, as it has been shown that high road density can result in altered drainage networks (Montgomery 1994; Wemple et al. 1996) which in turn often increases fine sediment load to streams and rivers (Reid and Dunne 1984; Goode et al. 2011). In addition, increased road density can result in greater mass wasting events and erosion than in a less disturbed watershed (Montgomery 1994; Wemple et al. 1996). Increased sediment delivery to streams can have significant effects on aquatic systems, such as reducing suitable spawning habitat; smothering salmon eggs (Lisle 1989); clogging hyporheic flow paths (Boulton et al. 1998); reducing substrates for aquatic plants, biofilms, and aquatic invertebrates (Henley et al. 2000); as well as impacting channel morphology and water clarity (Waters 1995; Wood and Armitage 1997). Road density was calculated using an ArcGIS layer developed by the Chelan County Conservation District (Walker 2008). Road density was assessed for the Wenatchee River watershed (Hydrologic Unit Code [HUC]-10 1702001107) which is within the Wenatchee River subbasin (HUC-8 17020011).

Criteria: From USFWS (1998), modified by USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Watershed Condition	Effective Drainage network and Watershed Road Density	Increase in Drainage Network/Road Density	Zero or minimum increase in active channel length correlated with human-caused disturbance **And** Road density <1 *miles/mile²*	Low to moderate increase in active channel length correlated with human-caused disturbance **And** Road density 1 to 2.4 *miles/mile²*	Greater than moderate increase in active channel length correlated with human-caused disturbance **And** Road density >2.4 *miles/mile²*

Assessment Results

Road density for the HUC-10 Wenatchee River watershed was 2.8 miles per square mile. Based on the rating criteria, the watershed is functioning at an **unacceptable** condition; however, the impact of watershed road density and the effective drainage network is greater on smaller tributary streams than it is on the mainstem lower Wenatchee River.

REI Rating

Watershed Rating: **Unacceptable**

INDICATOR: DISTURBANCE REGIME (NATURAL & HUMAN-CAUSED)

Metric Overview

Disturbance is an integral part of natural systems (Ward 1998). Natural disturbance regimes create habitat and biological diversity (Nakamura et al. 2000; Ward 1998) that maintain the larger ecosystem processes. Natural disturbance regimes include events such as landslides, fire, flood, drought, and windstorms. Human activities such as flow regulation, channelization, bank stabilization, road construction, and land-use modifications (conversion to agriculture, development, etc.) can change how systems respond to natural events, frequency of events, and ability to recover (Waples et al. 2009).

Criteria: From USFWS (1998)

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Watershed Condition	Disturbance Regime	Natural/Human Caused	Environmental disturbance is short lived; predictable hydrograph; high quality habitat and watershed complexity providing refuge and rearing space for all lifestages or multiple life-history forms. Natural processes are stable.	Scour events, debris torrents, or catastrophic fires are localized events that occur in several minor parts of the watershed. Resiliency of habitat to recover from environmental disturbance is moderate.	Frequent flood or drought producing highly variable and unpredictable flows, scour events, debris torrents, or high probability of catastrophic fire exists throughout a major part of the watershed. The channel is simplified, providing little hydraulic complexity in the form of pools or side channels. Natural processes are unstable.

Assessment Results

The Upper Wenatchee Watershed Assessment (Inter-Fluve 2012) determined that the disturbance regime for the upper portion of the Wenatchee River watershed is functioning at an **at risk** condition. This rating was determined based on historical accounts of riparian timber harvest, splash damming, log drives, and development in and around the floodplain (Inter-Fluve 2012). Similar alterations in the lower watershed include past human disturbance as well as on-going disturbances that limit the resiliency of habitat to recover from disturbance events. For example, along the lower Wenatchee River roads and railroads as well as other land use development has constrained river channel migration, disconnected habitat, and decreased woody debris abundance (WWPU 2006). Based on the rating criteria, the watershed is functioning at an **at risk** condition for this indicator.

REI Rating

Watershed Rating: **At Risk**

INDICATOR: STREAMFLOW (CHANGE IN PEAK/BASE FLOW)

Metric Overview

The magnitude, timing, duration, and frequency of stream flows within a watershed are important drivers within the ecological system. Stream discharge and channel morphology are directly linked to these processes and largely controlled by climate, vegetation, geology, and human alterations and impacts. Alterations to the natural hydrology of a watershed can affect timing and magnitude of peak flow and low flow events. The frequency of high-flow events can also be dramatically affected by human actions, potentially decreasing due to flow regulation (e.g., dams) and water withdrawals (e.g., for irrigation), or increasing from widespread timber harvest, increased impervious surfaces, or extensive road networks.

Criteria: From USFWS (1998), modified by USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Watershed Condition	Streamflow	Change in Peak/Base flows	Magnitude, timing, duration and frequency of peak flows within a watershed are not altered relative to natural conditions of an undisturbed watershed of similar size, geology, and geography.	Some evidence of altered magnitude, timing, duration and frequency of peak flows relative to natural conditions of an undisturbed watershed of similar size, geology, and geography.	Pronounced evidence of altered magnitude, timing, duration and frequency of peak flows relative to natural conditions of an undisturbed watershed of similar size, geology, and geography.

Assessment Results

In the Wenatchee River watershed, precipitation falls mostly as snow; the snowmelt in spring and early summer is the primary source of surface water (MWG et al. 2003). Spring snowmelt dominates the seasonal flow pattern in the watershed, with peak runoff from April through July, with the highest rates in May and June (Figure 1).

Top flood events have not noticeably increased in frequency or magnitude since 1929 (Table 1), with the largest 20 events spread out over the 1940s through 2000s. Figure 2 shows base flows and peak flows calculated for the Wenatchee River at Peshastin gage (USGS 12459000) since 1929. While human alterations to the watershed may have contributed to a change in peak flows, determining this causal relationship would require more complex analysis than is possible for this assessment (Hall et al. 2014).

Climate change projections indicate that rainfall may increase 1 to 2 percent by 2040, and 4 percent by 2080 (e.g., Mote and Salanthe 2009). Climate change models (synthesized by CIG 2009) also predict an increase in winter stream flows, earlier and lower peak runoff, and lower

summer baseflows (Figure 3). These analyses suggest that human-induced climate change is likely to alter the magnitude, timing, duration, and frequency of streamflows.

Therefore, based on the potential effects of climate change on watershed hydrology, this indicator is rated **at risk**.

REI Rating

Watershed Rating: **At Risk**

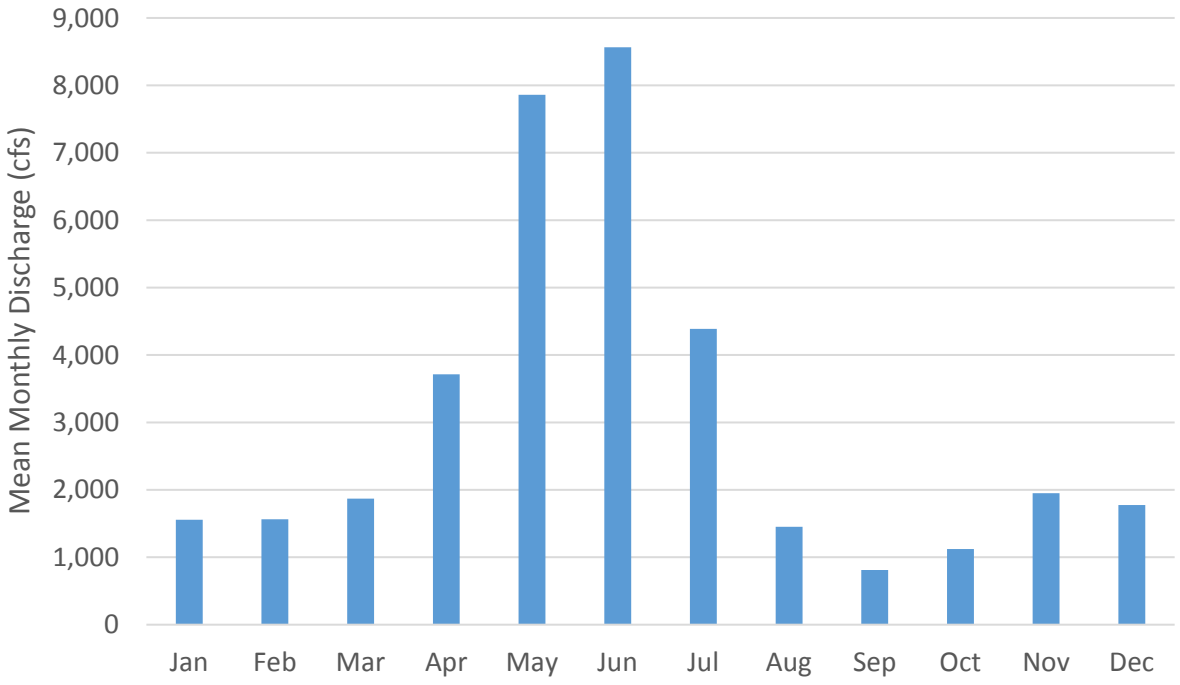

Figure 1. Mean Monthly Discharge at Peshastin for period 1929 to 2014 (USGS Gage 12459000)

Table 1. Top 20 Flood Events since 1929

Event Rank	Water Year	Discharge (cfs)
1	1996	41300
2	1991	40000
3	1948	32300
4	2007	30300
5	1981	27000
6	1974	26300
7	1972	26000
8	1976	25200
9	1956	24200
10	1955	23400
11	1999	23100
12	1949	22700
13	1950	21800
14	1961	21500
15	1997	21400
16	2006	21100
17	1958	21000
18	1951	20600
19	1983	20600
20	2008	20500

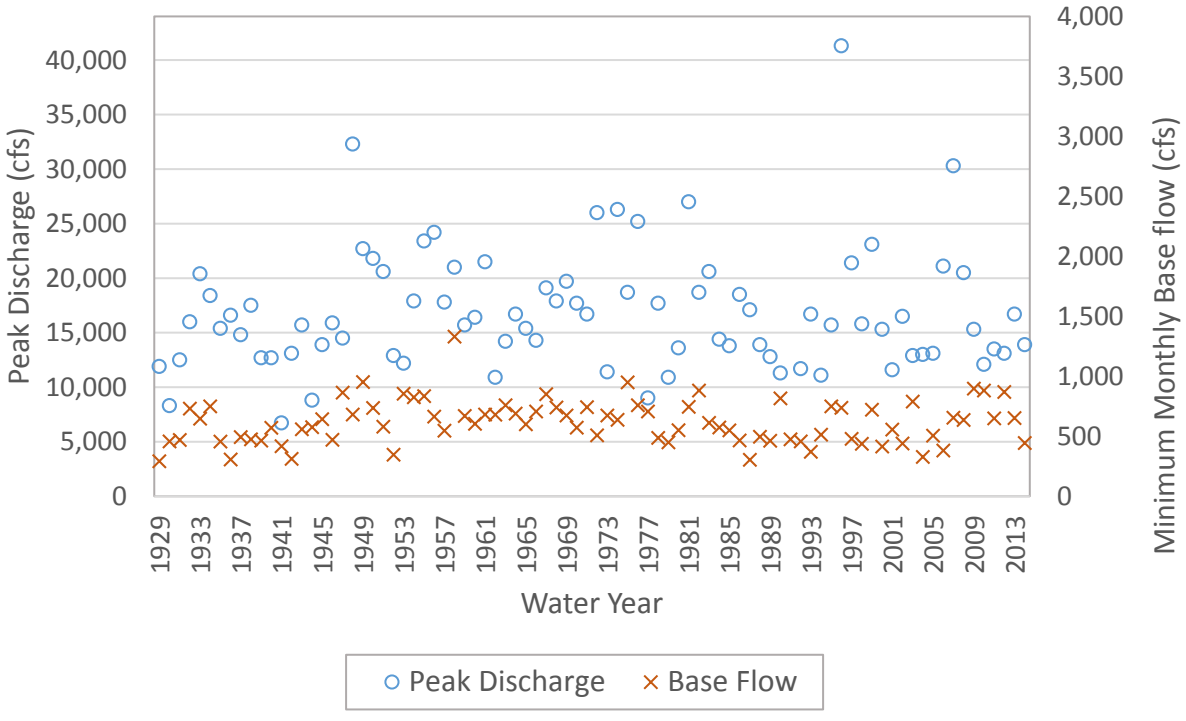

Figure 2. **Peak and Base Flows of the Wenatchee River at Peshastin from 1929 to 2013 (USGS Gage 12459000).**

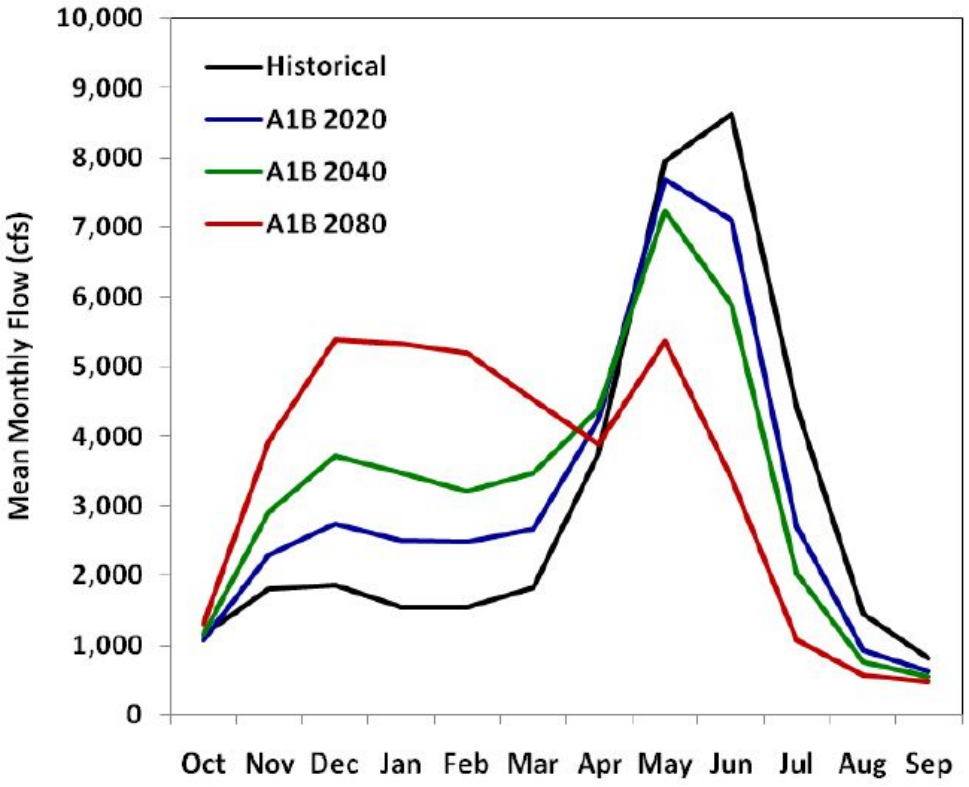

Figure 3. Projected Impacts of Climate Change on Mean Monthly Flows of Wenatchee River at Peshastin (Elsner 2011)

3. PATHWAY: REACH-SCALE HABITAT ACCESS

INDICATOR: PHYSICAL BARRIERS – MAIN CHANNEL BARRIERS

Metric Overview

Physical barriers restrict movement of aquatic species, such as salmonids, throughout a watershed. This can result in reduced genetic diversity within populations and reduced distribution of marine derived nutrients throughout the system, and may also impact transport of woody debris material downstream from source areas. This indicator evaluates the presence or absence of fish passage barriers in the lower Wenatchee River.

Criteria: From USFWS (1998), modified by USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Habitat Access	Physical Barriers	Main Channel Barriers	No manmade barriers present in the mainstem that limit upstream or downstream fish passage at any flows	Manmade barriers present in the mainstem that prevent upstream or downstream migration at some flows that are biologically significant	Manmade barriers present in the mainstem that prevent upstream or downstream migration at multiple or all flows

Assessment Results

No complete fish passage barriers are present on the lower Wenatchee River. Dryden Diversion Dam, located on the mainstem (just downstream of the Peshastin Creek confluence), has two functioning fish passage and trapping facilities (right and left bank) for broodstock collection with improved and updated fish screens in 2001 (Andonaegui 2001). Therefore, all reaches are considered **adequate**.

Main Channel Barriers REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10
adequate	adequate	adequate	adequate	adequate	adequate	adequate	adequate	adequate	adequate

4. PATHWAY: REACH-SCALE HABITAT QUALITY

INDICATOR: SUBSTRATE – DOMINANT SUBSTRATE FINE SEDIMENT

Metric Overview

Stream substrate is important for salmon spawning, egg incubation, and rearing. High-quality spawning areas generally include gravel/cobble dominated substrates with relatively low amounts of interstitial fine sediments. These factors provide conditions suitable for egg incubation (proper aeration and not smothered by fines) and young-of-the year rearing (available

interstitial spaces for cover and refuge). Streambed substrate was based on complete pebble counts to document substrate differences and ocular estimates of substrate composition for each channel unit.

Criteria: Modified from USFWS (1998) and USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Habitat Quality	Substrate	Dominant Substrate/Fine Sediment	Dominant Substrate is gravel or cobble (interstitial spaces clear), or embeddedness < 20%, <12% fines (<0.85mm) in spawning gravel or <12% surface fines of <6mm	Gravel and Cobble is subdominant, or if dominant, embeddedness is 20-30%; 12-17% fines (<0.85mm) in spawning gravel or 12-20% surface fines of <6mm	Bedrock, sand, silt, or small gravel dominant, or if gravel and cobble dominant, embeddedness > 30%; >17% fines (<0.85mm) in spawning gravel or >20% surface fines of <6mm

Assessment Results

Reaches 2 through 7 and 9 are considered **adequate** due to dominant cobble and gravel substrate. However, Reaches 2 through 7 are dominated by coarse cobbles with very few areas with spawning sized gravels whereas Reach 9 has abundant spawning sized gravels. Reaches 8 and 10 are considered **at risk** due to a higher incidence of boulders. Reach 1, the mouth of the Wenatchee River, is rated **unacceptable** with respect to substrate due to the dominance of sand/fines. However, this is the expected condition in Reach 1 given the backwater effects of the Columbia River.

Substrate Size Class Distribution by Reach

Substrate Size Class	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10
Sand (<2 mm)	80%	10%	9%	10%	7%	10%	13%	14%	23%	15%
Gravel (2 to 64 mm)	5%	10%	13%	10%	11%	10%	14%	4%	33%	13%
Cobble (64 to 256 mm)	15%	68%	66%	55%	43%	45%	50%	22%	39%	35%
Boulder (256 to 4096 mm)	0%	12%	10%	20%	21%	25%	22%	43%	6%	38%
Bedrock	0%	0%	3%	5%	18%	10%	2%	17%	0%	0%

Dominant Substrate/Fine Sediment REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10
unaccept-able	adequate	adequate	adequate	adequate	adequate	adequate	at risk	adequate	at risk

INDICATOR: LARGE WOODY DEBRIS (LWD)

Metric Overview

Large woody debris (LWD) provides critical habitat structure and helps create and sustain channel complexity over time. Large pieces and log jams can generate quality pools, offer refuge, and provide potential food sources for salmonids. This indicator evaluates the quantity of LWD in pieces per mile. Although the federal targets for properly functioning are 20 pieces per mile (USFWS 1998), Fox and Bolton (2007) determined that standard was low since larger eastern Washington streams (16 to 164 feet bankfull width) surveyed in unmanaged forested basins had an average of over 42.5 pieces per mile. In addition, the Upper Wenatchee River Stream Corridor Assessment found LWD quantities much higher at over 140 pieces per mile (Inter-Fluve 2012). For the purposes of this analysis, the criterion of 42.5 pieces per mile was chosen.

Criteria: Modified from USFWS (1998) and Fox and Bolton (2007)

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Habitat Quality	Large Woody Debris (LWD)	Pieces per mile at bankfull	>42.5 pieces/mile >12" dbh > 35' length; and adequate sources of woody debris available for both long- and short-term recruitment.	Current levels meet piece frequency standard for **Adequate**, but lacks potential sources from riparian areas for wood debris recruitment to maintain that standard.	Does not meet standards for **Adequate** and lacks potential large woody material recruitment.

Assessment Results

All of the reaches in the Assessment Area are considered **unacceptable** due to a general lack of LWD. Future LWD recruitment is also limited by insufficient riparian vegetation (see Pathway: Riparian Condition below). The quantity of LWD historically present in the mainstem lower Wenatchee River is uncertain. Previous studies have found that the abundance of instream LWD does decrease with basin area in large rivers as a result increased transport potential. However, the current conditions in most large rivers of the Pacific Northwest do not accurately represent historical conditions due to widespread modification, riparian clearing, and snag removal (Collins et al. 2002). Qualitative historical records indicate that extensive log jams sometimes miles in length and channel-spanning were historically present on many large rivers across North America (Wohl 2013).

Large Woody Debris Pieces per Mile

Large Woody Debris (LWD)	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10
Pieces/mile	2.5	0.0	4.7	1.1	0.0	1.4	9.9	2.2	5.4	3.3

LWD REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10
unacceptable	unacceptable	unacceptable	unacceptable	unacceptable	unacceptable	unacceptable	unacceptable	unacceptable	unacceptable

INDICATOR: POOLS – POOL FREQUENCY & QUALITY

Metric Overview

As was done in the Upper Wenatchee Watershed Assessment (Inter-Fluve 2012), the pool frequency and quality indicator was adapted for the lower Wenatchee River, due to the difference in channel widths between the lower Wenatchee River and those provided in the NMFS matrix. The largest bankfull channel width provided in the NMFS matrix is 65 to 100 feet, and 4 pools per mile is the standard for this width. Lower Wenatchee River bankfull widths generally exceed the criteria: most of the study length ranged from 102 to 300 feet bankfull width. Only six channel units (totaling less than one mile) spread out among Reaches 3, 4, 6, and 8 had bankfull widths within the NMFS criteria, ranging from 66 to 93 feet bankfull width. Because of this, reaches were primarily evaluated based on the pool quality indicator provided by NMFS (1996) (e.g., depth, substrate, cover, refugia), rather than against a specific threshold number of pools.

Criteria: Adapted from NMFS (1996).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Habitat Quality	Pools	Pool Frequency and Quality	Pools have good cover and cool water and only minor reduction of pool volume by fine sediment; each reach has many large pools > 1m deep with good cover	Meets pool quality standards, but does not meet LWD standards, so unable to maintain pools over time; reaches have few deep pools (>1m) present with good fish cover	Lacking pools, pool quality is inadequate and there has been a major reduction of pool volume by fine sediment; reaches have no deep pools (> 1m) with good fish cover

Assessment Results

Pool frequency ranged from 0.5 to 3.3 pools/mile, with total pools ranging from 1 to 9 per reach. As described in the Reach Assessment, Reach 1 is effectively one large backwater pool at the confluence with the Columbia River. Reaches 10 and 8 had the next largest proportions of pool habitat, at 63 percent and 34 percent, respectively. Reaches 6 and 8 had the greatest number of deep pools with residual depths exceeding 3 feet (n=9 in both reaches). The majority of the pools throughout the lower Wenatchee River were relatively deep, with shallow residual depths (less than 3 feet) comprising approximately 17 percent of total pools. All reaches were rated at risk due to not meeting LWD standards and lack of sufficient fish cover (see Section 4 of the Reach Assessment).

Pool Characteristics by Reach

Pool Characteristics	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10
Residual Pool Depth (ft)										
Pools < 3	0%	100%	29%	33%	25%	10%	0%	0%	0%	0%
Pools 3-6	0%	0%	57%	67%	0%	40%	0%	11%	0%	100%
Pools 6-9	100%[1/]	0%	0%	0%	50%	10%	100%	56%	100%	0%
Pools 9-12	0%	0%	0%	0%	25%	10%	0%	33%	0%	0%
Pools >12	0%	0%	14%	0%	0%	33%	0%	0%	0%	0%
Number of pools	1	1	7	9	4	10	2	9	2	1
Pools/mile	1.3	1.2	2.2	1.6	1.7	1.8	0.5	3.3	1.1	3.3

Notes:
[1/] Reach 1 consists of one large backwater pool, with a maximum depth of 7.4 feet. No pool crest depth exists, and therefore residual pool depth is not possible to calculate.

Pool Frequency and Quality REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10
at risk	at risk	at risk	at risk	at risk	at risk	at risk	at risk	at risk	at risk

INDICATOR: OFF-CHANNEL HABITAT

Metric Overview

Off-channel habitats, sloughs, wetlands, oxbow lakes, backwaters, floodplain channels, and blind and flow-through side-channels can provide important rearing habitat for juvenile salmonids (Roni et al. 2002). These areas can provide high-flow refugia, temperature refuge, and protection from predators, as well as productive feeding areas.

Criteria: Modified from USFWS (1998) and USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Habitat Quality	Off-Channel Habitat	Connectivity with main channel	Reach has ponds, oxbows, backwaters, and other low-energy off-channel areas with cover; similar to conditions that would be expected in the absence of human disturbance	Reach has some ponds, oxbows, backwaters, and other low-energy off-channel areas with cover; but availability or access is less than what would be expected in the absence of human disturbance	Reach has few or no ponds, oxbows, backwaters, or other off-channel areas relative to what would be expected in the absence of human disturbance.

Assessment Results

The lower Wenatchee River generally lacks adequate off-channel habitat. Reaches 2 and 4 through 7 are all considered **unacceptable** due to limited side-channels and other off-channel areas. In Reaches 1, 3, and 9, the abundance of off-channel habitat is considered **at risk**, with some off-channel habitat present (more in Reaches 1 and 9) but less than would be expected prior to human development. Reach 1 has relatively abundant off-channel habitat in the distributary channels on the left bank but this is still less than expected in the absence of human disturbance because the distributary channels on the right bank have been disconnected due to human alterations. Reaches 8 and 10 are rated **adequate** for this indicator because they are naturally confined and would not be expected to have off-channel habitat in the absence of human disturbance.

Channel Type Distribution

Channel Type	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10
Main Channel	33%	100%	70%	85%	100%	91%	92%	100%	50%	100%
Side Channel (fast)	0%	0%	5%	11%	0%	9%	8%	0%	5%	0%
Side Channel (slow)	67%	0%	25%	4%	0%	0%	0%	0%	45%	0%

Off-Channel Habitat REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10
at risk	unacceptable	at risk	unacceptable	unacceptable	unacceptable	unacceptable	adequate[1/]	at risk	adequate[1/]

1/ These reaches are naturally confined and would not be expected to have off-channel habitat in the absence of human disturbance.

5. PATHWAY: CHANNEL FORMS & PROCESSES

INDICATOR: CHANNEL DYNAMICS – FLOODPLAIN CONNECTIVITY

Metric Overview

Floodplains serve a number of significant geomorphic and ecological functions including conveyance of flood waters, sediment source and storage, supply of large wood, and development of diverse habitat for aquatic and terrestrial species (e.g., Allen 1970; Zwolinski 1992; Nanson and Croke 1992). Floodplain connectivity was evaluated based on the results from the hydraulic modeling, floodplain inundation and geomorphic mapping. For this analysis, the floodplain was divided into connected and disconnected floodplain to determine a percent disconnected. The connected floodplain was that would be inundated with over-bank flows under a 100-year flood. The disconnected floodplain was defined as the area that would likely be inundated under a 100-year-flood event in the absence of human alterations such as levees, roads, bridges, agriculture and other development that restrict floodplain connectivity.

Criteria: Modified from USFWS (1998).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Channel	Dynamics	Floodplain Connectivity	Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession	Reduced linkage of wetlands, floodplains, and riparian areas to main channel; overbank flows are reduced relative to historic frequency, as evidenced by moderate degradation of wetland function, riparian vegetation/succession	Severe reduction in hydrologic connectivity between off-channel wetland, floodplain, and riparian areas; wetland extent drastically reduced and riparian vegetation/succession altered significantly

Assessment Results

In Reaches 2, 7, 8 and 10, floodplain connectivity is considered **adequate**. However, the adequate rating was determined because those reaches are naturally confined by the topography and have limited floodplains available. Reaches 3 through 6 and 9 are considered **at risk** due to more substantial alteration to geomorphic conditions that limit connectivity. Although there is a wide floodplain in Reach 9, it is rated at risk because floodplain disconnection due to legacy sediment accumulation on the floodplain as a result of the Lamb-Davis Lumber mill pond dam. Reach 1 is rated **unacceptable** with respect to floodplain connectivity due to the right bank floodplain and distributary channels being disconnected due to human alterations.

Percent Disconnected Floodplain

Floodplain Connectivity	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10
Percent Disconnected	87%	4%[1/]	43%	66%	54%	62%	9%[1/]	0%[1/]	13%	7%[1/]

[1/] Reaches 2, 7, 8, and 10 are naturally confined by topography and have limited functional floodplains.

Floodplain Connectivity REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10
unacceptable	adequate	at risk	at risk	at risk	at risk	adequate	adequate	at risk	adequate

INDICATOR: BANK STABILITY/CHANNEL MIGRATION

Metric Overview

Channel migration and bank erosion are natural processes that maintain river habitats by recruiting substrate, LWD, and introduction of new channel dynamics. Low gradient alluvial channels, such as much of the lower Wenatchee River, adjust laterally via bank erosion and channel avulsions (rapid shifting of channel location). Natural channel migration rates are a result of numerous physical and biological processes including hydrologic regime, underlying geology, sediment supply, streambank vegetation, and floodplain hydraulic roughness. Human actions can affect these processes, which subsequently can alter channel migration rates and erosion locations. Bank armoring, levee construction, and channelization restrict flow to generally more straightened paths as well as limiting where erosion can occur; water withdrawals and dams can alter the hydrologic regime, affecting when and how much water interacts with the channel margins; and changes in riparian vegetation such as removal of streambank vegetation and development within the floodplain can affect erosion rates and how a river interacts with the channel margins.

Criteria: From USBR (2012)

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Channel	Dynamics	Bank Stability/ Channel Migration	Channel is migrating at or near natural rates.	Limited amount of channel migration is occurring at a faster/slower rate relative to natural rates, but significant change in channel width or planform is not detectable; large woody debris is still being recruited.	Little or no channel migration is occurring because of human actions preventing reworking of the floodplain and large woody debris recruitment; or channel migration is occurring at an accelerated rate such that channel width has a least doubled, possibly resulting in a channel planform change, and sediment supply has noticeably increased from bank erosion.

Assessment Results

Overall, the lower Wenatchee River has not shifted substantially over the past 100 years. An analysis of historical data from the 1884 General Land Office (GLO) survey maps (BLM 2015) and the 1911 plan and profile surveys of the Wenatchee River conducted by the USGS (USGS 1914) indicates that only two locations in the lower Wenatchee River have shifted and/or straightened significantly compared to earlier conditions: between approximately river miles (RM) 2 and 5 in Reach 3, and at approximately RM 10 in Reach 4, near Cashmere. Chelan

County's Channel Migration Zone Study Phase II also found that the lower Wenatchee River is a relatively stable system (Jones & Stokes 2004). In isolated areas however (e.g., RM 2.2 in Reach 3), channel migration rates as high as 15 feet per year were observed from 2007 to 2013. In addition, downcutting of the channel leading to partially incised or entrenched in many areas is considered primarily a result of post-glacial downcutting through glacial fluvial deposits (Jones & Stokes 2004). Therefore, it is possible the limited channel migration may be at or near natural rates in many areas.

However, there has been significant human alteration and armoring of streambanks that has reduced the ability of the river to migrate laterally. Bank armoring in the form of riprap, concrete walls, concrete stairways, bridge abutments, and levees were mapped as part of the geomorphic assessment. The total length of bank armoring was calculated as a percentage of reach length. This does not include areas of channel upstream and downstream of bridges where channel migration might be affected by the bridge. Reaches with greater degrees of bank armoring were considered more impaired than those with less armoring. For this analysis, reaches with less than 5 percent armoring were assumed **adequate**, between 5 and 10 percent **at risk**, and more than 10 percent **unacceptable**. Overall, bank erosion is not a major concern in most of the lower Wenatchee River.

Bank Characteristics by Reach

Bank Characteristics	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10
Armored Banks	13.6%	0.0%	13.6%	27.1%	17.8%	10.1%	5.7%	0.5%	0.6%	16.0%
Eroding Banks	0.0%	0.0%	4.3%	0.0%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%

Bank Stability/ Channel Migration REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10
unacceptable	adequate	unacceptable	unacceptable	unacceptable	unacceptable	at risk	adequate	adequate	unacceptable

INDICATOR: VERTICAL CHANNEL STABILITY

Metric Overview

Under natural conditions, alluvial river systems tend toward a balanced state in which some erosion and deposition occurs during sediment transporting events but no net change in dimension, pattern and profile over the course of years. These systems are frequently referred to as regime channels and are in a state of dynamic equilibrium in which there is a continuous inflow and output water and sediment. Changes in the conditions including sediment supply, channel form modification, flow, or bank strength can upset the balance leading to higher rates and a trend of aggradation or incision. This can result in or disconnection from the floodplain due to incision. Channel form modification can be the result of human actions including bank armoring, removal of riparian vegetation, levee building, channel straightening, and channelization which can reduce vertical channel stability.

Criteria: From USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Channel	Dynamics	Vertical Channel Stability	No measurable trend of aggradation or incision and no visible change in channel planform.	Measurable trend of aggradation or incision that has the potential to but not yet caused disconnection of the floodplain or a visible change in channel planform (e.g., single thread to braided).	Enough incision that the floodplain and off-channel habitat areas have been disconnected; or, enough aggradation that a visible change in channel planform has occurred (e.g., single thread to braided).

Assessment Results

Reach 1 is considered **adequate** because, in the absence of changes to Rock Island Dam and reservoir, it is vertically stable. Reaches 7 through 10 are considered **adequate** because post-glacial incision has cut to bedrock grade controls limiting further incision. Reaches 2 and 6 are considered **at risk** because there is observed channel incision but it has not lead to considerable floodplain disconnection. Reaches 3 through 5 are considered **unacceptable** due to significant incision causing floodplain and off-channel habitat areas to be disconnected most flows. However, Reach 5 does have frequent exposed bedrock grade controls, which may limit further incision.

Vertical Channel Stability REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10
adequate	at risk	unaccept-able	unaccept-able	Unaccept-able	at risk	adequate	adequate	adequate	adequate

6. PATHWAY: RIPARIAN CONDITION

INDICATOR: STRUCTURE

Metric Overview

Riparian areas have many important geomorphic and ecological roles within the river system. Intact riparian corridors help maintain streambank stability, provide large wood material, water filtration processes, organic input, streamside habitat and cover, hydraulic regulation, and temperature fluctuation modification (Gregory et al. 1991). The structure of riparian areas indicates how intact the riparian system is currently. This indicator is evaluated based on how well the seral stage, species composition, and complexity approximate natural conditions that would be expected in the absence of human alterations.

Criteria: From USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Riparian Vegetation	Condition	Structure	>80% species composition, seral stage, and structural complexity are consistent with potential native community.	50-80% species composition, seral stage, and structural complexity are consistent with potential native community.	<50% species composition, seral stage, and structural complexity are consistent with potential native community.

Assessment Results

Overall, riparian vegetation along the lower Wenatchee River is sparse. There are not many trees (see Indicator: Canopy Cover below), and of those present, minimal large trees only in Reaches 7, 8, and 10. Hardwood species are most common throughout the lower Wenatchee River, with relatively greater conifer concentrations in Reaches 7 and 8. Except for Reaches 8 and 10, all reaches are considered **unacceptable** with respect to riparian structure due to the lack of structural complexity and vegetation presence that would have occurred in the absence of human disturbance. In Reaches 8 and 10, the riparian zone is naturally limited by steep hillslopes; however, these reaches are still considered **at risk** due to reduced size class diversity.

Riparian Structure REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10
unacceptable	unacceptable	unacceptable	unacceptable	unacceptable	unacceptable	unacceptable	at risk	unacceptable	at risk

INDICATOR: DISTURBANCE (HUMAN)

Metric Overview

Human disturbance changes how a river interacts with its floodplain and riparian areas. Often human disturbance in the floodplain results in reduced occurrence of mature seral stages of vegetation and riparian structure, and limits channel migration and erosion processes. This can affect riparian processes including bank stability, wood recruitment, shade, and water quality. Riparian disturbance was assessed using information from the habitat assessment and an analysis of development and road densities within the 100-year floodplain. Road density was calculated based on the Chelan County Conservation District's road layer, clipped to the 100-year floodplain and divided into the Project reaches.

Criteria: From USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Riparian Vegetation	Condition	Disturbance (human)	>80% mature trees (medium-large) in the riparian buffer zone (defined as a 30 m belt along each bank) that are available for recruitment by the river via channel migration; <20% disturbance in the floodplain (e.g., agriculture, residential, roads, etc.); <2 mi/mi^2 road density in the floodplain.	50-80% mature trees (medium-large) in the riparian buffer zone (defined as a 30 m belt along each bank) that are available for recruitment by the river via channel migration; 20-50% disturbance in the floodplain (e.g., agriculture, residential, roads, etc.); 2-3 mi/mi^2 road density in the floodplain.	<50% mature trees (medium-large) in the riparian buffer zone (defined as a 30 m belt along each bank) that are available for recruitment by the river via channel migration; >50% disturbance in the floodplain (e.g., agriculture, residential, roads, etc.); >3 mi/mi^2 road density in the floodplain.

Assessment Results

As discussed above, sufficient mature trees are lacking throughout the lower Wenatchee River. Based on that aspect of the above criteria, all reaches would be considered unacceptable. Taking into account the current percent of development (land cover category) and road density. Reaches 4 through 6 are considered **unacceptable**. The remaining reaches are rated **at risk** due to lower levels of development and road construction within the 100-year floodplain. This floodplain definition may delineate a smaller area of land than considered by other previous research of human impact on the Wenatchee River floodplain; in one case study, researchers found that as of 1949 about 55 percent of the Wenatchee River floodplain had been converted to agriculture, and by 2006, an overall 62 percent had been modified by development (of which 20 percent was urban) (Tomlinson et al. 2011). This context affirms that the "at risk" reaches should still be considered substantially impacted by human disturbance.

Development and Road Density in 100-year Floodplain

Floodplain Disturbance	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10
Percent developed	20%	2%	32%	62%	50%	23%	13%	11%	16%	32%
Road density (mi/mi^2)	0	0.9	3.3	8.4	8.0	4.4	0.5	0.3	0.9	3.1

Disturbance (Human) REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10
at risk	at risk	at risk	unacceptable	unacceptable	unacceptable	at risk	at risk	at risk	at risk

INDICATOR: CANOPY COVER

Metric Overview

Riparian canopies provide shade and moderate light availability and quality to the stream and riverbed. This affects water temperature and algae growth. Water temperature is a main driver of the health, productivity, and life cycles of many aquatic organisms, including salmonids. High water temperatures during the summer and fall can often be a factor limiting habitat quality for rearing and spawning salmonids. The percentage canopy cover is based on the extent of canopy closure within riparian areas (150-foot buffer approximating one site potential tree height), not the percentage of the stream that is covered. Canopy cover was estimated using the first return, also referred to as highest hit data, from the light detection and ranging (LiDAR) dataset to estimate tree height. Tree heights of greater than 25 feet were included in the canopy coverage area.

Criteria: Modified from USFWS (1998) and USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Riparian	Condition	Canopy Cover	Trees and shrubs within one site potential tree height distance have >80% canopy cover that provides thermal shading to the river.	Trees and shrubs within one site potential tree height distance have 50- 80% canopy cover that provides thermal shading to the river.	Trees and shrubs within one site potential tree height distance have <50% canopy cover that provides thermal shading to the river.

Assessment Results

Canopy cover is rated unacceptable throughout all reaches. Percent canopy cover ranged from 11.8 percent in Reach 2 to 30.1 percent in Reach 10, all far below the “adequate” target of >80 percent.

Canopy Cover Percentage within 150 Feet of Stream Bank

Canopy Cover	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10
Percent coverage	12.0%	11.8%	14.3%	14.5%	13.4%	12.5%	17.4%	24.9%	17.4%	30.1%

Canopy Cover REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10
unacceptable	unacceptable	unacceptable	unacceptable	unacceptable	unacceptable	unacceptable	unacceptable	unacceptable	unacceptable

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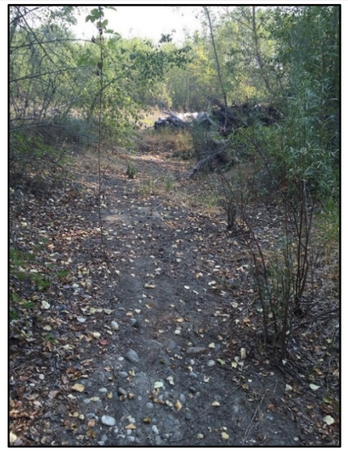
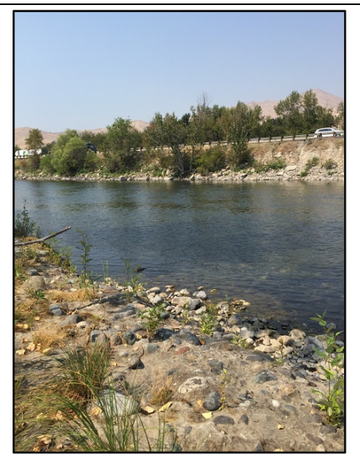
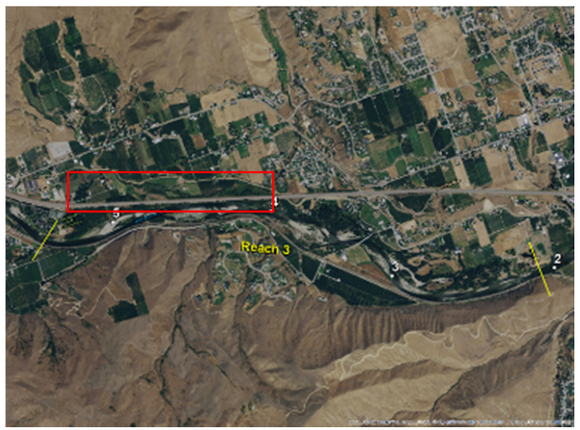
APPENDIX E

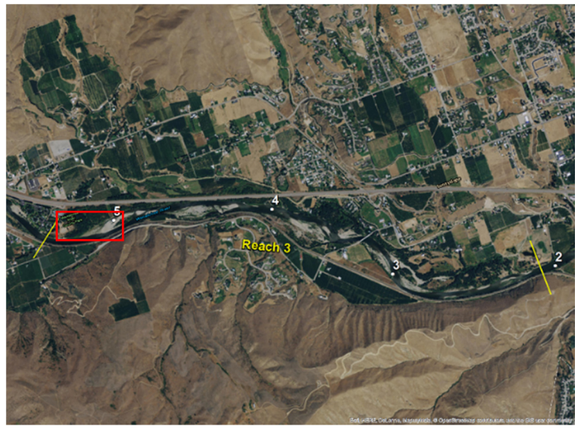
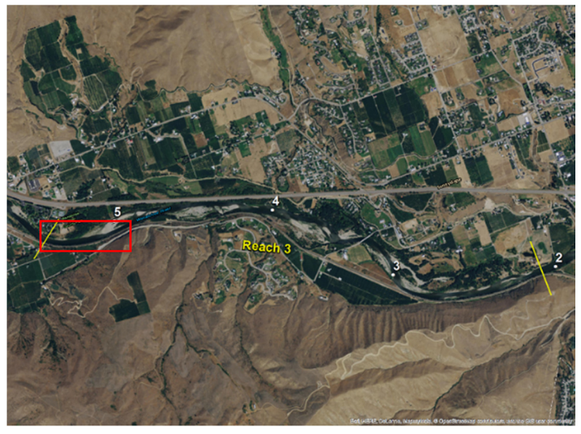
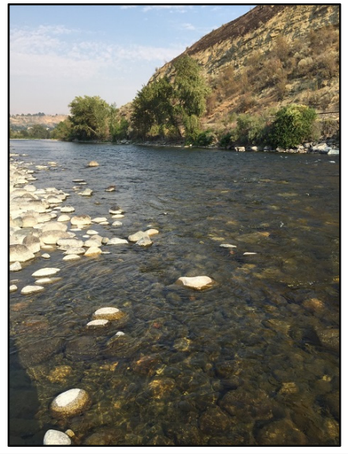
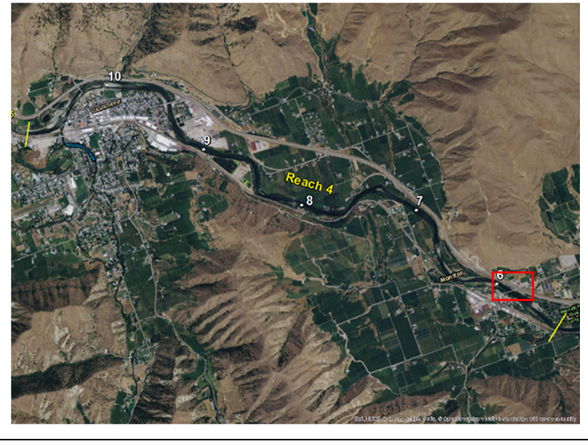
Potential Project Opportunities

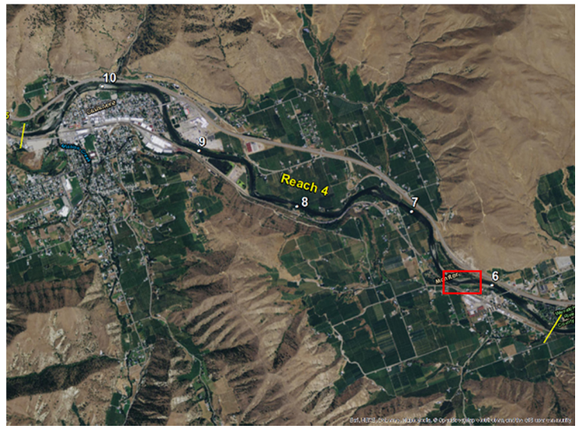
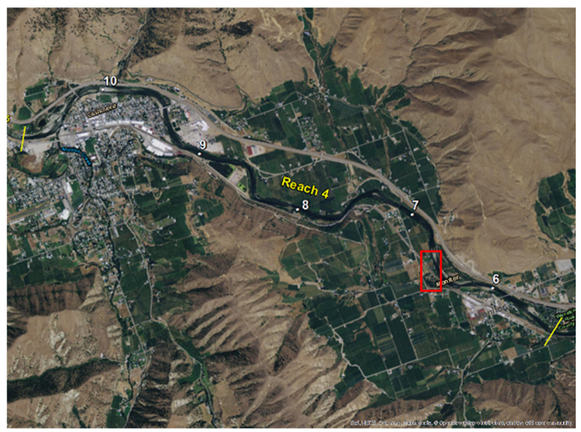
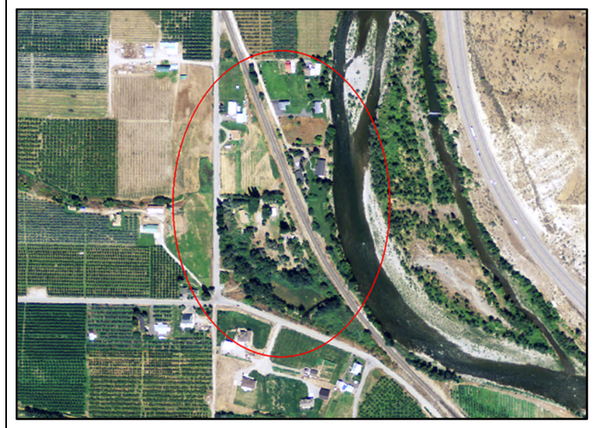
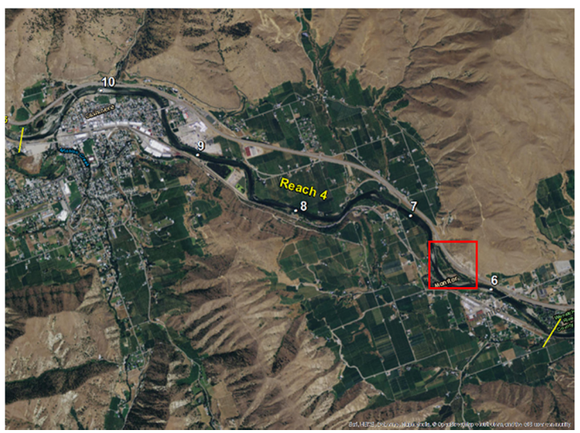
Geomorphic Reach	Project Opportunity Location	Name	Action Type	Potential Restoration Actions	Description and Rationale	Tier	Photo/Imagery
Reach 1		Project Area 1 RM 0.3 to 0.8 Left Bank	Install Habitat Structures	• Remove non-native plants • Riparian planting • Install LWD structures (whole trees, jams, etc.)	Existing distributary channels lack complex instream habitat and cover. Installing LWD habitat structures would create habitat complexity and cover in distributary channels. Heavy equipment access to distributary channels may be limited requiring additional design considerations.	3	
		Project Area 2 RM 0.3 to 0.9 Right Bank	Floodplain Habitat Reconnection	• Remove non-native plants • Riparian planting • Remove or setback levee • Bank stabilization with LWD and bioengineering • Install LWD structures (whole trees, jams, etc.) • Remove or relocate floodplain infrastructure • Perennial side channel creation/enhancement • Secondary channel (non-perennial) creation/ enhancement • Wetland creation/ enhancement • Alcove creation/enhancement	Historical distributary channels are disconnected from mainstem river. Past restoration efforts have focused on wildlife habitat. Reconnecting historical distributary channels, wetlands, and floodplain habitat would increase rearing habitat availability. Bank stabilization with LWD and bioengineering would provide added instream habitat and cover. Riparian vegetation restoration in cleared areas would provide shade and long-term recruitment potential. This project would require modification of existing trails and infrastructure.	1	
Reach 2		Project Area 3 RM 1.8 to 2.0 Left Bank	Floodplain Habitat Reconnection	• Remove non-native plants • Riparian planting • Riparian fencing • Install LWD structures (whole trees, jams, etc.) • Perennial side channel creation/enhancement • Wetland creation/ enhancement • Alcove creation/enhancement	Existing irrigation ditch (Highline Ditch return) currently functions as a cold water return source. There is also a small existing alcove providing limited habitat. Realigning and enhancing this irrigation return ditch with pools and LWD structures as well as expanding and enhancing the existing alcove would increase rearing habitat availability. Riparian vegetation restoration in cleared areas would provide shade and long-term recruitment potential.	1	

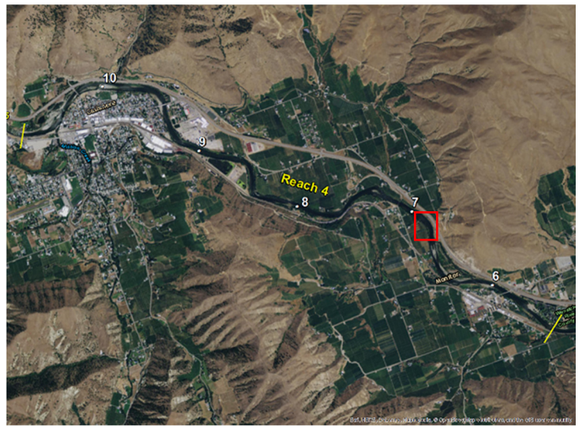
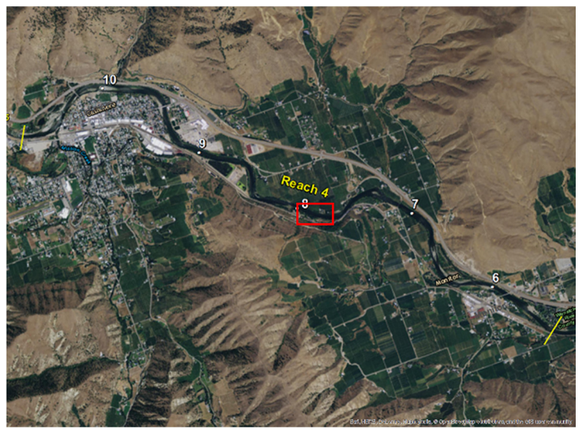
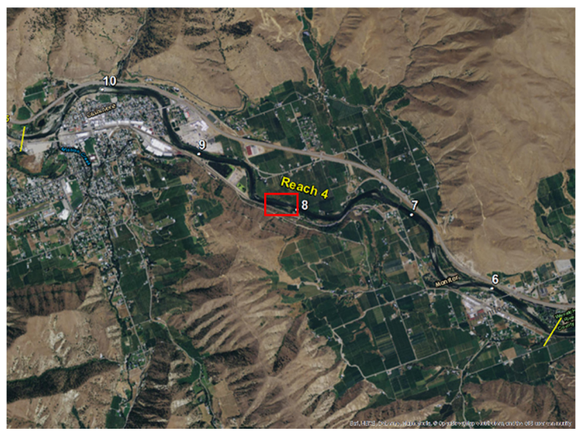
Geomorphic Reach	Project Opportunity Location	Name	Action Type	Potential Restoration Actions	Description and Rationale	Tier	Photo/Imagery
Reach 3		Project Area 4 RM 2.2 to 3.0 Left Bank	Floodplain Habitat Reconnection	• Remove non-native plants • Riparian planting • Install LWD structures (whole trees, jams, etc.) • Perennial side channel creation/enhancement • Secondary channel (non-perennial) creation/ enhancement • Wetland creation/ enhancement • Alcove creation/enhancement • Groundwater fed off-channel creation/enhancement	There is a network of existing side channels that are disconnected at lower flows. The project area is relatively large with considerable potential. Reconnecting side channels and installing LWD structures would increase available rearing habitat. Riparian vegetation restoration would provide shade and long-term recruitment potential. This project would require excavating the inlet and LWD structures to control inlet flows.	1	
		Project Area 5 RM 3.1 to 3.2 Right Bank	Floodplain Habitat Reconnection	• Remove non-native plants • Riparian planting • Install LWD structures (whole trees, jams, etc.) • Wetland creation/ enhancement • Alcove creation/enhancement • Groundwater fed off-channel creation/enhancement	The low floodplain topography in this project area is currently inundated at the 2-yr flood event. Reconnecting this floodplain habitat and constructing or enhancing alcoves, wetlands, and off-channel areas would require minimal excavation and would increase available rearing habitat. This project would require excavation and/or LWD structure upstream to encourage perennial flows. Riparian vegetation restoration in cleared areas would provide shade and long-term recruitment potential.	2	
		Project Area 6 RM 3.3 to 3.4 Right Bank	Enhance Existing Bank Protection	• Bank stabilization with LWD and bioengineering	The existing boulder groins in this project area provide bank stability, but only minimal habitat benefit. Incorporating LWD into the bank protection would create local habitat complexity and cover. LWD structures would also provide opportunity to create local scour pools. The design of bank stabilization structures in this project area would need to consider recreational boater safety.	3	

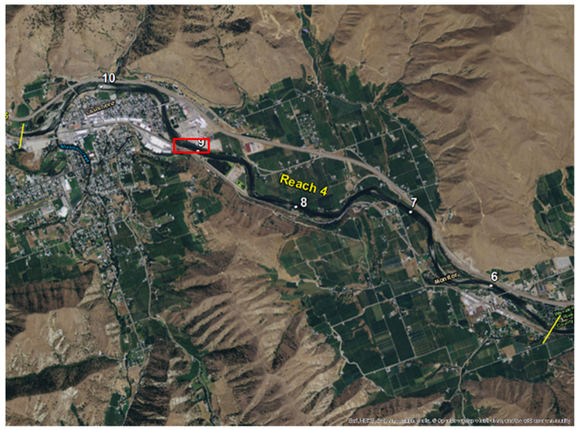
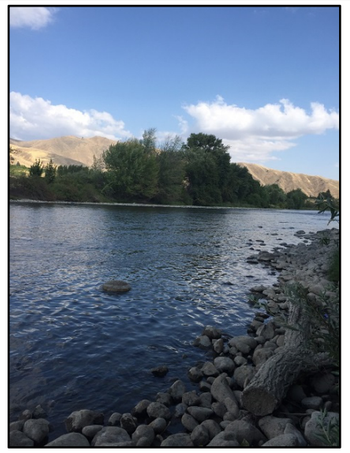
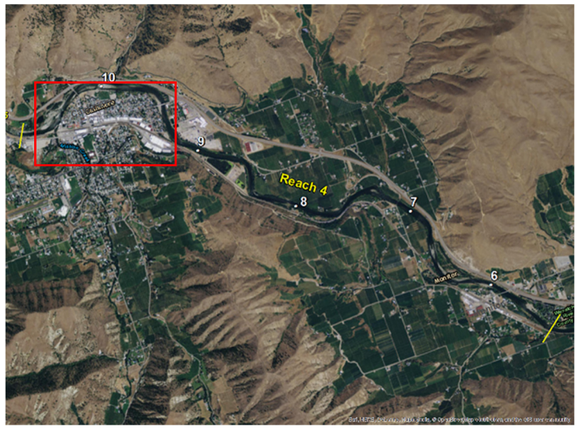
Geomorphic Reach	Project Opportunity Location	Name	Action Type	Potential Restoration Actions	Description and Rationale	Tier	Photo/Imagery
Reach 3		Project Area 7 RM 3.6 to 4.0 Right Bank	Floodplain Habitat Reconnection	• Remove non-native plants • Riparian planting • Install LWD structures (whole trees, jams, etc.) • Perennial side channel creation/enhancement • Secondary channel (non-perennial) creation/enhancement • Alcove creation/enhancement	The downstream section of existing side channel has good habitat complexity and cover, while upstream section is lacking. There is currently no defined inlet to the side channel. Reconnecting side channels and enhancing alcove habitat with LWD for habitat complexity and cover would increase available rearing habitat. Riparian vegetation restoration in disturbed areas would provide shade and long-term recruitment potential. This project will require a relatively large excavation to initiate side channel and/or LWD structure to control inlet flows.	1	
		Project Area 8 (CMZ 6) RM 3.9 to 4.1 Left Bank	Floodplain Habitat Reconnection (Modify Existing Restoration Site)	• Install LWD structures (whole trees, jams, etc.) • Perennial side channel creation/enhancement	This existing side channel restoration project (CMZ 6) has good habitat complexity and cover, but does not receive perennial flow. Sediment accumulation at the inlet has reduced connectivity. Installing LWD structures and modifying the side channel inlet would improve function by providing perennial flow and an increase in available rearing habitat.	2	
		Project Area 9 RM 4.3 to 4.6 Left Bank	Enhance Existing Bank Protection	• Bank stabilization with LWD and bioengineering	The existing boulder groins in this project area provide bank stability, but only minimal habitat benefit. Incorporating LWD into the bank protection would create local habitat complexity and cover. LWD structures would also provide opportunity to create local scour pools. The design of bank stabilization structures in this project area would need to consider recreational boater safety.	3	

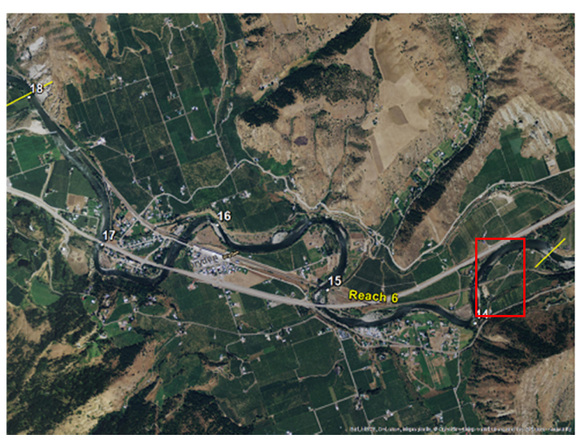
Geomorphic Reach	Project Opportunity Location	Name	Action Type	Potential Restoration Actions	Description and Rationale	Tier	Photo/Imagery
Reach 3		Project Area 10 RM 4.4 to 4.7 Right Bank	Floodplain Habitat Reconnection	• Remove non-native plants • Riparian planting • Install LWD structures (whole trees, jams, etc.) • Perennial side channel creation/enhancement • Secondary channel (non-perennial) creation/enhancement • Alcove creation/enhancement	The existing alcove in this project area has good complexity but cover is limited. Expanding and enhancing the existing alcove would increase available rearing habitat. Reconnecting side channels and installing LWD structures would also increase available rearing habitat Riparian vegetation restoration in disturbed areas would provide shade and long-term recruitment potential.	2	
		Project Area 11 RM 4.0 to 5.2 Left Bank	Floodplain Habitat Reconnection	• Remove non-native plants • Riparian planting • Install LWD structures (whole trees, jams, etc.) • Perennial side channel creation/enhancement • Secondary channel (non-perennial) creation/ enhancement • Wetland creation/ enhancement • Alcove creation/enhancement • Groundwater fed off-channel creation/enhancement • Road relocation or modification • Remove or relocate floodplain infrastructure • Reconnect historical meander bend	A large portion of the historical floodplain in this project area is disconnected by U.S. Highway 2. The project area is relatively large with considerable potential. Reconnection of this section of floodplain would greatly increase rearing habitat availability. This project would evaluate several alternatives for floodplain restoration and reconnection including groundwater-fed, off-channel habitat. Installing new bridges or realigning the highway would need to be considered as a part of this project.	1	

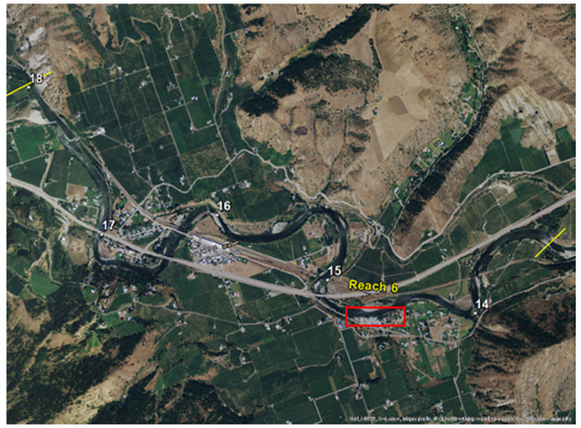
Geomorphic Reach	Project Opportunity Location	Name	Action Type	Potential Restoration Actions	Description and Rationale	Tier	Photo/Imagery
Reach 3		Project Area 12 RM 4.9 to 5.4 Left Bank	Floodplain Habitat Reconnection	• Remove non-native plants • Riparian planting • Install LWD structures (whole trees, jams, etc.) • Perennial side channel creation/enhancement • Alcove creation/enhancement • Groundwater fed off-channel creation/enhancement	The existing side channel in this project area has good habitat complexity and cover, but is disconnected at lower flows. Reconnecting side channels and creating/enhancing alcove habitat with LWD for habitat complexity and cover would increase available rearing habitat. Riparian vegetation restoration would provide shade and long-term recruitment potential.	2	
		Project Area 13 RM 4.9 to 5.5 Right Bank	Enhance Existing Bank Protection	• Bank stabilization with LWD and bioengineering	The existing boulder groins in this project area provide bank stability, but only minimal habitat benefit. Incorporating LWD into the bank protection would create local habitat complexity and cover. LWD structures would also provide opportunity to create local scour pools. The design of bank stabilization structures in this project area would need to consider recreational boater safety.	3	
Reach 4		Project Area 14 RM 5.7 to 6.0 Left Bank	Enhance Existing Bank Protection	• Bank stabilization with LWD and bioengineering	The existing boulder groins in this project area provide bank stability, but only minimal habitat benefit. Incorporating LWD into the bank protection would create local habitat complexity and cover. LWD structures would also provide opportunity to create local scour pools.	3	

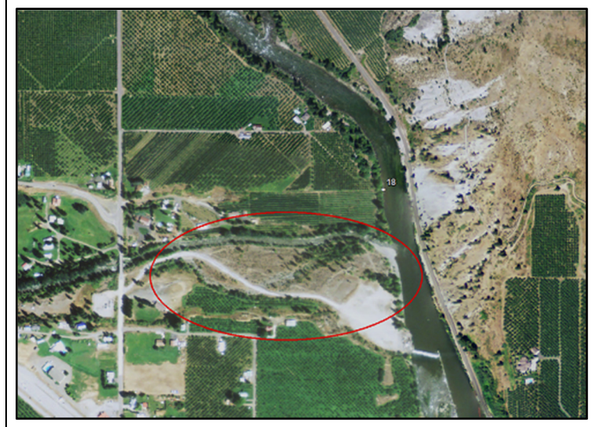
Geomorphic Reach	Project Opportunity Location	Name	Action Type	Potential Restoration Actions	Description and Rationale	Tier	Photo/Imagery
Reach 4		Project Area 15 RM 6.2 to 6.4 Mid-channel	Install Habitat Structures	• Install boulder structures	This section of river is lacking instream habitat complexity. Addition of mid-channel boulder clusters would create local scour pools and increase the instream habitat complexity in areas where hydraulic characteristics are suitable.	3	
		Project Area 16 RM 6.4 to 6.5 Right Bank	Floodplain Habitat Reconnection	• Remove non-native plants • Riparian planting • Install LWD structures (whole trees, jams, etc.) • Alcove creation/enhancement • Groundwater-fed off-channel creation/enhancement • Railroad modification	The floodplain and off-channel habitat in this project area is currently disconnected by the BNSF Railway. Reconnecting floodplain habitat and constructing or enhancing alcoves, wetlands, and off-channel areas would increase available rearing habitat. Riparian vegetation restoration in cleared areas would provide shade and long-term recruitment potential. BNSF Railway water crossing structures would need to be considered as a part of this project.	1	
		Project Area 17 (Pioneer Side Channel) RM 6.2 to 6.6 Left Bank	Install Habitat Structures (Modify Existing Restoration Site)	• Remove non-native plants • Riparian planting • Install LWD structures (whole trees, jams, etc.) • Perennial side channel creation/enhancement • Wetland creation/enhancement • Alcove creation/enhancement	This existing side channel restoration project (Pioneer Side Channel) lacks habitat complexity and cover. Incorporating LWD structures would increase habitat complexity and cover. Other alternatives to consider for this project include channel reconstruction (e.g., with pools associated with LWD structures) and construction of wetland and alcove habitat which would increase available rearing habitat.	1	

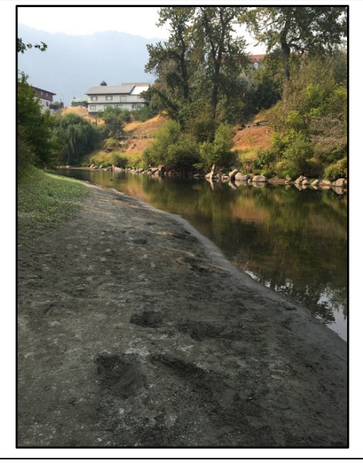
Geomorphic Reach	Project Opportunity Location	Name	Action Type	Potential Restoration Actions	Description and Rationale	Tier	Photo/Imagery
Reach 4		Project Area 18 RM 6.8 to 7.0 Mid-channel	Install Habitat Structures	• Install boulder structures	This section of river is lacking instream habitat complexity. Addition of mid-channel boulder clusters would create local scour pools and increase the instream habitat complexity in areas where hydraulics characteristics are suitable.	3	
		Project Area 19 RM 7.8 to 8.0 Mid-channel	Install Habitat Structures	• Install boulder structures	This section of river is lacking instream habitat complexity. Addition of mid-channel boulder clusters would create local scour pools and increase the instream habitat complexity in areas where hydraulics characteristics are suitable.	3	
		Project Area 20 RM 8.0 to 8.2 Right Bank	Floodplain Habitat Reconnection	• Remove non-native plants • Riparian planting • Install LWD structures (whole trees, jams, etc.) • Remove or relocate Floodplain Infrastructure • Perennial side channel creation/enhancement • Secondary channel (non-perennial) creation/enhancement	There is a historical side channel in this project area that has been altered by man-made construction. There are residential structures in low lying topography near the existing sided channel. Reconnecting side channels and installing LWD structures would also increase available rearing habitat. Reconnection would require some excavation at the inlet and fill removal. An LWD structure at the inlet would control inlet flows and create habitat complexity and cover. Riparian vegetation restoration in disturbed areas would provide shade and long-term recruitment potential.	2	

Geomorphic Reach	Project Opportunity Location	Name	Action Type	Potential Restoration Actions	Description and Rationale	Tier	Photo/Imagery
Reach 4		Project Area 21 RM 8.4 to 9.0 Right Bank	Floodplain Habitat Reconnection	• Remove non-native plants • Riparian planting • Relocate sewage treatment facility • Perennial side channel creation/enhancement • Secondary channel (non-perennial) creation/enhancement • Wetland creation/enhancement • Alcove creation/enhancement	The City of Cashmere wastewater treatment facility is located within the historical floodplain in this project area. Relocating the facilities and restoring the floodplain in this area would provide much-needed habitat complexity in a section of river that lacks both rearing habitat and cover. The floodplain restoration would require large amounts of excavation with soil and site remediation in addition to traditional restoration techniques to for floodplain and riparian restoration.	1	
		Project Area 22 RM 9.0 to 9.2 Mid-channel	Install Habitat Structures	• Install boulder structures	This section of river is lacking instream habitat complexity. Addition of mid-channel boulder clusters would create local scour pools and increase the instream habitat complexity in areas where hydraulic characteristics are suitable.	3	
		Project Area 23 RM 9.2 to 10.6 Right Bank	Floodplain Habitat Reconnection	• Remove non-native plants • Riparian planting • Install LWD structures (whole trees, jams, etc.) • Remove or setback existing levees • Remove or relocate Floodplain Infrastructure • Perennial side channel creation/enhancement • Secondary channel (non-perennial) creation/ enhancement • Alcove creation/enhancement • Reconnect historical meander bend	There is an existing levee system providing flood protection for the City of Cashmere in this project area. Modification of the existing levee would allow for floodplain restoration and reestablish the historical meander pattern, which would provide much-needed habitat complexity in a section of river that lacks both rearing habitat and cover. This project opportunity has many potential constraints and would require the relocation of many residences and businesses.	1	

Geomorphic Reach	Project Opportunity Location	Name	Action Type	Potential Restoration Actions	Description and Rationale	Tier	Photo/Imagery
Reach 5		Project Area 24 RM 11.7 to 12.1 Left Bank	Floodplain Habitat Reconnection	• Install LWD structures (whole trees, jams, etc.) • Perennial side channel creation/enhancement • Secondary channel (non-perennial) creation/enhancement • Groundwater fed off-channel creation/enhancement	The existing side channel in this project area has good habitat and cover but is disconnected at lower flows. There are relatively large quantities of existing LWD in the side channel. Reconnecting side channels and installing LWD structures would increase available rearing habitat. There may also be potential for incorporating groundwater flows in this project area. Reconnection would require some excavation at the inlet. This project may require modification of large log jam at inlet of side channel.	1	
Reach 6		Project Area 25 (CMZ 11) RM 13.3 to 13.4 Left Bank	Floodplain Habitat Reconnection (Modify Existing Restoration Site)	• Install LWD structures (whole trees, jams, etc.) • Perennial side channel creation/enhancement • Secondary channel (non-perennial) creation/enhancement • Alcove creation/enhancement	This existing side channel restoration project (CMZ 11) lacks habitat complexity and cover and does not receive perennially flow. Excavating the channel inlet and incorporating LWD structures would increase habitat complexity and cover and provide perennial flows. Other alternates to consider for this project include channel reconstruction (e.g. with pools associated with LWD structures) and construction alcove habitat which would increase available rearing habitat.	2	
		Project Area 26 RM 13.5 to 13.9 Right Bank	Floodplain Habitat Reconnection	• Remove non-native plants • Riparian planting • Install LWD structures (whole trees, jams, etc.) • Railroad modification • Remove or relocate Floodplain Infrastructure • Perennial side channel creation/enhancement • Secondary channel (non-perennial) creation/enhancement • Alcove creation/enhancement	The floodplain in this project area is dissected by the BNSF Railway and the river is constrained by the bridge crossing. Modification of the BNSF Railway would allow for floodplain restoration including perennial and secondary side channels and alcoves which would provide much needed rearing habitat in this section of river. Complete floodplain reconnection in this project area would require construction of BNSF Railway bridges and a relatively large amount of excavation.	1	

Geomorphic Reach	Project Opportunity Location	Name	Action Type	Potential Restoration Actions	Description and Rationale	Tier	Photo/Imagery
Reach 6		Project Area 27 RM 14.4 to 14.7 Right Bank	Enhance Existing Bank Protection	• Bank stabilization with LWD and bioengineering	Existing groins provide some bank protection, but minimal habitat benefit to river. Additions of large wood would create local habitat complexity and cover. ELJ and large wood additions provide opportunity to create local scour pools. The design of bank stabilization structures in this project area would need to consider recreational boater safety.	3	
		Project Area 28 (CMZ 12 and 13) RM 14.4 to 14.8 Left Bank	Floodplain Habitat Reconnection (Modify Existing Restoration Site)	• Install LWD structures (whole trees, jams, etc.) • Perennial side channel creation/enhancement • Alcove creation/enhancement	This existing side channel restoration project (CMZ 12 and 13) has good habitat complexity and cover but is disconnected at lower flows and is accumulating fine sediments. Excavating the channel inlet and incorporating LWD structures would provide perennial sediment flushing flows and increase habitat complexity and cover. Construction of alcove habitat would also increase available rearing habitat.	2	
		Project Area 29 RM 15.0 to 15.1 Right Bank	Floodplain Habitat Reconnection	• Remove non-native plants • Riparian planting • Install LWD structures (whole trees, jams, etc.) • Alcove creation/enhancement • Groundwater fed off-channel creation/enhancement	There is an existing cold water spring in this project area. Constructing a perennial alcove at this existing groundwater spring would provide high-quality rearing habitat. The installation of LWD structures to protect inlet and to create habitat complexity and cover in the alcove. Riparian vegetation restoration in cleared areas would provide shade and long-term recruitment potential.	2	

Geomorphic Reach	Project Opportunity Location	Name	Action Type	Potential Restoration Actions	Description and Rationale	Tier	Photo/Imagery
Reach 6		Project Area 30 (Dryden Fish Enhancement Project) RM 15.2 Right Bank	Floodplain Habitat Reconnection (Modify Existing Restoration Site)	• Bank stabilization with LWD and bioengineering • Install LWD structures (whole trees, jams, etc.) • Levee modification • Improve fish passage	This existing alcove and wetland restoration project (Dryden Fish Enhancement Project) that has high quality rearing habitat, but fish access is restricted due to a beaver dam at the narrow outlet of the alcove cut into the existing levee. Expanding the size of the outlet channel and constructing multiple outlet channels would improve fish passage and provide greater access to this restoration site.	2	
		Project Area 31 RM 17.8 to 17.9 Right Bank	Tributary Restoration	• Remove non-native plants • Riparian planting • Install LWD structures (whole trees, jams, etc.) • Road relocation or modification • Remove or relocate Floodplain Infrastructure • Tributary channel relocation and enhancement • Perennial side channel creation/enhancement • Alcove creation/enhancement	Peshastin Creek is currently straightened and simplified near the Wenatchee River confluence. Relocating Peshastin Creek into its historical channel and adding a perennial side channel and alcove would create habitat complexity and cover. Large wood structures would increase habitat complexity and cover in restored channels. Riparian vegetation restoration in cleared areas would provide shade and long-term recruitment potential. Peshastin Creek channel realignment would require modifications to the existing access road.	1	
Reach 7		Project Area 32 RM 18.3 to 18.6 Left Bank	Install Habitat Structures	• Perennial side channel creation/enhancement • Install LWD structures (whole trees, jams, etc.)	The existing side channel in this project area receives perennial flow, but lacks complex habitat and cover. Installing LWD structures would increase habitat complexity and cover. This project would require an extensive stability analysis for LWD structures as this side channel receives large volumes of water during high flow events. The design of LWD structures would also need to consider recreational boater safety.	2	

Geomorphic Reach	Project Opportunity Location	Name	Action Type	Potential Restoration Actions	Description and Rationale	Tier	Photo/Imagery
Reach 7		Project Area 33 RM 20.5 Left Bank	Remove Instream Structures	• Remove or relocate Floodplain Infrastructure	There is existing infrastructure within the river channel in this project area. The removal of this structure would increase flood capacity and eliminate the risk of structure failure and debris entering the river.	3	
Reach 9		Project Area 34 (CMZ 19A – Boat Launch) 24.4 to 24.6 Right Bank	Floodplain Habitat Reconnection (Modify Existing Restoration Site)	• Install LWD structures (whole trees, jams, etc.) • Perennial side channel creation/enhancement • Alcove creation/enhancement	This existing alcove restoration project (CMZ 19A – Boat Launch) lacks cover. The alcove is disconnected at lower flows and is accumulating fine sediments. Excavating an inlet channel may be required to create sediment flushing flows at the outlet and maintain perennial access. Installing LWD structures in the perennial side channel and alcove would increase habitat complexity and cover.	2	
		Project Area 35 (Blackbird Island) RM 24.6 to 24.7 Left Bank	Install Habitat Structures	• Install LWD structures (whole trees, jams, etc.) • Perennial side channel creation/enhancement	The existing side channel in this project area (Blackbird Island) lacks complex instream habitat. There is evidence of large wood under streambed creating grade controls. There are also signs of scour around existing bridge abutments. Installing LWD structures would promote the formation of scour pools and provide instream habitat and cover. Restoration designs in this project area would identify alternatives to protect existing bridge abutments and would also need to consider recreational boater safety.	2	

Geomorphic Reach	Project Opportunity Location	Name	Action Type	Potential Restoration Actions	Description and Rationale	Tier	Photo/Imagery
Reach 9		Project Area 36 (CMZ 19) RM 24.6 to 24.7 Right Bank	Install Habitat Structures	• Install LWD structures (whole trees, jams, etc.) • Perennial side channel creation/enhancement	The existing side channel in this project area receives perennial flow, but lacks complex habitat and cover. Installing LWD structures would promote the formation of scour pools and increase habitat complexity and cover. LWD structure designs in this project area would need to consider recreational boater safety.	1	
		Project Area 37 (ICTU Blackbird Island) RM 24.7 to 24.9 Left Bank	Floodplain Habitat Reconnection (Modify Existing Restoration Site)	• Install LWD structures (whole trees, jams, etc.) • Perennial side channel creation/enhancement • Improve fish passage	This existing restoration site (ICTU Blackbird Island) has high quality rearing habitat, but fish access is restricted by a beaver dam at the narrow channel outlet. Expanding the size of the outlet channel and constructing multiple outlet channels would improve fish passage and provide greater access to this restoration site. There are also potential alternatives to excavate an upstream inlet to provide a combination of perennial side channel and alcove habitat in this project area.	2	
		Project Area 38 (CMZ 20) RM 24.9 to 25.6 Right Bank	Floodplain Habitat Reconnection (Modify Existing Restoration Site)	• Remove non-native plants • Riparian planting • Install LWD structures (whole trees, jams, etc.) • Perennial side channel creation/enhancement • Groundwater-fed off-channel creation/enhancement	This existing restoration project (CMZ 20) has good complexity, but is mostly disconnected at lower flows and is accumulating large volumes of fine sediment. Excavating this side channel would provide perennial sediment flushing flows. Installing LWD structures would promote the formation of scour pools and increase habitat complexity and cover. Riparian vegetation restoration in disturbed areas would provide shade and long-term recruitment potential. LWD structure designs in this project area would need to consider recreational boater safety.	1	

APPENDIX F

Project Opportunities Geodatabase

(provided on DVD)

This appendix is provided separately.

APPENDIX G

Project Opportunities Prioritization Matrix

(provided on DVD)

This appendix is provided separately.

TETRA TECH