Methow River

Assessment of the Twisp to Carlton Reach

January 2017, Final

Shaping the Future

Document Information

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Table of Contents

Appendices

Tables

Figures

Acronyms

°C	degrees Celsius
2D	two-dimensional
Assessment Reach	Twisp to Carlton Reach of the Methow River (RM 28–41)
BAER	Burned Area Emergency Response
CCFEG	Cascade Columbia Fisheries Enhancement Group
CFR	Code of Federal Regulations
cfs	cubic feet per second
DPS	distinct population segment
Ecology	Washington Department of Ecology
ELJ	engineered log jams
eRAMS	Environmental Risk Assessment and Management Systems
ESA	Endangered Species Act
ESU	evolutionarily significant unit
FLIR	forward-looking infrared
fps	feet per second
FR	Federal Register
GIS	Geographic Information System
HAWS	Height Above Water Surface
LiDAR	light detection and ranging

LWD	large woody debris
m^3	cubic meters
mi^2	square miles
NMFS	National Marine Fisheries Service
NPDES	National Pollution Discharge Elimination System
NOAA	National Oceanic and Atmospheric Administration
ppm	parts per million
Reclamation	U.S. Bureau of Reclamation
RM	river mile
RTT	Upper Columbia Regional Technical Team
SWE	snow water equivalent
UCSRB	Upper Columbia Salmon Recovery Board
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
YNF	Yakama Nation Fisheries

1 Introduction

1.1 Overview

The Methow River, a major tributary of the Upper Columbia River draining the North Cascades mountain range in north-central Washington state, once supported robust populations of spring Chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*O. mykiss*), and bull trout (*Salvelinus confluentus*) (Upper Columbia Regional Technical Team [RTT] 2014). Over the last 100 years, their numbers have declined precipitously due in part to a significant loss in the quantity and quality of river habitats essential for their support. In recent years there has been a renewed effort to address these instream habitat limitations, as part of the larger-scale efforts to recover salmon populations throughout the Columbia Basin. The goal of this Twisp to Carlton Reach Assessment is to determine how best to improve critical habitat needs for Endangered Species Act (ESA)–listed salmonid species and associated fish species in the Twisp to Carlton reach (Assessment Reach) of the Methow River (river mile [RM] 41.3-28.1). This Reach Assessment was conducted within the context set by the *Methow Subbasin Geomorphic Assessment* (U.S. Bureau of Reclamation [Reclamation] 2008). It seeks to enhance, but not duplicate, the vast body of work accomplished during that earlier project, and to provide more detailed information that directly informs project implementation (which covers the steps “Alternatives Evaluation” through “Construction” of Figure 1-1).

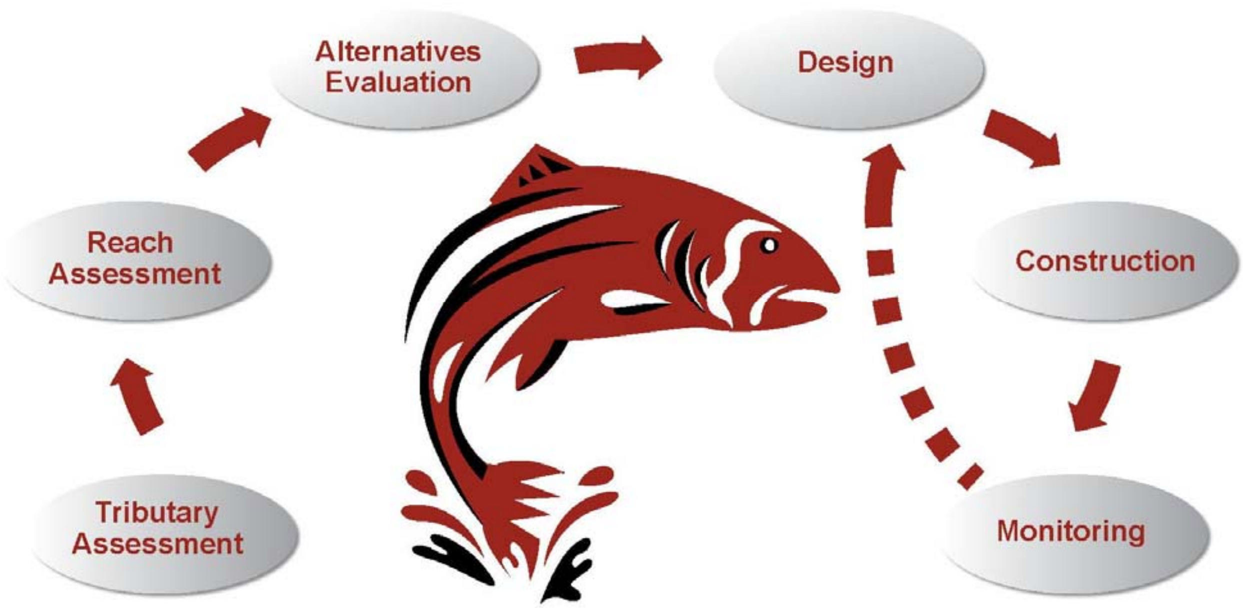


Figure 1-1 Bureau of Reclamation (2011) flow chart showing the reach assessment in the context of habitat restoration design, implementation, and monitoring.

This Reach Assessment follows the fundamental premise that enhancement of key *habitat-forming river processes* is the best self-sustaining course for improving habitat conditions for specific species. However, in many cases “creating” habitat at discrete locations is a necessary stop-gap measure to prevent further loss of habitat quality, especially where habitat-forming processes may take many decades to achieve a more sustainable end point, or where societal constraints simply do not allow such processes to unfold.

To achieve this outcome, the following steps were taken:

> Defining the environmental baseline for the Assessment Reach by characterizing existing geomorphic conditions and key habitat-forming processes at the watershed, reach, and sub-reach scale. This was

accomplished through review of prior studies, new fieldwork, and analyses that emphasized the identification, distribution, and magnitude of "physical, chemical, and biological processes that create and sustain river and floodplain ecosystems" (Beechie et al. 2010) and the specific locations where they have been impaired by human activities in the Assessment Reach.

> Defining what enhancement actions might be most effective in addressing limiting factors, either by direct intervention to construct habitats or by taking actions to support the habitat-forming processes that can create and sustain these habitats.

> Identifying locations where habitat conditions for spring Chinook salmon, steelhead, and bull trout could be enhanced. The *Recovery Plan and Biological Strategy for the Middle Methow River Subwatershed* (Upper Columbia Salmon Recovery Board [UCSRB] 2007; RTT 2014) identified several limited habitat types that currently reduce the potential to recover depleted populations of spring Chinook, steelhead, and bull trout in the Assessment Reach. These ecological concerns (limiting factors) were used as the basis for identification and selection of suitable restoration opportunities that target the habitat needs of specific species and life-history stages.

> Recommending a sub-reach priority ranking for these actions.

This report summarizes a logical sequence of analyses for implementation in the Assessment Reach, and this approach is applicable to future restoration efforts as well, because it provides a transparent framework for identifying and analyzing relevant indicators of reach-scale processes and conditions from which a prioritization of actions can guide a program of "process-based restoration."

This report has the following organization in line with RTT (2014) recommendations for a reach assessment:

> *Background* for the report, including a summary of the administrative, regulatory, and biological context.

> A summary of *assessment area conditions* (extending from RM 41.3 to 28.1), including setting, geology, pre-settlement conditions, subsequent human disturbances, and existing conditions, which draws upon previous studies, historical information, and habitat surveys performed for this Assessment.

> A characterization of *conditions* in the three sub-reaches: TC3 (RM 41.3–40.3), TC2 (RM 40.3–33.7), and TC1 (RM 33.7–28.1).

> A summary of the resulting *restoration strategy*, including the approach to identifying and prioritizing specific actions. The restoration strategy outlines actions that target either specific habitats that sustain critical life-history requirements or the watershed and instream processes that are needed to support those features.

2 Background

2.1 Purpose

This report, produced by Cardno in concert with the Cascade Columbia Fisheries Enhancement Group (CCFEG), identifies opportunities for protection areas and restoration projects through an integrated assessment of geomorphic and habitat processes and conditions in the Assessment Reach. Specific objectives of this Reach Assessment include:

> Develop reach-scale refinement of the data and analyses presented in the geomorphic assessment (2008) and other watershed-scale characterizations, while not duplicating information from previous efforts.

> Identify protection areas and process-based habitat restoration opportunities within the Assessment Reach by synthesizing results of a quantitative habitat survey and applying existing information supplemented by additional analyses.

> Develop a sub-reach-scale prioritization of habitat restoration opportunities along the Assessment Reach.

> Provide quantitative information describing the physical characteristics of the Assessment Reach and its sub-reaches for future restoration project identification, development, prioritization, and design.

> Connect the sub-reach characterization and restoration strategy to ecological concerns (limiting factors) previously identified for the Assessment Reach (RTT 2014).

The Reach Assessment is a part of a much larger, multi-agency effort to recover native populations of anadromous salmonids in the Upper Columbia Basin (UCSRB 2007). This Assessment builds off a large body of existing watershed- and reach-scale assessments that have been performed in this region, in particular the *Methow Subbasin Geomorphic Assessment* (Reclamation 2008) and the *Middle Methow Reach Assessment* (Reclamation 2010). The first of these (Reclamation 2008) fully encompasses the Assessment Reach (subdivided in that report into sub-reaches TC1 [RM 28.1–33.7], TC2 [RM 33.7–40.3], and TC3 [RM 40.3–41.3], Figure 2-1), providing systematic analyses of geology, historical channel alignments, human-built features impinging on the channel, vegetative communities, spawning sites, temperature, and related data. Findings from these previous reports have been incorporated into this Assessment and updated with field observations to address changes in conditions over the intervening 8 years and provide greater detail in areas that were deemed important to either the characterization of key processes or the identification of potential restoration sites.

2.2 Study Area

The Methow River is one of the few remaining undammed tributaries of the Columbia River, draining the east side of the North Cascades in north-central Washington state. The Assessment Reach extends between the towns of Twisp and Carlton (RMs 41.3–28.1, Figure 2-1), and contains the first unconfined alluvial channel encountered by immigrating salmonids migrating from the confluence with the Columbia River. The relatively broad valley has also drawn historical settlement and widespread agricultural use, resulting in intense alteration to the Methow River channel and its floodplain.

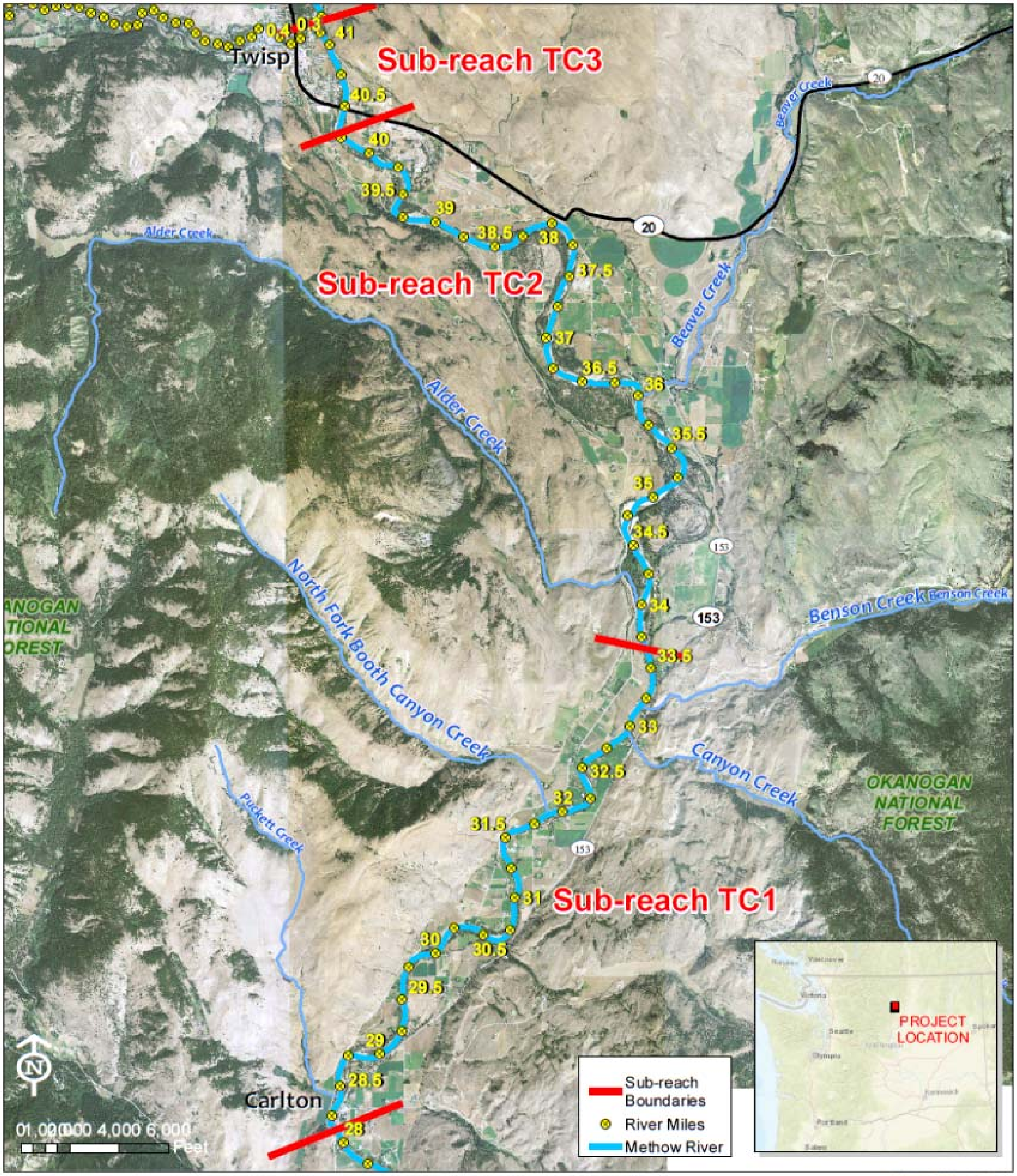


Figure 2-1 **Twisp to Carlton Assessment Reach. Sub-reach boundaries are as follows: TC1 [RM 28.1–33.7], TC2 [RM 33.7–40.3], and TC3 [RM 40.3–41.3].**

2.3 Fish Use and Population Status

The fish species of concern found in the Assessment Reach include the locally adapted runs of spring and summer Chinook salmon, Upper Columbia River steelhead, Columbia River bull trout, Pacific lamprey (*Entosphenus tridentatus*), and coho (*O. kisutch*). Life-stage usage and ESA status for these species in the Assessment Reach are summarized in Table 2-1 and Figure 2-2.

Table 2-1 Fish Usage in the Twisp to Carlton Reach of the Methow River

Population	ESA Status	General Usage
Spring Chinook	Endangered	M (j,a), OW, R
Steelhead	Threatened	M, OW (j,a), R, S
Bull trout	Threatened	F, M, OW
Summer Chinook	-	M, S
Coho	-	M, S
Pacific lamprey	-	M, R, S
Sockeye	-	P, S

Notes: F = Forage; M = Migration; OW = Overwintering; P = Present; R = Rearing; S = Spawning
Letters in Parentheses: (j) = juvenile; (a) = adult
Source: Reclamation 2008; RTT 2014; UCSRB 2007

The primary target species for restoration actions in the Assessment Reach are spring Chinook and steelhead, but it is expected that other native species would also benefit from restoration actions. Additional details on these species are provided below. Bull trout, both adults and sub-adults, are also described as using this reach as they migrate between the Columbia River and the upper Methow watershed when temperature conditions allow. It is assumed that restoration actions selected to benefit spring-run Chinook and steelhead would also benefit bull trout.

The Upper Columbia River spring-run Chinook salmon evolutionarily significant unit (ESU) was listed as *endangered* on March 24, 1999 (64 *Federal Register* [FR] 14308); this listing was reaffirmed on June 28, 2005 (70 FR 37160). The Upper Columbia River steelhead distinct population segment (DPS) was listed as *endangered* under the ESA on August 18, 1997 (63 FR 43937) and reclassified to *threatened* on January 13, 2007 (71 FR 834); this listing was reaffirmed on August 24, 2009 (74 FR 42605). Bull trout were listed as *threatened* on November 1, 1999 (64 FR 58910). On September 2, 2005, the National Marine Fisheries Service (NMFS) designated critical habitat for Chinook (Figure 2-3) and steelhead (Figure 2-4) in the Assessment Reach (70 FR 52630). The U.S. Fish and Wildlife Service designated critical habitat for bull trout throughout their U.S. range on September 30, 2010 (50 Code of Federal Regulations [CFR] 63898), which includes the Assessment Reach.

Spring Chinook, which begin returning from the ocean in early spring, enter the Upper Columbia River tributaries from April through July. After migration they hold in freshwater tributaries until spawning occurs in late summer, peaking in mid-to-late August. Juvenile spring Chinook spend a year in fresh water before migrating to salt water in the spring of their second year of life. Most Upper Columbia River spring Chinook return as adults after 2 to 3 years in the ocean. Within the Assessment Reach, the spring Chinook population is not currently viable and has a high risk of extinction (UCSRB 2007; NMFS 2016).

Steelhead adults return to the Columbia River in late summer/early fall, with a portion of the returning run overwintering in the mainstem reservoirs and then passing into the Upper Columbia River tributaries in April/May of the following year. Spawning occurs in late spring of the calendar year following entry into the river. Juvenile steelhead spend 1 to 3 (and up to 7) years rearing in fresh water before migrating to the ocean. Most adults return after 1 or 2 years in the ocean. Some adult steelhead may return to spawn more than once in their lives, unlike other salmon. Within the Assessment Reach, the steelhead population is not currently viable and has a moderate to high risk of extinction (UCSRB 2007; NMFS 2016).

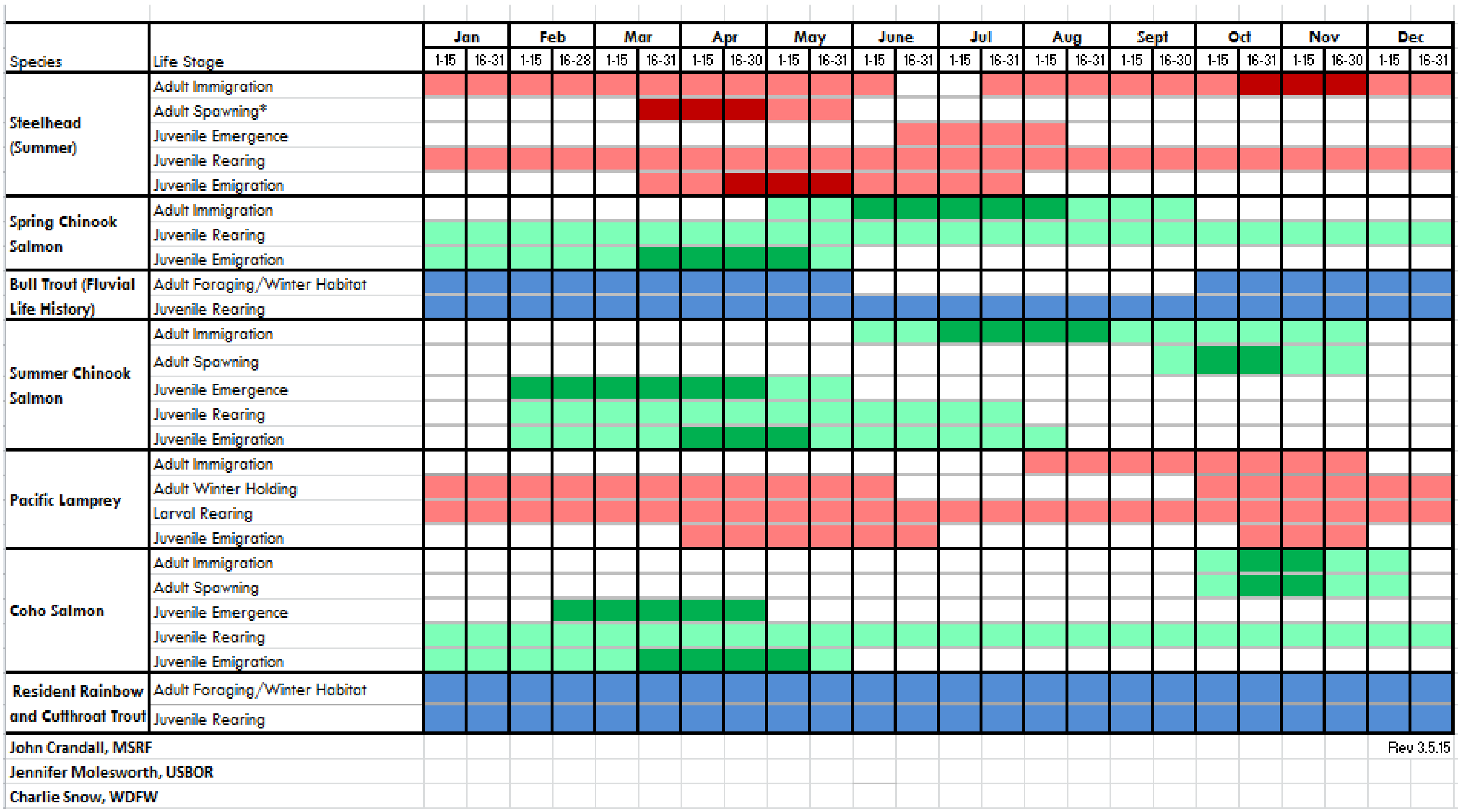


Figure 2-2 **Middle Methow River (Twisp to Carlton reach) fish periodicity chart.**

Bull trout in the Upper Columbia Basin exhibit a wide variety of life-history patterns, including both resident and migratory life-history strategies. Resident bull trout complete their entire life cycle in the tributary stream in which they spawn and rear, whereas migratory bull trout spawn in tributary streams where juvenile fish rear for 1 to 4 years before migrating to either a lake (adfluvial form) or river (fluvial form). Migrating bull trout have been observed within spawning tributaries as early as mid to late June, while spawning occurs in mid-September to late October/early November. Resident and migratory forms may be found together, and either form may give rise to offspring exhibiting either resident or migratory behavior (UCSRB 2007). Within the Assessment Reach, the bull trout population is declining and has a high risk of extinction (50 CFR 63898).

For the ESA-listed salmonid species of concern, as judged by the characterization of limiting factors offered by the RTT (2014), the available rearing habitat and overwinter refuge habitat is limited in the Twisp to Carlton reach of the Methow River (as confirmed by this Assessment). These preferred habitat areas are typically found in main channel pools, on channel margins, and within side channels that are only inundated during high seasonal flows, but that can remain wetted and connected with the channel for considerable periods of the year. They are characterized by slow water velocities (<2 feet per second [fps]), water depths generally less than 3 feet, cooler summer temperatures (<18 degrees Celsius [°C] in the summer, when associated with upwelling locations), warmer winter temperature waters, and abundant cover (overhanging and submerged vegetation) that provides refuge from predation.

2.4 Recovery Planning Context

2.4.1 Process-Based Restoration and Project Prioritization

A key concept underlying much of the current restoration planning throughout the Columbia Basin is that of "process-based restoration," articulated most explicitly by Beechie et al. (2008, 2010). This concept applies the hierarchical understanding of streams in their watershed context to a philosophy guiding stream restoration, advocating that the restoration of watershed-scale *processes* should, in general, supersede the restoration of strictly reach-scale *conditions*. Beechie et al. (2008) grouped these watershed-scale processes under the categories of hydrology, sediment, riparian, channel, floodplain connectivity, and water quality. Subsequently, Beechie et al. (2010) recommended a restoration focus on "…reestablish[ing] normative rates and magnitudes of physical, chemical, and biological processes that sustain river and floodplain ecosystems," and they further emphasized that "restoration actions should address the root causes of degradation…" (Beechie et al. 2010:209). These works echo the earlier guidance of Roni et al. (2002:1), whose summary recommendations are as follows:

> *Initially, efforts should focus on protecting areas with intact processes and high-quality habitat. Following a watershed assessment, we recommend that restoration focus on reconnecting isolated high-quality fish habitats, such as instream or off-channel habitats made inaccessible by culverts or other artificial obstructions. Once the connectivity of habitats within a basin has been restored, efforts should focus on restoring hydrologic, geologic (sediment delivery and routing), and riparian processes through road decommissioning and maintenance, exclusion of livestock, and restoration of riparian areas. Instream habitat enhancement (e.g., additions of wood, boulders, or nutrients) should be employed after restoring natural processes or where short-term improvements in habitat are needed (e.g., habitat for endangered species).*

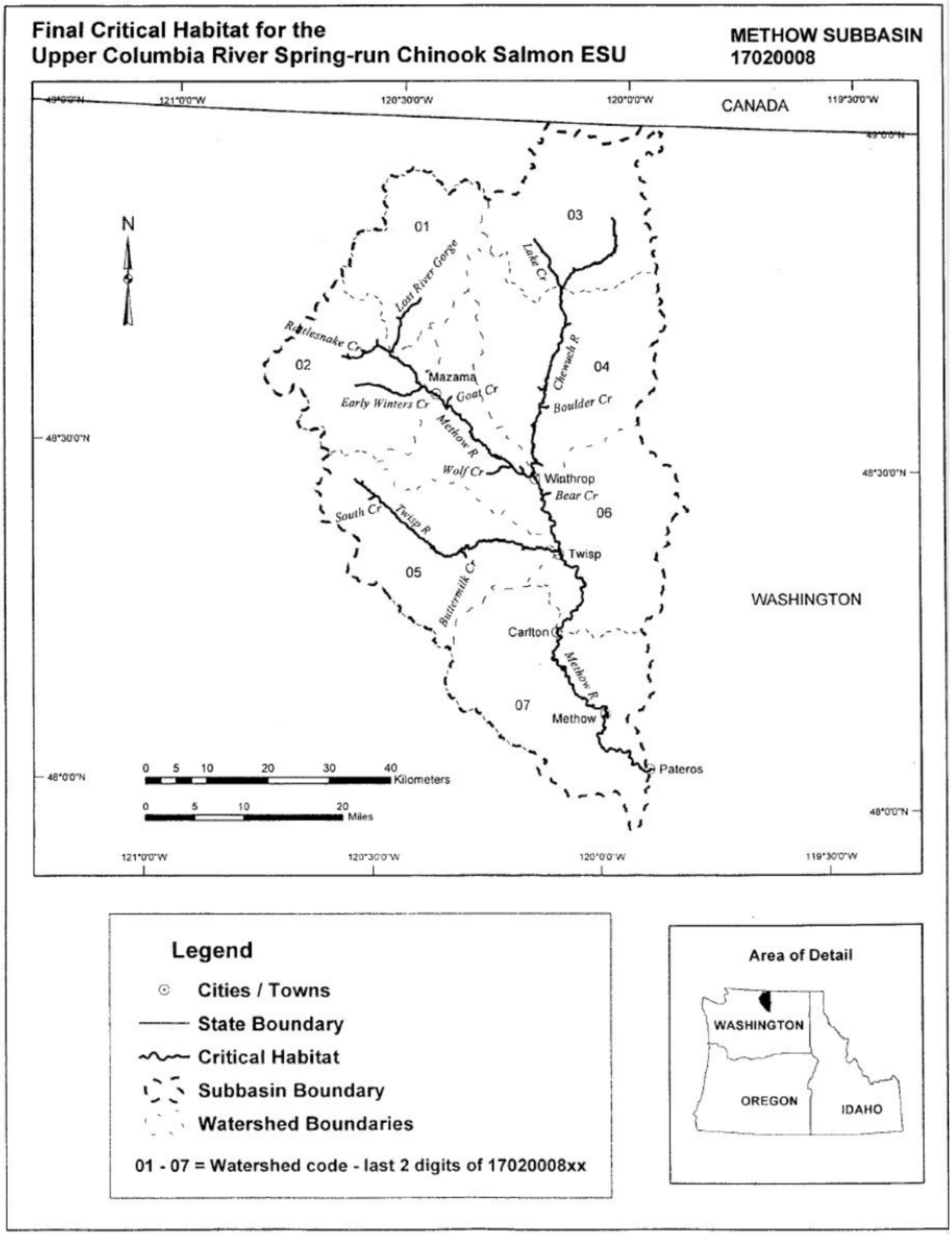


Figure 2-3 Upper Columbia River spring-run Chinook salmon critical habitat for the Methow Subbasin. Reproduced from 70 FR 52630 (2005).

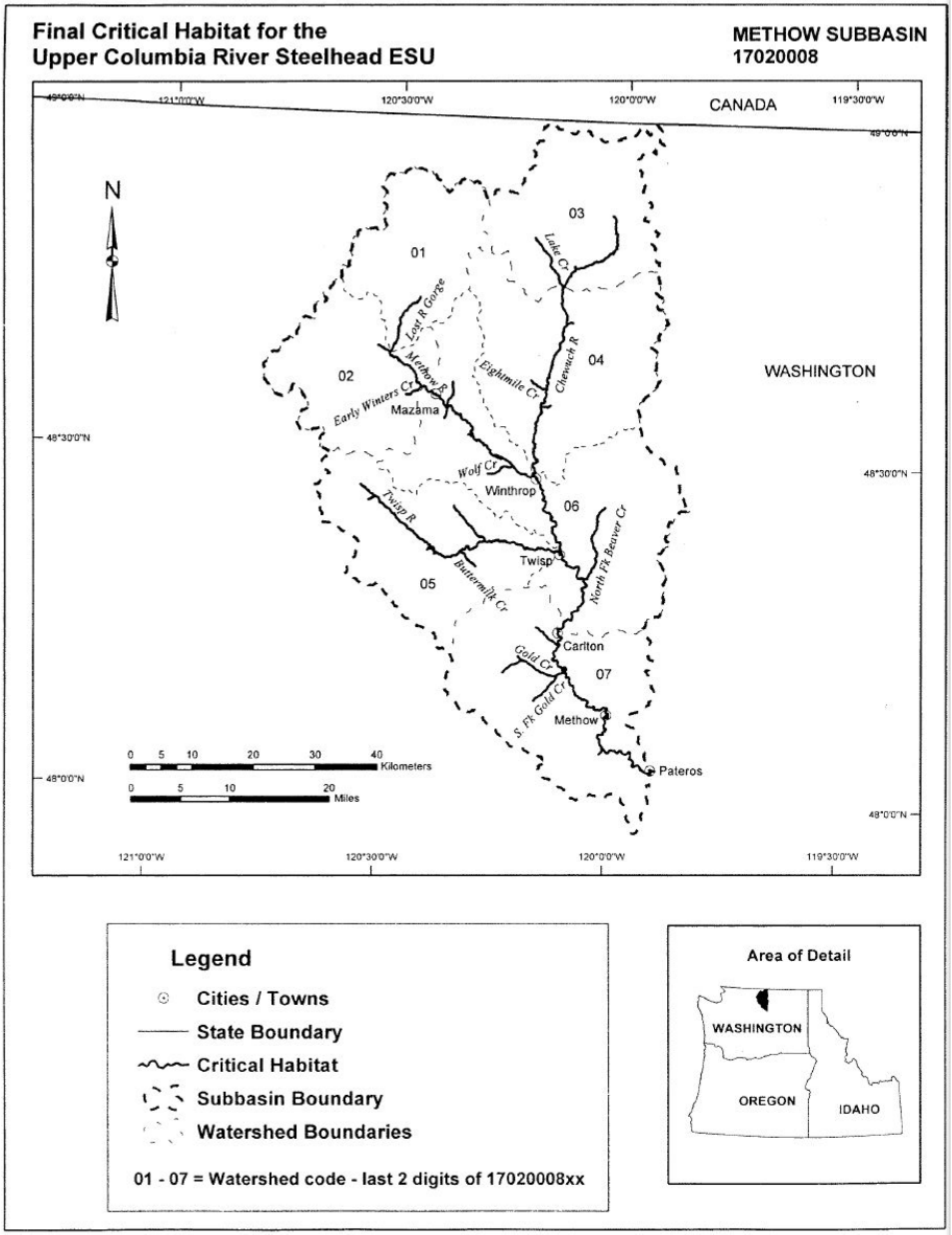


Figure 2-4 Upper Columbia River steelhead critical habitat for the Methow Subbasin. Reproduced from 70 FR 52630 (2005).

The restoration perspective emphasized by Beechie et al. and Roni et al. highlights the importance of protecting and/or restoring processes rather than simply attempting to build or rebuild particular attributes or features of a channel. Generic examples of restoration actions that embrace this approach include disconnecting a road network from the channel network to reduce delivery of fine sediment loads into stream channels and alteration of hillslope drainage patterns, planting riparian areas to resolve high temperatures and low wood loadings, removing bank armoring to encourage greater habitat complexity through channel migration or reconnection of surface flows with historical floodplain areas, and controlling inputs of pesticides or mining leachate from surrounding land uses to achieve cleaner water.

Even though this Reach Assessment has an explicit goal of identifying discrete actions to restore or create critical habitat features, these overarching concepts provide the basis to consider the full complement of river/riparian conditions within the watershed. Key to implementing a process-based restoration framework is identifying those locations where near-natural rates and patterns of river and riparian processes are well-expressed and are largely unaffected by human activities. Once identified, these areas can be evaluated for protection or to consider whether further enhancements of these areas might improve habitat conditions for target species in the Assessment Reach. At the scale of individual sub-reaches, there also may be discrete areas where natural processes of river migration and large woody debris (LWD) input and retention have been highly constrained that would clearly benefit from actions to resolve those constraints. These areas may benefit from restoration actions to simply create habitat features in the absence of long-term processes that would otherwise be needed to sustain them; however, the cited studies of recent decades suggest that such actions (however feasible and easily identifiable) are less effective or cost-effective in comparison to higher-ranked efforts focused on remediation of constraints on natural river processes.

2.4.2 Key Factors Limiting Salmon Productivity in the Area

Limiting factors, or ecological concerns, are those biological, physical, or chemical conditions and associated ecological processes and interactions that limit a species' viability (NMFS 2014). The factors threatening Upper Columbia River populations of spring-run Chinook, bull trout, and steelhead, all of which are listed under the ESA, are numerous and varied. Their present depressed condition is the result of several long-standing, human-induced factors that exacerbate natural environmental variability (64 FR 14308). The RTT (2014) has identified six key ecological concerns for the Assessment Reach and identified a relative priority ranking as shown in Table 2-2. The primary causes for these ecological concerns are related to the use of riprap for bank armoring, clearing of trees from riparian areas, reduced supply and removal of in-channel LWD, and agricultural activity in the Assessment Reach. These actions have impaired processes that support stream complexity, wood and gravel recruitment and retention in the river, nutrient cycling, floodwater retention, and water quality. In addition, late summer and winter instream flow conditions, due to interannual variability and exacerbated by irrigation withdrawals, can in some years reduce migration, spawning, and rearing habitat for native salmonids (RTT 2014), ultimately compromising recovery efforts.

Identification and prioritization of potential habitat actions in this Assessment have a direct linkage to the ecological concerns outlined by the RTT (2014), and specifically focus on improving riparian habitat conditions, increasing off-channel habitat (side channel reconnection and floodplain restoration), increasing habitat diversity, and/or restoring bed and channel form. These actions are expected to result in an increase in adult and juvenile overwinter survival, provide additional spawning habitat, and improve adult passage, holding areas, and spawning success (UCSRB 2007) in the Assessment Reach.

Table 2-2 Middle Methow Ecological Concern Prioritization from the Upper Columbia Biological Strategy (RTT 2014)

Ecological Concern	Priority
Peripheral and Transitional Habitat (Side Channel and Wetland Conditions, NOAA ID 5.1)	High
Channel Structure and Form (Instream Structural Complexity, NOAA ID 6.2)	↓
Channel Structure and Form (Bed and Channel Form, NOAA ID 6.1)	
Water Quantity (Decreased Water Quantity, NOAA ID 9.2)*	
Riparian Conditions (Riparian Conditions and LWD Recruitment, NOAA IDs 4.1 and 4.2)	
Species Interactions (Introduced Competitors and Predators, NOAA ID 2.1)*	Low

* Excluded from identification and prioritization of habitat restoration actions, for reasons discussed in the text.
NOAA = National Oceanic and Atmospheric Administration

Habitat restoration projects identified and prioritized in this Assessment do not address two of the ecological concerns outlined by the RTT (2014): Decreased Water Quantity and Introduced Competitors and Predators. While irrigation diversions have significantly reduced summer flows in the Methow River and in the Assessment Reach, this Assessment did not identify—in the field or through literature review—any major diversions within the Assessment Reach (as discussed in Section 3.4.3). All major irrigation diversions that affect the Assessment Reach are located upstream of the Assessment Reach, with the exception of those in the Beaver Creek drainage. Addressing these diversions is clearly an important restoration target, but they fall outside of the geographic focus of this Assessment. The second ecological concern excluded from this Assessment relates to competition from brook trout (RTT 2014), which is primarily a management issue and has a lesser connection to habitat restoration focused on in this Assessment.

2.4.3 Methods

The approach to identifying restoration/protections for the Assessment Reach involved the following general steps:

> Review historical information and previous studies on the Assessment Reach to evaluate the natural and functioning form and processes prior to European settlement.

> Perform a geomorphic and habitat survey to evaluate baseline conditions, as well as existing impairments (e.g., riprap), along the Assessment Reach. Habitat surveys used a modified form of the U.S. Forest Service (USFS) Stream Inventory Approach (2015).

> Review existing studies to further inform the understanding of existing conditions, agents of change, and impairments along the reach. These studies include hydraulic modeling results from Reclamation (2014), riparian and floodplain vegetation mapping (Reclamation 2008), review of remotely sensed data (including light detection and ranging [LiDAR] and forward-looking infrared [FLIR] data), and a range of previous studies on the geomorphology and hydrology of the Assessment Reach.

> Identify protection and restoration actions within the Assessment Reach that address ecological concerns (limiting factors) identified by previous studies and are deemed to be addressable with habitat restoration/protection actions. The approach to identifying restoration/protection actions for the Assessment Reach was predicated on identifying and applying an *a priori* set of criteria that allowed us to distinguish actions that address protection or restoration of processes as well as complementary actions that would input habitat features otherwise unlikely to develop without some strategic intervention at specific locations.

> Develop a sub-reach-scale prioritization of restoration/protection actions based on the discussion above, and in the context of known habitat preferences of the target species and their limiting factors as identified by the RTT (2014).

> Develop general recommendations and maps of project actions that begin the initial process of restoration project development.

3 Assessment Area Conditions

3.1 Setting

Located in Okanogan County, Washington, the Methow River drains 1,890 square miles (mi^2) in total, flowing into the Columbia River near RM 524 (Figure 1-1). About 89 percent of the subbasin is in public ownership and the remaining 11 percent is under private ownership, primarily along the valley bottoms. The Methow subbasin is composed of the Upper, Middle, and Lower Methow River, into which drain nine named anadromous accessible subwatersheds: Early Winters Creek, Lost River, Goat Creek, Wolf Creek, Chewuch River, Twisp River, Beaver Creek, Gold Creek, and Libby Creek (UCSRB 2007).

The Twisp to Carlton reach of the Methow River flows from RM 41.3, in the town of Twisp at the confluence with the Twisp River, to RM 28.1, near Carlton at the crossing of the Highway 153 bridge. It is a sixth field Hydrologic Unit Code watershed (#170200080605). The drainage area of this reach is 1,301 mi^2 at the U.S. Geological Survey (USGS) gage (#12449500) just downstream of the confluence with the Twisp River, and 1,531 mi^2 at its downstream end (an 18 percent increase over this 13.2-mile reach).

3.2 Geology

The watershed-scale context of the Assessment Reach has been determined by the region's geologic history, and by past and present-day hydrologic and geomorphic processes. The regional geologic context is described most comprehensively by Haugerud and Rowland (2009), who describe a sequence of ancient, largely oceanic-derived sedimentary and volcanic rocks that constitute the "Methow Block," one of the multiple north/northwest-south/southeast-trending lithologic complexes that make up much of the North Cascade Range. The Methow River through the Twisp to Carlton reach follows this same south-southeast trend over its upper length, flowing through a valley carved down the middle of these rocks; however, at approximately RM 34 the river turns to the south-southwest to follow the western boundary of a very resistant metamorphic rock of the adjacent Okanogan Block. This rock type forms the eastern edge of the bedrock valley from this point downstream to the town of Carlton, and its presence almost certainly contributes to the confinement of the Methow River valley that is readily observed through this lowermost sub-reach of the Assessment Reach.

Within this bedrock framework, glacial ice originating from the high mountains of the North Cascades and British Columbia coalesced on multiple occasions throughout the last one (or more) million years, extending ice tongues down each of the valleys draining the mountains into the Columbia Plateau. The most recent such advance, culminating about 17,000 years ago (Booth et al. 2004), completely buried the Methow River valley under more than 3,000 feet of ice, as part of the Okanogan lobe of the Cordilleran Ice Sheet (the lobe that, farther east, was also responsible for diverting the Columbia River through Grand Coulee). As the ice retreated, it would have left a discontinuous mantle over the bedrock of glacial till, an unsorted deposit derived from sediments carried at the base of the ice sheet, and valley-filling terrace deposits of fluvial gravel and sand carried by abundant meltwater channels from the backwasting ice tongues. These terraces would have been deposited at elevations substantially above those of the modern river, owing to extremely high sediment loads, high discharges, and likely an elevated base level in the Columbia Basin as the sediments of deglaciation were still being deposited and reworked. Over time, the post-glacial Methow River would have reworked these sediments, reduced its gradient, and settled into the general form and profile that we see today.

Within this geologic template, Reclamation (2008) divided the Assessment Reach into three sub-reaches defined largely on the basis of present-day channel confinement. The three sub-reaches, numbered TC1, TC2, and TC3, extend from RMs 28.1 to 33.7, 33.7 to 40.3, and 40.3 to 41.3, respectively. The

Reclamation numbering of M1, M2, and M3 has been revised to avoid confusion with reach numbering in other Methow River assessments. These sub-reaches are described in more detail below.

3.3 Conditions Prior to European Settlement

3.3.1 Channel Form and Process

While we have little observational data on the channel conditions and geomorphic processes prior to European settlement of the Methow River valley, a number of inferences are possible given our knowledge of channel form and its natural organization across the landscape. The slope of the Assessment Reach is typical of pool-riffle channels (Montgomery and Buffington 1997). In planform view, the Assessment Reach would have alternated between a relatively straight channel in confined reaches and an anabranching (a.k.a. anastomosing or island braided) channel pattern, based on statistical modeling of natural channel pattern by Beechie and Imaki (2014), through more unconfined valley segments.

Anabranching channels are characterized by multiple active, low-flow channels formed around islands with mature forest. This pattern is sustained by typically moderate channel migration rates (i.e., more than single-thread channels and less than braided channels) that involve a combination of bend migration and avulsions switching between the stable forested islands (Beechie et al. 2006). In the presence of old-growth forests and corresponding recruitment of large key member forming logs, these stable islands were often formed around a nucleus of a large log jam, or “hard point,” that helped to stabilize islands for many decades or centuries (Montgomery and Abbe 2006; Collins et al. 2012). These hard points and their old-growth forests provided additional large logs to help perpetuate the process of hard-point formation. The rate and style of channel migration in anabranching channels has been connected with an intermediate disturbance regime, which maximizes complexity of aquatic and terrestrial habitats in floodplains (Beechie et al. 2006). Thus, the floodplain biodiversity would have likely been high in the Assessment Reach, particularly in the anabranching sections. Floodplain complexity and biodiversity would have been further enhanced by extensive beaver activity in floodplain ponds and wetlands and along channel banks.

Historical accounts of flooding and channel change support an anabranching channel pattern through the unconfined portions of the Assessment Reach. In particular, flooding in 1896 caused an avulsion that destroyed the historic mining town of Silver near the midpoint of the Assessment Reach. Residents of Silver reported that the channel had switched multiple times prior to 1896. More recently in the 1950s, an avulsion at the same point caused the channel to switch to its current position. During this gradual avulsion process, multiple threads were present for about a decade (as discussed in further detail in Section 3.5.3), suggesting the river channel is still capable of maintaining multiple threads if given greater access to its floodplain.

3.3.2 Hydrological Regime

The historical hydrologic regime of the Methow River would have, in a similar manner to present day, been dominated by seasonal snowmelt in the late spring and early summer. During the time of European settlement, the Methow Basin would have been emerging from the Little Ice Age, when glaciers and snowlines in the Pacific Northwest were approximately 400 feet lower than at present (Burbank 1981).

3.3.3 Large Woody Dynamics

The ecological role of wood in rivers throughout the world has been well documented (Gregory et al. 2003). For thousands of years, large wood accumulations in Pacific Northwest rivers have shaped key geomorphic processes and ecological functions (Abbe and Montgomery 1996; Bilby and Bisson 1998; Bisson et al. 1987) and habitat conditions that native salmon and trout have evolved to exploit. Accumulations of large wood, either singly or in jams, create hydraulic complexity and channel bed form changes that include deep pools, alcoves, gravel bars, and multiple channel threads. These in turn provide increased complexity in the types and distributions of aquatic habitats that support diverse aquatic communities (e.g., Reeves et al. 1998). These topics are thoroughly discussed in the scientific literature, as it relates to the Methow River and its tributaries, by Reclamation (2008), Interfluve, and the Yakama Nation (Yakama Nation Fisheries [YNF] 2013).

Woody debris recruited to the Methow River channel would have formed into natural configurations (or jams) that can be mimicked with restoration projects. Abbe and Montgomery (2003) identified a series of natural jam types and their typical abundance with watershed position and channel size. In relatively large channels like the Methow River, the most abundant jams would likely have been the bar apex type, composed of a single key member with racked material. The key requirement for formation of a bar apex jam is a large log with a rootwad capable of lodging on bars and forming a key member. These jams are known for their role in habitat formation through pool scour on the upstream side, and deposition of finer gradations of gravel on the lee side, both of which contribute overall habitat complexity (Abbe and Montgomery 1996). Over decades, these jams help to form forested islands discussed in sections above. The second most abundant jam type would have likely been the meander jam, which forms when one or more key members lodge at the outside of meander bends and rack additional logs through time. Meander jams help form deep scour pools, and cause tightened meander bend radii, further helping to form scour pools and increase channel complexity. A third jam type potentially present in the Assessment Reach is the flow deflection jam, which forms when in situ key members fall into the channel (usually from bank erosion) and accumulate additional wood. These jams do not fully span the channel, but can deflect flows nearly orthogonal to the banks and in turn cause scour and deposition on the upstream and downstream sides, respectively.

3.4 Human Disturbance

3.4.1 Early Disturbance

As is true throughout the Northwest, the westward expansion of exploration and settlement in the latter half of the nineteenth century initiated the gradual process of altering the landscape of the Methow River valley. As an unintended consequence of the cumulative effects of these settlements, fundamental components of the natural river ecosystem were changed in ways that have contributed to aquatic and riparian habitat degradation in the Methow Basin. A more detailed account of the history of human settlement of the valley and associated activities that changed the character of the river is provided in Appendix O of the *Methow Subbasin Geomorphic Assessment* (Reclamation 2008). A brief thumbnail sketch of that history is provided below.

Native peoples have populated the Methow River valley for thousands of years, but their overall impact on natural processes was negligible when compared to that of later settlers. The Methow Indians practiced a nomadic hunter/gatherer lifestyle and navigated the river using canoes carved from large cedar trees once common in the upper valley. They set up seasonal fishing camps to take advantage of the then-abundant runs of Chinook, coho, steelhead, lamprey, and other native fish (West 2011).

After treaties were signed with Oregon Territorial Governor Stevens, most of the native peoples were restricted to occupying specific lands set aside by the treaties. Initial incursion into the valley was focused on beaver trapping, which began in the early 1800s and undoubtedly had an effect on riparian conditions. Miners later discovered what appeared to be promising traces of gold and silver deposits, some on lands set aside for native peoples. Mining began in the Methow Basin in the 1870s. Early prospectors discovered small deposits of gold near Polepick Mountain, about 5 miles south of the town of Twisp, in the late 1880s. This led to the settlement of Silver and the nearby Red Shirt Mine and the mill site, which is now located near Twisp. Another site, in the headwaters of Alder Creek, was also developed, and included a mill site. The mining boom fizzled out by the turn of the twentieth century (late 1890s). Water diversion began in the mid-1880s, reducing streamflow and, in some cases, may have come close to completely drying up the river, which would have affected adult migration and rearing capacity (RTT 2014). After the former tribal reserve land boundaries were changed in 1883 and 1886 (under two administrations) by presidential executive orders, these lands were opened up to mineral prospecting. Mining activity increased significantly after this time, and was probably the first major activity affecting riparian and stream conditions (RTT 2014), though by no means the last (West 2011).

Increased mining activity brought settlers and gave rise to merchants eager to satisfy the needs of miners for food and equipment. The next phase of settlement came when homesteads were established bent on agricultural development and livestock grazing. Initially focused on subsistence farming, this settlement quickly grew to include attempts at commercial orchards, dairy and livestock production, and later hay and livestock forage production (which is still common today). State and federal lands in the valley still support grazing allotments for the livestock industry. Grazing pressure was highest from the late 1800s to the 1930s, with subsequent reductions as allotment systems replaced the open range approach to cattle and sheep grazing (RTT 2014).

3.4.2 Modern Disturbance

Several local towns, notably Twisp and Carlton, grew out of the growing population of miners and settlers who took up agriculture. Local business sprang up to support this new economy as agricultural commodities were sold downriver. Transportation infrastructure developed, with new roads generally following the path of least apparent resistance along the east and west banks of the river reach. However, many of the commercial orchards suffered great losses after prolonged droughts in the early 1900s. As a result, irrigation systems were planned and built throughout the valley to provide a more reliable water supply. Irrigation districts, allowed and encouraged under state water laws, were established, and extensive irrigation systems were developed in and around the valley to provide water to farmers throughout the valley and its tributary valleys. Water rights (under the constitutional provision allowing rights “first in time – first in right”) were established and granted for nearly every tributary stream in the valley, as well as for the river, primarily upstream of Twisp. These withdrawals and irrigation works changed the delivery of water, wood, and sediment to the Methow River, but quantifying their cumulative effect is speculative.

Timber harvesting began as a natural consequence of providing construction materials for mining and homesteading. It was most likely during this period that riparian forests were cut and milled to provide lumber for building homes and the growing town sites, and to provide cleared lands for expansion of agricultural areas. Removal of trees from the riparian zone both within and upstream of this reach has interrupted the input and retention, over time, of large wood that would otherwise occupy the channel and provide instream habitat complexity. Timber harvest began in the 1920s, and up until 1955 selective harvest or “high grading” was the primary harvest method. By the 1940s, commercial logging was big business in the valley, and a large mill was built in Twisp to process significant harvest of trees from the upper valleys of the Chewuch, Twisp, and Methow Rivers. Log drives down the river were a common practice in the early days, as they afforded an easy way to transport logs downstream to the mill site near Twisp (suggesting log drives had their greatest impact in the upper reach). The Wagner Mill was developed in Twisp (by the Wagner family) and operated until 1982. The now abandoned and cleared mill site occupies the left bank of the river round RM 40.5 to 40.75. Since then, partial cutting and clear-cutting have been the predominant practices. The 1980s represent the period of most intense harvest (RTT 2014) in the recorded history of logging in the region.

Fire is a natural part of the ecology of the lands adjacent to the Methow River from Twisp to Carlton, as is the case everywhere in the valley. A detailed history of fire in the valley reconstructed from the 1700s to the present, but excluding the Carlton Complex Fire of 2014, is discussed in Appendix L of the 2008 *Methow Subbasin Geomorphic Assessment* (Reclamation 2008). Fire has shaped the current character of the upland forests (primarily Ponderosa pine *[Pinus ponderosa]* and Douglas-fir *[Pseudotsuga menziesii]* stands), the riparian zone (transitional mixed conifer/deciduous species), and the arid shrub-steppe lands (primarily sagebrush [*Artemesia* spp.], bitterbrush [*Purshia tridentate*], and rabbitbrush [*Chrysothamnus* spp.]). The Assessment Reach has a history of fire within the valley that predates European settlement, and is a part of the natural history of the valley and surrounding sagebrush steppe and forested plant communities. Fire is considered to be an essential feature of the ecology of this valley. The severity of fires has grown in the last century as fire suppression efforts have unwittingly allowed the accumulation of fuel loads that exacerbate the behavior of fires. These phenomena contributed in part to the widespread and severe fires witnessed in the 260,000+ acre Carlton Complex Fire in the summer of 2014. Large sections of the narrow riparian area downstream of Carlton burned in these fires.

The 2008 *Methow Subbasin Geomorphic Assessment* (Reclamation 2008, Appendix O) provides an account of human history as it relates to attempts at flood risk management in the valley. Land ownership within the Methow Subbasin is 84 percent federal, 11 percent private, and 5 percent state (Northwest Power and Conservation Council 2004).

3.4.3 Direct Habitat Alteration

Direct habitat impacts and alterations relate to hydro-modifications (levees and riprap), in-channel LWD, water quantity, and water quality, which are discussed separately below.

Hydro-Modifications

In the Assessment Reach, the most significant changes to river and floodplain processes are the result of construction of levees and the extensive transportation system evidenced by roads, riprap (bank armoring) to protect property and road corridors, and bridge abutments (cumulatively referred to as “hydro-modifications”) that limit the lateral extent to which seasonal flows occupy the active and historical floodplain. This legacy has isolated once-productive off-channel areas, some of which continue to hold water but are now physically cut off from joining the main river, even during seasonal high-flow events (Reclamation 2008, Appendices O and P). Recent surveys of bank armoring along the reach mapped over 6 miles of bank armoring, or roughly a quarter of the entire reach. In addition, nearly a mile of levees and/or roads actively disconnect floodplain, based on a comparison of mapped features relative to modeled floodplain inundation by Reclamation (2014). Table 3-1 details the length of hydro-modifications by sub-reach.

Table 3-1 Summary of Hydro-modifications as Mapped (in 2014 and 2016) for this Assessment

Sub-reach	Total Length Bank Hardening (ft)	% Bank Hardening*	Total Length of Levee or Road Actively Disconnecting Floodplain Inundation (ft)
TC1	10,130	17%	0
TC2	16,840	24%	5,050
TC3	5,400	51%	0

* Calculated as bank hardening length divided by twice the reach length to account for both banks.

In-channel Large Woody Debris

The input and retention of LWD in the channel appears to be very limited when compared with historical levels, which likely results from a combination of factors that have unfolded over the last century and especially following the rapid development of the valley in the 1920 through 1950 period and the aftermath of the historical flood of record in 1948 (see Reclamation 2008). Anecdotal accounts describe historical clearing of LWD from the Methow River, but only limited documentation of actual locations, frequency, or volumes is available (Andonaegui 2000). Undoubtedly, many logs were deposited and subsequently removed after the flood of record in 1948, as locals were galvanized to take action to reduce the risk of flood as much as possible (Reclamation 2008). Log drives, in the form of moving massive numbers of logs downstream to the local mill, were common in the early 1900s but were generally confined to the upper reaches of the Methow River. Logs were moved from the vicinity of Mazama and Winthrop downstream to the Wagner Mill in Twisp, which was the largest saw mill site in the valley. Several other lumber mills operated upstream of the present town of Winthrop (Reclamation 2008). These drives have been well-documented and photos do exist (YNF 2013). As historical wood accumulations diminished over the last century, fewer obstructions remained in the river, further reducing the retention of wood in the system. Today, very little LWD occurs in the river corridor of the Assessment Reach, except for those pieces that have floated to the margin of the channel. These pieces do little to contribute to the complexity of current habitat conditions.

Contemporary wood loading in the reach is very limited, and it is likely that historical levels exceeded current levels by several orders of magnitude, but there is little historical information on which to base typical wood loading levels (YNF 2013). A likely culprit is widespread timber harvesting throughout the basin, which has almost certainly limited inputs from headwater areas and tributaries. In major valley bottoms, like that of the Assessment Reach, extensive development has come with significant forest clearing as well as channel bank hardening, which reduces channel migration and associated wood recruitment. In-channel wood accumulations were likely systematically removed from the river as settlement progressed through the last 100 years, as settlers acted to “protect” their shoreline properties from flooding damage (Reclamation 2008).

Water Quantity

Hydrologic impacts from human activities in the Methow River basin have largely been localized in lower valleys. In contrast to nearly all other Columbia Basin river systems, habitat in the Methow River has not suffered from the direct effect of dams, but summer flows have been impacted by seasonal water withdrawals for agricultural and municipal water supply. According to estimates by Ely (2003), diversion rates during summer months are approximately 230 cubic feet per second (cfs), or roughly half of the mean streamflow for summer months at Twisp. All of the diversions tabulated by Ely (2003, Table 3), with the exception of those in Beaver Creek, are diverted upstream of the Assessment Reach. For this reason, flow projects are not addressed in the restoration strategy outlined in this report.

Beaver Creek, which flows into the Methow River at approximately RM 36, is classified by the Washington Department of Ecology (Ecology) as a Category 4c stream, indicating water quality impairment based on low instream flows. The Yakama Nation reported that the creek at Highway 153 was often dry in August and September from 1992 to 1994 (Ecology 2012). The one year of historical USGS flow measurements (2000–2001) reported the lowest single daily flow as 6.5 cfs, and the flow was never reported at zero (Ecology 2012). USGS does not currently maintain a gage at Beaver Creek. Ely (2003) estimated total irrigation diversions within the Beaver Creek watershed to be 17 cfs in June and July, and 12 cfs in August and September.

Water Quality and Temperature

The water quality of the Methow River is classified as Class A (excellent; Wilms and Kendra 1990), and it is classified as a Category 2 watershed where restoration and protection actions have been recommended (UCSRB 2007). Within the Assessment Reach, the Methow River from approximately RM 39.75 to RM 39 has been identified as having some evidence of water quality issues for pH (Category 2; Ecology 2012), but there are insufficient data to require the preparation of a Water Quality Improvement Project (i.e., total maximum daily load or Straight to Implementation tool). Data indicate that the reach meets other assessment criteria, particularly for ammonia-N, arsenic, and bacteria (Ecology 2012).

The town of Twisp wastewater treatment plant discharges effluent to the Methow River at approximately RM 39.8 on the left bank of the Methow River (sub-reach TC2). The plant—a Biological Nutrient Removal type—is permitted under Ecology with a National Pollution Discharge Elimination System (NPDES) permit (#WA0023370). According to the town of Twisp, the discharge meets and far exceeds water quality standards laid out by the NPDES program (personal communication, Andrew Dunham, Public Works Director, 2016). Discharged concentrations of Total Suspended Solids and Biological Oxygen Demand are typically 2 to 4 parts per million (ppm) (standard is 30 ppm). In addition, discharged nutrient levels are typically less than 1 ppm for ammonia, and less than 5 ppm for nitrate, despite no regulatory standards for these constituents. The plant uses an "ultraviolet disinfection" treatment process, which, in contrast to chlorine treatment systems, does not discharge residual chlorine to receiving water bodies. Temperatures of discharged water are typically about 20°C in the summer, and 4°C in the winter. In recent years, the Methow River channel has migrated southwest-ward away from the discharge point. The town of Twisp is currently in preliminary planning phases to redesign the outfall and channel to discharge directly into the wetted channel of the river, and is considering pairing this project with habitat enhancement work.

Historical mining activity has impacted the Assessment Reach in two main locations: the Red Shirt Mill site (RM 39.5 on river left) and the Alder Creek confluence wetland (RM 34 to RM 34.5 on river right). The Red Shirt Mill site likely represents the greatest water quality risk to the Methow River and is considered a clean-up and restoration priority by Trout Unlimited (personal communication, Crystal Elliot, Washington Habitat Director of Trout Unlimited, 2016), whereas the Alder Mine site impacts are less severe in the Assessment Reach (though more severe near the mine site in the upper Alder Creek watershed) and should be a consideration when implementing restoration projects within its impact area.

The Red Shirt Mill processed ore from nearby gold and silver mines during the 1930s and 1940s. The extraction process involved tailing sluicing into the riparian area and the Methow River, leaving deposits of contaminated sediment adjacent to the channel that remain today. Active bank erosion adjacent to the site exposes contaminated sediments and introduces approximately 5 cubic yards of sediment to the Methow River on an annual basis (Peplow and Edmonds 2001). Ecology ranked this site with the highest potential hazard in their remedial investigation (2002) for high concentrations of arsenic, lead, cadmium, and copper and direct exposure pathways to the river and aquatic organisms. While Ecology performed interim actions to minimize exposure (2003), a large proportion of the contaminated sediment remains today.

The historic Alder Mine was located in the upper portions of the Alder Creek watershed. Alder Creek forms a large wetland complex at its confluence with the Methow River, providing winter rearing and high-flow refuge. Previous studies have shown elevated heavy metals in Alder Creek, and water quality impacts down to the confluence area (Peplow and Edmonds 1999, 2001). The studies identify contaminated sediments (particularly in fine sediments at the confluence) and food web impacts to be the most likely impacts to salmonids. While the exact nature and extent of these impacts within the confluence area are largely unknown, they are a consideration for any restoration actions proposed in the area.

The Methow River from approximately RM 41.3 to 36.0 is listed on the State of Washington's 303(d) list as exceeding water quality temperature criteria (Ecology 2012). Increased stream temperatures have the potential to negatively affect ESA-listed species by limiting growth, reducing metabolic rates, and creating thermal barriers to migration. Reclamation (2008, Appendix I) completed a water temperature study in 2005 that encompassed a portion of the Assessment Reach. Temperature monitors were installed at three locations—RM 34.0, RM 37.5, and RM 40.9—and two stream attributes were calculated (maximum 7-day average maximum temperature and highest 7-day average temperature) at each site. Results from the study, as compared to the NMFS and U.S. Fish and Wildlife Service (USFWS) temperature criteria, indicate that Chinook spawning habitat and Chinook and steelhead rearing habitat are not properly functioning from a thermal perspective, steelhead spawning and migration habitat is properly functioning, and Chinook and bull trout migration habitat ranges from properly functioning to not properly functioning. The summer temperature data collected as part of this study are presented in Table 3-2.

Table 3-2 Methow River 2005 Summer Temperature Data

Reach/Monitor Location	Max 7-day Average Max (°C)	Highest 7-day Average (°C)
Benson Creek to Beaver Creek/RM 34.0	21.66	19.04
Beaver Creek to Twisp River/RM 37.5	22.03	18.68
Beaver Creek to Twisp River/RM 40.9	19.44	16.88

Source: Reclamation 2008, Appendix I

3.5 Existing Forms and Processes

The subsequent section summarizes existing forms and processes as evaluated through field habitat surveys, previous reports, review of remotely sensed data, and additional analyses. Appendices A and B support this discussion directly. Appendix A is a map folio of the Assessment Reach containing existing condition maps. Appendix B provides a summary of habitat survey methods and data collected in that portion of the Assessment.

3.5.1 Hydrology

The Middle Methow River reach drains more than 1,300 mi^2 of the North Cascade Range, with a hydrograph typical of Pacific Northwest mountain regions east of the Cascade Crest: maximum runoff during the late-spring snowmelt season, episodic winter flood peaks during warmer periods of rain and rain-on-snow events, and generally stable low flows at other times of the year (Figure 3-1). The hydrology of the Methow River, including the overall hydrologic characteristics of this reach, was evaluated in detail by Reclamation (2008). Key aspects, discussed below, emphasize the hydrologic variables that have the greatest potential consequences for design and longevity of future restoration actions.

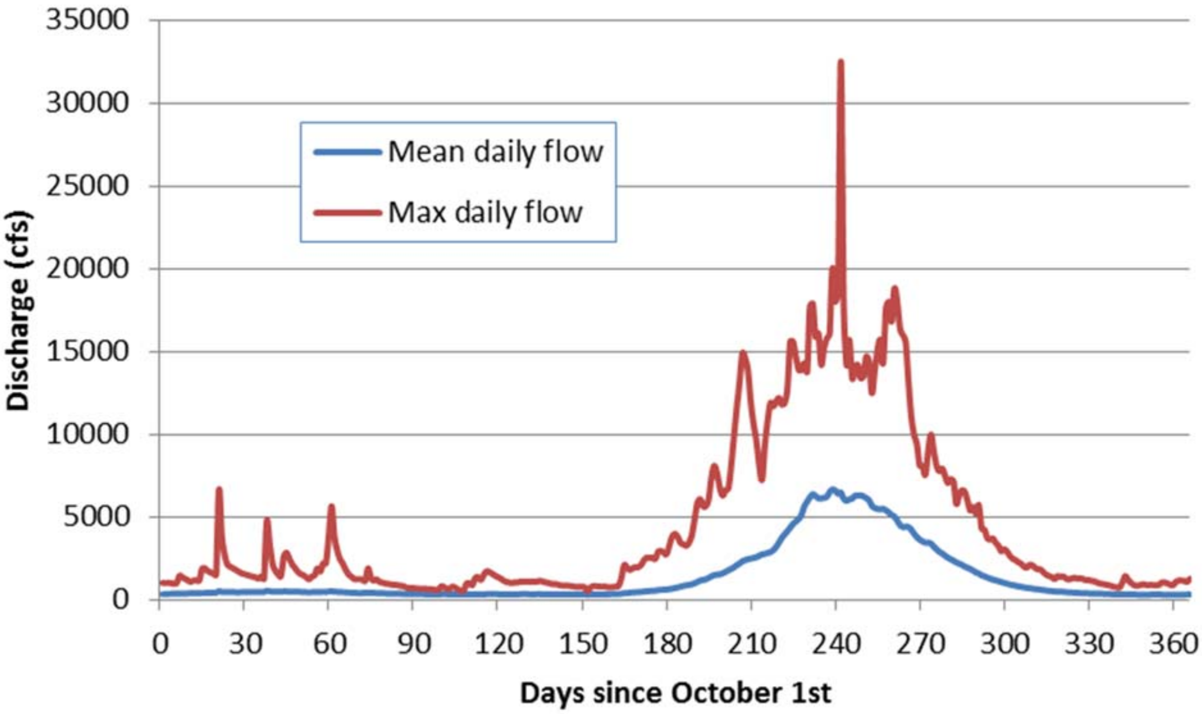


Figure 3-1 Mean and maximum daily flows of the Methow River at USGS gage 12449500, just downstream of the Twisp River confluence.

Note: Minimum flows are generally experienced in mid-winter (days 90–160), with the major floods occurring in the snowmelt season and less common (and less extreme) rain-driven high flows in the autumn.

The USGS has maintained a series of stream gage stations throughout the Methow Subbasin, which provide mean daily flow and instantaneous annual peak flow data used to characterize the reach hydrology (see Figure 3-2). The following hydrologic characterization utilizes gages along the Methow River, including the two bounding the Assessment Reach at Twisp (ID 12449500, operated 1920–1929, 1934–1962, and 1991–present, 1,301 mi^2 drainage area) and Carlton (ID 12449760, operated 2002–2003, 1,531 mi^2 drainage area), as well as an operating gage downstream at Pateros (ID 12449950, operated 1999–present, 1,772 mi^2 drainage area).

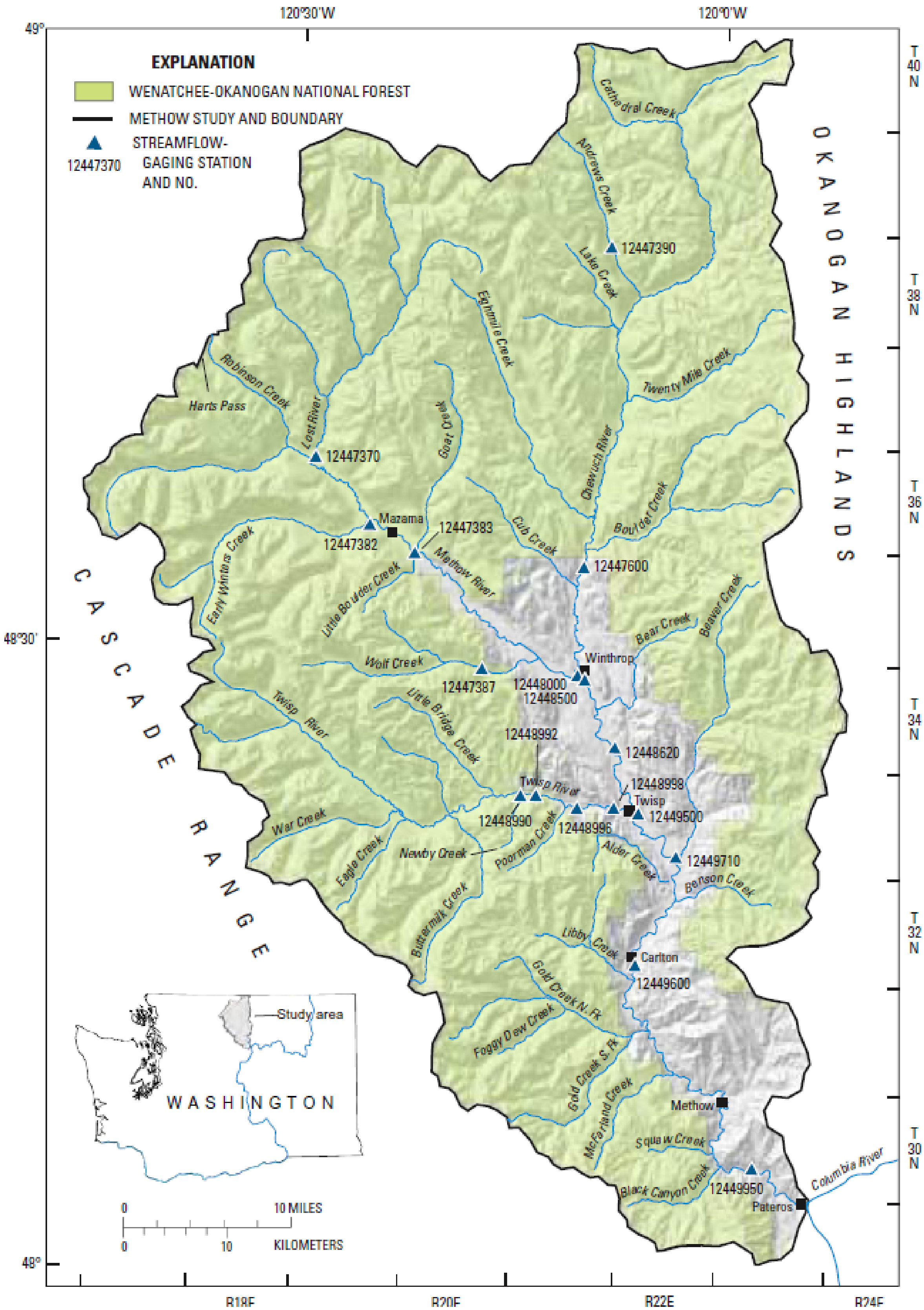


Figure 3-2 Methow Subbasin drainage and stream gage locations map (Konrad et al. 2003).

The drainage area gained along the reach is relatively minimal (230 mi^2), with tributaries Beaver Creek (110 mi^2, entering at ~RM 35 in mid-TC2) and Benson Creek (38 mi^2, entering at ~ RM 33 at upper end of TC1) being the most noteworthy. Correspondingly, the change in discharge from Twisp to Carlton is relatively minor. Flow increases along the reach are most pronounced at low flows, as is visible in Figure 3-3. Of the tributaries, only Beaver Creek has historical stream gage data, with USGS gage 12449710 at its mouth (operated in 2001 only).

During low-flow conditions, the Methow River experiences gains and losses in flow to groundwater (Konrad et al. 2003). The gaining and losing sections are best characterized by the sub-reaches between the major tributary inputs. These three groundwater reaches extend from Twisp to Beaver Creek (including all of TC3 and the upper portion of TC2), Beaver Creek to Benson Creek (lower portion of TC2), and Benson Creek to Carlton (TC1). The reach from Twisp to Beaver Creek consistently gained flow from groundwater inputs during the evaluation period of Konrad et al. (2003). The middle groundwater reach from Beaver to Benson Creek is a transient reach, with losses to groundwater or no change in flow during fall low flows, and flow gains during winter months. The lower reach consistently saw modest gains in flow (a large portion of which were within measurement error).

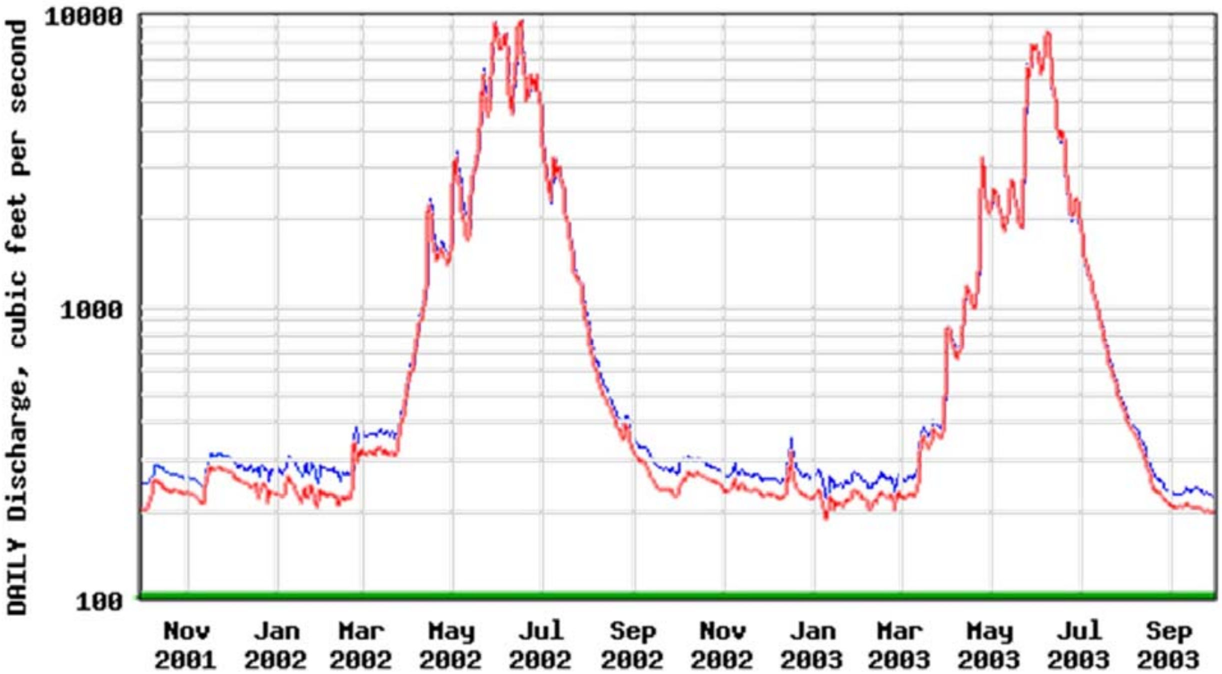


Figure 3-3 Comparison of USGS gage records for the Methow River at Twisp (12449500, in red) and Carlton (12449760, in blue).

Note: Wintertime baseflows are about 20% higher at the downstream location, mirroring almost precisely the 18% increase in drainage area through the reach, but differences in peak flows are negligible.

Annual Exceedance Statistics

Annual flow statistics directly inform restoration design along the Assessment Reach. Exceedance statistics were calculated using the flow records collected at the USGS Twisp and Carlton gages. Table 3-3 shows flow statistics for the reach endpoints, indicating the greatest flow gains during low-flow conditions, as visible in Figure 3-3. Low-flow gains are roughly in line with the drainage area increase along the reach (18 percent). The negligible difference in high flows likely results from the lower elevation watersheds and correspondingly earlier timing of snowmelt of tributaries (relative to the mainstem Methow River), or increased residence times due to overbank flows.

Table 3-3 Annual Exceedance Flow Statistics for the Twisp to Carlton Reach

Annual Exceedance Statistic	Discharge (cfs)				Discharge Ratio (Carlton/Twisp, %)**
	At Twisp (12449500)		At Carlton (12449760)*		
	Entire Flow Record	Previous Decade, 2006–2016	Entire Flow Record	Previous Decade, 2006–2016	
5%	6,320	7,110	6,343	7,136	100.4%
10%	4,150	4,850	4,344	5,077	104.7%
25%	1,360	1,608	1,366	1,614	100.4%
50%	449	519	502	580	111.7%
75%	289	345	340	406	117.5%
90%	230	284	268	331	116.6%
95%	206	268	239	311	115.9%

*Estimated by multiplying flow statistics at Twisp by discharge ratios shown in column to the far right.

**Determined using measured discharge ratios for the period when both gages were active (water years 2002–2003)

The annual hydrograph varies from year to year, as shown by the aggregate flow duration curve in Figure 3-4. Contained in this historical variation is an overall increasing trend in flow throughout the historical flow record at Twisp, as shown in Figure 3-5. The increases across the range flows may follow an increasing trend (averaging 0.12 inches per decade) in annual precipitation, as recorded at a long-term weather station in Winthrop (ID 459376, 1895–present, Office of the Washington State Climatologist, http://climate.washington.edu/trendanalysis/), but should not necessarily be considered a strong indication of future trends (which are discussed with respect to climate change below).

Historical Flood Events

The Methow Subbasin is subject to large late-spring and early-summer snowmelt-derived floods. The three largest floods in the valley occurred in 1894, 1948, and 1972. The flood of 1894 occurred prior to the establishment of streamflow records, but high water marks were used to estimate a peak discharge of 50,000 cfs.

The two largest floods of record were results of rain-on-snow events in years with large snowpacks. The largest flood on record occurred on May 29, 1948, with a peak discharge of 40,800 cfs recorded at Twisp. Above-average rainfall and high temperatures accelerated the rate of snowmelt, which resulted in a rapid rise in river discharge. The large flood in 1972 resulted from a similar set of conditions, with high snowpack and periods of high temperature. The 1972 flood occurred during a period of inactivity at the Twisp gage, but discharge is estimated to have been 26,400 cfs (based on a regression with the gage at Pateros, Figure 3-6), which corresponds to just less than a 50-year return period flood event (R.W. Beck and Associates 1973).

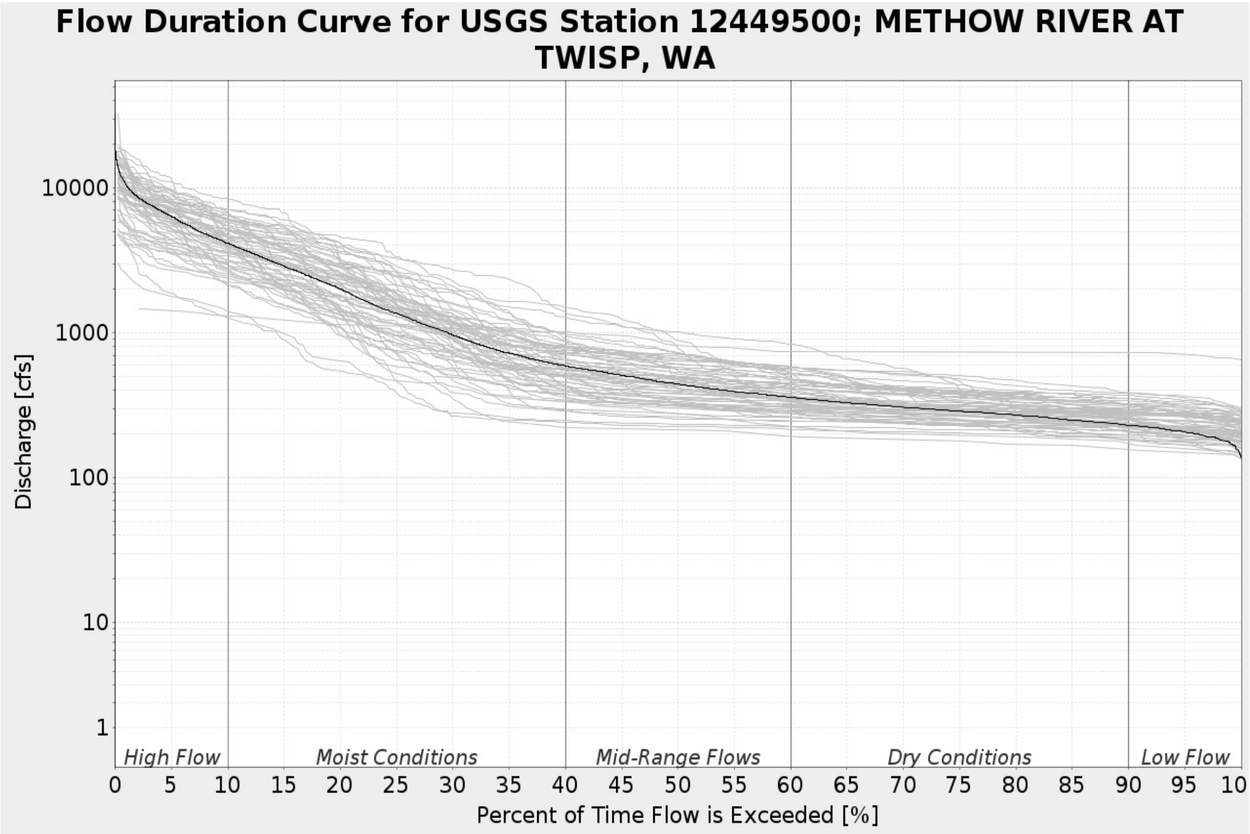


Figure 3-4 Aggregate flow-duration curve for the Methow River at the head of the Twisp to Carlton reach.

Note: The solid line is the median flow-duration curve for the 95 years of record; gray lines are plots of each individual year and show variability from year to year (plotted from www.erams.com).

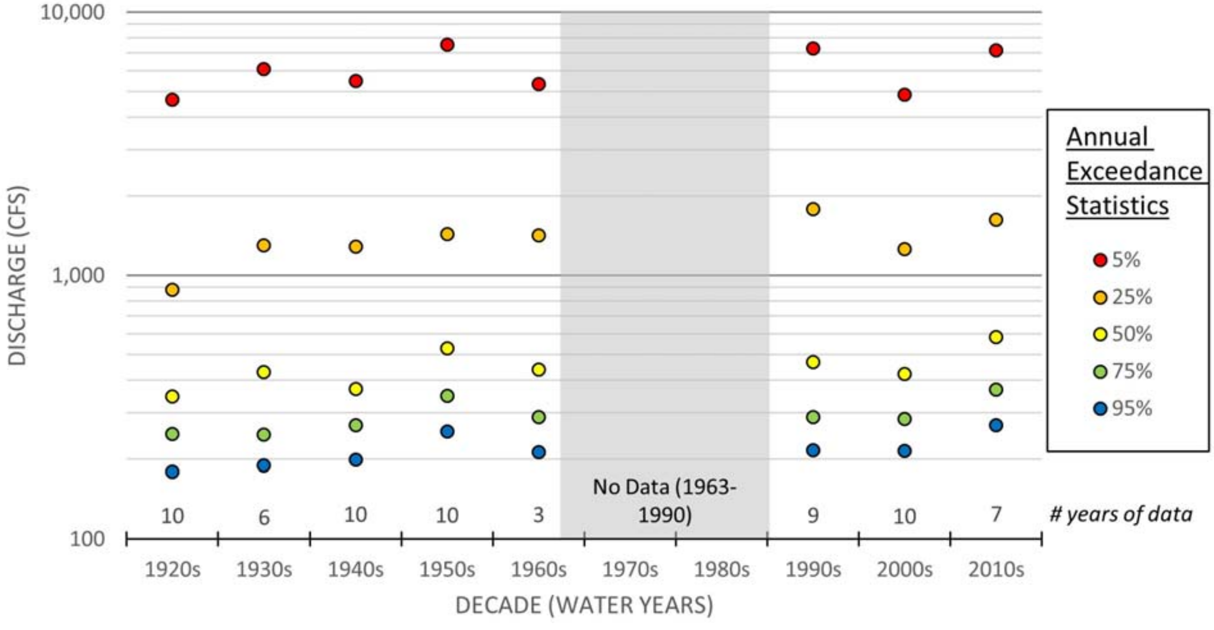


Figure 3-5 Annual exceedance statistics by decade for the flow record at Twisp (USGS gage 12449500).

Peak Flows

Annual peaks (Figure 3-6) reflect the relatively uniform snowmelt-dominated hydrologic regime from year to year, with nearly all annual peaks within a factor of two above or below the 2-year discharge of about 11,100 cfs. The most noteworthy exception is the flood of 1948, which had a maximum discharge of about 40,000 cfs, which is far above the statistical confidence limits for the projected 100-year flood (Figure 3-7). The second exception is the flood of 1972. Despite these exceptions, the overall consistency of this record suggests that restoration actions intended to promote the reactivation of floodplain areas and side channels on an annual or biannual basis will not normally need to withstand flows many times greater than about 20,000 cfs, a condition of general uniformity that is not necessarily experienced in other parts of Washington state (or elsewhere).

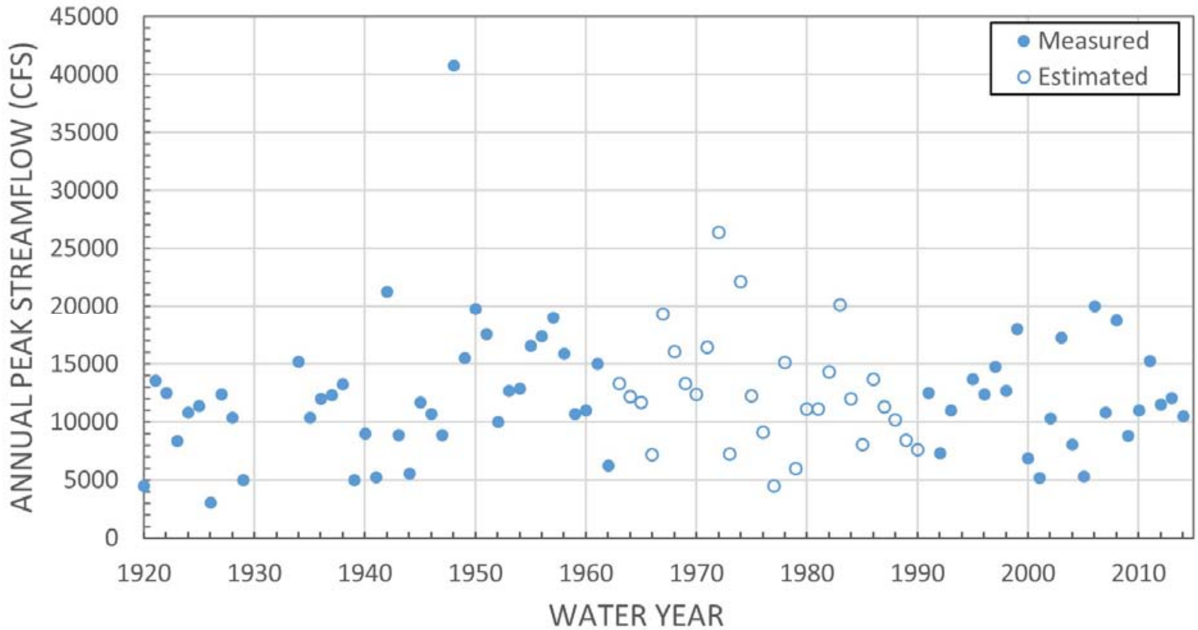
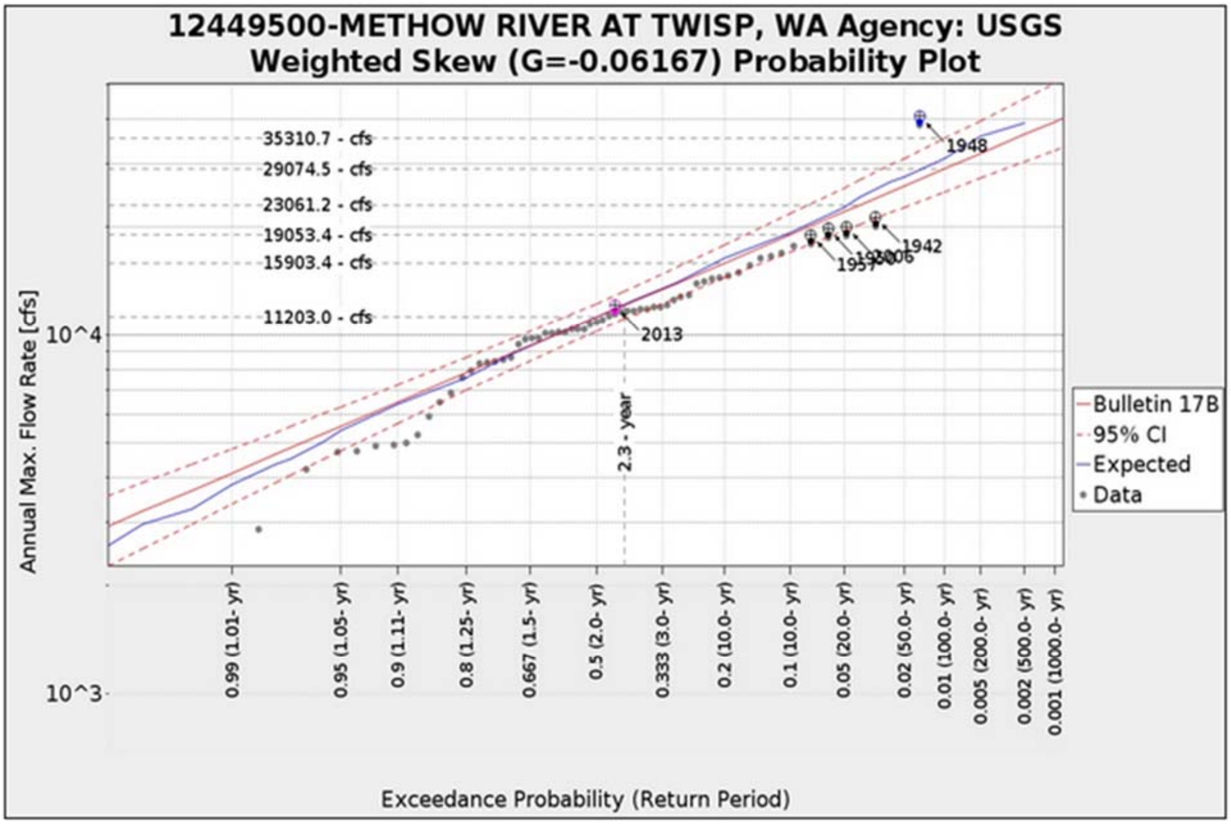


Figure 3-6 Historical peak flows for the stream gage at Twisp.

Note: Flow estimates (1963–1990) used a regression equation developed in this Assessment for the overlapping peak flow records of the Methow River gages at Twisp (12449500) and Pateros (12449950), which is $Q_{Twisp} = 0.88\ Q_{Pateros} + 982$ ($R^2 = 0.97$).



Return Period	Expected	Lower 95% CI for B17	B17	Upper 95% CI for B17
(year)	(cfs)	(cfs)	(cfs)	(cfs)
200	35755.2	27339.9	32118.0	39617.7
100	31005.1	25021.5	29074.5	35310.7
50	27633.7	22690.5	26062.1	31129.9
40	26741.6	21934.3	25096.0	29807.9
25	24234.6	20325.8	23061.2	27056.1
20	22695.2	19552.0	22092.7	25763.0
10	19286.1	17082.8	19053.4	21782.8
5.0	16392.6	14439.4	15903.4	17804.7
2.0	11203.0	10245.2	11203.0	12252.8
1.5	9293.3	8471.2	9342.2	10219.5
1.25	7591.8	7008.1	7843.9	8638.0

Figure 3-7 Annual peak flow hydrograph for the Methow River at Twisp (USGS gage 12449500).

Note: Top graph shows time series of peak discharges (from www. http://waterdata.usgs.gov). Bottom graph (with tabulated values, below) shows annual peak flows and calculated recurrence intervals using the methodology of Bulletin 17B (as implemented through the Environmental Risk Assessment and Management Systems [eRAMS.com]). Note that the 5-year discharge on the x-axis is mislabeled “0.2 (10.0-yr).”

In line with high-flow exceedance statistics (e.g., 5 percent exceedance flows in Table 3-3), peak flows are relatively consistent moving along the Assessment Reach. Therefore, the peak flows reported for Twisp in Table 3-4 apply to the reach as a whole.

Table 3-4 Peak Flow Data Computed for USGS Stream Gages within Middle Methow River Reach

Source	Description	Q2 (cfs)	Q5 (cfs)	Q10 (cfs)	Q25 (cfs)	Q50 (cfs)	Q100 (cfs)
12449500	Methow River at Twisp, WA (applies to entire reach)	11,100	16,000	19,200	23,000	25,700	28,300
USGS Stream Stats	Beaver Creek mouth (gage record too short to develop meaningful statistics)	326	741	973	1,170	1,370	1,860
USGS Stream Stats	Benson Creek (mouth)	99	248	338	415	496	702

Source: Reclamation 2014

Forecasted Hydrologic Changes Resulting from Climate Change

The Columbia Basin Climate Change Scenarios project provides site-specific streamflow forecasts for the stream gage at Twisp (Hamlet et al. 2013).[1] The project used the Variable Infiltration Capacity hydrologic model to estimate future streamflow changes under high (A1B) and low (B1) emissions scenarios. This model accounts for changes in precipitation and temperature under each scenario, as well as secondary effects like changes to snowpack, to forecast future hydrographs. The project included projected streamflow forecasts for the 2020s, 2040s, and 2080s. Below are a series of figures produced by Hamlet et al. for the Methow River gage at Twisp, including forecasted “combined flow” to represent the overall hydrograph, snow water equivalent (SWE), peak flows, and low flows. Each figure has a set of six graphs representing the combined time periods and two emission scenarios. Overall, the following changes are expected for each of the four metrics:

> *Overall hydrograph changes (see “combined flow” in Figure 3-8).* The hydrograph maintains its overall snowmelt-dominated signature; however, by the 2080s the hydrograph has characteristics of a transient hydrologic regime. In particular, snowmelt-generated peakflows are projected to shift about a month earlier. In addition, winter months (December–March) have higher and more variable flows, indicating a greater occurrence of rain events.

> *SWE (see right graphs in Figure 3-8).* Snowpack levels progressively decrease from the 2020s to 2080s relative to historical conditions. By the 2080s, annual maximum SWE is projected to be between 60 and 70 percent of historical conditions (based on ensemble averages).

> *Peak flows (see left graphs in Figure 3-9)*: Peak flows (20-, 50-, and 100-year recurrence interval floods) remain roughly consistent or modestly lower relative to historical values for the 2020s and 2040s. However, projections for the 2080s include peak flow increases for all recurrence intervals (roughly 10 to 25 percent increases for the high emissions scenario, and <10 percent increase for the low emissions scenario).

> *Low flows (see right graphs in Figure 3-9):* Low flows, as expressed by the 7Q10 statistic, generally decrease over the forecasted period. Decreases are roughly 10 percent and 5 percent relative to historical values for the high and low emissions scenarios, respectively.

The most dramatic predicted changes are with low flows, driven by the substantial reduction in SWE that results in less support for summertime baseflow and an earlier onset of low-flow conditions.

[1] Data, figures, or summary information were downloaded from the Columbia Basin Climate Change Scenarios Project website at http://warm.atmos.washington.edu/2860/. These materials were produced by the Climate Impacts Group at the University of Washington in collaboration with Ecology, Bonneville Power Administration, Northwest Power and Conservation Council, Oregon Water Resources Department, and the B.C. Ministry of the Environment.

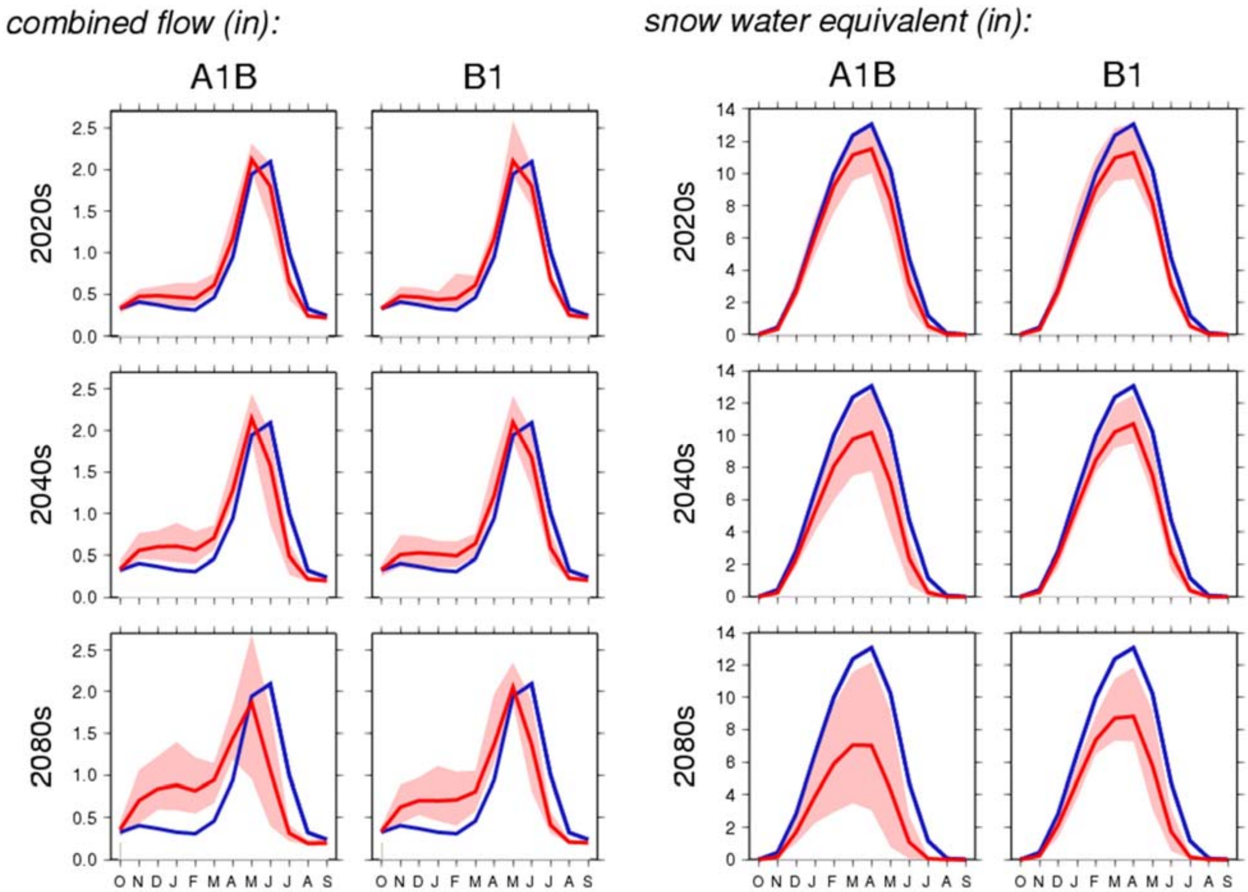


Figure 3-8 Projections of future hydrographs ("combined flow") and SWE under two emissions scenarios, for the 2020s, 2040s, and 2080s.

Note: Projections are for the USGS stream gage location at Twisp, and were produced for the Columbia Basin Climate Change Scenarios Project (Hamlet et al. 2013). "Combined flow" is the sum of baseflow and runoff in terms of depth averaged over the entire basin. Blue lines show simulated historical values. The light red band shows the range of all modeled scenarios (10 global climate models). Dark red lines show the average of all projections within the light red band.

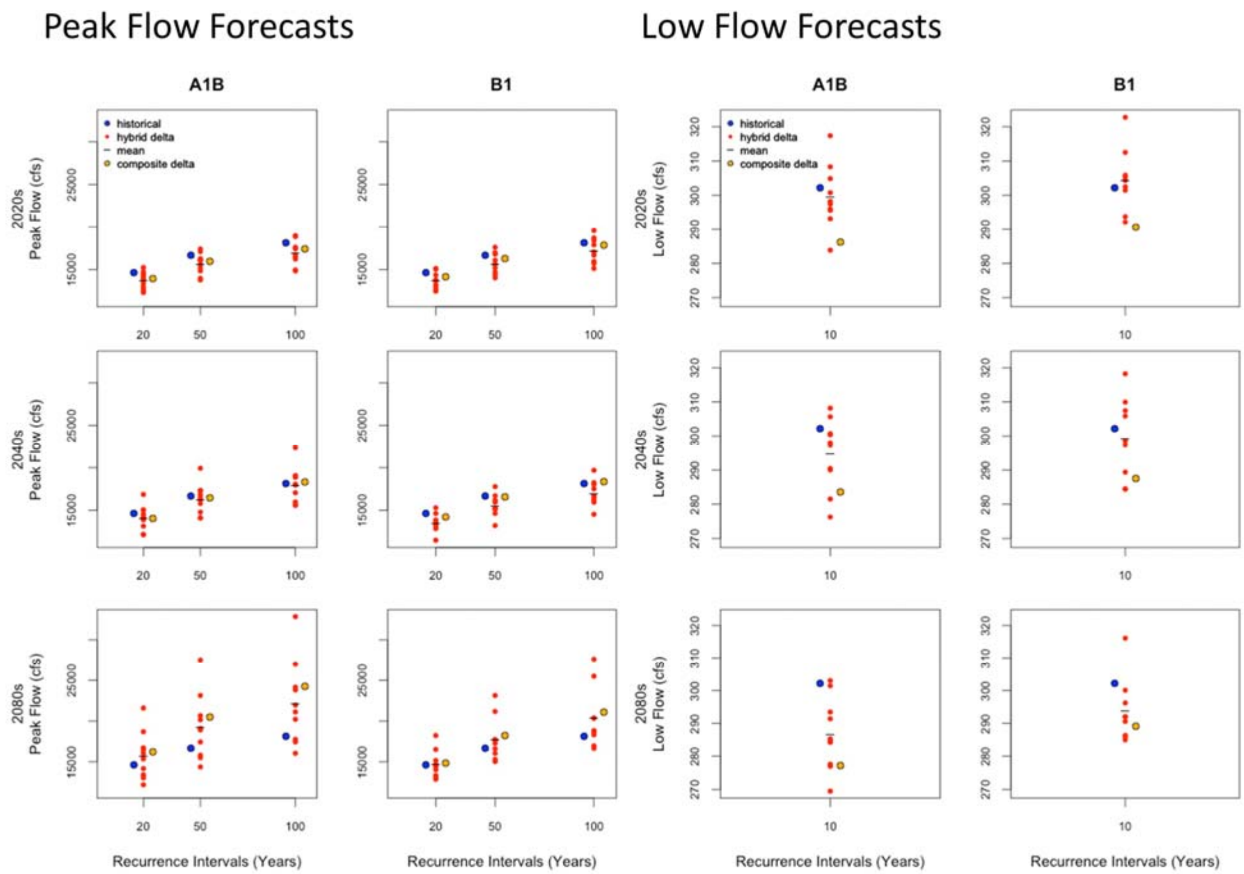


Figure 3-9 Projections of future peak and low flows under two emissions scenarios, for the 2020s, 2040s, and 2080s.

Note: Projections are for the USGS stream gage location at Twisp, and were produced for the Columbia Basin Climate Change Scenarios Project (Hamlet et al. 2013). Graphs show simulations of historical values (blue), modeled projections using the hybrid delta global climate model downscaling approach (red dots with black line for average), and projected values using the composite delta downscaling approach (yellow). Low-flow values are the 7Q10 statistic (7-day consecutive low flow with 10-year recurrence interval).

3.5.2 Hydraulics

Reclamation (2014) developed a two-dimensional (2D) hydraulic model for much of the Assessment Reach using SRH-2D modeling software, which forms the basis of the subsequent analysis. The model extends from RMs 29.4 to 40.4, meaning it excludes approximately 1.2 and 0.9 miles of the upper and lower ends of Assessment Reach, respectively. The model results were used to support an analysis of flood inundation and sediment transport conditions along the reach, as discussed below.

Floodplain Inundation and Side Channel Activation

The hydraulic modeling results help to map flood inundation patterns and activation of the existing network of ephemeral floodplain channels. Figure 3-10 shows floodplain inundation patterns by sub-reach, as well as mapped human constraints on inundation within the natural floodplain. Disconnected floodplain areas are concentrated within TC2, where about 5,000 feet of levee/road actively limit floodplain inundation. TC1 and TC3 are naturally confined, and therefore have no features disconnecting flooding, despite their extensive bank hardening (discussed Section 3.4.3 above).

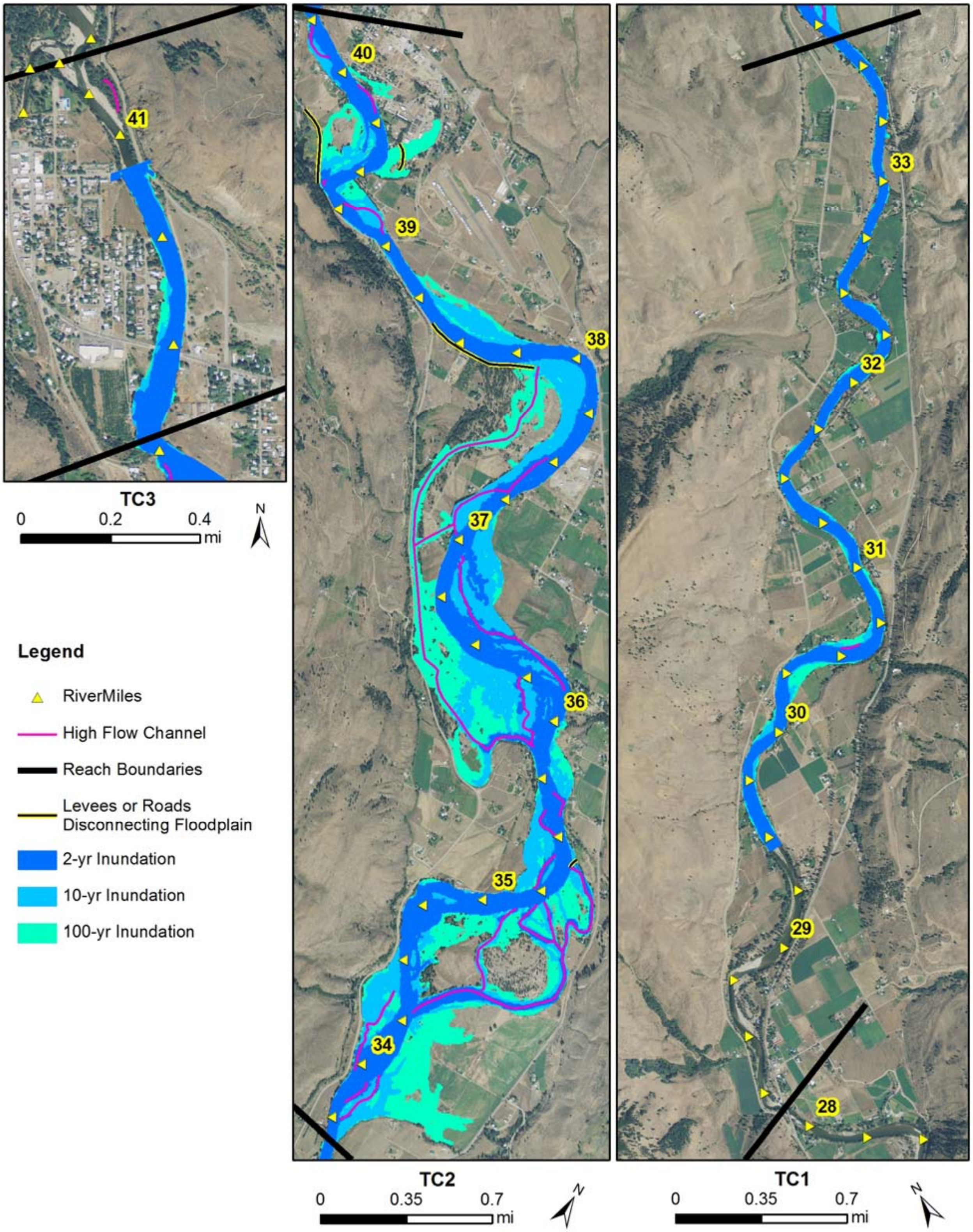


Figure 3-10 Modeled flood inundation along the sub-reaches (Reclamation 2014).

Sediment Transport Regime and Flow Competence

To evaluate sediment transport regimes along the Assessment Reach, the hydraulic modeling results were paired with pebble count data to calculate flow competence. Flow competence refers to whether the flow is competent to transport the sediment comprising the bed. Primary inputs to this analysis are shear stress (an output of the hydraulic model produced by Reclamation) and sediment size (sampled using pebble count techniques [Wolman 1954]). Pebble counts used in this analysis were collected by Reclamation (2008) and during habitat surveys for this Assessment. These pebble counts included samples collected on bars and along channel-spanning cross-sections. While this analysis includes competence calculations for both sample location types, the interpretations primarily use results from the bar samples since bars are more likely to have sediment in active transport. Competence calculations for the 2-year and 100-year floods inform interpretations of sediment regime described below.

Flow competence calculations used an empirical approach developed by Komar (1987), which evaluates mobility of a given particle size. In this case, the 84th percentile particle was chosen to capture mobility of roughly the entire bed under a given shear stress (τ). The shear stresses at each sample location and flow (2-year and 100-year) were extracted from the Reclamation (2014) hydraulic modeling results and used for the subsequent competence calculation. Using this approach, the critical shear stress (τ_c) at which the bed becomes mobilized is calculated in terms of the 50th and 84th percentile grain sizes (D_{50} and D_{84}), the densities of sediment and water (ρ_s and ρ_w), and the critical dimensionless shear stress (τ_c* assumed 0.031 according to reanalysis of Komar's approach by Buffington and Montgomery [1997]) using the following equation:

$$\tau_c = \tau_c^* \left(\rho_s - \rho_w\right) * D_{84}^{0.3} D_{50}^{0.7}$$

When the shear stress imposed by flowing water exceeds the critical shear stress, the bed becomes mobile in that location. A useful metric for flow competence is the simple ratio of shear stress to critical shear stress, referred to as the excess shear stress ratio (τ*):

$$\tau^* = \frac{\tau}{\tau_c}$$

When the excess shear stress ratio exceeds unity, the bed is assumed to become mobile (i.e., flows are competent to transport the bed material). In general, transport-limited (depositional) reaches will have relatively lower excess shear stress ratios, and supply-limited (erosional) reaches have higher excess shear stresses (Montgomery and Buffington 1997). In other words, transport-limited reaches will often have relatively fine beds reflecting their lower competence to transport sediment, and supply-limited reaches will have relatively coarse beds because of their high competence to transport all but the largest grains.

These above calculations were performed at the location of each grain size sample separately to (1) take full advantage of the 2-D hydraulic model, and (2) to avoid issues with averaging highly variable bed and flow conditions. Figure 3-11 and Table 3-5 display the results, demonstrating the variability in hydraulics and flow competence along the Assessment Reach. On a sub-reach basis, TC3 has the largest grain sizes, while TC1 and TC2 have broadly similar grain sizes on average (though with much variation). A similar variability exists in excess shear stresses, indicating localized zones of transport- versus supply-limited sediment regime.

Note, significant error is possible given uncertainty in the exact locations of Reclamation samples, which determined where shear stress values were gathered from the 2D modeling results. Interpretations of sediment transport regime are therefore largely based on relative differences, as opposed to absolute values, of excess shear stress ratios along the Assessment Reach.

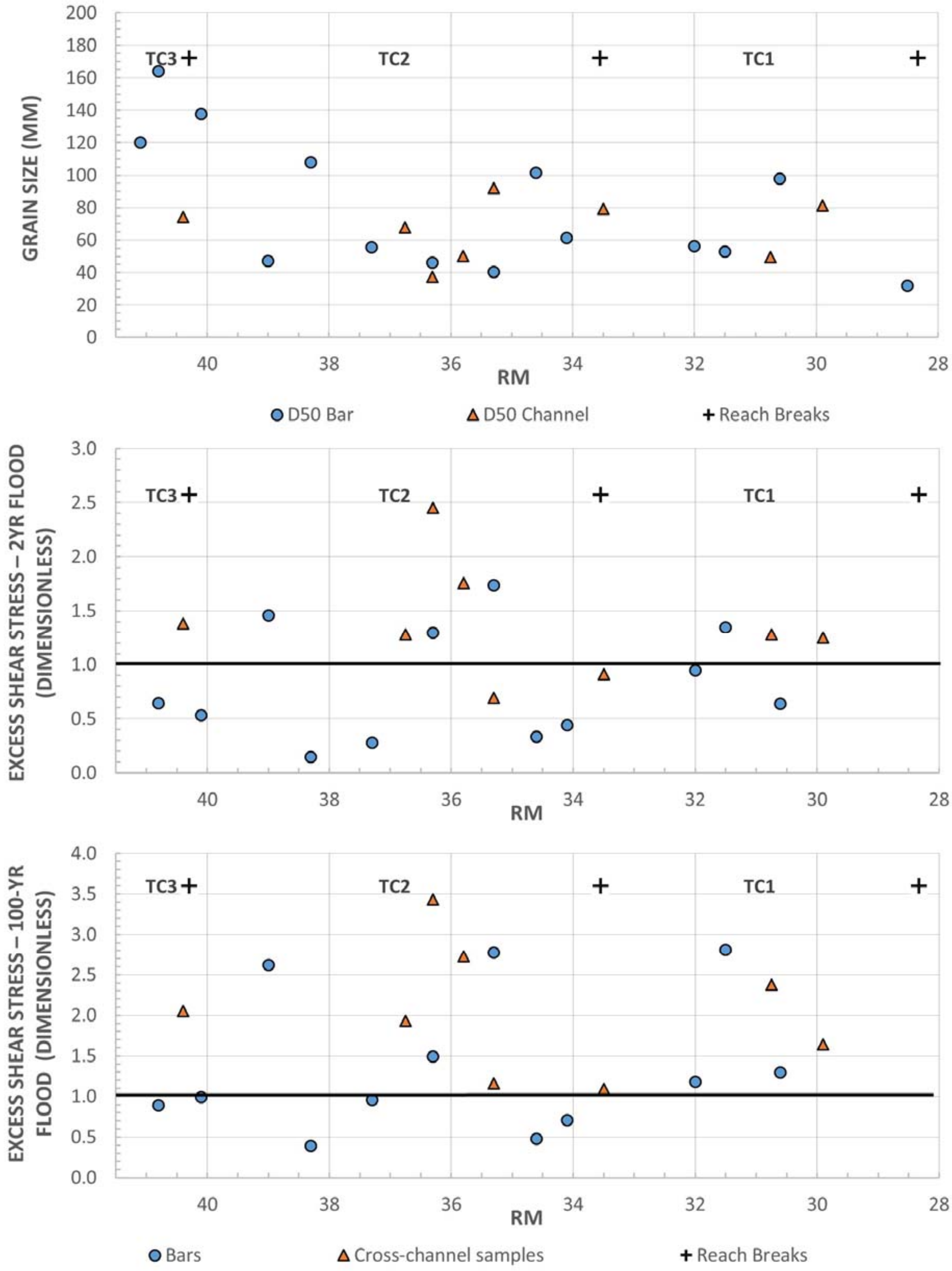


Figure 3-11 Grain sizes and excess shear stress ratios (2-year and 100-year floods) along the Assessment Reach.

Note: The upstream and downstream most sediment samples are outside the extent of the hydraulic model, and therefore have no associated calculations of excess shear stress ratios.

Sediment transport regimes along the Assessment Teach are characterized as follows.

> TC3 – Confined and relatively steep, this reach is largely **supply-limited**, with coarse-grained bars that are only mobilized during the largest of floods. This coarse sediment is being supplied by the Twisp River and steeper, more dynamic reaches farther upstream.

> TC2 – This sub-reach has a variable sediment regime ranging from transport-limited in the unconfined, response sections to supply-limited in naturally or artificially confined sections.

> TC1 – This confined sub-reach is near-equilibrium supply and transport, with beds mobilized fairly consistently around the 2-year flood. The consistent confinement between glacial terraces likely creates the consistency in sediment regime.

Table 3-5 Sub-reach Summary of Hydraulic and Sediment Transport Metrics

	2-year flood			100-year flood		
Sub-reach	**Mean Velocity (ft/s)**	**Shear Stress (lb/ft^2)**	**Mean Excess Shear Ratio on Bars**	**Mean Velocity (ft/s)**	**Shear Stress (lb/ft^2)**	**Mean Excess Shear Ratio on Bars**
TC1	8.1	0.9	1.0	11.1	1.5	1.8
TC2	6.7	0.8	0.8	8.9	1.2	1.3
TC3	9.0	1.2	0.6	12.9	2.0	0.9

3.5.3 Geomorphology

Valley Morphology

The Twisp to Carlton reach runs along a highly variable valley morphology shaped by glaciation and subsequent fluvial incision. Using floodprone width as a metric, the channel runs through a floodplain of varying width along the Assessment Reach (Figure 3-12). In the uppermost sub-reach (TC3), the channel is confined by a combination of bedrock and inactive river and glacial terraces, and has a straight planform. TC2 has the widest floodplain of the three sub-reaches, but also contains much variation. Three fully unconfined sections are distributed within the reach, including the “Red Shirt Mill” section from RM 40.0 to 39.3, the “Beaver Ponds” section from RM 38.4 to 35.8, and the “Silver Side Channel” section from RM 35.5 to 33.7. These three sub-sections were respectively referred to as M2c, M2b, and M2a in the *Methow River Geomorphic Assessment* (Reclamation 2008) (and are TC2c, TC2b, and TC2a here) and have the greatest diversity in floodplain landforms, with abundant high-flow and abandoned channels. These floodplain channels in part have resulted from historical channel migration, but also are a product of the multi-threaded, anabranching channel likely present before European settlement. Currently the TC2 channel is single-thread with a sinuosity of 1.33. In the intervening sections of narrow floodplain in TC2, the channel again comes into contact with bedrock valley walls and the glacio-fluvial terraces present in sub-reach TC3. TC1 is almost entirely confined by the glacio-fluvial terraces, with localized zones of inset floodplain typically no wider than the bankfull channel.

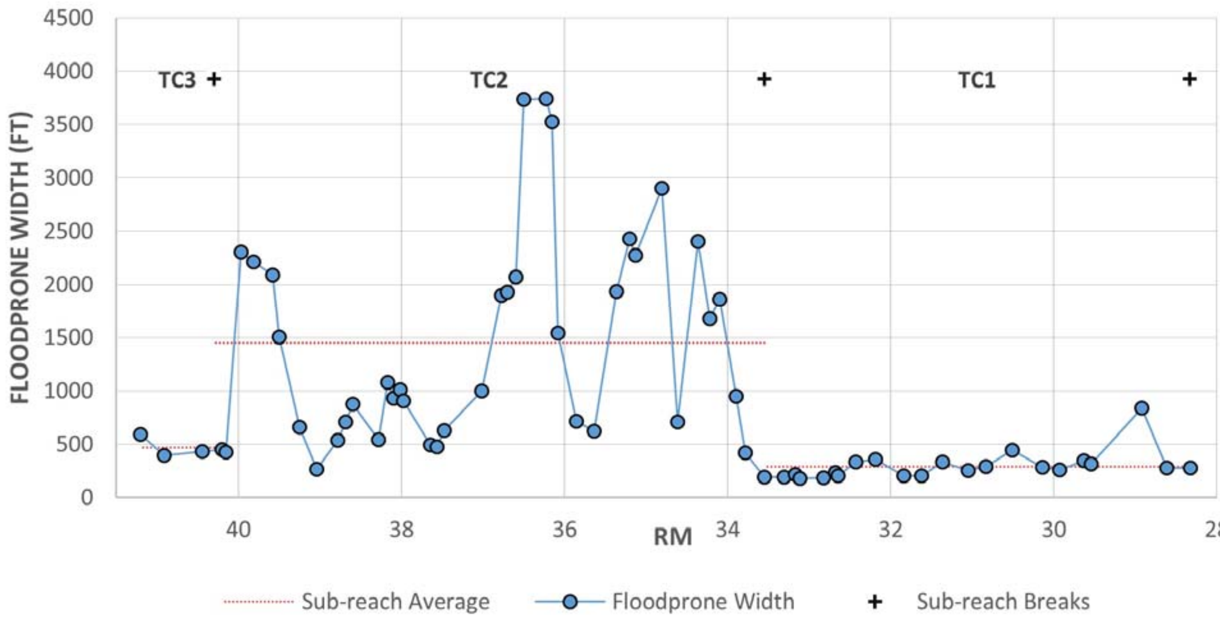


Figure 3-12 Floodprone width along the Assessment Reach.

Note: Floodprone width is the valley width measured at an elevation of two times the maximum bankfull depth.

Geomorphic mapping of the valley and floodplain used the same general approach as the Middle Methow Reach Assessment (2010) and provides a similar picture of valley form as the discussion above. Mapping involved classification of valley landforms into seven classes, including:

> Inner Zone: According to Reclamation (2010), “The inner zone is characterized by the presence of primary and secondary channels, a repetitious sequence of channel units, and relatively uniform physical attributes indicative of localized transport, transition, and deposition. They are generally associated with ground disturbing flows with sufficient frequency that mature deciduous and coniferous trees are rare. The active main channel was subdivided into eight inner zones based on local sediment transport and deposition trends interpreted from the channel unit mapping, channel gradient, channel confinement, hydraulics, and dominant substrate. Inner zones that are not hydraulically connected to the river because of anthropogenic features are described as disconnected inner zones.” In general, this zone encompasses what is traditionally considered the active channel.

> Outer Zone: According to Reclamation (2010), “[The] outer zone is typically a terrace tread(s) and generally coincidental with the historic channel migration zone unless the channel has been modified or incised leading to the abandonment of the floodplain. This zone includes side channels, overflow channels, and oxbows. An outer zone is further distinguished from an inner zone by the presence of flood deposits, a change in vegetation (mature deciduous and coniferous trees present unless removed for development), and bounding geologic landforms such as older terraces, valley walls, alluvial fans, colluvium, or glacial deposits.” In general, this zone encompasses what is traditionally considered the geomorphic floodplain (Wallick et al., 2013).

> Disconnected Inner Zone: Inner zone areas with disconnected or limited inundation as a result of levees or other features that limit floodplain connectivity.

> Disconnected Outer Zone: Outer zone areas with disconnected or limited inundation as a result of levees or other features that limit floodplain connectivity.

> Inactive Fluvial Surface: Alluvial terraces in the valley bottom that no longer are inundated by high flows. Multiple levels of fill terraces are present along the Assessment Reach that have resulted in long-term channel incision over the period since the last glaciation.

> Alluvial Fan: Alluvial fans along valley margins formed by tributaries.

> Bedrock-cored Landforms: These features are primarily bedrock valley walls, but also include high, bedrock-cored (strath) river terraces present along the valley margins.

Geomorphic maps produced using the above mapping scheme are available for review in Appendix A. Table 3-6 summarizes the inner and outer zone extent by sub-reach and reflects the narrow floodplains in TC1 and TC3 and wide active channel area and floodplain in TC2. Within TC2, disconnected inner and outer zone areas are respectively associated with the Silver Side Channel and the Beaver Pond complex behind levees. A small disconnected outer zone area is also present in the upper right floodplain of TC2 behind Twisp-Carlton Road.

Table 3-6 Summary Statistics of Geomorphic Mapping of Inner and Outer Zones, by Sub-reach

Geomorphic Unit	Metric	TC1	TC2	TC3
Inner Zone	(average width, ft)	235	374	201
Outer Zone	(average width, ft)	100	849	38
Disconnected Inner Zone	(area, acres)	0	28	0
Disconnected Outer Zone	(area, acres)	0	147	0

Channel Morphology

The channel morphology in the Assessment Reach is generally characterized as a pool-riffle morphology, which, according to the Montgomery and Buffington (1997) approach, is expected given the range of channel slopes from 0.15 percent to 0.37 percent (Figure 3-13). On average, TC3 is the steepest sub-reach, and TC2 and TC1 have roughly similar average slopes. Within the Assessment Reach and particularly within TC2, the channel has zones resembling the plane-bed morphology. These areas were identified as glides—fast, non-turbulent flow according to the employed USFS (2015) habitat survey methods—during habitat surveys. Glides are most abundant in TC2 and are uncommon or nonexistant in TC1 and TC3 (Table 3-7). Glide area appears to trade-off with riffle area (i.e., the increased glide area in TC2 has a corresponding decrease in riffle area), whereas pool area remains relatively constant (33 to 37 percent) across sub-reaches. TC2 also has a wider bankfull width (Figure 3-14), with particularly wide zones associated with sediment deposition and large gravel bars in the active channel.

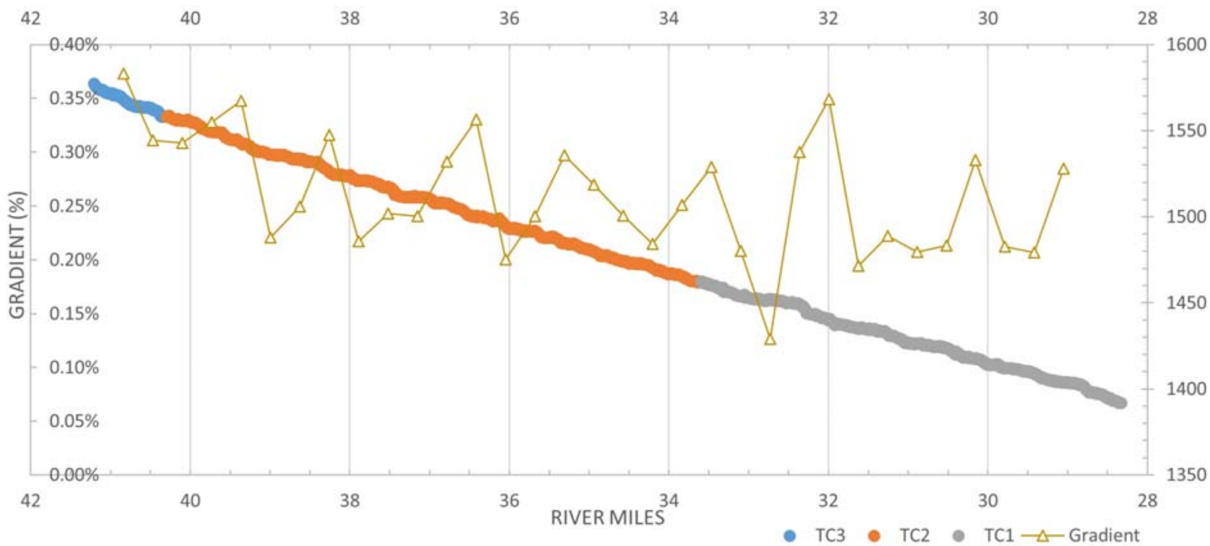


Figure 3-13 Longitudinal profile of the Assessment Reach.

Note: Measurements are taken from the 2006 LiDAR water surface. Gradients are measured over 4,000-foot sections, but points are spaced every 2,000 feet.

Table 3-7 Sub-reach Summary of Geomorphic Properties

Sub-reach	TC3	TC2	TC1
River Miles	40.3-41.3	33.7-40.3	28.1-33.7
Sinuosity	1.09	1.33	1.24
Gradient (%)	0.38%	0.27%	0.25%
Dominant Channel Morphology (Montgomery and Buffington 1997)	Pool-riffle	Pool-riffle/Plane-bed	Pool-riffle
Average Bankfull Width (ft)	207	293	193
Average Floodprone Width (ft)	471	1,448	292
% Habitat Unit Area			
Pool	36%	33%	37%
Riffle	64%	38%	53%
Glide	0%	28%	9%
Side Channel	0%	0%	1%
Average Habitat Unit Spacing			
Riffle Spacing (ft)	2,055	1,482	1,778
Riffle Spacing (multiples of bankfull width)	9.9	5.1	9.2
Pool Spacing (ft)	1,620	2,348	2,200
Pool Spacing (multiples of bankfull width)	7.8	8.0	11.4
Pool Frequency (#/mile)	3.3	2.2	2.4

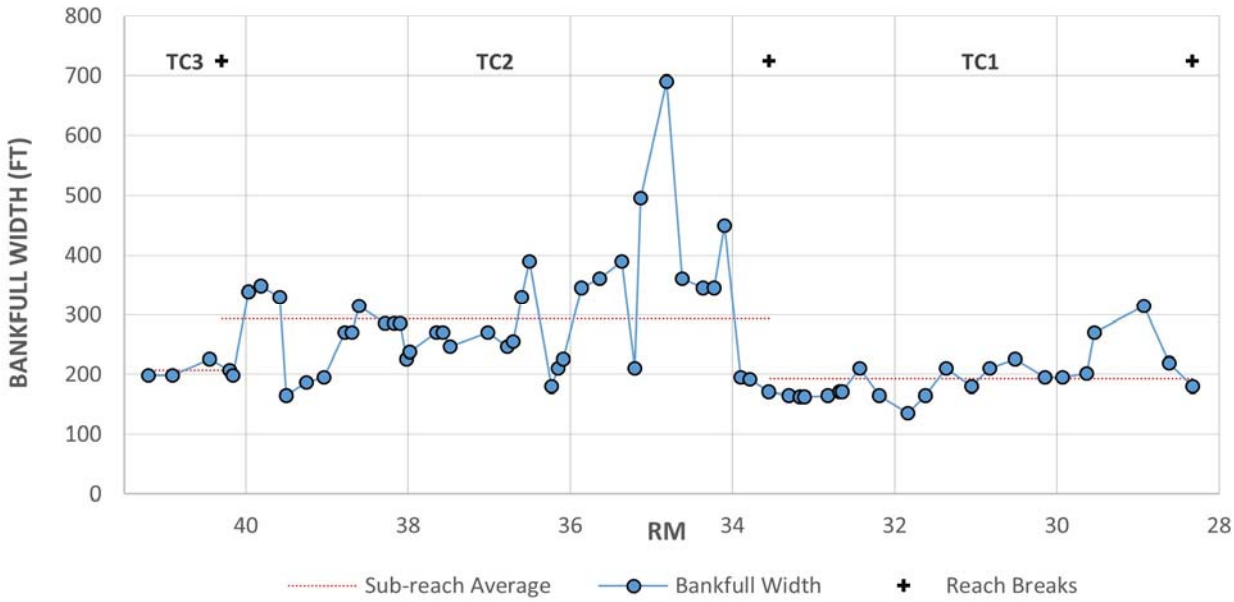


Figure 3-14 Bankfull width along the Assessment Reach.

Channel Migration and Habitat Formation

Lateral channel movement, or migration, is a key habitat formation process in floodplains, and therefore its historical locations and rates inform future process-based restoration projects. Channel migration measurements were taken along transects spaced 0.25 RMs apart (Figure 3-15). At each transect, active channel movements and width changes were measured (and rates calculated) from 1945 to 2013 over five intervening measurement periods defined by aerial images captured in 1945, 1948, 1964, 1974, 2004, and 2013. Rate calculations were adjusted for active channel width changes in each period according to an approach described by Konrad (2012).

Specific goals of the channel migration analysis were to:

> Evaluate historical channel migration rates prior to extensive bank stabilization and hardening

> Evaluate recent channel migration rates following reach-wide bank stabilization and hardening

> Correlate channel migration rates to high flows since the prior aerial image

A separate rate metric was developed during this Assessment to achieve the third objective. Rather than normalizing channel migration distances to time between aerial photographs (i.e., typical channel migration rate calculations), distances migrated are normalized to a measure of cumulative flood duration for each measurement period. The metric—referred to as the "High Flow Migration Rate (M_{HF})"—is expressed in distance migrated per day of high flow (feet/day) and calculated as follows:

$$M_{HF} = \frac{Distance\ Migrated\ in\ Measurement\ Period\ (ft)}{\#\ Days\ Exceeding\ High\ Flow\ Threshold\ (days)}$$

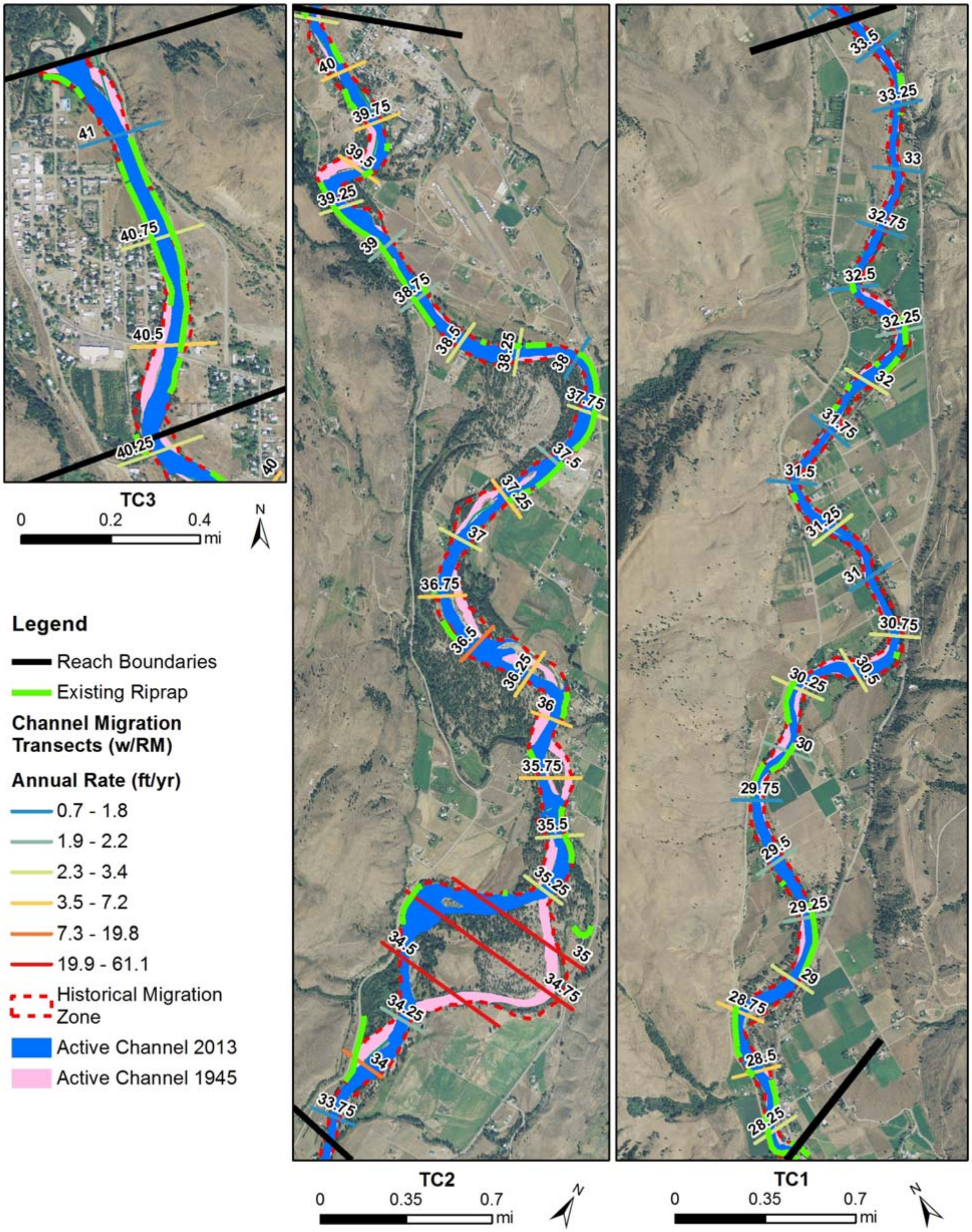


Figure 3-15 Map showing channel migration measurement transects and average annual rates along the each sub-reach (average rates for period of record).

Note: The historical migration zone is the contiguous zone containing all historical channel locations from 1945–2013.

A flow threshold equal to the historical 1 percent annual exceedance flow (10,300 cfs, as calculated for the period of record at the Twisp gage) defined the lower threshold for “high flows.” This flow is between the 1.5- and 2-yr recurrence interval peak flows (and thus near or just exceeding the expected bankfull discharge), and has the benefit of a known annual duration (averaging 3 to 4 days per year), allowing projections of annual channel migration rates with an expectation of flow statistics (for instance, if future climate change changes the annual hydrograph, projections could also be revised).

On average, historical channel migration rates have been relatively modest throughout the Twisp to Carlton reach, with punctuated instances of channel migration in space and time. Figure 3-15 shows the longitudinal distribution of average channel migration rates for the historical record. The greatest migration rates have occurred near the historical mining town of Silver (RMs 34.5–35), where a large avulsion occurred in the 1950s (discussed in greater detail below). On a sub-reach basis, average migration rates have generally been greatest in TC2 where the lateral constraint from valley walls and river terraces is least.

Channel migration has occurred disproportionately throughout the historical record from 1945 to 2013, with a period of initially fast migration followed by greatly reduced migration afterward. Figure 3-16 shows measured channel migration distances (chart A) and two forms of migration rates (annual migration rate in charts B and high flow migration rate in chart C) for the historical record. By both rate measures, channel migration was the fastest in the 1945 to 1948 measurement period and then abruptly decreased for the remaining measurement periods. This initial period of fast migration contains the historical flood of record, which likely has some role in the observed rates. However, on the basis of the high-flow migration rate (Figure 3-16, Chart C), flooding appears to have had a diminished erosive effect after that initial period, suggesting the disparity of rates was also caused by external factors. The most plausible explanation involves extensive, reach-wide placement of bank stabilization. Riprap would have likely been placed in response to the rapid migration and flooding of 1948, thus arresting rates afterward.

These two periods prior to and after 1948 inform our understanding of habitat formation, with and without riprap. The 1945 to 1948 rates reflect habitat formation rates in a relatively undisturbed state. Therefore, these rates can be used to project the habitat benefit of removing riprap. However, without riprap removal, channel migration rates and habitat formation can be expected to largely continue at the modest rates observed since about 1950. Figure 3-17 shows the disparity between these two historical periods along the entire Twisp to Carlton reach. In addition, Table 3-8 provides sub-reach projections of habitat formation rates for future scenarios with and without riprap. Habitat formation rates in Table 3-8 are equated to projections of area occupied or eroded by the river channel, and therefore refer to habitat formation in a broad sense. This eroded area provides habitat types ranging from in-channel to off-channel aquatic habitat to new surfaces for riparian vegetation growth or terrestrial habitat. Migrating channels also reoccupy areas in their adjacent floodplains (Konrad 2012), which should also be considered with these projections, especially considering that the tendency for reoccupation varies along the Assessment Reach. Given their confinement, the channel in sub-reaches TC1 and TC3 is more likely to reoccupy areas than the channel in TC2. Thus, the reported habitat creation rates in Table 3-8 likely inflate the benefit in TC1 and TC3, and downplay the potential benefits of habitat creation in TC2.

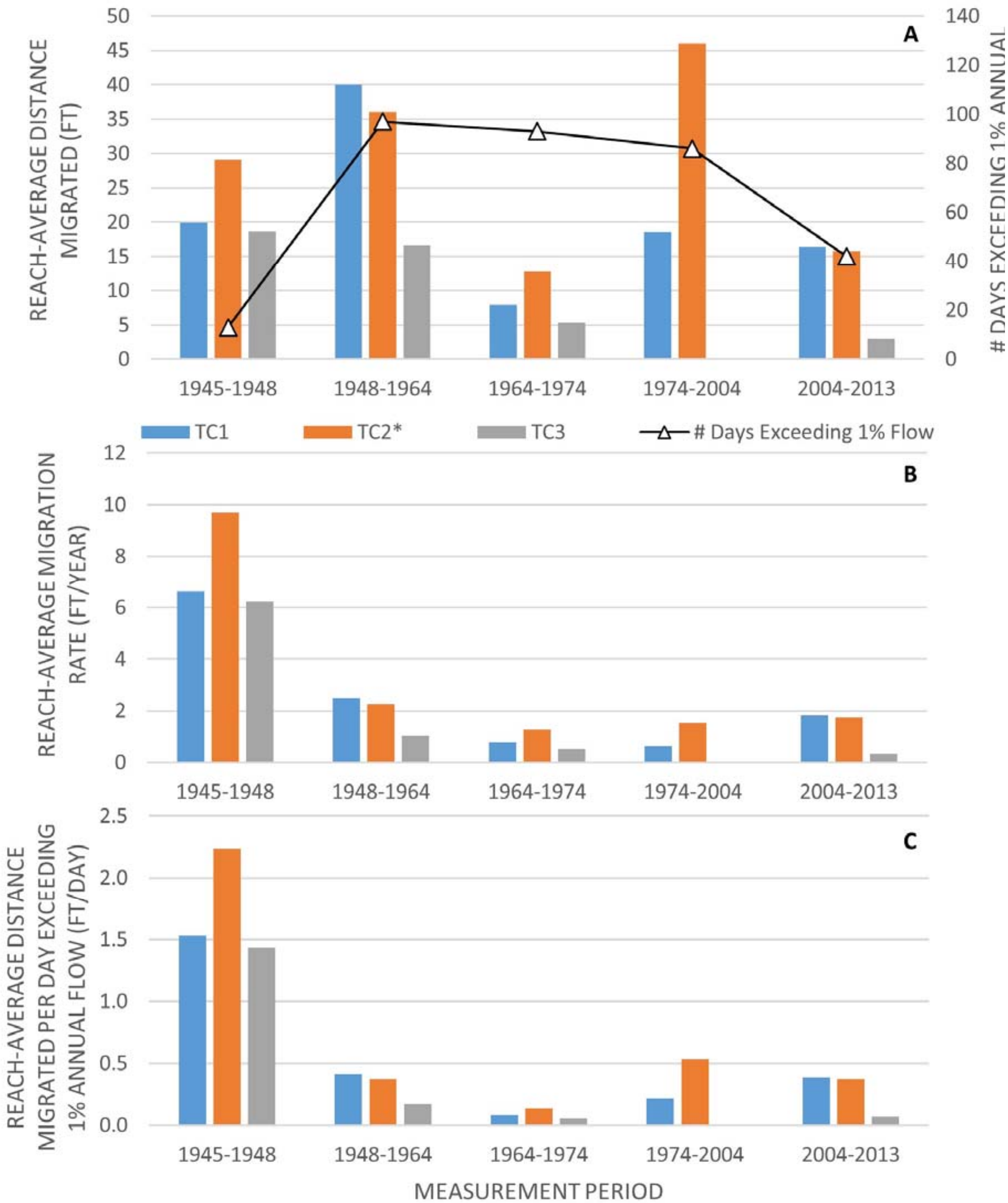


Figure 3-16 Temporal summary of channel migration on a sub-reach basis.

Note: Chart A shows distance migrated for each measurement period and the number of days in each period exceeding 1% annual flow as a measure of total duration of flood flows experienced in each period. Chart B shows annual migration rates. Chart C shows rates of migration (ft/day) relative to each day when flow exceeded the 1% annual discharge. * TC2 calculations excluded transects coinciding with the Silver Side Channel avulsion (RMs 34.5–35.0).

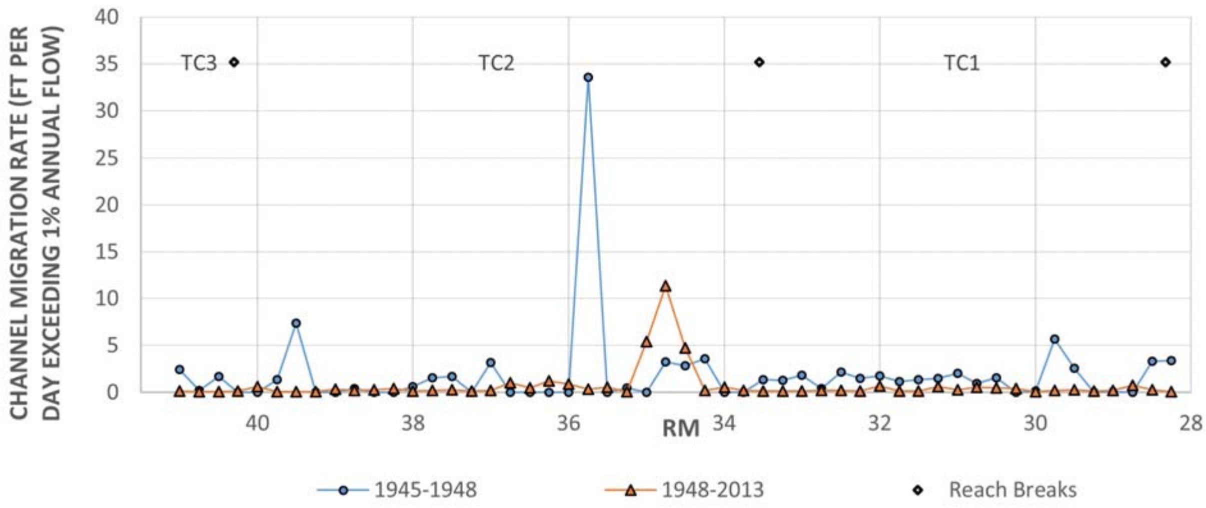


Figure 3-17 **Longitudinal channel migration rates (relative to flows exceeding the 1% annual flow) for two measurement periods.**

Note: The disparity in rates is interpreted to be a result of large rates of channel migration and subsequent bank hardening, as a result.

Table 3-8 **Estimation of Habitat Formation Rates by Sub-reach for Future Scenarios of Bankline Restoration**

Sub-reach	Annual Migration Rate (ft/yr)		Projected Habitat Formation Rate (acre/river mile/yr)	
	1945–1948	1948–2013	All Hardening Removed	No Bank Hardening Removed
TC1	5.6	1.0	0.7	0.1
TC2	8.2	1.3	1.0	0.2
TC3	5.2	0.3	0.6	0.0

Historical Avulsions near Silver

Large-scale avulsions of the Methow River near the historical mining town of Silver (RMs 34.5–35) have been a relatively frequent occurrence since settlement by Europeans. The channel in this reach currently follows the western valley wall, but has switched between its current position and the eastern valley wall multiple times. A reconstructed avulsion history (Robes Parrish, US Fish and Wildlife Service, personal communication, 2016) includes the following major events:

> Prior to 1894: The Methow River occupies its current position, though accounts from Silver residents indicate the channel may have switched multiple times prior to 1894 (http://www.ghosttownsusa.com/silver.htm)

> 1894: Large flood causes an avulsion to the eastern position. Mining town of Silver is destroyed.

> 1894–1948: Channel maintains position along the eastern valley wall.

> 1948: Flood of record erodes western channel so it carries perennial flow (though still less than the eastern thread in a post-flood 1948 aerial photograph; see Figure 3-18).

> 1948 to 1954: Channel maintains a perennial flow split and appears to have an increasing flow (proportionally) in the western channel through time (1954 aerial photograph has a majority flow in the

western channel thread), indicating a gradual switch toward the western thread which was complete by 1964.

> 1964-present: Channel is located in the western, present-day thread.

The above history demonstrates the style of avulsion activity in this particularly active segment of sub-reach TC2. Of particular note is the abrupt avulsion (1894) relative to the gradual avulsion occurring the 1940s and 1950s, and the recurrence of such events, suggesting a possibility of similar events in the future.

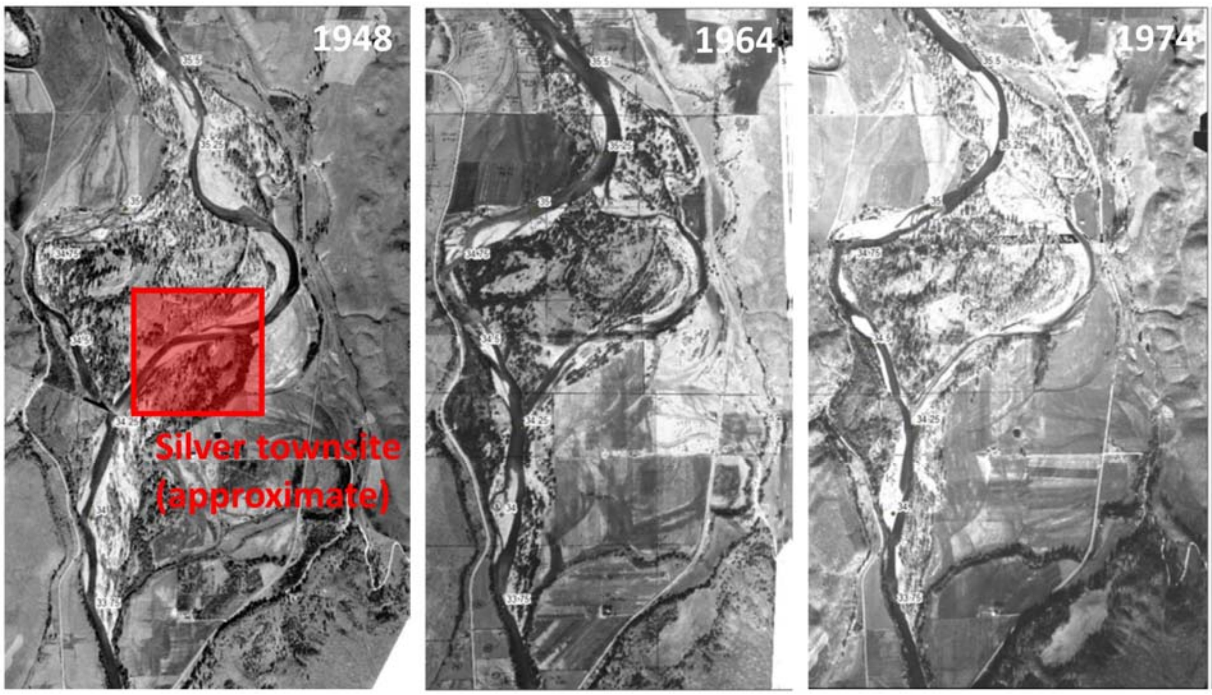


Figure 3-18 Channel migration and avulsion at the Silver townsite from 1948–1974.

3.5.4 Riparian Vegetation

Riparian plant communities along both banks of the Assessment Reach have been effectively eliminated or significantly reduced throughout the reach. Habitat surveys in summer of 2016 identified the species and size classes of the riparian vegetation overstory for each channel habitat unit within 100 feet of the active channel. Of the riparian vegetation that is present, cottonwood is the predominant species, with a lesser amount of ponderosa pine, and even lesser proportion of willow (Table 3-9). Ponderosa pine is most abundant (and cottonwood is least dominant) in TC1, reflecting the lack of floodplain from confining glacial terraces. The riparian vegetation size class is predominantly small to large trees, as shown by the distributions presented in Table 3-10.

Table 3-9 Species Composition of Overstory Vegetation within 100 Feet of the Active Channel, as Identified during Habitat Surveys (2016)

Species	TC3	TC2	TC1
Cottonwood	100%	78%	51%
Ponderosa pine	0%	11%	44%
Willow	0%	5%	3%
No Vegetation	0%	6%	3%

Table 3-10 Dominant Overstory Size Class, as a Percentage of Each Sub-reach, Based on Habitat Surveys Completed in 2016. Percentages Incorporate Both Banks

	TC3	TC2	TC1
No Vegetation	0%	6%	3%
Grassland/Forb (no DBH)	0%	0%	0%
Shrub/Seedling (1–4.9 in. DBH)	0%	1%	0%
Sapling/Pole (5–8.9 in. DBH)	0%	1%	0%
Small Trees (9–20.9 in. DBH)	80%	32%	17%
Large Trees Condition (21–31.9 in. DBH)	20%	60%	81%
Mature Trees Condition (>32 in DBH)	0%	0%	0%

DBH = diameter at breast height

Using riparian vegetation mapping from the Methow In-Channel Habitat Restoration Plan (Reclamation 2008), riparian widths were measured within 100-foot and 300-foot wide sampling transects spaced every 0.25 RM. Within each buffer distance, the average percent canopy cover was measured. These canopy cover percentages were then converted to non-contiguous riparian widths by multiplying canopy cover percent by buffer width. Figure 3-19 shows these riparian width measurements longitudinally along the Assessment Reach, with sub-reach averages reported in Table 3-11. In general, riparian buffers are most degraded in TC1 and TC3. While floodplain development is significant in TC2, some significant patches of vegetation are present.

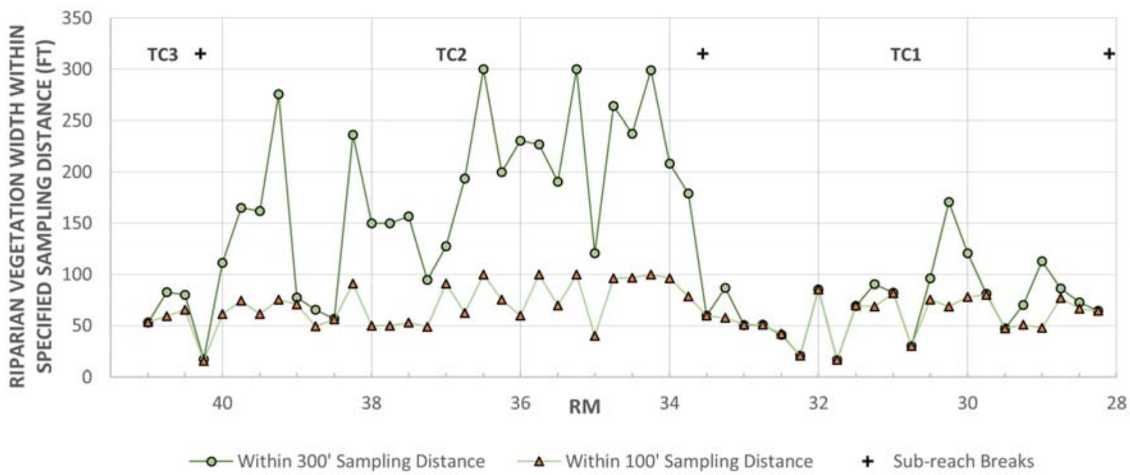


Figure 3-19 Widths of riparian vegetation as measured using 100-foot and 300-foot sampling buffers.

Note: Sampling encompassed 100 feet or 300 feet on both banks—the average of the two banks is reported. The reported widths are not necessarily contiguous given the approach of first measuring canopy cover percent and multiplying by sample distance (100 or 300 feet).

Table 3-11 Sub-reach Average Riparian Vegetation Extent as Measured within Two Buffer Distances

Distance Sampled from Channel	Non-Contiguous Riparian Width in Feet [% canopy cover]		
	TC3	TC2	TC1
100'	59 [59%]	71 [71%]	58 [58%]
300'	72 [24%]	173 [58%]	73 [24%]

Note: Measurement of canopy cover encompassed both banks – the averages of the two banks are reported.

3.5.5 Large Wood Dynamics

The habitat survey in 2016 counted woody debris present within the bankfull channel, classifying woody debris piece size according to the USFS Stream Inventory method (2015) for watersheds east of the Cascades. The size classifications include:

> Small Woody Debris: Pieces greater than 6-inch diameter and 20 feet long

> Medium Woody Debris: Pieces greater than 12-inch diameter and 35 feet long

> LWD: Pieces greater than 20-inch diameter and 35 feet long

For reference, the minimum size criteria for medium woody debris (above) equals the size criteria for “large” woody debris in Pacific Northwest eastside streams, according to the National Oceanic and Atmospheric Administration’s (NOAA’s) Matrix Pathways and Indicators (NMFS 1996) publication. Therefore, subsequent comparisons to NOAA’s recommendations for LWD frequency require a summation of the “medium” and “large” logs classified in this Assessment’s field surveys.

Figure 3-20 and Table 3-12 show the woody debris survey results for the Assessment Reach, in terms of pieces per mile. Figure 3-20 shows a moving sum of wood pieces over a mile of channel. The greatest frequency and abundance of large wood is present in TC2, with an average of 23 pieces per mile. TC1 has a moderate amount of wood (11 LWD pieces per mile), and TC3 is essentially devoid of wood.

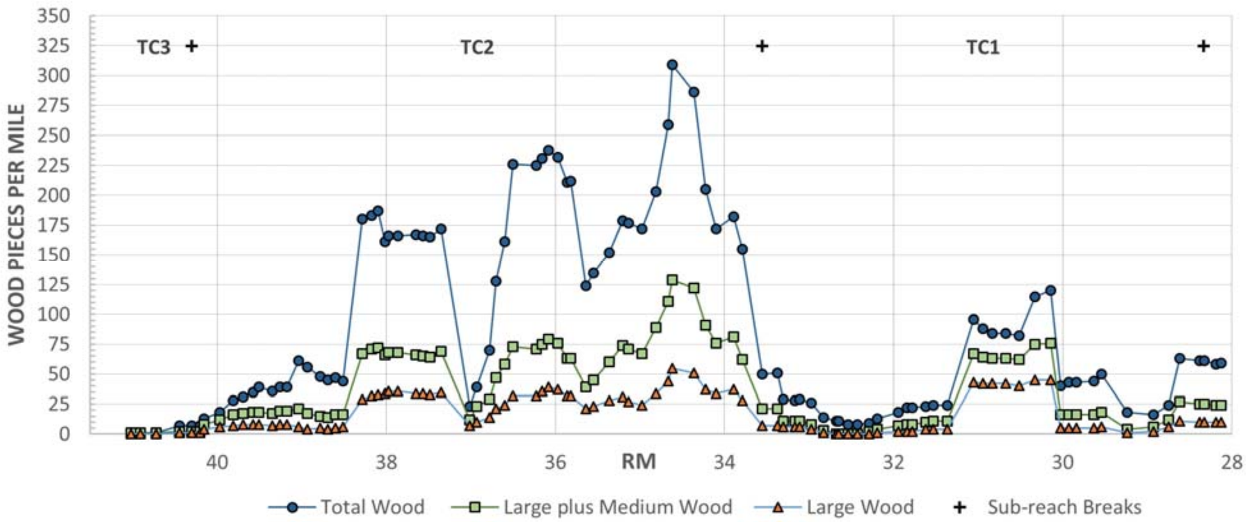


Figure 3-20 **Wood pieces per mile along the Assessment Reach (moving sums based on 2016 habitat survey).**

Note: Total wood counts include any piece over 20 feet long and 6-inch diameter. Medium wood pieces are greater than 35 feet long and 12-inch diameter. Large wood pieces are greater than 35 feet long and 20-inch diameter. Points record the number of woody debris pieces from that point and upstream for a mile.

Table 3-12 **Summary of Sub-reach Average LWD Abundance (pieces per mile) during the 2016 Habitat Survey.**

Sub-reach	Size Range	TC3	TC2	TC1
Reach Length (miles)	NA	1.0	6.6	5.6
Small Wood Pieces per Mile, USFS Definition (as surveyed and shown in Figure 3-20)	6"–12" diameter, >20' long	5	78	20
Medium Wood Pieces per Mile, USFS Definition (as surveyed and shown in Figure 3-20)	12"–20" diameter, >35' long	1	28	10
Large Wood Pieces per Mile, USFS Definition (as surveyed and shown in Figure 3-20)	>20" diameter, >35' long	1	23	11
Large Wood Pieces per Mile, NMFS Definition (sum of USFS Large and Medium Size Categories above)	>12" diameter, >35' long	2	51	21
Estimated Key Pieces per Mile (Fox and Bolton (2007) recommendation)	Volume > 10.75 m^3, or ~3.5' diameter, 35' long, with rootwad	<1	<5	<3
Total Wood Pieces per Mile	NA	***7***	***128***	***40***

Wood is delivered to river channels by a variety of mechanisms including wind throw and channel migration. In the Assessment Reach, where riprap severely limits channel migration and wood recruitment, most in-channel wood must originate from trees that have been transported in from upstream reaches of the Methow River and contributing streams. Likely major sources of LWD input are the Upper Methow and Chewuch rivers, where the valley is narrower, forested hillslopes are steeper, the riparian forests remain relatively intact, and channel migration is still active adjacent to standing riparian forests.

Modest amounts of woody debris also likely originate from the Twisp River and the few larger tributary streams such as Beaver Creek, but quantifying these amounts or differentiating the sources is difficult.

The varying longitudinal wood frequency along the Assessment Reach appears to be a function of wood accumulation and a tendency for particular reaches to retain wood, and less a function of varying wood supply. Woody debris is clearly most abundant in TC2 (Figure 3-20). While the abundance of riparian communities is greater in TC2 (see Figure 3-19), the extent of bank hardening and suppressed rate of channel migration (which limits wood recruitment) suggest that the greater wood abundance in TC2 is not a direct function of wood supply. Rather, wood presence in the reach must be a function of lower stream power and shallower channels (as discussed in sections above), which promote deposition of logs as they enter the reach. This discussion also points to a second essential role of artificial confinement in limiting wood loads in the Assessment Reach: levees focus flood flows within the channel, and thus artificially increase stream power and reduce the tendency of the channel to retain wood. Hydro-modifications therefore impact wood loading from both supply and retention perspectives. This latter point also suggests that TC1 and TC3 likely have a naturally lower tendency for wood retention, owing to their lateral confinement.

The frequency data presented Figure 3-20 and Table 3-12 to some degree inflate the magnitude of habitat benefits from wood along the Assessment Reach. A vast majority of observed wood was just within the bankfull channel (i.e., near the banks) and thus mostly out of contact with the low-flow channel. Log jams near the channel margins result in habitat benefit, but in general their direct habitat benefits (e.g., cover) for salmonids are infrequent (only occurring during near-bankfull and greater flows). The benefits of these logs jams near channel banks are primarily physical, and secondarily habitat. For instance, jams on the channel margins have the benefit of dissipating flood energy and diverting flood flows onto the floodplain, as has happened in response to a large log jam on river right near RM 35.6 (see Figure 3-21), which has maintained a high-flow channel and stabilized a vegetated island that began forming around the year 2000 (and now functions as beneficial habitat). One of the few locations where woody debris jams interact with the low-flow channel is at RM 38.4 (see Figure 3-21), where a series of flow splits around a series of large log jams provides edge habitat.

Figure 3-21 Photos showing geomorphic and habitat effects of localized log jams present in the Assessment Reach.

A likely reason for the wood accumulating almost exclusively near channel banks is the lack of large logs capable of acting as key members. Larger logs with expansive rootwads are less mobile and more likely to rack on mid-channel bars, where they accumulate additional logs to form apex-type structures (Abbe and Montgomery 1996). Bar apex jams interact with flow for a greater proportion of the year and cause localized scour pool formation, deposition of fine gravel, and increased overall complexity of the channel. The habitat survey methods used here aimed to characterize the overall size distribution of wood using established USFS methods, but the survey did not explicitly map or call out key-member logs. For a channel of the Methow River's size, Fox and Bolton (2007) recommend a key piece volume of 10.75 cubic meters (m^3), or roughly a 35-foot log with an average diameter of 3.5 feet and a rootwad diameter of 7 feet—well above the definition for "large" wood used in surveys. The frequencies of USFS-defined large logs (20–inch diameter and 35 feet length), ranging from 1 to 23 pieces per mile, likely outnumber the key member logs by an estimated factor of four or greater. Therefore, sub-reach average key piece frequencies are estimated to range from less than one to five pieces per mile. In contrast, Fox and Bolton (2007) recommend a restoration target of greater than 32 key pieces per mile for watersheds in Douglas Fir-Ponderosa Pine forest zones.

3.5.6 Habitat Conditions

Habitat surveys in the summer of 2016 documented and mapped habitat units, sediment sizes, woody debris, riparian conditions, and beaver activity along the Methow River channel. Surveyors used the USFS Stream Inventory Approach (2015), adapted to large channels such as the Methow River.

Habitat Units

Habitat surveys included mapping of pools, riffles, glides, and perennial side channels. As noted in Section 3.5.3, the greatest diversity in habitat units occurs in TC2, where there exists a greater abundance of glides and lower riffle frequency (Table 3-7). One perennial side channel is present in the Assessment Reach and is located in TC3 at RM 31.3, with a length of 600 feet. In addition, flow splits (secondary threads separated from the main channel by bars) are present at RMs 38.6, 38.3, 37.6, and 35.3 (all within TC2), with primarily glide habitat in the split channels.

Pool frequency ranges from 2.2 to 3.3 pools per mile along the Assessment Reach. Since the inventory mapped units with a minimum length equaling that of the wetted width, pool frequency statistics include larger area pools and exclude smaller area pools typically associated with log jams. However, as noted in the LWD discussion above, few logjams are located near the low-flow channel, and consequently few pools associated with LWD jams were present. Residual pool depths—calculated as the maximum wetted depths minus pool crest depths surveyed in 2016—have no apparent longitudinal trend along the Assessment Reach (Figure 3-22) and are greatest on average in TC2. The deeper pools generally were adjacent to bedrock exposures, boulder-rich glacial deposits, or riprap. Shallower pools tended to be in strictly alluvial channels lacking the above forcing agents.

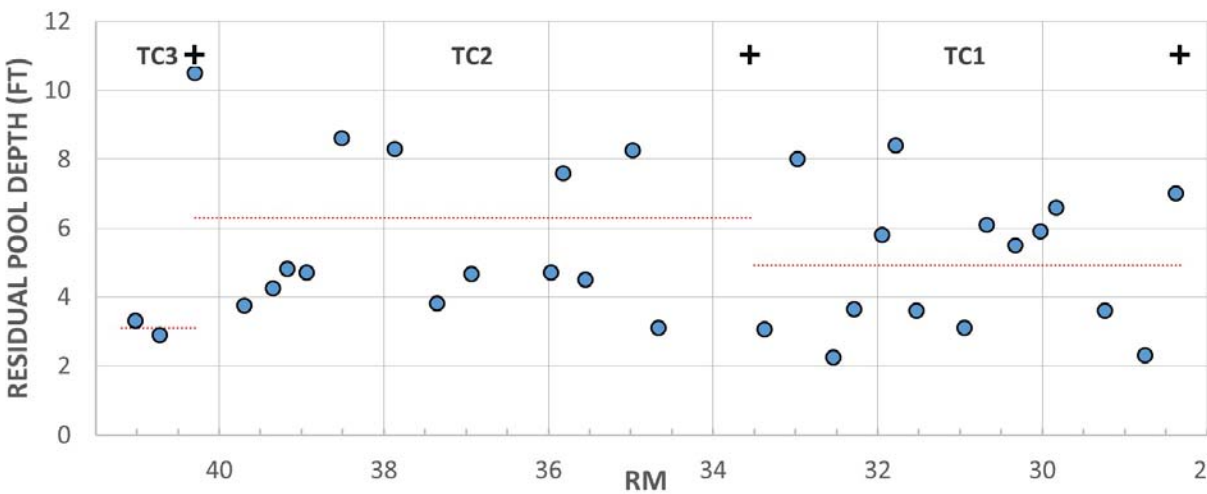


Figure 3-22 Residual pool depths measured along the Assessment Reach.

Note: Sub-reach boundaries are shown with black crosses, and reach average depths are shown with red horizontal lines.

Beaver Activity

The habitat survey also identified beaver activity—including chewed trees, lodges, and canals—along banks. The longitudinal distribution of these points is shown in Figure 3-23. Beaver activity is most concentrated in TC2 (1.5 indications per mile), less concentrated in TC3 (1 indication per mile), and least concentrated in TC1 (0.4 indications per mile). Floodplain beaver activity was not recorded. Based on an examination of mapped vegetation by Reclamation (2008), there appears to be a rough correspondence between beaver activity and the presence of deciduous shrubs and forest. However, the width of the riparian zone does not appear to correlate directly with beaver activity. The concentration of beaver activity in TC2 also likely corresponds with the availability of floodplain, the predominantly alluvial channel, and relatively low stream power, which likely help to increase the viability of beaver lodges along the main channel banks.

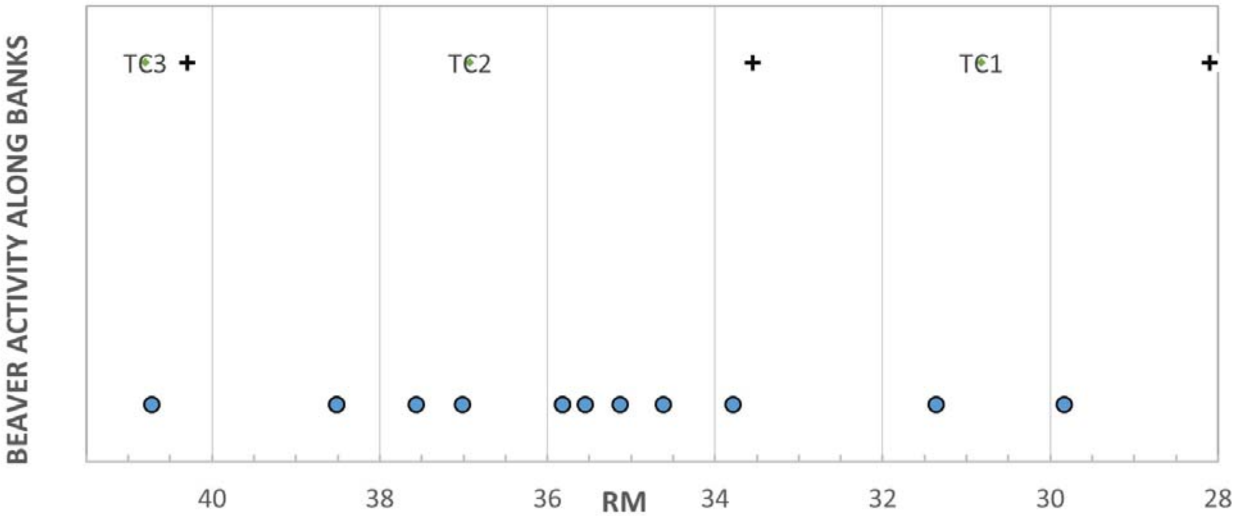


Figure 3-23 Locations of observed beaver activity along the Assessment Reach.

Substrate Size

Grain size data include pebble counts and ocular estimates of bed composition during habitat surveys. Pebble count data include samples collected by Reclamation (2008) and during the habitat surveys completed for this Assessment (2016). Table 3-13 summarizes those data. Median grain sizes in TC1, TC2, and TC3 are respectively 64, 71, and 119 mm. For comparison, Kondolf and Wolman (1993) report a range of spawning gravel median grain sizes of 21 to 47 mm for Chinook, suggesting the reach may be overly coarse to support its natural spawning potential. The coarse grain sizes may be a symptom of deficient wood and corresponding reduced channel roughness, which makes available greater stream power for sediment transport.

Pebble counts were predominantly collected on bars and riffles, but did not specifically target spawning locations. In general, grain sizes appear to exceed the preferable size range for Chinook spawning; however, some caution should be exercised in interpreting sub-reach-scale spawning suitability based solely on these numbers.

Table 3-13 Summary of Grain Size Data for the Assessment Reach*

	TC3	TC2	TC1
Pebble Counts (mm)			
D50	119	71	64
D84	274	130	137
D95	385	171	200
% Gravel (Ocular Estimate)			
Pools	23	34	28
Riffles	27	40	34
Glides	No Glides	41	35

	TC3	TC2	TC1
% Cobble (Ocular Estimate)			
Pools	50	36	38
Riffles	43	41	43
Glides	No Glides	38	43

* Pebble count statistics are averages for all samples (bar and cross-section samples) within each sub-reach.

Temperature

An aerial FLIR survey of stream temperature was completed in 2009 (Watershed Sciences, see maps in Appendix A), which shows temperatures at the time of the late-August flight. The most pronounced pattern in the survey is downstream warming along the Assessment Reach, from roughly 16.5^{oC} in the upper reach to roughly 18˚C at the lower end. The most pronounced warming appears to occur between RMs 35 and 33. While local variations in temperate exist, the only truly obvious cool temperature anomaly along the reach is located at RM 39.1. Besides that, cool water areas generally, but not exclusively, are associated with deep pools.

3.5.7 Summary and Rating of Existing Conditions

Existing conditions, as outlined in the sections above, are summarized in Table 3-14 relative to a series of habitat targets that tie directly to the ecological concerns identified for the Assessment Reach in the Upper Columbia Biological Strategy (RTT 2014) and discussed in Section 2.4.2 in this report. Target conditions were gathered from relevant regulatory and scientific literature, and are discussed in greater detail in Section 5.2. For each condition, a rating of “Adequate,” “At Risk,” or “Unacceptable” was assigned to reflect the current condition relative to the target. Adequate ratings are assigned when the target condition is met. Criteria for “At Risk,” or “Unacceptable” are outlined in Appendix C.

Table 3-14 Summary of Existing Conditions Relative to Target Conditions. Definitions for "Adequate," "At-Risk," and "Unacceptable" Conditions Ratings are Available in Appendix C

Condition / Process	Ecological Concern	Target Condition (Condition for "Adequate" on right)	Source	Sub-Reach Condition Ratings		
				TC3	TC2	TC1
Floodplain Connectivity	Side Channel and Wetland Conditions	Off-channel areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions and riparian vegetation and succession	NMFS, 1996	At-risk - extensive riprap, low natural potential	Unacceptable - levees and riprap	At risk - low natural potential
Off-channel Habitat	Side Channel and Wetland Conditions	Frequent backwaters with cover, and low energy off-channel areas (ponds, oxbows, etc.)	NMFS, 1996	At risk - low natural potential, few backwaters	Unacceptable - levees and riprap, few backwaters	At risk - low natural potential, few backwaters
Channel Migration	Multiple	Channel is migrating at or near natural rates	Reclamation, 2011; YNF 2012	At risk - low natural migration rates	Unacceptable - levees and riprap, limited migration	At risk - low natural migration rates
Wood Frequency	Instream Structural Complexity	>80 pieces/mile, >12" diameter > 35' length and adequate sources of woody debris recruitment in riparian areas	NMFS, 1996; Fox and Bolton, 2007	Unacceptable - 2 pieces per mile	Unacceptable - 51 pieces per mile	Unacceptable - 21 pieces per mile
Key Piece Frequency	Instream Structural Complexity	>16 key pieces/mile with minimum volume of 10.75 m^3 (roughly a 35' log, 3.5' diameter, and 7' diameter rootwad)	Fox and Bolton, 2007	Unacceptable - <1 key piece per mile	Unacceptable - <5 key pieces per mile	Unacceptable - <3 key pieces per mile
Pool Frequency	Bed and Channel Form	Meets standard of one pool per 6 channel widths and LWD recruitment standards for properly functioning habit	USFS, 1994, NMFS, 1996	Unacceptable – 11.4 channel widths per pool, diminished LWD	Unacceptable – 8.0 channel widths per pool, diminished LWD	Unacceptable – 7.8 channel widths per pool, diminished LWD
Pool Quality	Bed and Channel Form	Pools >1 meter deep with good cover and cool water, minor reduction of pool volume by fine sediment	NMFS, 1996	At risk - pools lack cover	At risk - pools lack cover	At risk - pools lack cover
Canopy Cover within 100'	Riparian Condition	Trees and shrubs within one site potential tree height distance (100') have >80% canopy cover that provides thermal shading to the river	Reclamation, 2011; YNF, 2012	At risk - 58% canopy cover within 100'	At risk - 71% canopy cover within 100'	At risk - 59% canopy cover within 100'

Condition / Process	Ecological Concern	Target Condition (Condition for “Adequate” on right)	Source	Sub-Reach Condition Ratings		
				TC3	TC2	TC1
Riparian Age Composition	Riparian Condition	>80% mature trees (medium-large) in the riparian buffer zone (defined as a 30-meter belt along each bank) that are available for recruitment by the river via channel migration	Reclamation, 2011; YNF, 2012	Unacceptable - 20% large/mature trees	At risk - 60% large/mature trees	Adequate - 81% large/mature trees

YNF = Yakama Nation Fisheries

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4 Sub-reach-Scale Conditions

The subsequent discussion of sub-reach-scale conditions will be aided by review of the map folio of existing conditions in Appendix A.

4.1 Sub-reach TC3 (RM 41.3 to RM 40.3)

4.1.1 Sub-reach Overview

TC3, the most upstream segment of this Assessment Reach, extends 1 mile from the Twisp River confluence downstream to the first side channels occupied most recently following the 1942 and 1948 floods. Within this sub-reach, the channel is single-thread, confined between terraces that stand 15 feet or more above the low-water surface and with no more than about 200 feet of space, bank-to-bank, for the channel to occupy. The channel path has been essentially constant for more than 50 years. A significant sediment load is delivered to the head of this sub-reach by the Twisp River, which has built a persistent fan with multiple shifting channels into the west side of the Methow River valley, but whose sediment load largely passes through TC3, with only minor deposition along the lateral margins of the mainstem Methow River (most persistently at RM 40.75).

Despite the high, relatively resistant banks (including bedrock on the left bank from RMs 41–40.8) and minimal historical channel shifting, riprap revetments are nearly ubiquitous through this sub-reach, with over 50 percent of the banks armored. The crossing of Highway 20 at RM 40.47 is one additional constraint on bank erosion and channel migration. On the right bank, parcels are generally small (0.5–1 acre) with residential structures set back 50 feet or more from the active channel; along the left bank, only about half a dozen parcels are located along the channel, with few constructed buildings (of which the closest, just downstream of Highway 20, is about 40 feet from the top of the bank).

4.1.2 Forms and Processes

Geology, Geomorphology, and Channel Migration Zones

The channel is bounded by presently inactive fluvial terraces for much of its extent, a pattern broken only by bedrock outcrops that extend for about 0.2 miles along the left bank downstream of RM 41 (and a localized outcrop at RM 40.25, just past the left bend that marks the downstream end of this sub-reach). While the precise ages of these terraces are unknown, they appear to reflect gradual (likely over the course of thousands of years) channel incision and eastward movement of the Methow River following the Pleistocene glacial epoch. Correspondingly, the terraces are likely composed of valley fill deposited during the Pleistocene glacial epoch, but have been sculpted with post-glacial incision and channel movement. The eastward channel movement is likely a consequence of the right-bank (west) entry of the Twisp River at the head of the sub-reach, where sediment deposition gradually pushed the Methow River eastward and has now pinned it against the bedrock of the eastern valley wall with limited opportunity for lateral movement in modern times. The history of incision and lateral pinning helps to explain the relative narrow geomorphic floodplain in this reach, as compared to TC2 directly downstream. Only where the flows move beyond the lateral and downstream end of the Twisp River's sediment deposition zone have the rates and amplitude of channel migration typical of the sub-reach immediately upstream of here (i.e., sub-reach M4, upstream of the study area, as defined by Reclamation [2008]) become expressed yet again (in TC2; Section 4.2).

Overall, minimal channel migration has occurred in this sub-reach over the last 70 years covered by aerial photographs. The terrace scarp along Alder Street, on the western terrace just upstream of the Highway 20 crossing, suggests a long-past location of lateral scour by an active channel; historical air-photo analysis from Reclamation (2008) places the 1893 channel at this location (Ron Gross, Reclamation, personal communication, 2014). If so, this suggests either a long-ago high-flow condition sufficient to reach this elevation or a systematic lowering of the channel in the intervening century to account for the approximate 15-foot elevation difference between the base of this scarp (the mapped 1893 channel location) and the modern low-flow channel. However, the occurrence of this incision appears to have been unlikely in the last century given that indications of such recent incision are not present in TC2 (i.e., floodplain areas known to be occupied by the channel in the 1800s around Silver are not vertically abandoned with respect to the modern channel). Therefore, the incision recorded by the TC3 terraces is more likely a result of the natural, post-glacial incision as opposed to impacts from human activity in the recent century.

Hydrology

USGS gage 12449500, the only long-term recording flow gage in the entire Assessment Reach, is located in this sub-reach and provides information allowing the overall characterization of reach hydrology as discussed in Section 3.5.1. No significant tributaries enter the mainstem Methow River in this sub-reach.

Vegetation

The riparian corridor along this sub-reach is limited to low shrubs and a narrow (and locally discontinuous) strip of primarily deciduous trees, commonly just one tree wide, along both banks. Somewhat broader patches of riparian forest are present at RM 41.1 (left bank), RM 40.6 (right bank), and RM 40.35 (right bank), but the overall density of trees is low. Only one piece of woody debris on the (limited) gravel bars could be identified from aerial photographs, in addition to those at the mouth of the Twisp River and presumably transported down that tributary.

Off-Channel Features

This reach has only one off-channel feature, an ephemeral floodplain channel on river left at the head of the sub-reach. Natural deposition appears to have closed off the inlet of the channel to all but the largest floods. Since the Reclamation (2014) hydraulic model did not extend to the floodplain channel, its activation cannot be connected to a particular discharge. The channel runs along mature cottonwood forest, and therefore may be an opportunity to increase floodplain activation into an intact riparian area within a generally confined sub-reach.

4.1.3 Effects of Human Alterations

Despite the intrinsic stability of the channel through this sub-reach, bank armoring is extensive on both sides of the river. A few locations with riprap mapped by Reclamation (2008) are now armor-free, but there is no suggestion that bank erosion has accelerated at these locations as a result. Much of the armoring appears to be associated with concern for the protection of East Twisp-Winthrop Road and Wagner Road (left bank), although bedrock along the upstream end of this sub-reach, an absence of buildings through the middle of this sub-reach, and substantial structural reinforcement of the Highway 20 bridge abutments near the lower end of this sub-reach suggest that such efforts may not have been completely necessary.

4.2 Sub-reach TC2 (RM 40.3 to RM 33.7)

4.2.1 Sub-reach Overview

TC2 (RM 40.3–33.7) is a broad, unconfined reach that was previously recognized (Reclamation 2008) as the appropriate focus of habitat-restoration efforts for the Assessment Reach. The channel generally meanders across a relatively wide active floodplain, with multiple secondary, overflow, and abandoned channels. The maximum width of recently active fluvial surfaces and active channels is more than 4,000 feet, with the greatest amount and diversity of floodplain features present in three sections within this sub-reach, referenced for convenience as “Red Shirt Mill” (with the most diverse portions of this section between RMs 40.0 and 39.3; referred to as TC2c), the “Beaver Ponds” (RMs 38.4–35.8; referred to as TC2b), and the “Silver Side Channel” (RM 35.5–33.7; referred to as TC2a).

4.2.2 Forms and Processes

Geology, Geomorphology, and Channel Migration Zones

In this reach, the Methow River has reworked valley and terrace deposits from the last glaciation to their greatest degree in the entire Assessment Reach. Although bedrock lines both valley walls in the upper half of this sub-reach to a similar extent as in the upstream sub-reach, TC3, the channel here has laterally eroded the inset glacial terraces wall-to-wall, particularly from RM 38.7 to 38.0, where the channel traverses the entire valley width, impinging first on the western bedrock wall and then almost directly across to the eastern bedrock.

In both the Red Shirt Mill and Beaver Pond sections, the primary flow paths have been largely unchanged throughout the history of recorded channel positions, but secondary and overflow channels, particularly associated with secondary channel positions in the 1940s, are still prominently expressed in the floodplain topography. Both the main and secondary channels are flanked by recently active fluvial surfaces; they are slightly too high to experience regular inundation or reworking by annual floods but, based on vegetation ages, are products of fluvial activity over the past century. An excellent example of these recent surfaces is provided by the Height Above Water Surface (HAWS) mapping of the upper half of the Beaver Pond section (Figure 4-1), which clearly highlights the active point bar of the modern channel (blues and turquoise on Figure 4-1 just east of the channel at RM 37.75) from the higher, but still fluvially modified, terrace immediately west (shaded in greens, yellows, and browns). The recently active side channel behind (i.e., west of) this bar complex is also well displayed, with elevations locally lower than those of the main channel. Also clearly displayed in this imagery is the narrow west-to-east-trending levee, which separates the main channel from its side channels on the right bank at RMs 38.4 to 38.2.

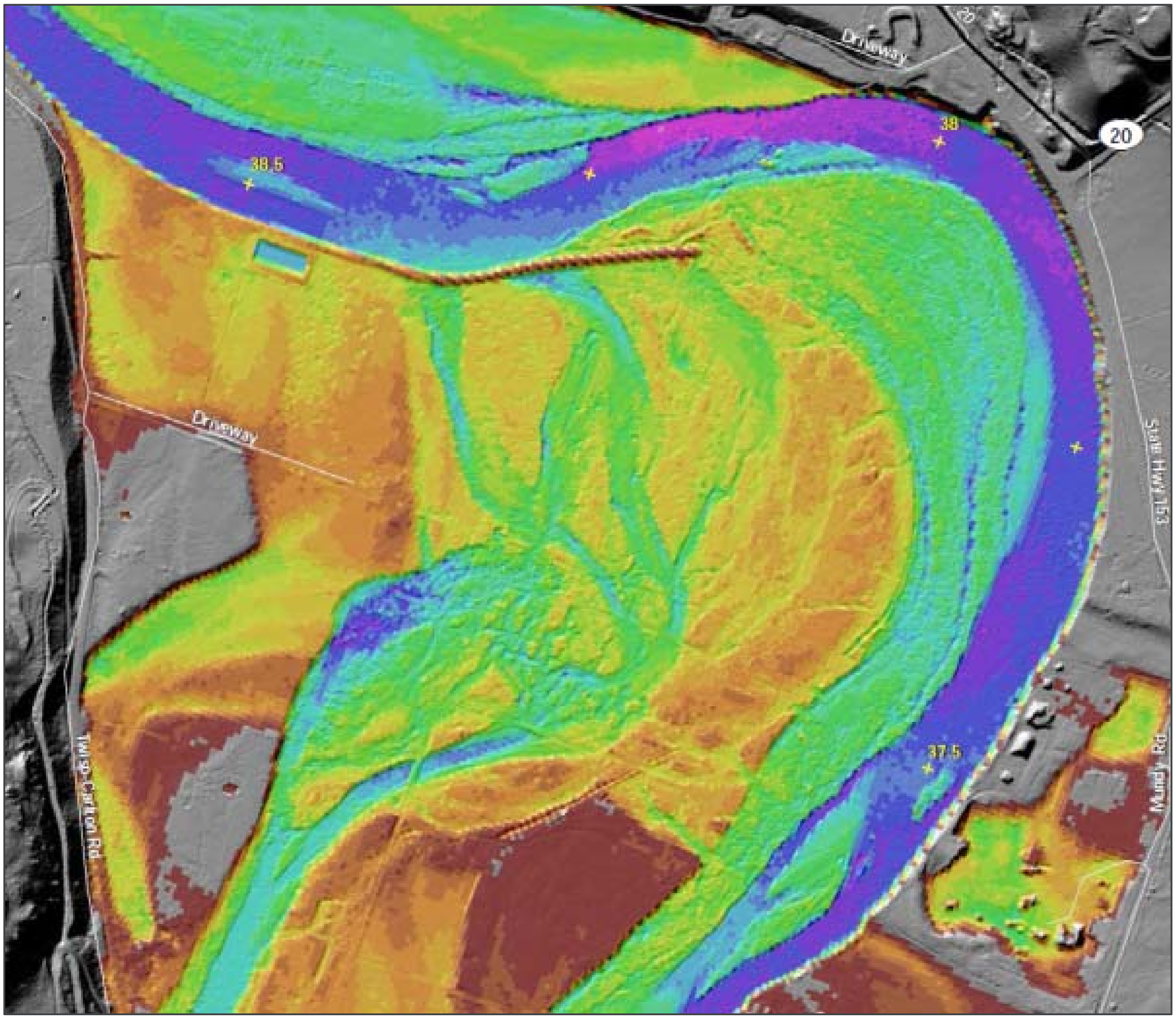

Figure 4-1 Extracted HAWS imagery (Appendix A) for the upper part of the Beaver Pond section of TC2.

Note: Elevations are displayed relative to the adjacent water-surface elevation: blue/turquoise = 0–5 feet higher; greens = 5–8 feet higher; yellow/tan/brown = 8–15 feet. Based on reported field measurements of the USGS at gage 12449500, for which a flow of about 11,000 cfs raises the stage about 6 feet at the gage from baseflow levels, the 2-year flood likely inundates up into the green areas wherever floodwaters have access to the floodplain. North is up in the image, which spans about 0.8 miles in lateral (E-W) extent.

The Red Shirt Mill section ends at about RM 39.3, where the active channel directly impinges on bedrock forming the west valley wall and maintains close contact with that boundary for over 0.5 mile. The glacial-age terraces to the east are largely intact, forming a relatively narrow slot no more than 500 feet wide for the Holocene flow of the river through this section of the valley.

The Beaver Pond section begins at about RM 38.4, where the historical secondary and/or overflow channel complex from the 1940s has been blocked by a levee, the prominent east-west-trending linear feature just below RM 38.25 (Figure 4-1). The section is abruptly terminated at RM 35.8 by the dual effects of bedrock on the west bank and the alluvial fan of Beaver Creek on the east bank, forming a narrow passageway about 550 feet wide through which every recorded position of the Methow River over the last century has flowed.

Downstream about 0.5 mile, the valley of the Silver Side Channel section opens into the least confined portion of the entire Assessment Reach, with bedrock impinging only on the west bank of the active channel from RM 34.8 to 34.6 and glacial-age terraces eroded back far to the east. Arcuate traces on the terrace surfaces east of RM 34.25 suggest relatively recent channel occupation of this portion of the floodplain, but no historical channels have been mapped in this area, suggesting either older or relatively brief (i.e., not recorded by the episodic air-photos) formation and occupation of these features. The active channel narrows at the bottom of this section between glacial terraces, although flanking bedrock is exposed not far from the channel along both sides of the valley and may be providing additional, unrecognized constraints at shallow depth.

Hydrology

Through TC2, the drainage area of the Methow River increases by about 125 mi^2 (a 9 percent increase). Nearly all of this (112 mi^2) is from the addition of Beaver Creek, a steeply sloping left-bank tributary that reaches as high as 7,360 feet at its watershed divide. Much of the Beaver Creek watershed was burned during the Carlton Complex Fire of July 2014, which will increase the hydrologic contribution of this tributary to the mainstem for several years post-fire. Hydrophobic soils that resulted from the severity of the fires have contributed substantially to the runoff potential and contributed to soil erosion via overland flows associated with multiple fall and winter storm events (Burned Area Emergency Response [BAER] 2014). This channel was also a substantial source of fine sediment during the rainstorm of August 2014, with heavy (but likely only temporary) accumulations of fine sediment blanketing much of the bed of the river over 0.5 mile downstream of the confluence (Figure 4-2).

Figure 4-2 Fine sand and silt on the bed of the Methow River at RM 35.5, about 0.5 mile downstream of the confluence with Beaver Creek, in October 2014 (left).

Note: At that time, these accumulations of fine sediment became progressively less thick and continuous over the next mile downstream, although local accumulations up to a few inches thick still fringed gravel bars at low-water levels as far downstream as RM 34.6 (right).

Vegetation

Riparian vegetation is quite diverse along this sub-reach, but within this overall variability some consistent patterns are well-expressed. Trees with understory shrubs are common on active fluvial surfaces standing a few feet above the level of low water, particularly adjacent to active point bars on the inside of meander bends (RMs 39.1, 38.3, 38 to 37, 36.8, 36.1, 35.3, 34.8, and 34.1; see Figure 4-3 for one such example). In some locations, dense tree cover extends onto adjacent (and somewhat higher) "recent" fluvial surfaces, but in most localities these rarely inundated surfaces have been cleared of most woody vegetation and converted to pasture. Exceptions to this pattern of denuded recent fluvial surfaces are present only in a few locations, where geographical isolation has encouraged the maintenance of a native vegetation cover (RMs 39.3 [left bank], 38.2 [right], 36.4 [right], 35.4 [right], and 35 [left]).

Elsewhere, the riparian zone is a discontinuous strip of shrubs or scattered trees with sparse coverage and is no more than about 100 feet wide (and commonly much less, or absent altogether). Zones of particularly sparse riparian vegetation as a consequence of adjacent land uses are found from RM 39 to 38.4 (both banks), 38.2 to 37.1 (left bank), 36.9 to 36.7 (right bank), 35.1 to 34.9 (right bank), and 33.9 to the bottom of the reach at RM 33.7 (and beyond) (right bank).

Figure 4-3 Aerial view of the point bar at RM 36.8, displaying the development of a floodplain forest on the active fluvial surface on the inside bend (flow from top [north] to bottom).

Note: Note the even more recent deposition of sediment without significant vegetation on overflow channels to the lower right of the figure. Cleared areas to the north and east of the forest (upper left) lie primarily on a recent fluvial surface about 5 feet higher in elevation than the adjacent forested floodplain. View spans about 0.4 mile in lateral extent.

Commensurate with the limited degree of lateral channel confinement, locally extensive riparian forests, and active channel migration, accumulations of LWD are greatest in this sub-reach. However, almost all LWD are confined to the channel banks and margins, with only a few locations of accumulations on mid-channel bars or within the channel itself. Noteworthy accumulations that regularly interact with the flow are presently (2013 air-photo) found on the bar adjacent to the levee at RM 38.4, at the head (and presumably anchoring) a bar-top forest stand at RM 35.6, and on a mid-channel bar at RM 35.3. The largest accumulation is from RM 34.9 to 34.3, where the channel takes an abrupt left-hand bend through a complex of recently deposited mid-channel bars and somewhat older point-bar deposits. The result is a diverse mosaic of in-channel and overbank habitats, constrained only by the river's impingement on the (right-bank) Twisp-Carlton Road, which limits additional migration.

Off-Channel Features

While there are no perennial side channels in this sub-reach, a number of ephemeral floodplain channels are present. Table 4-1 summarizes the mapped channels and the discharges at which each activates based on the Reclamation (2014) hydraulic modeling results. Two major side channels currently have limited activation resulting from levees constructed at their inlets (Beaver Pond Complex and Silver Side Channels). Other floodplain channels represent possible opportunities to increase the frequency of floodplain inundation, and a subset of channels have alcoves currently wetted during low-flow conditions, which are possible targets for protection or enhancement.

Table 4-1 Information on Existing Floodplain Channels in TC2

Inlet RM	Outlet RM	Length (ft)	Bank	Low-Flow Alcove at Outlet?	Disconnected? *	$Q_{activation}$ (cfs)	Activation Flow Recurrence**	Dominant Vegetation (Reclamation 2008)	Notes
40.2	40.1	917	R	No	No	16,000	5-yr PF	Black cottonwood forest	-
39.9	39.8	758	L	No	No	8,000	1.25-yr PF	Mixed - bars with shrubs and black cottonwood forest	-
39.35	-	182	R	Yes	No	250	Low Flow	-	Wetted, low-flow alcove, no high-flow channel
39.25	39.05	1,258	L	No	No	16,000	5-yr PF	Mixed - bars plus mixed coniferous/deciduous forest	-
38.25	35.85	11,449	R	Yes	Yes	23,000	25-yr PF	Black cottonwood forest/mixed	Beaver Pond Complex - levee limits activation
37.5	37.25	1,169	R	No	No	1,000	25% Ann.	Bar (within active channel)	-
37.25	37	1794	R	No	No	16,000	5-yr PF	Mixed vegetated bars and black cottonwood forest	-
37	-	992	R	No	No	25,700	50-yr PF	Residential/ agricultural area	Secondary inlet to Beaver Pond complex
36.9	36.1	4,121	L	Yes	No	11,100	2-yr PF	Mixed - bars, black cottonwood/ coniferous forest	Side channel complex
36.25	35.85	1,730	R	Yes	No	16,000	5-yr PF	Black cottonwood forest	Reconverges with main channel at same location as Beaver Pond Complex
35.7	35.6	650	L	Yes	No	1,000	25% Ann.	Bar (within active channel)	Within active channel
35.6	35.5	819	R	Yes	No	3,000	15% Ann.	Bar (within active channel)	Within active channel

Inlet RM	Outlet RM	Length (ft)	Bank	Low-Flow Alcove at Outlet?	Disconnected? *	$Q_{activation}$ (cfs)	Activation Flow Recurrence**	Dominant Vegetation (Reclamation 2008)	Notes
35.4	35.2	896	R	No	No	6,000	5% Ann.	Vegetated bar/mixed forest	
35.35	34.25	7,041	L	Yes	Yes	10,000	1.5-yr PF	Upland forest/wetland	Silver Side Channel (including upstream-most entrance)
35.25	-	853	L		No	16,000	5-yr PF	Upland forest	Silver Side Channel (2nd entrance)
35.2	-	1,736	L		No	6,000	5% Ann.	Upland forest	Silver Side Channel (3rd entrance)
35.1	-	2,184	L		No	16,000	5-yr PF	Mixed coniferous/ deciduous forest	Silver Side Channel (4th entrance)
34.1	33.9	2,075	R	Yes	No	19,200	10-yr PF	Mixed deciduous shrubs	-
34	33.75	1,370	L	No	No	16,000	5-yr PF	Upland forest	-
33.9	33.8	679	L	No	No	5,000	7% Ann.	Black cottonwood forest/vegetated bars	-

* Disconnected indicates the channel has activation limited by a levee.

** PF denotes “Annual Peak Flow” and Ann. denotes “Annual Exceedance Statistic”

4.2.3 Effects of Human Alterations

Bank armoring is widespread in this sub-reach, although it also includes the greatest percentage of armoring mapped in 2008 that has since been eroded away by the river (Figure 4-4). Most prominent of the human alterations affecting river processes in the entire Twisp to Carlton reach is the right-bank levee at RM 38.3, whose eastern 1,000 feet block access of the river to an extensive side channel complex that constitutes the Beaver Ponds section. Sections of riprap line both banks of the channel between the Red Shirt Mill and Beaver Ponds sections (RM 38.8), a mile on the outside bend from RM 38.2 to 37.2 to protect State Highway 20 and adjacent property, and scattered armoring through the Silver Side Channel section, including armor of a stable bedrock face at RM 34.75 and nearly a mile of right-bank riprap beginning at RM 34.2 and continuing into the next sub-reach. Most of this armoring supports high-bank property and infrastructure on the upper, inactive fluvial surface, but in several locations the riprap is clearly limiting channel migration and floodwater occupation of recently active channels and floodplain surfaces. These areas are highlighted in the identification of potential projects, below.

Figure 4-4 RM 36.5, looking upstream.

Note: The pipe is at the approximate location of the right bank of the river in photos from 1998–2006; since that time, the bank at this site has been eroded by about 100 feet.

4.3 Sub-reach TC1 (RM 33.7 to RM 28.1)

4.3.1 Sub-reach Overview

Downstream of RM 33.7 to the end of the Twisp to Carlton reach at RM 28.1 (TC1), the channel is again confined between presently inactive surfaces and several alluvial fans. Bedrock only impinges on the channel in two locations, at RMs 31.4 and 29.8, but the valley as a whole is carved deeply within a bedrock landscape, now largely filled with late-glacial-age terrace deposits that stand well above the elevation of the active river channel. No historical channel positions outside of the present flow corridor have ever been recorded, and opportunities for expanding the active floodplain surface or providing access to side channels are not evident. Thus, off-channel restoration opportunities in this sub-reach are limited, a condition first documented by Reclamation (2008) and reaffirmed here. However, opportunities exist to create habitat along the channel banks and within the channel.

4.3.2 Forms and Processes

Geology, Geomorphology, and Channel Migration Zones

In direct contrast to TC2 immediately upstream, TC1 is distinguished by morphological simplicity in both the active channel and the adjacent fluvial surfaces. This simplicity is primarily a function of the natural confinement of the sub-reach. Nowhere is the width of the active floodplain more than twice that of the low-flow channel; in many locations the two are nearly the same, with the river bounded by steep valley walls mainly cut into inactive fluvial deposits. Flood flows are consequently focused throughout this sub-reach, and help to maintain a naturally simple channel. However, the minimal wood in the sub-reach also contributes to the channel simplicity, suggesting the possibility for habitat creation using LWD jams.

Sediment inputs from tributaries provide some localized complexity along the sub-reach. Two small left-bank alluvial fans deposited from tributaries, Benson Creek (RM 33.2) and Canyon Creek (RM 32.9), do not appear to have materially affected the long-term location of the river; however, a more extensive right-bank fan at RM 32.2, emerging from the intermittent drainage of Booth Canyon, has likely determined the lateral position of the river for over 0.25 mile both upstream and downstream. An alluvial fan complex draining the bedrock hills west of the river from RMs 31.2 to 29.8 does not appear to have extended far out onto the intervening fluvial terraces; but across the river at RM 30.65, an unnamed drainage emerging from Leecher Canyon produced one of the most prominent deposits of sediment into the Middle Methow River resulting from the August 21, 2014, rainstorm (Figure 4-5), a consequence of draining a watershed largely burned during the Carlton Complex Fire. Given its position at the outside of a very long-lived bend of the Methow River, it is surely a short-lived feature of the active channel, but it does reflect the episodic nature of sediment delivery into this system where lateral channel migration is minimal and fire-and-flood sequences are not uncommon.

Figure 4-5 View of the alluvial fan at RM 30.65, extending from the left bank across more than half of the active channel width, which was deposited during the August 21 rainstorm.

Hydrology

Few tributaries of any significant size enter the Methow River in this sub-reach. The largest, Benson Creek (38 mi^2 drainage area), provides almost half of the entire gain in overall watershed area from the head of this sub-reach (1,450 mi^2) to the end of the Twisp to Carlton reach (1,531 mi^2). The next USGS gage lies about 1 mile downstream of the end of this sub-reach (12449760, Methow River at Carlton), at about RM 27, but it was in operation only from 2001 to 2003. However, for those two (water) years, its record overlaps with that of the gage at the top of the Twisp to Carlton reach (USGS 12449500), and their records for all but the period of wintertime baseflow overlap almost perfectly (Figure 3-3).

Vegetation

This sub-reach is almost completely homogenous with respect to riparian vegetation. A thin screen of trees, typically no more than a single tree wide, lines most of the terrace edges. Vegetation at the water's edge is generally restricted to low shrubs and willows, owing to the steep banks and (to a lesser extent) sporadic bank armoring. The upland fluvial terraces, standing 10 to more than 50 feet above the water surface, are almost entirely in pasture or other cultivated crops, with scattered residences and two highways (Twisp-Carlton Road and State Route 153) that flank both sides of the river, locally impinging on meander bends and contributing to a general absence of overstory vegetation throughout this sub-reach.

As with TC3, LWD in this reach is sparse and almost entirely confined to lateral channel margins. This is both a cause and a consequence of the homogeneity of this sub-reach, whose lack of geomorphic diversity provides few opportunities for wood to lodge; the general paucity of logs limits occasions for multiple pieces to interact and form a persistent, flow-deflecting jam. The only exception is the narrow mid-channel bar at RM 31.3, where several dozen logs (each substantially shorter than the channel is wide) have interlocked to form a stable jam whose initiation postdates the 2006 air-photo (Figure 4-6). This secondary channel behind this mid-channel bar was mapped as perennial side channel in 2016 habitat surveys (as discussed below).

Figure 4-6 Aerial view of the log jam at RM 31.3, taken July 2013 (from Google Earth).

Note: Most logs are 40 feet long or less and would be insufficient as individual pieces to obstruct even the narrow side channel (yellow line = 50 feet). Flow is from top (north) to bottom.

Off-Channel Features

Owing to its consistent natural confinement, this sub-reach is almost entirely devoid of off-channel features with the exception of the perennial side channel present at RM 31.3 and an ephemeral floodplain channel at RM 30.6 (both on river right). This side channel is dominated by fast and turbulent flow (riffle habitat) and is separated from the main channel by an island of shrubs and some immature trees (roughly 10 years old). The high-flow channel at RM 30.6 currently activates at roughly 8,000 cfs, or the 1.25-year peak flow.

4.3.3 Effects of Human Alterations

Bank armoring is common throughout this sub-reach, particularly at the outside of bends (and ubiquitous where a roadway lies immediately adjacent). Its influence on riverine processes in this sub-reach is limited, however, because the channel has displayed little propensity for lateral migration over the past century. This suggests that much of the armoring, all of which postdates the 1893 channel position and may also be post-1940s, may not be particularly effectual or necessary, insofar as channel migration activity (and thus lateral erosion) are intrinsically low throughout this sub-reach. In some cases, this armoring has adjacent, relatively deep pools, suggesting it can act as a forcing agent for pool scour.

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5 Restoration Strategy

5.1 Introduction

Examination of the Twisp to Carlton reach of the Methow River has identified several watershed processes that are critical to the creation and maintenance of diverse habitats throughout this reach, and that have been significantly impaired by past human actions. These impairments have resulted in substantial reductions in specific habitat types that have been previously recognized as pervasive and persistent limiting factors at the watershed scale and diminished the carrying capacity of the river to support recovery of steelhead and spring Chinook salmon. We therefore believe that the Twisp to Carlton reach provides a textbook example of the critical linkages between impaired processes, degraded habitat, and reduced fish populations, and that the most successful approach to restoration in this reach and throughout this watershed will be to approach the identification and prioritization of specific restoration actions through the same lens.

5.2 Existing and Target Habitat Conditions

The gap between existing and target conditions is a key consideration for restoration strategy development and restoration prioritization. Table 3-14 outlined a summary of existing conditions relative to target conditions gathered from scientific literature and regional tributary and reach assessment literature. The rationale and strategy for each of these target conditions, as well as the addressed ecological concerns, are provided below:

> Floodplain Connectivity (Ecological Concern: Side channel and wetland conditions): The target condition for floodplain connectivity is: “Off-channel areas … frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession” (NMFS 1996). The target condition is sufficiently general to be applied along the entire reach while providing an established definition that captures the range of processes and features expected for a connected floodplain.

> Off-Channel Habitat (Ecological Concern: Side channel and wetland conditions): The target condition for off-channel habitat is: “Frequent backwaters with cover, and low energy off-channel areas (ponds, oxbows, etc.)” (NMFS 1996). This definition meets the same criteria as the target for floodplain connectivity above.

> Channel Migration (Multiple Ecological Concerns): To meet the target condition, the channel must be migrating at or near natural rates (Reclamation 2011; YNF 2012). This definition appropriately puts existing migration rates into context with natural rates, which naturally vary substantially along the Assessment Reach.

> Wood Frequency (Ecological Concern: instream structural complexity): The target condition is greater than 80 pieces per mile (larger than 12-inch diameter and 35-foot length), with adequate sources for woody debris recruitment in riparian areas, which is the NMFS (1996) definition altered according to Fox and Bolton (2007)’s suggestion for wood frequency targets in east-side Cascade rivers.

> Key Piece Frequency (Ecological Concern: instream structural complexity): The target condition is a frequency of greater than 16 key member forming logs meeting size criteria recommendations from Fox and Bolton (2007). The size criteria is defined volumetrically at 10.75 m^3, which translates to a 35-foot log roughly 3.5 feet in diameter, with a 7-foot diameter rootwad.

> Pool Frequency (Ecological Concern: bed and channel form): The target condition is derived from USFS (1994) criteria, which formed the basis for the NMFS (1996) definitions for Properly Functioning

Condition. The USFS suggests a pool frequency that scales with channel width: one pool per six channel widths. In the Assessment Reach, this translates to one pool per ~1,500 feet.

> Pool quality (Ecological Concern: bed and channel form): The target condition, taken from NMFS (1996), is “Pools >1 meter deep with good cover and cool water, minor reduction of pool volume by fine sediment.”

> Riparian Canopy Cover within 100 Feet (Ecological Concern: riparian condition): The target condition of 80 percent canopy cover within approximately one site potential tree height (100 feet) from Reclamation (2011) and YNF (2012) was chosen to be consistent with similar reach assessments in the region.

> Riparian Age Composition (Ecological Concern: riparian condition): The target condition of 80 percent mature trees in the riparian buffer zone is again consistent with Reclamation (2011) and YNF (2012).

Table 3-14 provides qualitative ratings, on a sub-reach basis, of existing conditions relative to the above target conditions. Sub-reaches meeting target conditions are assigned an “Acceptable” condition rating, and those not meeting the target condition are assigned either an “At-risk” or “Unacceptable” condition rating according to definitions provided in Appendix C.

A vast majority of conditions ratings are either At-risk or Unacceptable, with the only Acceptable rating associated with riparian age composition in TC1. The greatest concentration of “Unacceptable” ratings is associated with metrics of large wood, key piece, and pool frequencies, for which all sub-reaches are rated as Unacceptable. On a sub-reach basis, TC2 has the lowest average rating, with six of eight conditions rated “Unacceptable.” This concentration in part reflects the higher natural potential of TC2 compared to the others, which are largely confined and therefore have less available improvement potential in floodplain connectivity, off-channel habitat, and channel migration conditions.

5.3 Trajectories under a No Action Alternative

In terms of almost all measures, the overall degradation of the Assessment Reach is expected to continue without intervention and restoration. A fundamental constraint on the natural recovery of the Assessment Reach (particularly in TC2) is the pervasive bank hardening and levees that limit the processes of channel migration, wood recruitment, floodplain connection, riparian vegetation establishment, and overall habitat formation. The limited rates of these processes means that the current trajectory toward improvement is marginal to nonexistent. Under a no action alternative, bank armoring and flood protection features will generally remain in place, and, in cases were the river does manage to erode them, the structures are likely to be replaced with even more substantial material. Therefore, from a process rate perspective, the currently suppressed rates are expected to continue. In terms of channel migration and habitat formation rates, the minor rates observed during recent decades (as shown in Table 3-8) are likely to continue. As a result, conditions in channels, riparian zones, and the overall floodplain are expected to remain in their relatively degraded state for the foreseeable future under a no action alternative. While quantitative rates toward target conditions cannot be feasibly calculated for most metrics, comments are provided for each below:

> Channel Migration and Habitat Formation (Multiple Ecological Concerns): Likely to continue at rates observed over recent decades (Table 3-8).

> Floodplain Connectivity (Ecological Concern: Side channel and wetland conditions): Likely to remain relatively unchanged without removal of riprap and levees and improved in-channel wood frequency.

> Off-Channel Habitat (Ecological Concern: Side channel and wetland conditions): Same as floodplain connectivity above.

> Wood Frequency (Ecological Concern: instream structural complexity): The frequency of in-channel wood may marginally improve over time with delivery of logs following large fires and reduced logging

in tributary headwater areas. However, recruitment of wood from riparian zones in major valleys is likely to remain suppressed. Similarly, the lack of key member logs, which are likely to remain highly deficient, will limit the ability of the Assessment Reach to retain small and medium-sized wood.

> Key Piece Frequency (Ecological Concern: instream structural complexity): The frequency of key-member forming logs is likely to remain low without intervention, given limited recruitment of large logs. Even if delivery of wood from tributaries and headwater areas increases relative to recent decades, the wood delivered from these areas is likely to be relatively small (i.e., smaller channels are likely to retain the largest logs).

> Pool Frequency (Ecological Concern: bed and channel form): Without the presence of large log jams, the frequency of pools is likely to remain relatively constant.

> Pool Quality (Ecological Concern: bed and channel form): Current pool depths (many of which meet depth targets) likely reflect equilibrium for the current condition, but the lack of wood and cover is expected to remain diminished.

> Riparian Canopy Cover and Age Composition (Ecological Concern: riparian conditions): While existing riparian forests are expected to mature through time, their extent will likely remain limited without protection and restoration efforts.

5.4 Identification of Potential Habitat Actions

The identification of potential habitat actions is a direct outcome of identifying those riverine processes that are most highly constrained and understanding the consequences of those constraints on the ecological functions that play a dominant role in determining habitat availability for native fishes. For example, if juvenile rearing and overwinter habitat is thought to be one of the factors most limiting to restoration of spring Chinook and steelhead, and these habitats are typically found in off-channel and backwater areas with slow velocity, cool summer temperatures, moderate depths, and abundant cover, one would focus on those processes that allow the river to occupy its historical floodplain areas.

For this Assessment, our key working assumptions are as follows:

1. In this reach of the Methow River, poor growth and survival of the juvenile life stage of Chinook and steelhead, rather than a lack of adult spawning habitat, is the most important factor in the recovery of steelhead and spring Chinook populations (RTT, 2014).
2. Habitat carrying capacity to support recovery of spring Chinook and steelhead within this reach has been limited by an overall loss of connectivity with historical floodplain habitat features, the simplification of in-channel habitats, and a reduced extent and diversity of native riparian plant communities (RTT, 2014).
3. Restoration actions focused on restoring river processes that allow the river to reoccupy historical channel surfaces, promote growth of extensive riparian areas, and allow recruitment and retention of channel roughness elements (thus supplying LWD to the channel) will ultimately provide and sustain habitat complexity and off-channel habitats that would benefit the juvenile/pre-smolt life-history stages of the species of concern.

A focus on these fundamental river processes allows for identification of discrete areas in the Assessment Reach where investments in habitat protection and restoration supportive of those processes are warranted. Restoration actions appropriate for sites that address the current constraints on these processes would, by extension, help resolve current habitat limitations and thus contribute to increasing carrying capacity for juvenile and sub-adult Chinook and steelhead.

Within these areas of protection and restoration actions, the following activities are likely to be most effective at restoring key river processes that will ultimately help to address key limiting conditions for fish species of concern:

> Recover river processes that allow the river to reoccupy historical floodplain surfaces by removing artificial constraints to lateral channel migration, expand the seasonal availability of off-channel habitats to support juvenile salmon, recharge hyporheic flow pathways, promote floodplain forest rejuvenation, and develop greater hydraulic (and thus habitat) complexity within the reach. This would be accomplished through removal and/or regrading of artificially filled areas (riprap and levees) of the floodplain to reestablish channel migration, habitat formation, and inundation of disconnected side channels (both active and relict) or historical off-channel features such as old flow pathways, alcoves, and backwater beaver ponds. Reconnection of floodplain features, over time, would increase juvenile rearing and winter refuge habitat, which in turn would provide slow-water habitat to accommodate foraging behavior and provide cover (from predators) for juvenile steelhead and spring Chinook. Ancillary actions could include riparian restoration and structural improvements along the margins of the existing channel to improve cover. The specific design of these enhancements would require evaluation of the flow events (or seasons) that would connect these features to the main channel, a task that is invariably executed during the project design phase.

> Reestablish riparian forest through conservation easements or other mechanisms to provide increased shade and cover, provide a source for the long-term recruitment of LWD, and increase riparian shade, undercut banks, and cover along existing channel margins to improve juvenile foraging and edge/holding habitat.

> Reestablish in-channel obstructions to flow to promote physical heterogeneity by inducing localized scour and deposition and varied bed topography, and promoting localized exchange of surface and hyporheic flow. This would increase vertical and lateral hydraulic complexity and locally sort bed substrate materials to create a wider range of more diverse patches. Enhancing these processes would increase localized habitat functions, increasing juvenile rearing and foraging habitat and facilitating adult migration in the main river. These actions might include boulder cluster placement and placement of LWD on gravel bars and in other naturally occurring locations.

5.5 Development of Criteria for Project Prioritization

Beechie et al. (2008) provide a conceptual framework for determining how best to prioritize a list of identified restoration projects based on the principles of process-based restoration, suggesting five prioritization strategies by which projects may be ranked:

1. *By project type* (sequence projects in the following order: [a] protect intact habitats, [b] remove migration barriers to intact habitats, [c] restore watershed processes, and [d] enhance instream habitat);
2. *By suitability as refugia* (start by protecting intact habitat with intact populations and then expand spatially—where proximity to existing intact habitats is presumed to indicate greater habitat value);
3. *As benefiting a single species* (use population modeling to predict net project benefit, typically in population size, to a selected focal species);
4. *As benefiting multiple species* (use population modeling to predict net project benefits to multiple species as indicators of broader ecosystem health); and
5. *Cost effectiveness* (evaluate the quantifiable presumed benefit per unit dollar cost, and begin with the projects having the best ratios).

To facilitate the selection process, Beechie et al. (2008) also included *decision-support systems* within their list of alternative prioritization approaches (i.e., any system that uses a numerical ranking approach to quantify ratings), but they noted that these are typically used to implement any of the other approaches rather than constituting a stand-alone category themselves. Many such systems are now available, and they each require different levels of information and offer a range of complexity.

Prior reach assessments (e.g., Reclamation 2010) have used the first strategy (project type) to prioritize actions. This reflects the absence of reliable fish population modeling needed to implement the single- or multi-species approach or any biologically meaningful cost-effectivity metrics. According to this project type approach, projects should be prioritized in the following order:

1. Protect intact habitats
2. Remove migration barriers to intact habitats
3. Restore watershed processes
4. Enhance instream habitat

Within the gross ranking of these four project types, however, prior reach assessments have not sought to implement a numerical decision-support framework. This reticence acknowledges that the necessary steps extend well beyond the scope of a reach assessment, as they would require some reliable estimate of the extent of specific habitat types to be gained. Moreover, in addition to technical information, selection criteria required to effectively prioritize projects include political and economic factors (e.g., landowner willingness, infrastructure constraints, cost, and risk). For example, the Entiat River's Gray Reach Assessment states (Reclamation 2013:98): "The potential habitat actions outlined in this report can be grouped in any number of ways or places to form projects. In some instances, only one course of action may be appropriate, whereby project development is relatively simple. In other instances, multiple groupings may be appropriate requiring prioritization based on collaboration amongst project stakeholders."

The prioritization criteria used in this Reach Assessment follows the guidance of these previous examples with a decreasing priority from protection to process restoration to habitat enhancement. Thus, it employs a process that is consistent with prior efforts and likely applicable to future work elsewhere in the Columbia River system. However, this Reach Assessment has strived to make the individual steps and underlying assumptions for the prioritization more explicit than in some of the other recent reach assessments. The intent is not only to make the process more transparent but also to allow for site-specific modifications within the overall framework if subsequently applied elsewhere. We have used an organizational structure for prioritization based on project type and a priority ranking that follows the sequencing of Beechie et al. (2008), using a hierarchical framework for project prioritization that reflects the guidance of process-based restoration.

5.6 Prioritization of Restoration Actions

This Reach Assessment and prioritization focuses on the conceptual linkages identified by Beechie et al. (2008) to identify actions at a landscape scale that can effect a positive biological response for listed species (Figure 5-1). Habitat actions identified within the Assessment Reach focus on improving riparian habitat conditions, increasing off-channel habitat (side channel reconnection and floodplain restoration), increasing habitat diversity, and/or improving bed and channel form. These actions, in part or collectively, are expected to increase steelhead, spring Chinook, and bull trout juvenile overwinter survival, increase pre-smolt foraging opportunities by increasing hydraulic habitat complexity, and provide additional adult holding and migratory habitat, and spawning success (UCSRB 2007).

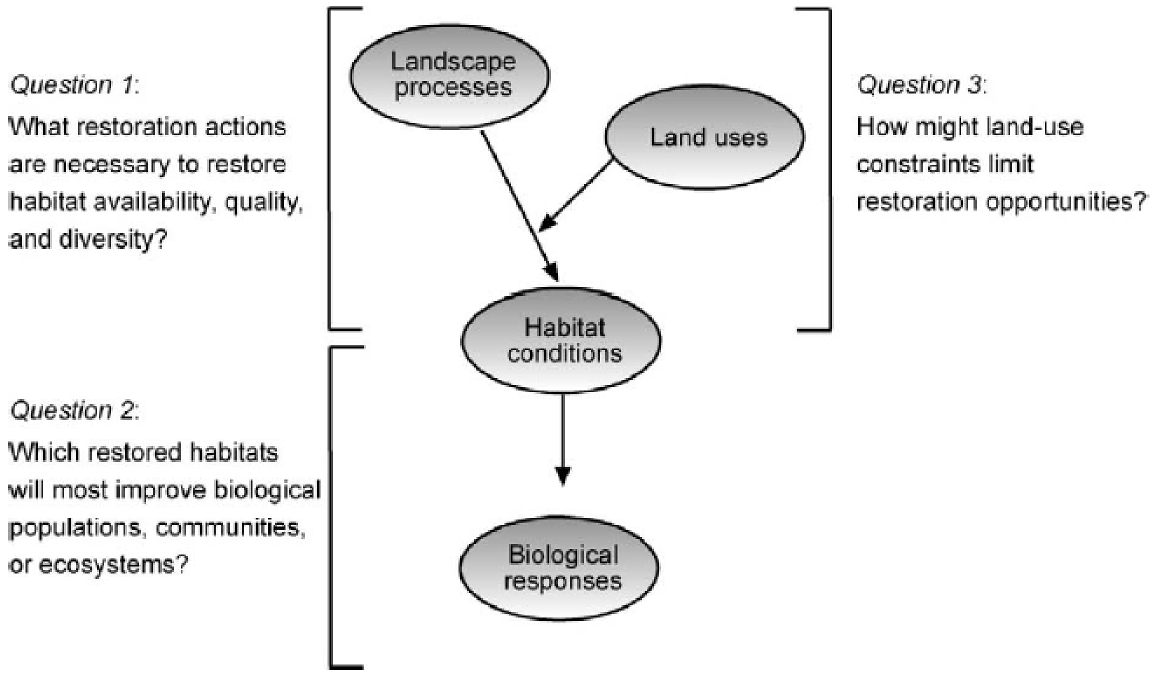

Figure 5-1 Conceptual Framework (Beechie et al. 2008).

The prioritization of restoration actions within the Twisp to Carlton reach was developed in coordination with CCFEG staff and stakeholders and resulted in simple decision matrices to display the range of options. The prioritization follows the logical methodology outlined by Beechie et al. (2008) and Roni et al. (2002), recognizing the physical and biological processes that yield ecological functions that support aquatic communities. The prioritization employed here relies on simple tools that were vetted through a systematic consideration of potential protection/restoration actions and ranked in consideration of their contribution to:

1. Protection of intact habitats;
2. Restoration of watershed processes, and
3. Enhancement of instream habitat at strategic and complementary locations.

Recommendations for protection of existing high-quality habitat were given a higher priority than habitat restoration, as it is easier to maintain existing habitat than restore degraded habitat (Roni et al. 2002). Therefore, our primary recommendations are for the protection of high-quality riparian corridors in the Assessment Reach. The next tier of actions relates to restoration of watershed processes. Projects that have a high probability of success and relatively quick response time would ideally be implemented prior to projects whose outcomes are more uncertain and require a longer response time (i.e., less consistent results). For example, riparian restoration projects may not produce results for many years and should be considered after projects that focus on reconnecting high-quality isolated habitat (Roni et al. 2002). Although habitat creation projects are often successful at locally increasing short-term fish production (Roni et al. 2002), they focus on treating symptoms of degradation rather than its cause (Beechie et al. 2010). In recognition of both the benefits and the limitations, habitat creation actions recommended in this Assessment include the introduction of boulder clusters and large wood into the system. While these activities would provide immediate improvements in channel diversity, riparian restoration and actions promoting channel migration would address the underlying process impairments more effectively and will be more likely to provide long-term benefits.

The potential actions identified below have been identified using sound scientific principles and information from relevant biologic, geomorphic, and engineering disciplines. Accordingly, they would be expected to address limiting factors and provide biological benefits within the Assessment Reach while maintaining the natural characteristics of the reach. This ensures that recommended restoration actions would improve habitat for multiple aquatic species present in the reach, as they would create habitat akin to conditions that local fish populations have adapted to.

Prioritized actions identified for the Assessment Reach are provided in reach-specific strategy tables below. Based on Reclamation's 2008 reach assessment and the site-specific sub-reach assessment presented in this report (Section 4), TC2a, b, and c present the highest restoration potential, with TC2b, the Beaver Pond section, providing the best overall opportunity to restore riverine processes and positively affect key salmonid limiting factors. TC3 has limited restoration potential, but it could nonetheless benefit from selective introduction of instream complexity to create habitat heterogeneity and riparian protection/enhancement activities. TC1 has low restoration potential; its primary ecological function is material transport, providing a corridor for adult migration and juvenile foraging, and contributing to food web dynamics (Bellmore et al. 2013). The strategy presented in Section 5.8 follows the rationale described above of prioritizing protection, restoration of process, and then habitat improvement actions. Within each of these categories, individual actions were further ranked based on the opportunity for improvement based on the sub-reach assessment. This ranking generally follows the summary above with higher priority given to projects in TC2a–c and lower priority to projects in TC3 and TC1. Conceptual locations and schematics of restoration actions are provided in Appendix A.

Restoration and protection actions discussed in this Assessment, by intent, are concept-level only. The reach-scale scope of this Assessment and the lack of detailed engineering on a site-specific level of detail limit the ability to quantify the relative feasibility or to develop a cost estimate for any specific project. Further evaluation and development of potential actions within the Assessment Reach should be undertaken by basin stakeholders knowledgeable of the local conditions and feasibility constraints. Once this filter has been applied and a more feasible list of projects has been identified, detailed project evaluations can proceed. These might include additional site assessments, hydraulic modeling, and detailed project design alternatives.

5.7 Action Type Descriptions

Below are descriptions of the restoration action types outlined in the restoration strategy. Each action type is categorized by approach (protection, process restoration, and habitat creation).

5.7.1 Riparian Protection (Protection Approach)

This action type includes protection of existing, intact patches of riparian forest exceeding roughly 150 feet width. In general, the riparian forests are discontinuous and narrow along the Assessment Reach, but enclaves of intact forests remain (commonly in areas of historical channel migration). Protection can be accomplished through landowner agreements, conservation agreements, and/or land acquisition.

5.7.2 Protection of Existing Floodplain Habitats (Protection Approach)

This action type involves protection of floodplain areas with floodplain inundation that nearly approximates natural conditions. These floodplain areas were identified using modeled inundation (Reclamation 2014), topography, and field observations. In general, these relatively low and active floodplain areas have unaltered floodplain topography, and therefore accommodate inundation regularly; however, given that floodplain inundation naturally would be enhanced by in-channel LWD jams, the present-day flood inundation may not fully reflect natural conditions. As a result, these areas are likely to benefit from in-channel woody debris placement focused on splitting and deflecting flow onto the floodplain, an action type outlined below.

5.7.3 Riparian Planting and Restoration (Process Restoration)

With the exception of those areas already highlighted for riparian protection, virtually every section of bank would benefit from additional plantings. Highlighted zones are those where at least a 50-foot buffer adjacent to the river is unconstrained by structures or roads, and where the adjacent floodplain or terrace stands no more than about 10 feet above the active channel.

5.7.4 Levee or Riprap Removal/Setback (Process Restoration)

Riprap, and to a lesser degree levees, line the banks of much of the Assessment Reach. Removal of these human modifications restores key habitat forming processes of channel migration and floodplain inundation, and also makes available additional area for riparian planting. All locations of riprap were considered for potential removal, but any area of bank armoring that is clearly protecting structures or roadways was excluded from further consideration regardless of whether historical channel migration had been documented at that location.

5.7.5 Floodplain/Off-Channel Habitat Reconnection via Grading (Process Restoration)

Reconnection of floodplain habitats via selective regrading and excavation of the floodplain will often be required in concert with levee and/or riprap removal. These project sites were recommended where a wide, active channel/floodplain corridor, together with evidence of side channels or past channel occupation, suggests that minimal regrading could open or reopen secondary channels that would have a reasonable likelihood of ongoing self-maintenance. This activity type is within the process restoration approach given that excavation and regrading are only proposed to reconnect or enhance inundation of existing features (as opposed to creating entirely new floodplain habitat features). Floodplain regrading is typically recommended in conjunction with placement of in-channel wood structures that split/redirect flow and provide the hydraulic diversity commonly associated with persistent side channels.

5.7.6 Beaver Reintroduction (Process Restoration)

Reintroduction of beaver to the Methow River floodplain has numerous habitat benefits in the floodplain and along the main channel banks, including increased floodplain connectivity, vegetation diversity, wetland area, hydraulic complexity, floodplain water tables, and pool habitat. Reintroduction of beavers should focus on areas with broad riparian areas, which are localized in sub-reaches TC2b and TC2a.

5.7.7 In-Channel LWD Placement – Flow Splitting and Deflection (Habitat Creation/Process Enhancement)

Placement of LWD structures aimed at splitting or deflecting flow can increase floodplain or side channel inundation, induce local scour, and facilitate sorting and deposition of gravel. These structures often will be paired with floodplain habitat restoration or enhancement projects. In addition, these structures can induce localized scour adjacent to jams (e.g., bar apex style jams of Abbe and Montgomery [1996]), or multiple engineered log jams (ELJs) can be placed to constrict main channel flow and induce scour of larger pools. This latter approach should particularly target existing glide habitats, which have the potential to be converted to pools.

5.7.8 In-Channel LWD Placement – Habitat Focus (Habitat Creation/Process Enhancement)

Given the deficient amount of wood throughout the Assessment Reach, almost any site would benefit from the introduction of additional wood. Specific zones were identified where at least one side of the river is unconstrained by human development of any type, and where larger ELJs are not already recommended, and which therefore have correspondingly degraded habitat for much of the reach. While the focus of these structures is habitat creation, they often will enhance the physical and hydraulic processes of bank stabilization, pool scour, and sediment sorting that occur in response to natural log jams.

5.7.9 Boulder Clusters (Habitat Creation/Process Enhancement)

These structures are recommended wherever bedrock outcrops reach down to river level, and are intended to enhance the existing processes of boulder delivery and flow deflection that are closely associated with deep pools in this river.

Table 5-1 Summary of Restoration Action Types and Their Expected Benefits to Ecological Concerns and Impaired Processes

Action Type	Ecological Concern	Impaired River Process	Potential Benefit to Ecological Concerns and Process Impairments
Levee or Riprap Removal	All	Channel migration, bank erosion, bar formation, and floodplain scour and sediment deposition	High
Floodplain/Off-Channel Habitat Reconnection via Floodplain Regrading	Side Channel and Wetland Conditions		High
In-Channel LWD Placement - Flow Splitting and Deflection	Side Channel and Wetland Conditions, Instream Structural Complexity, Bed and Channel Form		Medium
Riparian Planting and Restoration	Riparian Conditions	Riparian plant succession, shading, wood recruitment, litterfall	Low short-term, High long-term
Riparian Forest Protection			Low short-term, High long-term
Protection of Existing Floodplain Habitats	Side Channel and Wetland Conditions	Floodplain habitat creation, flood inundation. Riparian plant succession	Low short-term, High long-term
Beaver Reintroduction	Side Channel and Wetland Conditions, Riparian Conditions	Sediment and wood input, sediment transport and storage, creation of hydraulic diversity. Floodplain habitat creation. Riparian plant succession	Medium
In-Channel LWD Placement - Habitat Focus	Instream Structural Complexity, Bed and Channel Form	Sediment and wood input, sediment transport and storage, creation of hydraulic diversity	Medium
Bedrock Clusters	Bed and Channel Form	Pool scour and sediment transport, creating hydraulic diversity	Medium

5.8 Sub-reach-Scale Strategies

Discrete segments (or sub-reaches) have been delineated and characterized for their potential to maintain or restore fluvial processes and provide habitat features that address specific limiting factors or ecological concerns. Conceptual-level restoration actions for each sub-reach are described in more detail below. In creating these concepts we have emphasized the restoration concepts articulated by Reclamation (2008) (i.e., floodplain restoration via side channel reconnection and levee setbacks, riprap removal and bank restoration, riparian replanting, LWD reintroduction), with refinement based on specific site characteristics as needed. Restoration actions are categorized by type, which include protection of existing habitats; reconnection of isolated habitats in both the riparian zone and between key habitat features such as proximal off-channel rearing areas; and restoration of fluvial and hyporheic processes that form and sustain suitable conditions, including nutrient fluxes and cool-water inputs.

Each of the sub-reach strategies provided below contains a table listing recommended restoration actions and a priority for each. The priority designations assign the relative priority for each action within the context of the entire Assessment Reach. Therefore, the three sub-reach strategy tables can be combined and sorted by priority to assess the overall reach-scale prioritization in terms of action types and the best sub-reaches for those actions. These tables also list possible project opportunities within each sub-reach, but the prioritization does not extend to a level of detail necessary to prioritize these project-scale opportunities within each sub-reach. These project opportunities are depicted in the map folio in Appendix A. Prioritization of project opportunities will depend on landowner constraints and project feasibility relating to a number of factors.

5.8.1 Sub-reach TC3 (RM 41.3 to 40.3)

Given the moderate channel confinement of the river corridor, there are no high-priority projects recommended in this sub-reach. This sub-reach exhibits the low wood loading common to reaches upstream, and would certainly benefit from the addition of LWD at those areas identified in the map book. There are some opportunities to create lateral constrictions and scour pool hydraulics using features anchored on (and therefore mimicking/expanding) the bedrock outcrops. Single-log and small ELJ installations would improve habitat diversity at specific locations, as described in Table 5-1. Larger ELJ installations focused on splitting and/or contracting flow have potential to create back-bar channels and force flow contraction and pool formation. Modest opportunities exist for improvement in riparian forest community diversity, but these are restricted to low areas on the right bank.

5.8.2 Sub-reach TC2 (RM 40.3 to 33.7)

This sub-reach offers the most promising opportunities for restoration and protection. Large areas of the floodplain have been cut off from the main channel by an extension of a levee system at the upper end. Removal or setback of this levee system could provide multiple opportunities to channel water back into the historical floodplain depressions, now cut off from inflow from the main river. Relic side channels, now represented as isolated beaver ponds, could be reconnected with inflow from upstream, or partially restored by connecting them and providing an outlet to the main channel at ~RM 37.8. Large areas for restoration of cottonwood gallery forests once common to these floodplains are located here. These actions might allow reintroduction of beaver populations that could lead to additional habitat complexity in both riparian and instream habitats. Stable wood structures or wood supply replenishment in strategic locations (see Tables 5-2 through 5-4), phased in over time, could incrementally increase habitat complexity and expand the surface area for riparian and instream, off-channel habitats.

5.8.3 Sub-reach TC1 (RM 33.7 to 28.1)

There are opportunities of moderate priority to enhance processes and riparian and instream habitats in this reach. These include some removal of riprap that restricts growth of native vegetation, some floodplain regrading at or near side channels to facilitate seasonal inundation of floodplain areas currently restricted, and reintroduction of beavers assuming adequate deciduous vegetation can be established to support their habitat requirements. At key locations, the replenishment of wood available to be entrained by the river, or the installation of small footprint ELJ structures should be considered, to allow a hold-fast to trap wood that may float into the area from upstream wood replenishment efforts. Larger ELJ installations can also be placed in the relatively unconfined sections to encourage flow splitting, deflection, and contraction to encourage greater complexity. Also at some locations, small boulder clusters could be installed to provide channel roughness, where currently lacking, to improve habitat complexity (by creating pools and eddy areas).

Table 5-2 Restoration Strategy for Sub-reach TC3

Action	Restoration Approach	Details	Conditions Addressed	Ecological Concerns Addressed	Location(s)	Priority
Protection of Existing Floodplain Habitats	Protection	Protect areas of existing floodplain habitat with natural inundation of off-channel features such as floodplain channels, alcoves, and wetlands.	Floodplain connectivity, off-channel habitat	Side Channel and Wetland Conditions	LEFT BANK: 41.2-41.0	1e
Riparian Protection	Protection	Protect intact enclaves of riparian forest to help maintain floodplain building, channel edge habitat, bank stabilization, and LWD supply.	Riparian Canopy Cover and Composition	Riparian Condition and LWD Recruitment	LEFT BANK: 41.15-41.05	1e
In-Channel LWD Placement - Flow Splitting and Deflection	Habitat Creation/Process Enhancement	Position stable wood structures to encourage flow splitting, more frequent occupation of existing side channels, and to induce local scour and gravel sorting. Greatest benefits likely to accrue in unconfined reaches where lateral deflection of flow can create new flow pathways.	Channel migration, Floodplain connectivity, Off-channel habitat, pool frequency and quality	Side Channel and Wetland Conditions, Instream Structural Complexity, Bed and Channel Form	40.4-40.3	2d
Riparian Planting and Restoration	Process Restoration	Replant degraded zones to foster floodplain building, improve channel edge habitat, improve bank stabilization, and provide long-term top of bank improvements in vegetation plant community diversity and density, structure, and LWD supply	Riparian Canopy Cover and Composition	Riparian Condition and LWD Recruitment	RIGHT BANK: 41.10-40.75, (in coordination with potential community access project) 40.45-40.30	2h
In-Channel LWD Placement - Habitat Type	Habitat Creation/Process Enhancement	Single-Log and Small ELJ Installations that are intrinsically stable, to foster diversity of bars, pools and other in-channel features. Design should account for relatively high stream power in this reach.	LWD frequency, key piece frequency, pool quality	Instream Structural Complexity, Bed and Channel Form	BOTH BANKS: 40.8-40.3 (small-scale installations only to improve local habitat diversity)	3c

Table 5-2 Restoration Strategy for Sub-reach TC3

Action	Restoration Approach	Details	Conditions Addressed	Ecological Concerns Addressed	Location(s)	Priority
Boulder Clusters	Habitat Creation/Process Enhancement	Increase hydraulic diversity, and create lateral constrictions and scour pool hydraulics using boulder clusters that either mimic or expand bedrock outcrops. Boulders to be sized appropriately to achieve proper function.	Pool Frequency and Quality	Bed and Channel Form	LEFT BANK: 41.0-40.8 (adjacent bedrock outcrop and undeveloped land)	3d

Table 5-3 Restoration Strategy for Sub-reach TC2c

Action	Restoration Approach	Details	Conditions Addressed	Ecological Concerns Addressed	Location(s)	Priority
Protection of Existing Floodplain Habitats	Protection	Protect areas of existing floodplain habitat with natural inundation of floodplain channels, alcoves, and wetlands. Possible enhanced inundation through placement of flow-splitting LWD in the main channel (see separate action).	Floodplain connectivity, off-channel habitat	Side Channel and Wetland Conditions	LEFT BANK: 39.30-39.05 RIGHT BANK: 40.2-39.9 39.80-39.35	1b
Riparian Protection	Protection	Protect intact enclaves of riparian forest to help maintain floodplain building, channel edge habitat, bank stabilization, and LWD supply.	Riparian Canopy Cover and Composition	Riparian Condition and LWD Recruitment	LEFT BANK: 39.45-39.05 RIGHT BANK: 40.2-39.9 39.80-39.35	1b
Floodplain/Off-Channel Habitat Reconnection via Grading	Process Restoration	Re-grade entrance and/or exit of side channels to encourage reoccupation by flows; excavation of new channels in locations likely to persist under unconstrained conditions of flow and channel migration. Pair with in-channel ELJs focused on splitting or deflecting flow.	Channel migration, Floodplain connectivity, Off-channel habitat	Side Channel and Wetland Conditions	LEFT BANK: 39.85-39.75 (regrade floodplain in conjunction with reconnection of Twisp wastewater treatment plant outfall)	2b
In-Channel LWD Placement - Flow Splitting and Deflection	Habitat Creation/Process Enhancement	Position stable wood structures to encourage flow splitting and more frequent occupation of existing side channels. Greatest benefits likely to accrue in unconfined reaches where lateral deflection of flow can create new flow pathways. Also target existing glide habitat with constricting ELJs to promote pool formation.	Channel migration, Floodplain connectivity, Off-channel habitat, pool frequency and quality	Side Channel and Wetland Conditions, Instream Structural Complexity, Bed and Channel Form	40.2 39.9 39.8 (to improve not only side-channel formation but also flushing of sewage outflow)	2b

Table 5-3 Restoration Strategy for Sub-reach TC2c

Action	Restoration Approach	Details	Conditions Addressed	Ecological Concerns Addressed	Location(s)	Priority
Levee and Riprap Removal/Setback	Process Restoration	Remove artificial bank cover to promote growth of native riparian vegetation	All	All	LEFT BANK: 40.10-40.05 RIGHT BANK: 40.30-40.25 39.35: Reconnect off-channel wetland on west side of Twisp-Carlton Road	2b
Riparian Planting and Restoration	Process Restoration	Replant degraded zones to foster floodplain building, improve channel edge habitat, improve bank stabilization, and provide long-term top of bank improvements in vegetation plant community diversity and density, structure, and LWD supply	Riparian Canopy Cover and Composition	Riparian Condition and LWD Recruitment	LEFT BANK: 40.3-40.1 39.9-39.75	2f
In-Channel LWD Placement - Habitat Type	Habitat Creation/Process Enhancement	Install intrinsically stable large wood emplacements to foster diversity of bars, pools, and other in-channel features; may pose some conflicts with human recreation uses	LWD frequency, key piece frequency, pool quality	Instream Structural Complexity, Bed and Channel Form	40.15-39.10; particularly 39.9-39.1, where active channel is unconstrained on one or both banks having wide setback of undeveloped property	3a
Boulder Clusters	Habitat Creation/Process Enhancement	Increase hydraulic diversity, and create lateral constrictions and scour pool hydraulics using boulder clusters that either mimic or expand bedrock outcrops. Boulders to be sized appropriately to achieve proper function.	Pool Frequency and Quality	Bed and Channel Form	RIGHT BANK: 40.25 39.35-39.25	3b

Table 5-4 Restoration Strategy for Sub-reach TC2b

Action	Restoration Approach	Details	Conditions Addressed	Ecological Concerns Addressed	Location(s)	Priority
Protection of Existing Floodplain Habitats	Protection	Protect areas of existing floodplain habitat with natural inundation of floodplain channels, alcoves, and wetlands. Possible enhanced inundation through placement of flow-splitting LWD in the main channel (see separate action).	Floodplain connectivity, off-channel habitat	Side Channel and Wetland Conditions	LEFT BANK: 37.0-36.1 RIGHT BANK: 38.15-37.0	1a
Riparian Protection	Protection	Protect intact enclaves of riparian forest to help maintain floodplain building, channel edge habitat, bank stabilization, and LWD supply.	Riparian Canopy Cover and Composition	Riparian Condition and LWD Recruitment	LEFT BANK: 37.0-36.1 (includes zone of recent channel migration with potential for cottonwood recruitment) 36.0 (protect confluence zone with Beaver Creek) RIGHT BANK: 38.35-37.00 36.75-35.80	1a
Floodplain/Off-Channel Habitat Reconnection via Grading	Process Restoration	Re-grade entrance and/or exit of side channels to encourage reoccupation by flows; excavation of new channels in locations likely to persist under unconstrained conditions of flow and channel migration; removal and regrading of artificial dam at outlet of beaver complex would allow use by juvenile fish as off-channel habitat. Pair with in-channel ELJs focused on splitting or deflecting flow.	Channel migration, Floodplain connectivity, Off-channel habitat	Side Channel and Wetland Conditions	RIGHT BANK: 38.3-38.15 (adjacent and down valley of potential levee removal) 36.70-35.85 (possible reconnection of lower Beaver Pond complex at 36.75 or 36.5, and/or enhance inundation of floodplain channel at 36.25, which currently activates at 16,000 cfs) 35.85 (downstream end of Beaver Pond complex - remove artificial dam)	2a

Table 5-4 Restoration Strategy for Sub-reach TC2b

Action	Restoration Approach	Details	Conditions Addressed	Ecological Concerns Addressed	Location(s)	Priority
In-Channel LWD Placement - Flow Splitting and Deflection	Process Restoration	Position stable wood structures to encourage flow splitting and more frequent occupation of existing side channels. Greatest benefits likely to accrue in unconfined reaches where lateral deflection of flow can create new flow pathways. Also target existing glide habitat with constricting ELJs to promote pool formation.	Channel migration, Floodplain connectivity, Off-channel habitat, pool frequency and quality	Side Channel and Wetland Conditions, Instream Structural Complexity, Bed and Channel Form	38.35 (to encourage reoccupation of side-channel complex following levee removal) 37.25-36.20 (to encourage flow splitting through this very wide active-channel reach)	2a
Levee and Riprap Removal/Setback	Process Restoration	Remove bank armoring to allow channel migration, occupation of prior side channels, and creation of new channels	All	All	LEFT BANK: 38.75 (riprap) 38.25-38.15 (riprap) RIGHT BANK: 38.45-38.2 (levee at head of Beaver Pond complex) 36.75 (Detroit Riprap) 36.6 (riprap)	2a
Beaver Reintroduction	Process Restoration	introduce beavers in areas with sufficient riparian zone extent to provide adequate habitat; can physically modify the environment, creating new instream habitat and raising floodplain water tables without further human intervention	Riparian Canopy Cover and Composition, Off-channel habitat, floodplain connectivity	Side Channel and Wetland Conditions, Riparian Conditions	An excellent sub-reach for reintroduction throughout	2c
Riparian Planting and Restoration	Process Restoration	Replant degraded zones to foster floodplain building, improve channel edge habitat, improve bank stabilization, and provide long-term top of bank improvements in vegetation plant community diversity and density, structure, and LWD supply	Riparian Canopy Cover and Composition	Riparian Condition and LWD Recruitment	LEFT BANK: 39.0-38.0 37.2-37.0 RIGHT BANK: 39.9-39.8 36.95-36.70	2e

Table 5-4 Restoration Strategy for Sub-reach TC2b

Action	Restoration Approach	Details	Conditions Addressed	Ecological Concerns Addressed	Location(s)	Priority
In-Channel LWD Placement - Habitat Type	Habitat Creation/Process Enhancement	Install intrinsically stable large wood emplacements to foster diversity of bars, pools, and other in-channel features; may pose some conflicts with human recreation uses	LWD frequency, key piece frequency, pool quality	Instream Structural Complexity, Bed and Channel Form	Throughout sub-reach where flow-splitting ELJs are not planned, further LWD introductions would be beneficial	3a
Boulder Clusters	Habitat Creation/Process Enhancement	Increase hydraulic diversity, and create lateral constrictions and scour pool hydraulics using boulder clusters that either mimic or expand bedrock outcrops. Boulders to be sized appropriately to achieve proper function.	Pool Frequency and Quality	Bed and Channel Form	RIGHT BANK: 35.85	3b

Table 5-5 Restoration Strategy for Sub-reach TC2a

Action	Restoration Approach	Details	Conditions Addressed	Ecological Concerns Addressed	Location(s)	Priority
Protection of Existing Floodplain Habitats	Protection	Protect areas of existing floodplain habitat with natural inundation of floodplain channels, alcoves, and wetlands. Possible enhanced inundation through placement of flow-splitting LWD in the main channel (see separate action).	Floodplain connectivity, off-channel habitat	Side Channel and Wetland Conditions	RIGHT BANK: 35.6-35.5 (existing floodplain channel activated 3,000 cfs) 35.4-35.2 (existing floodplain channel activated 6,000 cfs) 34.5-34.0 (Alder Creek confluence wetland with existing floodplain channel)	1c
Riparian Protection	Protection	Protect intact enclaves of riparian forest to help maintain floodplain building, channel edge habitat, bank stabilization, and LWD supply.	Riparian Canopy Cover and Composition	Riparian Condition and LWD Recruitment	LEFT BANK: 35.8-35.6 (protection & enhancement) 35.10-34.35 33.8-33.7 RIGHT BANK: 35.6-35.15 34.5-34.0	1c
Beaver Reintroduction	Process Restoration	Introduce beavers in areas with sufficient riparian zone extent to provide adequate habitat; can physically modify the environment, creating new instream habitat and raising floodplain water tables without further human intervention	Riparian Canopy Cover and Composition, Off-channel habitat, floodplain connectivity	Side Channel and Wetland Conditions, Riparian Conditions	An excellent sub-reach for reintroduction throughout	2c

Table 5-5 Restoration Strategy for Sub-reach TC2a

Action	Restoration Approach	Details	Conditions Addressed	Ecological Concerns Addressed	Location(s)	Priority
Floodplain/Off-Channel Habitat Reconnection via Grading	Process Restoration	Re-grade entrance and/or exit of side channels to encourage reoccupation by flows; excavation of new channels in locations likely to persist under unconstrained conditions of flow and channel migration (See restoration plan being prepared for Silver Side Channel, being done for CCFEG under separate contract). Pair with in-channel ELJs focused on splitting or deflecting flow.	Channel migration, Floodplain connectivity, Off-channel habitat	Side Channel and Wetland Conditions	LEFT BANK: 35.4-35.1 (Silver Side Channel Complex with four inlets and a levee blocking the upstream-most inlet)	2c
In-Channel LWD Placement - Flow Splitting and Deflection	Habitat Creation/Process Enhancement	Position stable wood structures to encourage flow splitting and more frequent occupation of existing side channels. Greatest benefits likely to accrue in unconfined reaches where lateral deflection of flow can create new flow pathways. Also target existing glide habitat with constricting ELJs to promote pool formation.	Channel migration, Floodplain connectivity, Off-channel habitat, pool frequency and quality	Side Channel and Wetland Conditions, Instream Structural Complexity, Bed and Channel Form	Most of reach is well-suited to ELJ installations, especially 35.6-33.9 where flow into existing floodplain channels could be enhanced.	2c
Levee and Riprap Removal/Setback	Process Restoration	Remove bank armoring to allow channel migration, occupation of prior side channels, and creation of new channels	All	All	LEFT BANK: 35.65-35.55 35.35 (levee at head of Silver Side Channel) RIGHT BANK: 35.25	2c
Riparian Planting and Restoration	Process Restoration	Replant degraded zones to foster floodplain building, improve channel edge habitat, improve bank stabilization, and provide long-term top of bank improvements in vegetation plant community diversity and density, structure, and LWD supply	Riparian Canopy Cover and Composition	Riparian Condition and LWD Recruitment	LEFT BANK: 35.8-35.6 (protection & enhancement) 34.25-33.85 RIGHT BANK: 35.8-35.6 35.15-35.00	2f

Table 5-5 Restoration Strategy for Sub-reach TC2a

Action	Restoration Approach	Details	Conditions Addressed	Ecological Concerns Addressed	Location(s)	Priority
In-Channel LWD Placement - Habitat Type	Habitat Creation/Process Enhancement	Install intrinsically stable large wood emplacements to foster diversity of bars, pools, and other in-channel features; may pose some conflicts with human recreation uses	LWD frequency, key piece frequency, pool quality	Instream Structural Complexity, Bed and Channel Form	Throughout sub-reach where flow-splitting ELJs not already recommended (at least one unconstrained bank is present everywhere)	3a
Boulder Clusters	Habitat Creation/Process Enhancement	Increase hydraulic diversity, and create lateral constrictions and scour pool hydraulics using boulder clusters that either mimic or expand bedrock outcrops. Boulders to be sized appropriately to achieve proper function.	Pool Frequency and Quality	Bed and Channel Form	RIGHT BANK: RM 34.65–34.6	3b

Table 5-6 Restoration Strategy for Sub-reach TC1

Action	Restoration Approach	Details	Conditions Addressed	Ecological Concerns Addressed	Location(s)	Priority
Riparian Protection	Protection	Protect intact enclaves of riparian forest to help maintain floodplain building, channel edge habitat, bank stabilization, and LWD supply.	Riparian Canopy Cover and Composition	Riparian Condition and LWD Recruitment	LEFT BANK: 32.5-32.3 30.5-30.1 RIGHT BANK: 30.75-30.45	1d
Floodplain/Off-Channel Habitat Reconnection via Grading	Process Restoration	Re-grade entrance and/or exit of side channels to encourage reoccupation by flows; excavation of new channels in locations likely to persist under unconstrained conditions of flow and channel migration. Pair with in-channel ELJs focused on splitting or deflecting flow.	Channel migration, Floodplain connectivity, Off-channel habitat	Side Channel and Wetland Conditions	RIGHT BANK: 30.6-30.5 (presently activated at ~8,000 cfs)	2d
In-Channel LWD Placement - Flow Splitting and Deflection	Habitat Creation/Process Enhancement	Position stable wood structures to encourage flow splitting, more frequent occupation of existing side channels, and to induce local scour and gravel sorting. Greatest benefits likely to accrue in unconfined reaches where lateral deflection of flow can create new flow pathways.	Channel migration, Floodplain connectivity, Off-channel habitat, pool frequency and quality	Side Channel and Wetland Conditions, Instream Structural Complexity, Bed and Channel Form	30.8-30.4 29.1-28.6	2d
Levee and Riprap Removal/Setback	Process Restoration	Remove artificial bank cover to promote growth of native riparian vegetation	All	All	RIGHT BANK: 32.1-32.05	2d

Table 5-6 Restoration Strategy for Sub-reach TC1

Action	Restoration Approach	Details	Conditions Addressed	Ecological Concerns Addressed	Location(s)	Priority
Riparian Planting and Restoration	Process Restoration	Replant degraded zones to foster floodplain building, improve channel edge habitat, improve bank stabilization, and provide long-term top of bank improvements in vegetation plant community diversity and density, structure, and LWD supply	Riparian Canopy Cover and Composition	Riparian Condition and LWD Recruitment	LEFT BANK: 33.25-33.15 32.0-31.8 31.55-31.30 28.85-28.75 RIGHT BANK: 32.20-31.95 31.35-31.20 31.05-30.75 29.35-28.75	2g
In-Channel LWD Placement - Habitat Type	Habitat Creation/Process Enhancement	Install intrinsically stable large wood emplacements to foster diversity of bars, pools, and other in-channel features	LWD frequency, key piece frequency, pool quality	Instream Structural Complexity, Bed and Channel Form	32.5-31.9 31.4-31.1 (including enhancement of existing perennial side channel) 30.1-29.85 29.3-29.1	3c
Boulder Clusters	Habitat Creation/Process Enhancement	Increase hydraulic diversity, and create lateral constrictions and scour pool hydraulics using boulder clusters that either mimic or expand bedrock outcrops. Boulders to be sized appropriately to achieve proper function.	Pool Frequency and Quality	Bed and Channel Form	33.35 32.85 32.25 31.4 28.45	3d

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