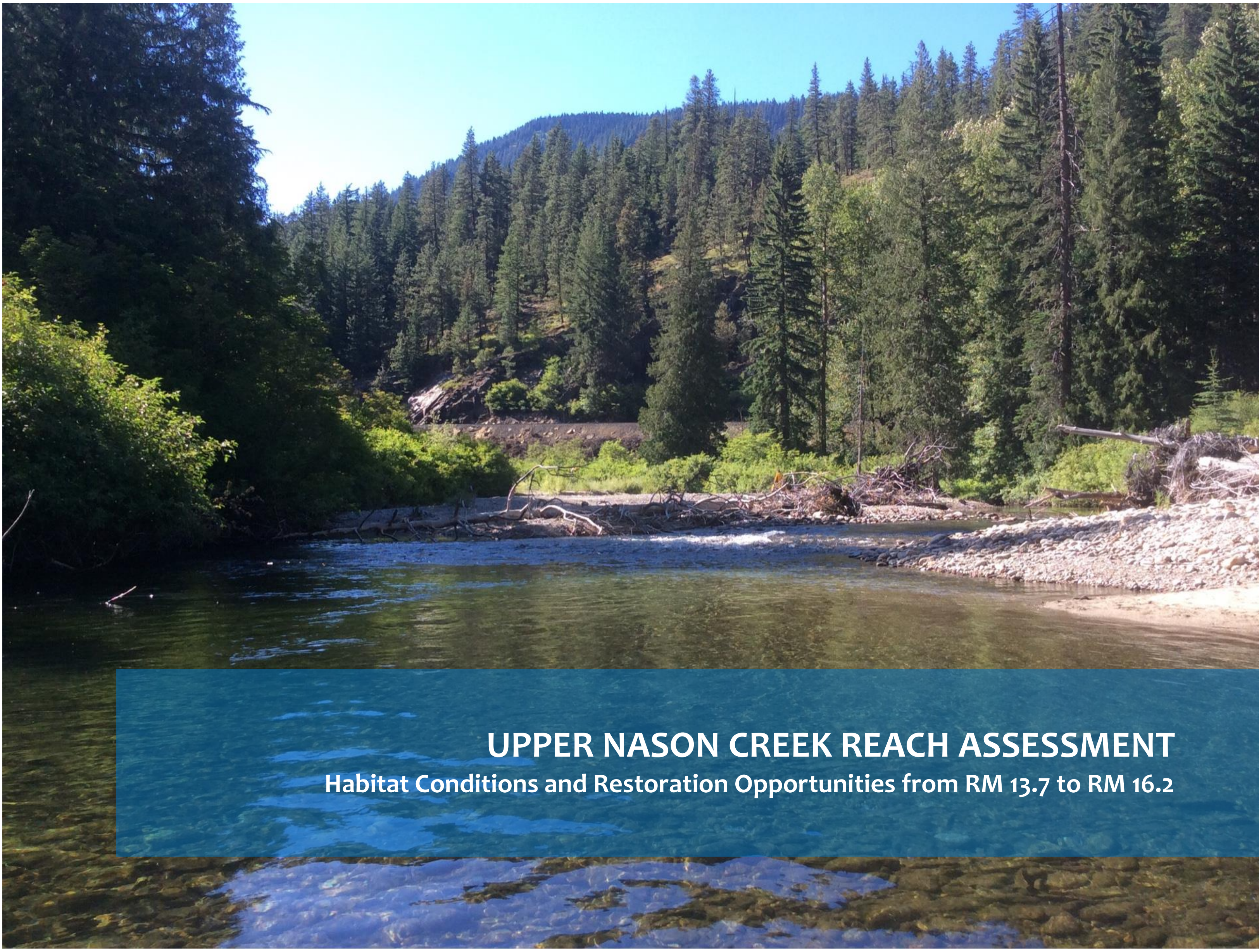


UPPER NASON CREEK REACH ASSESSMENT

Habitat Conditions and Restoration Opportunities from RM 13.7 to RM 16.2

March 2019

Yakama Nation Fisheries
P.O. Box 151
Toppenish, WA 98948
(509) 881-1462

Natural Systems Design
1900 N. Northlake Way, Suite 211
Seattle, WA 98103

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF MAPS

LIST OF APPENDICES

THIS PAGE INTENTIONALLY LEFT BLANK

1. INTRODUCTION

The Upper Nason Creek Reach Assessment is designed to evaluate existing conditions, habitat limitations, and restoration potential along 2.5 miles of Nason Creek, in the Wenatchee River watershed of central Washington State.

This project is being conducted by the Yakama Nation Fisheries Upper Columbia Habitat Restoration Project (YN UCHRP) to identify and implement targeted riverine restoration projects to benefit federal Endangered Species Act (ESA) listed salmonids, including Chinook salmon (*Oncorhynchus tshawytscha*), and steelhead (*O. mykiss*). Working with the Wenatchee Subbasin Watershed Action Team, the YN UCHRP identified the Upper Nason Reach as a potential area for targeted riverine habitat restoration, in accordance with the Upper Columbia Spring Chinook and Steelhead Recovery Plan (Recovery Plan, UCSRB 2007) and the Revised Biological Strategy to Protect and Restore Salmonid Habitat in the Upper Columbia Region (Revised Biological Strategy, UCRTT 2014).

This report proposes and evaluates potential restoration actions based on an analysis of current habitat conditions, geomorphic restoration potential, project feasibility, and existing infrastructure needs. Potential project areas are systematically identified, evaluated, mapped, ranked, and described in detail to facilitate informed design and implementation of habitat restoration projects in the reach. Future site-specific surveys and analyses will build upon this work to refine project ideas, present restoration alternatives, and develop detailed designs for implementation.

Numerous restoration actions have already been conducted in the Nason Creek drainage, and this project is intended to build upon existing restoration work in the area. Additionally, this investigation extends the area of Nason Creek that has been considered for restoration potential. Reach assessments of the lower 14 miles of Nason Creek were conducted by the U.S. Bureau of Reclamation and area available at https://www.usbr.gov/pn/fcrps/habitat/projects/uppercolumbia/index.html

1.1 Purpose

The purpose of this project is to expand the science-based salmon habitat restoration strategy for the Nason Creek Assessment Unit from Rivermile (RM) 13.7 to RM 16.2. The RM designations adopted for this project are from the US Bureau of Reclamation Nason Creek Tributary Assessment (2008). Consistent with previous downstream assessments this approach includes assessment of current riverine conditions, investigation of ecological concerns limiting salmonid population viability, identification of key habitat restoration and protection opportunities, and evaluation of project alternatives to maximize potential for salmon recovery. A combination of channel unit-level habitat surveys, field geomorphic assessment, and evaluation of hydrologic processes forms the basis of information for this restoration strategy. Evaluating existing physical conditions and biological limitations is critical to effective restoration planning and prioritization.

Specific objectives for the assessment include:

1. Evaluate and quantify existing habitat conditions, geomorphic conditions, and anthropogenic degradations throughout the study reach with a focus on the needs of threatened and endangered salmonids.
2. Identify, prioritize, and conceptually develop restoration projects in the study reach that benefit threatened and endangered salmonids.

1.2 Project Organization

This project includes three primary components:

1. Reach Assessment: Habitat and geomorphic evaluation based on field surveys and USFS Level II stream inventory (USFS 2012).
2. REI Analysis: Analysis of ecological condition of the Upper Nason study area using Reach-Based Ecosystem Indicators (REI).
3. Restoration Strategy: Science-based restoration opportunity identification targeting recovery of ESA-listed salmonids.

2. STUDY AREA CHARACTERIZATION

The study area for this assessment includes Nason Creek and its floodplain from approximately RM 13.7 (at the BNSF railroad bridge) to near RM 16.2 (about 0.07 RM above the confluence with Whitepine Creek). This builds upon several previous reach assessments conducted downstream on Nason Creek. Relevant data, scientific literature, and technical reports were compiled and reviewed to inform this assessment.

The following contains a partial list of previous assessments and reports reviewed for this project:

- Washington State Salmon and Steelhead Stock Inventory (WDFW 1993)
- Salmon, Steelhead, and Bull Trout Limiting Factors for the Wenatchee Subbasin (Water Resource Inventory Area 45) and Portions of WRIA 40 within Chelan County (Squilchuck, Stemilt, and Colockum drainages) (Andonaegui 2001)
- Washington State Salmonid Stock Inventory: Bull Trout/Dolly Varden (WDFW 2004)
- Wenatchee Watershed Management Plan (WWPU 2006)
- Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (UCSRB 2007)
- Nason Creek Tributary Assessment (USBR 2008)
- Lower White Pine Reach Assessment (USBR 2009a)
- Upper White Pine Reach Assessment (USBR 2009b)
- Kahler Reach Assessment (USBR 2009c)
- Lower Nason Assessment of Geomorphic and Ecologic Indicators (USBR 2011)
- Upper Wenatchee River Stream Corridor Assessment and Habitat Restoration Strategy (Inter-Fluve 2012)
- Surveys of Pacific Lamprey Distribution in the Wenatchee River Watershed 2010-2011 (Johnsen and Nelson 2012)
- A Biological Strategy to Protect and Restore Salmonid Habitat in the Upper Columbia Region (UCRTT 2014)

Additionally, the structure for this report was designed to match the Regional Technical Team's recommendations for Reach Assessment Reports. The study area characterization includes information on setting and climate, geology and glacial history, human disturbance history, wildfires, water quantity and quality, fish use population status, and ecological concerns.

2.1 Setting and Climate

The Nason Creek drainage is located on the eastern slope of the Cascade Mountains and on the western edge of the Columbia River Basin, in Chelan County, Washington. Nason Creek begins near Stevens Pass at Lake Valhalla (elevation 4,850 feet) and flows approximately 27 miles to its confluence with the Wenatchee River at RM 53.7 (elevation 1,865 feet). Along the way it is fed by numerous tributaries, including Mill Creek, Whitepine Creek, Coulter Creek, and Kahler Creek. The drainage is located within Water Resource Inventory Area (WRIA) 45 and the Wenatchee River watershed (8-digit HUC 17020011). The Nason Creek drainage includes the Lower Nason Creek subwatershed (12-digit HUC 170200110203; 128.2 square kilometers), the Upper Nason Creek subwatershed (12-digit HUC 170200110201; 90.4 square kilometers), and the Whitepine Creek subwatershed (12-digit HUC 170200110202; 63.3 square kilometers). The Nason Creek drainage is 78% publicly owned and 22% privately owned; most of the public land is managed by the United States Forest Service (USFS). 21% of the Nason Creek drainage is part of the Alpine Lakes Wilderness Area and 3% of the Nason Creek drainage, including Lake Valhalla, is part of the Henry M. Jackson Wilderness Area (USBR 2008). At 7,993 feet of elevation, Snowgrass Mountain is the highest point in the drainage.

The Nason Creek drainage exists along a dramatic precipitation gradient. Prevailing westerly winds move moist air from the Pacific Ocean over the Cascade Mountains, leaving heavy precipitation on the western slopes and a rain shadow on the eastern side. Annual precipitation in the Nason Creek drainage ranges from about 90 inches at the Cascade Crest to about 30 inches at the mouth. In contrast, annual precipitation at the mouth of the Wenatchee River is only 8.5 inches (Andonaegui 2001). Most precipitation falls from late fall through the winter, and most winter precipitation in the Nason Creek drainage falls as snow. As a snowmelt-dominated hydrologic system, Nason Creek has consistently high flows from late spring through early summer as snowpack melts, followed by low flows in late summer during seasonal drought. Nason Creek contributes about 18% of total low flow in the Wenatchee River (Andonaegui 2001).

The study area for this assessment includes the Nason Creek channel and floodplain from RM 13.7 (at the train bridge over Nason Creek) to RM 16.2 (0.07 miles above the confluence with Whitepine Creek. All 2.5 river miles were classified as one survey reach (Upper Nason Creek Reach), based on USFS stream inventory protocols (USFS 2012). The reach falls into the Lower Nason Creek and Upper Nason Creek 12-digit hydrologic units. Tributaries to Nason Creek within the study reach include Whitepine Creek at RM 16.2, and several additional unnamed creeks to the south between RM 15.8 and 14.75. See Figure 1 for a map of the study area. The U.S. Bureau of Reclamation (BOR) has already conducted several reach assessments on Nason Creek downstream of RM 13.7 (see https://www.usbr.gov/pn/fcrps/habitat/projects/uppercolumbia/index.html).

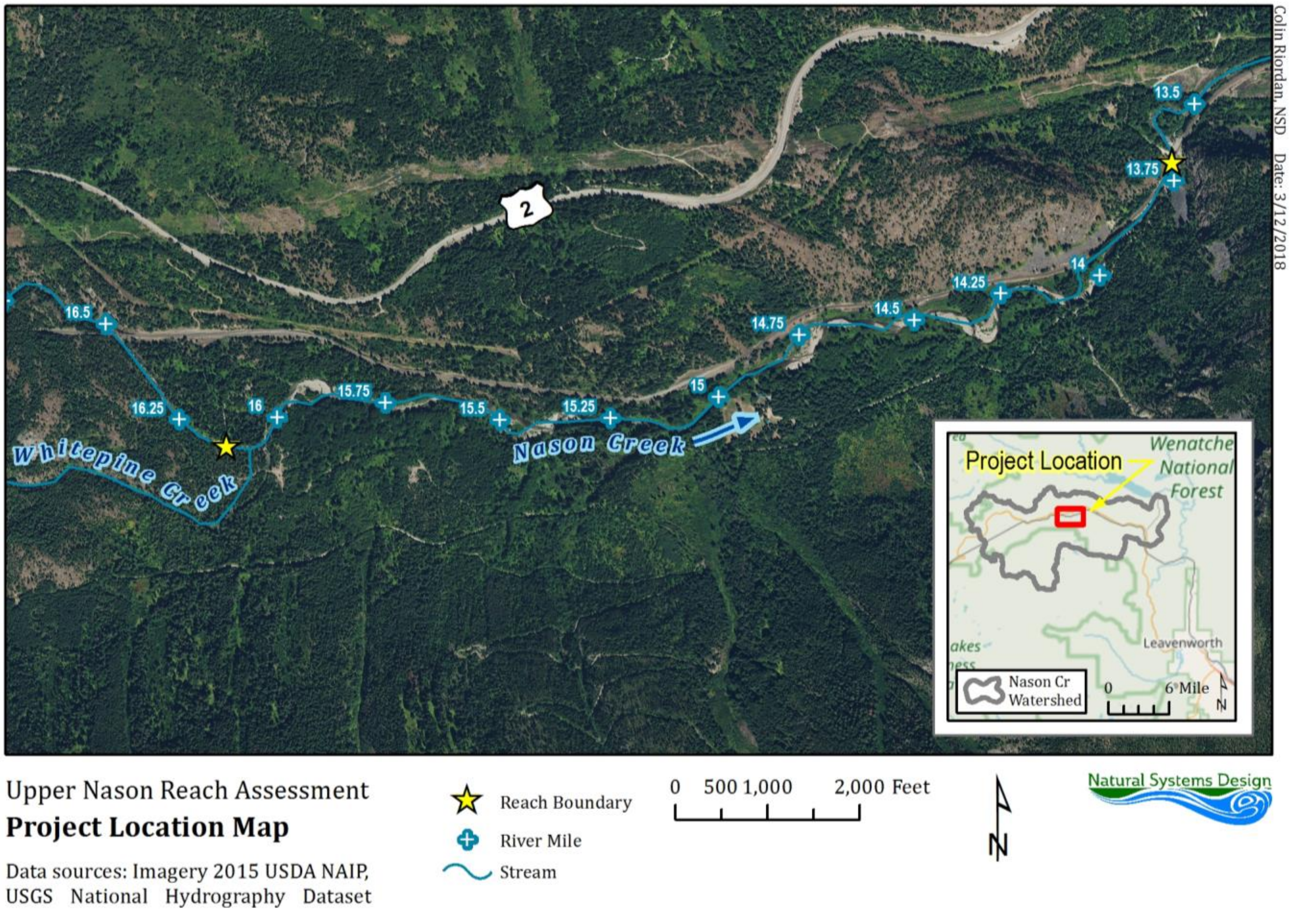


Figure 1. Upper Nason Creek Reach: RM 13.7 to RM 16.2 Study Area

2.2 Geology and Glacial History

The bedrock geology of the project reach is within the late Cretaceous Nason Terrane (Figure 2). This is composed of the Chiwaukum Schist and associated banded gneiss (Tabor et al. 1987). The bounding graded contact between these units is near RM 14.75 and is overlain by Quaternary alluvium in the valley bottom and Pleistocene glacial drift on the north side of the valley. Both bedrock geologic units originated as fine-grained sedimentary rocks and were subsequently metamorphosed to varying degrees and uplifted during development of the modern Cascade Range (Oligocene and Miocene). Upstream of RM 14.75 the project reach is underlain by biotite schist and amphibolite sub-units of the Chiwaukum schist (Late Cretaceous). Downstream the underlying lithology is a suite of gneiss, schist and amphibolites representing a higher-grade metamorphism relative to the adjacent (upstream) Chiwaukum schist.

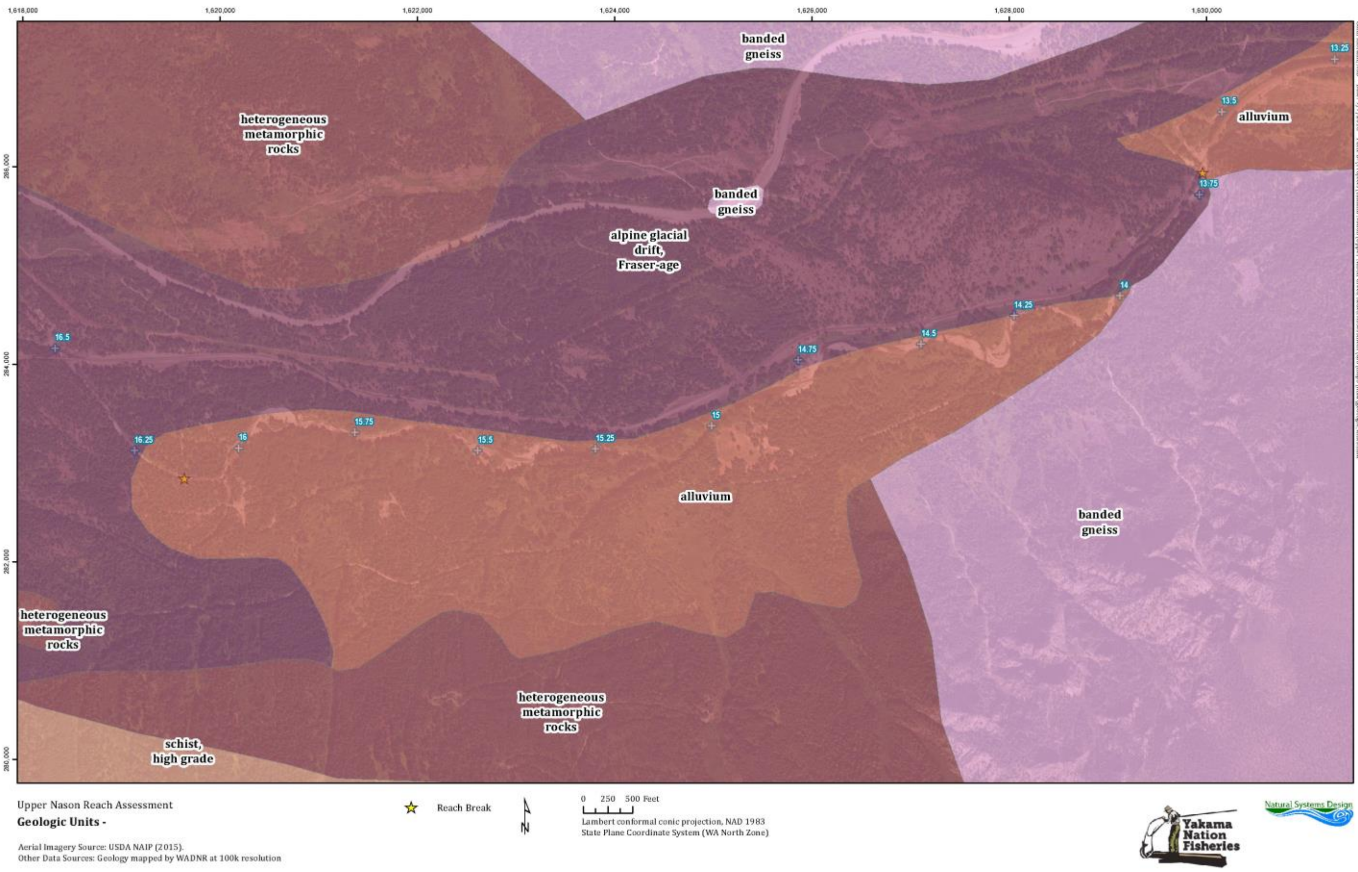


Figure 2. Geologic Units

Alpine glaciers formed in the upper watershed during cooler periods of the Pleistocene Epoch, advanced downslope, and carved out portions of the Nason Creek Valley. The two most recent alpine glaciations in the region occurred between 140,000 and 130,000 years ago, and between 18,000 and 11,500 years ago (Porter 1976, Waitt 1979). During the last deglaciation as many as four recessional moraines developed behind the terminal moraine (Tabor et al. 1987). The glacial drift exposed on the northern side of the valley through the project reach pinches the valley width to less than 100-ft downstream of RM 14. The form of the deposit suggests a recessional moraine is forcing the valley confinement at the downstream end of the project reach.

Alluvial fans emanating from tributaries along the northern extent of the Chiwaukum Mountains protrude out into the valley bottom, confining the channel to the northern side of the valley. A prominent fan at the Cascade Meadows Camp emanating from an unnamed tributary to the south, confines the channel along the northern edge of the valley margin at RM 15. Similar confinement of the floodplain occurs at the upstream end of the project reach as fans from Whitepine Creek and unnamed tributaries coalesce to form a large fan along the southern margin of the valley. These alluvial fan features influence the adjacent floodplains by altering surface and groundwater flow, particularly upstream of the confined section of the channel due to the fan. The channel confinement constricts flows creating a backwater upstream, resulting in higher water surface elevations and a more connected floodplain. An example of this effect is upstream of the Cascade Meadows Camp, where a large beaver wetland complex has formed over time.

2.3 Human Disturbance History

Human activity in the Wenatchee River watershed goes back thousands of years and can generally be defined in two distinct phases: 1) pre-colonization inhabitation by Wenatchee Indians and 2) post-colonization occupation by European settlers and the United States of America. Only the second phase of human activity has significantly degraded aquatic habitats and changed riverine processes in the Wenatchee River watershed.

Typical resource use by Wenatchee Indians included low-impact hunting, fishing, and gathering activities. Pacific salmon were an integral part of the diet of native people of the upper Columbia Region (NPCC 2004a). Over the last 150 years, post-colonial activities have significantly altered riverine habitats and processes in the Wenatchee River watershed, including the Nason Creek drainage. Road, rail, and power infrastructure has disconnected instream and floodplain habitats, changed sediment transport dynamics, and damaged riparian communities. Existing major anthropogenic features along Nason Creek include U.S. Highway 2, Washington State Route 207, freight rail lines, and Bonneville Power Administration (BPA) and Chelan County transmission line corridors (Figure 3). Additionally, there are private residences and numerous logging roads within the basin. Timber harvest and logging road development increased dramatically in the 1970s and 1980s (Andonaegui 2001).

Channel constraints and channelization of Nason Creek by highway and railroad corridors has led to channel incision, as well as changes in peak flow timing, intensity, and duration (Andonaegui 2001). Elevated instream temperatures are a concern throughout much of Nason Creek due to degraded riparian condition and disconnection from off-channel features. Summer water temperatures are elevated throughout much of Nason Creek, with documented exceedances of Washington State water temperature standards (DOE 2007). Several sections of Nason Creek were included on the 2004 Washington State 303(d) list of impaired waters due to temperature exceedances.

Anthropogenic features include the railroad grade along river left (with a railroad bridge over Nason Creek at RM 13.7), the unpaved Whitepine Creek Road along river right (with a bridge over Nason Creek at RM 13.75), several unofficial/dispersed campsites (mostly clustered near the confluence with Whitepine Creek), and the Cascade Meadows Camp on river right at RM 15. The study area is in a unique stretch of Nason Creek that is removed from all state and federal highway corridors.

Figure 3. Railroad Grade Running Along Nason Creek Within the Upper Nason Reach.

2.4 Physical Disturbance History

Forest fires, flooding, and mass wasting are the primary forms of natural disturbance in the Nason Creek watershed. The frequency and magnitude of these events varied depending largely on weather events, and would lead to channel changes (sediment and/or wood inputs) Anthropogenic disturbances in the watershed from logging and associated road construction have altered the frequency and magnitude of these natural disturbances, with detrimental effects to instream habitat.

Significant forest fuels, seasonal summer drought, and heavy recreation in the watershed contribute to increased wildfire risk. Despite a high potential for wildfires in the area, there have been no major fire events in the Nason Creek drainage in the 21st century. The 2014 Chiwaukum Creek Fire burned only slightly into the Nason Creek drainage, near the headwaters of Coulter Creek (USGS 2018).

The steep valley slopes are mantled with unconsolidated non-cohesive soils with moderate to high subsurface water storage capacity, resulting in a high debris slide potential in the watershed (Andonaegui 2001). Extensive logging and associated road construction, especially during the 1970s and 1980s, led to more frequent mass wasting events in the watershed as a result of the destabilized hillsides (Andonaegui 2001).

2.5 Fish Use and Population Status

Nason Creek provides important habitat for native fish species. Native salmonids include spring-run Chinook (*Oncorhynchus tshawytscha*), steelhead/rainbow trout (*O. mykiss*), coho salmon (*O. kisutch*), sockeye salmon (*O. nerka*), bull trout (*Salvelinus confluentus*), westslope cutthroat trout (*O. clarki lewisi*), and mountain whitefish (*Prosopium williamsoni*). Nason Creek is also used by non-salmonid fishes, including various species of dace, sculpin, and suckers. Invasive brook trout (*Salvelinus fontinalis*) are also present. Many of these species use the upper Nason study area for migration, spawning, and rearing.

2.5.1 Salmonids

Salmonids are present year-round in the Nason Creek drainage, and use Nason Creek and its tributaries for spawning, rearing, and migration. Three local salmonid species are listed under the Endangered Species Act (ESA): spring Chinook are listed as endangered, while steelhead and bull trout are listed as threatened. Fish use varies spatially and temporally among different ESA-listed species (Table 1 and Table 2).

Nason Creek and other upper Columbia waterways historically produced abundant anadromous salmonid stocks, but populations have declined drastically over the last century. Overfishing in the lower Columbia, extensive irrigation diversion networks, and habitat degradation left anadromous runs decimated by the 1930s. Additionally, the development of Columbia River hydroelectric projects further depressed salmon runs and population resilience. There are currently seven mainstem Columbia River dams and two smaller Wenatchee River dams that Nason Creek salmonids must pass when migrating to or from the Pacific Ocean (Andonaegui 2001).

Table 1. ESA-listed salmonid status and use of Upper Nason Creek Reach (RM 13.7 to RM 16.2) (UCRTT 2014).

SPECIES	SPRING CHINOOK	STEELHEAD	BULL TROUT
ESA STATUS	Endangered	Threatened	Threatened
USE of UPPER NASON CREEK REACH (RM 13.7 to RM 16.2)	Spawning, rearing, migration	Spawning, rearing, migration	Spawning, rearing, migration, foraging, overwintering

Table 2. Generalized Fish Use Timing for ESA-Listed Salmonids in Nason Creek. Adapted from Andonaegui (2001) And WWPU (2006).

SPECIES	LIFESTAGE	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEPT	OCT	NOV	DEC
Spring Chinook	In-Migration												
	Spawning												
	Incubation												
	Rearing												
Steelhead	In-Migration												
	Spawning												
	Incubation												
	Rearing												
Bull trout	Spawning												
	Incubation												
	Rearing												

	Indicates periods of peak use and high certainty that the species is present at the given life stage.
	Indicates periods of less frequent use and less certainty that the species is present at the given life stage.
	Indicates periods of rare use or no use.

Chinook Salmon

Nason Creek is a major spawning area for spring Chinook salmon, which were listed as endangered under the federal Endangered Species Act in 1999 (UCRTT 2014). Chinook salmon use Nason Creek from the mouth up to the natural fish barrier at Gaynor Falls (RM 17.2). Nason Creek hosts one of the four identified Wenatchee Basin spring Chinook stocks, which were all classified as "depressed" by the Washington Department of Fish and Wildlife (WDFW 1993).

Chinook salmon typically spawn in Nason Creek in August and September (Figure 4), and rear throughout Nason Creek year-round. Chinook salmon in Nason Creek are a "stream-type" salmonid, meaning juveniles spend one or more years in freshwater before outmigration to the Pacific Ocean. This extended freshwater residence time makes spring Chinook salmon more vulnerable to impacts from tributary habitat degradation. Wenatchee River summer Chinook, which are not ESA-listed, do not use Nason Creek (Andonaegui 2001).

Figure 4. This Adult Chinook Salmon Was Observed Using an Undercut for Cover in Nason Creek (RM 14.9) During Snorkel Surveys in August 2016.

Steelhead / Rainbow Trout (*O. mykiss*)

Anadromous *O. mykiss* (steelhead) and resident *O. mykiss* (rainbow trout) use Nason Creek for spawning, rearing, and migration. Nason Creek is classified as major spawning area for steelhead (UCRTT 2014). *O. mykiss* can pass Gaynor Falls (RM 17.2) but are unable to pass the natural bedrock falls at RM 20.9 (Andonaegui 2001). Upper Columbia summer steelhead, which inhabit Nason Creek, were listed as Endangered under the federal Endangered Species Act in 1997, and the Wenatchee River summer steelhead stock was classified as "depressed" by the WDFW (WDFW 1993).

Summer steelhead typically spawn in Nason Creek from February through May each year, and rear throughout Nason Creek year-round. Though the tendency towards anadromy is genetically linked in *O. mykiss*, the offspring of anadromous steelhead can display a resident trout life history and the offspring of resident rainbow trout can display an anadromous steelhead life history (Andonaegui 2001).

Bull Trout

Upper Columbia bull trout were listed as threatened under the federal Endangered Species act in 1998. Nason Creek hosts one of 11 distinct bull trout populations found in the Wenatchee Basin (WDFW 1998). Bull trout use Nason Creek for foraging, migration, and overwintering, and use upper portions of Nason Creek (including Upper Nason Creek) for spawning and rearing (UCRTT 2014). Migratory bull trout can pass Gaynor Falls (RM 17.2), but are unable to pass the natural bedrock falls fish barrier at RM 20.9 (Andonaegui 2001). Only fluvial bull trout, which spawn in headwaters and migrate to the mainstem Wenatchee and Columbia Rivers, are present in Nason Creek (Andonaegui 2001). Juvenile fluvial bull trout generally remain in their natal streams for one to four years before undertaking any migration (NPCC 2004a).

Bull trout have more specific habitat requirements than other salmonids in the Wenatchee River Basin. They are one of the most temperature sensitive fish species in western North America, and are limited by water temperatures over 15°C. Bull trout distribution, abundance, and habitat quality have declined across their range in response to human impacts (NPCC 2004a). Invasive brook trout may impact Nason Creek bull trout populations (Andonaegui 2001). Brook trout mature earlier, have a higher reproductive rate, are more aggressive, and are more tolerant of degraded habitat conditions than bull trout, which can lead to replacement of bull trout with brook trout in certain areas (NPCC 2004a).

Coho Salmon

Natural populations of coho salmon were extirpated from the upper Columbia River and its tributaries as a result of overfishing, impassable dams, irrigation diversions, habitat loss, grazing, mining, logging, and water management practices. The federal Endangered Species Act does not address extinct or extirpated populations, so upper Columbia populations are not ESA-listed (Andonaegui 2001). The upper extent of coho salmon presence on Nason Creek is likely the natural fish barrier at Gaynor Falls (RM 17.2).

The Yakama Nation has spearheaded efforts to reintroduce coho salmon in the upper Columbia region, and began introducing coho salmon to the Wenatchee River Basin in 1999 (CRITFC 2012). Lower Columbia River stock have been used for coho reintroduction in the upper Columbia (Andonaegui 2001, Inter-Fluve 2012). Over 20,000 Wenatchee River coho returned in 2011, and a naturalized upper Columbia population is taking hold (CRITFC 2012). The UCRTT (2014) listed Nason Creek as a “stronghold” for coho salmon, with the greatest potential in the Wenatchee Basin to support self-sustaining coho populations.

Sockeye Salmon

Lake Wenatchee hosts both anadromous and non-anadromous (kokanee) populations of sockeye salmon, which may use Nason Creek for spawning, rearing, and migration. The upper extent of sockeye presence on Nason Creek is likely the natural fish barrier at Gaynor Falls (RM 17.2) (Andonaegui 2001). Wenatchee River sockeye salmon are not listed under the federal Endangered Species Act.

Westslope Cutthroat Trout

Westslope cutthroat spawn and rear in Nason Creek (USFS 2003). Cutthroat trout are known to exhibit fluvial, adfluvial, and non-migratory life histories, but typical Nason Creek cutthroat trout life histories are not well documented. In the upper Columbia region, cutthroat trout are often abundant in headwater streams (and above partial fish barriers).

Mountain Whitefish

Mountain whitefish are widely distributed in western North America, and are generally common in the upper Columbia River tributaries, including Nason Creek (Wydoski and Whitney 2003).

Brook Trout

Brook trout are non-native and were intentionally introduced as a game species to several lakes in the Nason Creek watershed. Current brook trout distribution and abundance in Nason Creek is not well understood (Andonaegui 2001). Brook trout can hybridize with and out-compete ESA-listed bull trout, and robust populations of brook trout have been linked with the decline of bull trout in some upper Columbia tributaries (USFWS 2010). Brook trout mature earlier, have a higher reproductive rate, are more aggressive, and are more tolerant of degraded habitat conditions than bull trout (NPCC 2004a).

2.5.2 Non-Salmonid Species of Interest

Multiple non-salmonid species are present within the Nason Creek drainage, including various species of sculpin, suckers, and dace. Pacific lamprey (*Lampetra tridentata*) are of particular interest due to their ecological role, anadromous nature, and importance in tribal customs and fisheries.

Pacific Lamprey

It is likely that Pacific lamprey used to occur throughout the Wenatchee River Basin wherever anadromous salmonids were also present. Pacific lamprey have many similar habitat needs as salmon, but they spawn in sandy substrates, often on the margins of mainstem habitats. Evidence suggests that lamprey populations have declined across the Columbia River Basin, but there is a lack of information on the current abundance and distribution of Pacific lamprey in the region (NPCC 2004a). Johnsen and Nelson (2012) surveyed sites along the mainstem Wenatchee River and found no lamprey above Tumwater Dam (RM 30.9). Lamprey have lost an estimated 40% of their former habitat in the Columbia River Basin due to dams alone (Crandall and Wittenbach 2015).

Since 2008, the Yakama Nation has been working to restore natural production of Pacific lamprey to a level "that will provide robust species abundance, significant ecological contributions and meaningful harvest within the Yakama Nations Ceded Lands and in the Usual and Accustomed areas" (YNF 2018). The Yakama Nation program includes investigation of historic and current lamprey distribution, identifying limiting factors for Pacific lamprey by watershed, and lamprey habitat restoration. Additionally, the Yakama Nation has released Pacific lamprey at various points in the Wenatchee and Methow Rivers, including at the confluence with the Chewuch River (YNF 2018). The Pacific Lamprey Habitat Restoration Guide was published in 2015 to provide current information on population status and needs of Pacific lamprey and to encourage lamprey recovery efforts across the Columbia River Basin (Crandall and Wittenbach 2015).

2.6 Ecological Concerns

Targeted tributary habitat restoration depends on an understanding of local environmental factors that are limiting the recovery of salmonid populations. These ecological concerns, also known as limiting factors, are the "biological, physical, or chemical conditions and associated processes and interactions that limit a species' viability" (NOAA NMFS 2016) and are directly tied to specific life stages that are most limiting the production of the population (i.e. where survival is the lowest). The Revised Biological Strategy (UCRTT 2014) contains the most recent information on ecological concerns for Nason Creek, and is consistent with the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (UCSRB 2007). It identifies key threats to salmonid population viability that should be considered in protecting quality habitat and restoring degraded habitat.

The Revised Biological Strategy identified seven ecological concerns, listed in priority order, for the Nason Creek Assessment Unit (UCRTT 2014):

1. Peripheral and Transitional Habitat (Floodplain Condition)
2. Channel Structure and Form (Bed and Channel Form)
3. Riparian Condition (Riparian Condition and Large Wood Recruitment)
4. Channel Structure and Form (Instream Structural Complexity)
5. Food (Altered Primary Productivity or Prey Species Composition & Diversity)
6. Sediment Conditions (Increased Sediment Quantity)
7. Species Interactions (Introduced Competitors and Predators)

Each ecological concern is tied to specific changes in riverine habitat and processes (UCRTT 2014):

- **Channel Structure and Form:** Includes loss of instream structures (wood, boulders, etc.); poor hydrologic function; inadequate quantity or depth of pools; inadequate spawning substrate; and loss of instream roughness, channel morphology, and habitat complexity.
- **Food:** Includes alteration of ecological dynamics affecting the quantity, quality, and/or species composition of phytoplankton or detritus; addition of competing salmonid stocks, species, or hatchery-produced fish; and alteration of ecological dynamics affecting the species composition, distribution, or nutritional quality of zooplankton, macroinvertebrates, forage fish, or other prey.
- **Peripheral and Transitional Habitats:** Includes impaired access to floodplain habitats (seasonal wetlands, off-channel habitat, and side channels); loss of floodplain and hyporheic flow connectivity; degradation of floodplain habitats; and reduced overwintering and refuge habitats.
- **Riparian Condition:** Includes loss, degradation, or impairment of riparian conditions important for shading, bank stabilization, nutrient and chemical mediation, control of surface erosion, production of large woody material for stream recruitment, and production of food organisms and organic material.
- **Sediment Conditions:** Includes streambed sedimentation, high levels of suspended sediment, high turbidity, increased fine sediments in spawning gravel, and embedded substrate.
- **Species Interactions:** Includes competition with or predation by introduced species or native species that benefit from anthropogenic changes in river conditions.

Additionally, restoration should consider the impacts of anthropogenic climate change on restoration needs and effectiveness. Beechie et al. (2013) estimated that summer base flows will decrease, winter flood events will become more common, and stream temperatures will increase between 2 and 6°C across the Pacific Northwest by 2070-2099. Hydrologic regimes across the Columbia Basin will increasingly be dominated by rainfall rather than snowmelt (Figure 5). This will place extreme challenges on Chinook and steelhead populations already limited by altered hydrology and degraded water quality. Beechie et al. (2013) also found that restoring floodplain connectivity, restoring stream flow regimes, and re-aggrading incised channels are the restoration actions most likely to ameliorate for climate change effects and increase salmonid population resilience over the long term. In contrast, restoration actions focused solely on instream habitat rehabilitation are less likely to ameliorate for climate change effects. Thermal refugia and high flow refugia, which are characteristic of dynamic river systems with high floodplain connectivity, will likely become especially important habitat features in the face of climate change.

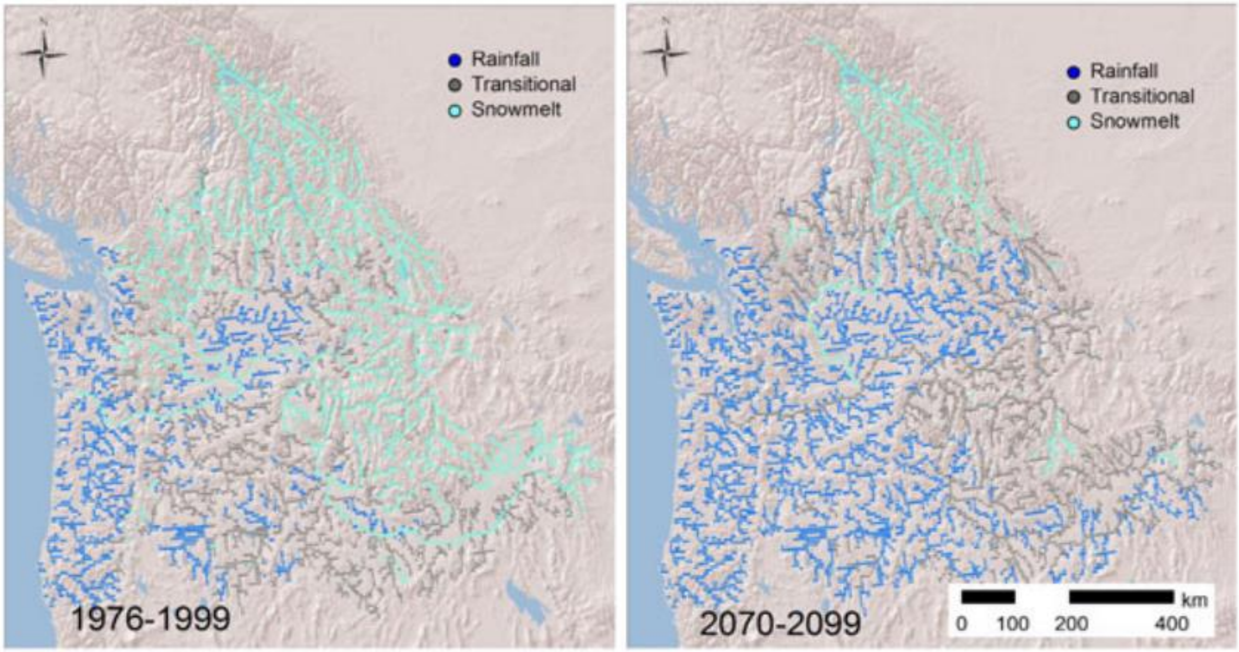


Figure 5. Modeled Hydrologic Regimes of the Columbia River Basin Over Time (From Beechie Et. Al 2013). The Transition from Snowmelt-Dominated to Rainfall-Dominated Hydrologic Regimes Across the Region Will Have Significant Impacts on the Long-Term Viability of Salmonid Populations.

3. METHODS

3.1 Geomorphic Surveys

Baseline geomorphic data and observations were collected during field surveys to document active and impaired geomorphic processes and to characterize existing conditions. The data collected supported the characterization of channel morphology, connection to the adjacent floodplain (degree of incision), controls and patters of sediment transport, presence and influence of instream wood, active bank erosion, and impediments to natural processes. All information was collected digitally in the field, providing georeferenced locations for all data and observations. Opportunities for restoration and current habitat were documented during the field surveys to inform project identification and prioritization.

3.2 USFS Stream Inventory

The entire 2.5 river mile study area was classified as one survey reach (Upper Nason Creek) based on USFS stream inventory protocols (USFS 2012). The bottom 0.25 mile stretch of the Upper Nason Creek Reach is more confined than the rest of the reach, but is not long enough to justify classification as its own survey reach. The majority of the study reach is Rosgen class C3, is minimally confined and moderately sinuous, and flows through frequent stands of large and mature conifers.

USFS Level I and Level II protocols were used to conduct a comprehensive stream inventory of the study reach. Level I stream inventory involves basic computer-based procedures to identify standard attributes of the reach (e.g. gradient, sinuosity, reach breaks, etc.), and to plan for field surveys. Level II stream inventory is field-based and involves an extensive stream channel, riparian vegetation, and aquatic habitat condition assessment throughout the study reach at a channel unit scale (USFS 2012).

Level II field surveys were conducted on all 2.5 miles of the study reach from November 13 to November 15, 2017. Two biologists assessed the reach on a channel unit scale, collecting information on channel unit type, unit area, gradient, eroding banks, large woody debris resources, riparian vegetation, temperature, substrate, bankfull characteristics, and pool embeddedness. The USFS Stream Inventory Handbook (USFS 2012) details all field data collection protocols that were used on Nason Creek. See Appendix A for the full USFS stream inventory data summary.

3.3 Field Identification of Restoration Opportunities

Field surveys were used to identify preliminary restoration and habitat enhancement opportunities across the upper Nason Creek study area. Surveyors made note of local geomorphology; anthropogenic features, human impacts, and infrastructure risks; impaired instream habitats, disconnected floodplain areas, and disturbed riparian zones that could benefit from restoration; and high-functioning habitat features that should be preserved. Project concepts were developed from these observations, and these concepts were refined using data from the USFS stream inventory and geomorphic analysis. Restoration opportunities were selected to address specific ecological concerns and reach-scale restoration targets within a watershed context. Potential restoration actions are discussed in Section 5.2.

3.4 Geomorphic and Habitat Analyses

3.4.1 Hydrology

The hydrologic character of the Upper Nason Creek reach was assessed to understand the timing and magnitude of flows over a range of discharges. This characterization of the hydrologic regime includes a flood frequency assessment to identify discharges correlated to specific return intervals (2-yr, 100-yr floods). Additionally, baseflow conditions were assessed to understand low-flow conditions in the reach.

3.4.2 Channel Morphology and Recent Evolution

Channel form and condition were assessed using current and historic air photos and geologic and topographic maps to evaluate the current condition of the channel in context with the historic, pre-disturbance condition. Natural controls on geomorphic processes, including bedrock outcrops and alluvial fans, contribute to the reach and local scale processes that drive potential habitat. These natural controls, as well as anthropogenic constraints have all contributed to the current condition and were considered in characterizing current processes.

Historic air photos and the 1904 land survey map were used to evaluate channel changes over time in response to both natural and human disturbances (Appendix F). The historic condition of the channel, and the response to flood events over time can be used to assess the current condition in historic context. Evidence including the growth and/or loss of instream gravel bars, channel migration rate in response to flood events, establishment and/or loss of vegetation of gravel bars, and channel avulsions can all be used to establish a detailed recent history of channel evolution within the project reach. This historic context is critical to interpretation of existing conditions and processes.

3.4.3 Habitat

Habitat metrics were compiled based on data collected under the USFS Level II stream inventory protocols. Field data was collected electronically and entered into Microsoft Excel 16 along with data gathered in desktop portion of the level II protocol (USFS 2012). QA/QC was performed on tabular data to rectify data entry errors and verify integrity of the dataset. Metrics of interest were identified by Yakama Nation Fisheries and were subsequently derived from the raw data with Excel formulas. QA/QC was once again performed to verify the efficacy of the calculations.

3.5 Reach-Based Ecosystem Indicators

Reach-based ecosystem indicators (REI) are a standardized approach for assessing habitat conditions. REI analysis has been applied across many reaches and basins within the Upper Columbia. In Nason Cr., REI analyses been conducted by the Bureau of Reclamation as part of reach assessments from the mouth to RM 14 (USBR 2009a, 2009b, 2009c, 2011).

We used a combination of survey data from the USFS Level II assessment and the geomorphic assessment performed as part of this reach assessment, existing reports and studies on Nason Cr., and geospatial data.

4. REACH ASSESSMENT RESULTS

4.1 Upper Nason Creek Reach Overview

The Upper Nason Creek Reach, located from the train bridge over Nason Creek at RM 13.7 to RM 16.2 (0.07 miles above the confluence with Whitepine Creek), flows westerly through a wide, flat-floored valley with steep side walls in a stretch of Nason Creek that is uniquely apart from the U.S. Highway 2 road corridor (Figure 6). Most of the reach is minimally confined and moderately sinuous, with mature forested floodplains on either side, side channel and off-channel area development, and frequent meanders. In contrast, the lower 0.25 miles of the reach are severely confined by the BNSF railroad grade, Whitepine Creek Road, and steep hillslopes. The reach has ample high-quality salmonid spawning habitat, and there is relatively little human disturbance in the reach compared to other sections of Nason Creek. Most of the reach fits a Rosgen C3 channel classification. Map 1 presents the current conditions as surveyed by NSD field staff.

Figure 6. Steep Valley Walls and Flat Valley Bottom of the Upper Nason Reach.

4.2 Hydrology

The Upper Nason Creek Reach is above all major diversions and is subject to a natural snowmelt runoff hydrologic regime. Two tributaries (an unnamed creek and Whitepine Creek) flow into the reach. The unnamed creek contributes about 1% of total flow and Whitepine Creek contributes about 40% of total flow (Figure 7).

The hydrologic regime of Nason Creek through the project reach is characterized by snowmelt floods in late spring, diminishing flows over the summer months to baseflow conditions, and rainfall events in the fall and winter months. Due to a lack of long-term streamflow monitoring data in Nason Creek, the nearby Icicle Creek gage (USGS 12458000) was used as a proxy for Nason Creek to develop flood frequency in the project reach. The Icicle Creek gage has 68 years of peak flow records, beginning in 1912 (gaps in data from 1915-36 and 1980-93). Flood frequency statistics were calculated for Icicle Creek and adjusted by drainage area and precipitation ratios to estimate peak flows for the project reach (Table 3). The watershed contributing to the project reach is 64.7-mi^2, compared to the much larger contributing area to the Icicle Creek gage of 193-mi^2 (Table 4). Mean annual precipitation is 74.8-in at Nason Creek, an 11% increase relative to Icicle Creek (67-in).

Following the spring freshet instream flows typically gradually diminish as the snow recedes from the high watershed. Flows reach their annual minimum typically in September, with brief increases following isolated summer thunderstorms. Baseflow statistics were calculated from the daily mean streamflow data from the Department of Ecology gage in lower Nason Creek. Mean monthly flows for September ranged between 27 and 116-cfs over the 16 years of data collection, with an average of 55-cfs during the month of September.

Road density from the downstream extent of the reach at RM 14.1 to the headwaters of Nason Creek. is 0.95 mi/mi^2, which lies within the adequate condition. However, the density is an under-representation of total road length because some logging and forest service roads are not included, which can be seen in aerial imagery. In all likelihood, road density is within the 1-2.5 mi^2/mi range, putting the condition into the at risk category.

A prior assessment of Nason Creek (USFS 1998) found significant increases in drainage network were only attributable to road and railroad grades. They concluded the indicator rating for effective drainage network in Nason Creek should reflect the road density rating, therefore the REI rating is at risk.

Table 3. Flood Frequency Statistics Calculated for the Reference Gage at Icicle Creek (1912-2015) and the Corresponding Estimates for the Project Reach Based on Application of the Drainage Area and Precipitation Ratios.

ANNUAL EXCEEDANCE PROBABILITY	RECURRENCE INTERVAL (YEARS)	ICICLE CREEK #12458000 PEAK FLOW (CFS)	NASON CREEK AB RM 13.7 PEAK FLOW (CFS)
0.99	1.01	1,960	730
0.8	1.25	3,160	1,180
0.5	2	4,450	1,660
0.2	5	6,600	2,470
0.1	10	8,290	3,100
0.04	25	10,770	4,030
0.02	50	12,880	4,820
0.01	100	15,230	5,700

Table 4. Comparison of Drainage Area and Precipitation Between Nason Creek and the Reference Gage in Icicle Creek.

	DRAINAGE AREA (SQUARE MILES)	MEAN ANNUAL PRECIPITATION (INCHES)
Icicle gage (RM 5.8)	193	67
Nason Creek (RM 13.7)	64.7	74.8
Ratio (Nason/Icicle)	**0.33**	**1.12**

Figure 7. Confluence of Whitepine Creek and Nason Creek.

4.3 Hydraulics

A hydraulic analysis of existing conditions was conducted to characterize hydraulic parameters and current riverine conditions. Graphics of results and methods used to setup and perform modeling efforts are described in Appendix D. The hydraulic modeling software developed by Hydronia, (RiverFlow2D GPU) and Aquaveo (SMS v12.3) was employed in this study. The modeled sub-reach is between RM 14.6 and 13.5, limited geographically to the lower mile of the project reach where existing 2015 LiDAR topography is currently available (DOGAMI, 2016). The 1-year, 2-year, and 100-year recurrence interval discharges were modeled to characterize flow depth, velocity, shear, and floodplain connectivity over a range of flood conditions.

At the upstream end of the modeled sub-reach (RM 14.6), Nason Creek meanders through a 600 ft wide forested valley. Average channel width is approximately 75 ft in this reach, with bank heights ranging between 6 to 8 ft. Flow depths in the channel for the 1- and 2-year discharges range from 4 to 5 ft and 5 to 6 ft, respectively. Flow is completely contained within the main channel during the 1-yr flow, with several gravel bars remaining dry within the active channel. As flows increase to the 2-yr discharge, 3 floodplain side channels become activated, with flow depths ranging from 1-3 ft and velocities typically between 1-2 ft/s (Appendix E). Overbank flow is largely contained within floodplain side channels during the 2-yr flow, with much of the adjacent floodplain remaining dry until flows exceed the 5-yr recurrence flow. At the 100-yr discharge, flows increase to 10-12 ft deep in the main channel and 1-6 ft on the adjacent floodplain. Velocities are between 8-12 ft/s in the main channel and 1-4 ft/s on the floodplain. The valley constricts near RM 13.9 to a narrow canyon downstream, creating a backwater effect that extends upstream to RM 14.1 that is reflected in the 100-yr model results. Flow depths upstream of the canyon are 2-3 ft deeper in the channel relative to further upstream, and the channel velocities diminish significantly to 6 ft/s upstream of the canyon entrance.

Within the narrow (60 ft wide), highly-confined canyon the channel gradient increases from 0.3% to 0.9%. Channel velocity in the wider valley upstream ranges from 5 to 6 ft/s, and increases to 10 to 15 ft/s in the canyon sub-reach, for the 2-year flow. Significant infrastructure includes the White Pine Rd bridge (RM 13.75) and a railroad bridge (RM 13.7). Water surface elevation for the 100-year flow (2250 ft) is 2 to 3 ft below the abutment approach for the White Pine Rd bridge. The railroad bridge abutment approach is over 20 ft above the modeled 100-year water surface elevation.

The results of this hydraulic assessment are representative of the condition for this sub-reach of Nason Creek when the LiDAR topography was collected in 2016. There appears to not be significant channel changes between 2016 and 2018, thus the results are representative of the current condition. This sub-reach is unique to the larger project reach in that it captures the transition from an unconfined valley to confined canyon, where a significant backwater effect occurs during larger floods. This backwater effect increases the magnitude and frequency of floodplain inundation, the ability of the channel to transport sediment

4.4 Habitat Conditions

The Upper Nason Creek Reach exhibits a Rosgen C3 classification and pool-riffle morphology though most of the reach. Riffles were the dominant habitat, and account for 46.0% of the total wetted area. Pools were also relatively abundant, accounting for 23.9% of the wetted area at a frequency of 10.1 mainstem pools/mile. Pool frequency may seem low compared to the proportion of the reach they occupy, but average pool length was relatively long (150 feet). The pools were also fairly deep with an average maximum depth of 3.9 feet, and no max depth less than 2.5 feet, although fish cover in pools averaged only 6.8%. The remaining wetted area was 1.9% rapid and 17.2% fast non-turbulent (glide). There are several side channels and off-channel habitats in the reach. Surveyors identified a total of five side channels, all of which were dominated by slow water habitat. One of these side channels (channel unit 44) connected to a large off-channel pool area on river right with at least four active beaver dams and substantial woody debris (Figure 8). Over 38% of qualifying woody debris pieces in the Upper Nason Creek Reach were recorded in this off-channel area. Side channel and off channel habitat made up 11.0% of the total area, with the majority of side and off channel area coming from the one off-channel unit described above, indicating that, while some side and off channel habitat is present, the vast majority of the reach is a single thread.

Seventeen percent of streambanks were classified as actively eroding, typically located at the outside of meander bends in the channel and indicative of stable channel. Bank armoring or alteration is low throughout the reach at approximately 1% of the overall bank length, almost entirely from the railroad grade.

Ocular substrate estimates indicate that gravel is the dominant streambed substrate across the entire reach, with cobble being subdominant, and the D_{50} (based on two Wollman pebble counts) in riffles was 75mm.

Woody debris is deficient through most of the reach, with only two log jams present in the entire study area. Surveyors recorded 34.2 small (minimum 6in x 20ft) pieces per mile, 19.1 medium (minimum 12in x 35ft) pieces per mile, and 7.0 large (minimum 20in x 35ft) pieces per mile. However, over 38% of total woody debris resources were recorded in the off-channel area of channel unit 44. Mainstem woody debris is low, and excluding the wood from off-channel area, frequencies drop to 21.0 small pieces/mi, 10.5 medium pieces/mi, and 5.8 large pieces/mi. The reach has moderate woody debris resources available for both long-term and short-term recruitment, however the residence time of recruited trees is low due to a lack of key sized trees capable of remaining stable during high flow events. Estimates of key member size based on the bankfull flow depth and width are greater than 60 in DBH and 100 ft long, with rootwad attached (Abbe and Montgomery 2003). The largest trees observed in the channel and along the channel banks approach 48 in DBH and exceeded 100 ft in length, however there are very few trees of this size in the project reach. The vast majority of trees available for recruitment will be mobile during high flow events, and with few obstructions in the channel capable of accumulating wood in transport the residence time of recruited wood will remain low within the project reach.

Figure 8. Large Off-Channel Area. Four Active Beaver Dams and Over 38% of the Total Woody Debris Resources Were Found in this Unit.

The reach flows through large and mature stands of western red cedar (*Thuja plicata*), black cottonwood (*Populus trichocarpa*), Douglas fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*), and Engelmann spruce (*Picea engelmanii*) (Figure 9). Most of the banks on either side of the channel are forested upstream of the Cascade Meadows Camp, with trees exceeding the large LWD size threshold (minimum 20in x 35ft) (USFS 2012). Downstream of the camp the banks are more commonly lined with small shrubs and trees, including red osier dogwood (*Cornus sericea*), red alder (*Alnus rubra*), willow (*Salix* sp.), and periodic locations where the channel abuts large (21-32 in DBH) to mature trees (> 32 in DBH) (USFS 2012). Riparian wood resources are only entirely absent in limited stretches where the denuded Whitepine Road grade and/or BNSF railway grade run immediately alongside Nason Creek. However, the lack of large wood jams and pieces of sufficient size (60 in DBH and 100 ft long) to remain stable during common flood events diminishes the potential for local bank erosion and LWD recruitment in the reach (Abbe and Montgomery 2003).

Figure 9. Stands of Mature Conifers and Black Cottonwood Along the River Banks that Are Typical Throughout the Reach.

Summer water temperatures are elevated throughout much of Nason Creek, with documented exceedances of Washington State water temperature standards (DOE 2007). Two separate sections of Nason Creek that fall within the reach were included on the 2004 Washington State 303(d) list of impaired waters due to temperature exceedances. The Wenatchee River Watershed Temperature Total Maximum Daily Load (TMDL), approved by the U.S. Environmental Protection Agency in 2007, currently addresses these impaired sections (see Washington 303(d) listings 42923 and 42924). There are no irrigation diversions within or upstream of the reach.

4.5 Geomorphology

4.5.1 Channel Morphology

The geomorphic character of the Upper Nason Creek Reach is typified by a single thread pool-riffle channel with an average slope of 0.63%, and intermittently confined valley due to alluvial fans emanating from tributaries entering the river from the south. These fans confine the channel to the northern side of the valley bottom near the upstream end of the reach at White Pine Creek and at the Cascade Meadows Camp. Between these confining alluvial fans the floodplain is broader and increasingly connected to the adjacent channel in the downstream direction. Immediately upstream of the fan confining the channel at the Cascade Meadows Camp there is a large beaver wetland complex between RM 15.2 – 15.5 with several deep and wide pools and four active beaver dams connected to the main stem channel at the outlet and surrounded by mature forested floodplain. Upstream of this wetland complex the adjacent floodplain is progressively less connected continuing upstream, with perched side channel inlets indicating less frequent floodplain connection. The channel is again confined through a bedrock constriction at the downstream end of the project reach.

The river through the project reach is primarily a single thread channel, with multiple locations where the channel is laterally confined. Based on the median grain size (D50), formative discharge (Q*; ~Q1.5), and channel gradient, Eaton et al (2010) predicts channel form for natural channels. The channel through the project reach in the single thread region of the plot (Figure 10). The channel form predicted by Eaton is a function of the recent geomorphic history at the site, as changes to sediment supply and wood loading can change Q*. Increasing wood loading can decrease the average grain size on the channel bed through shear stress partitioning, resulting in a higher Q*. Increases in sediment supply have a similar effect increasing Q*, pushing the channel toward the anabranching and braided domains. Increasing the shear stress resulting from historic incision can decrease Q*, trending toward the single thread region of the plot (Figure 10).

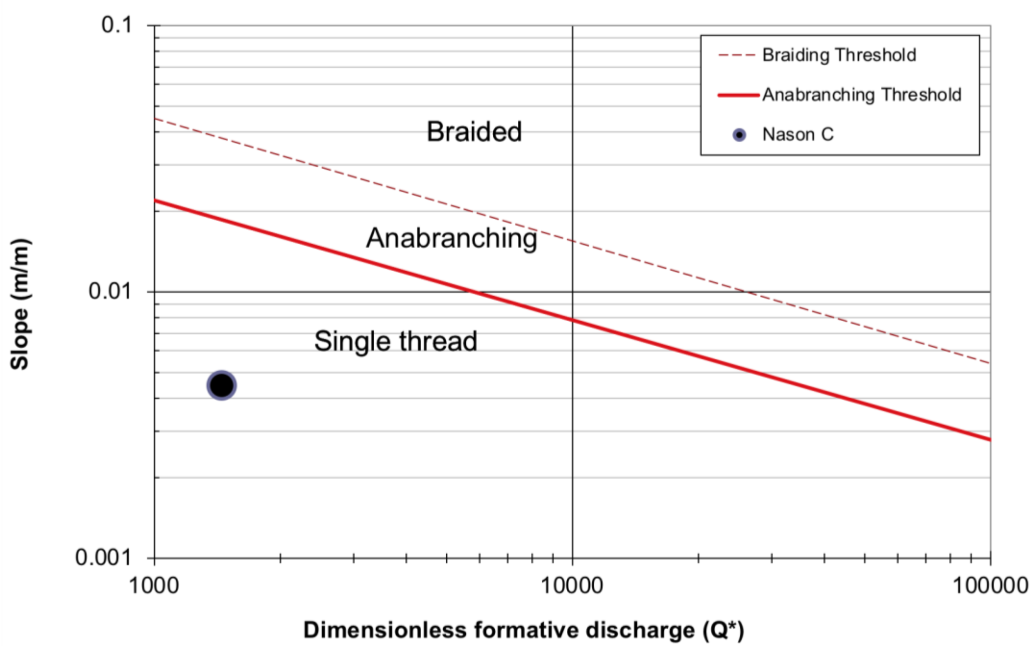


Figure 10. Plot of Predicted Channel Form Based on Easton et al (2010).

The current lack of large wood current in the channel has diminished habitat conditions over time and has led to a more simplified planform and coarser substrate on average. Undisturbed rivers in the Alpine region of Washington of similar size to Nason Creek record 34 pieces of wood/100-m (Fox and Bolton 2007). Surveys of the channel through the project reach recorded 3.8 pieces/100-m, nearly 10% of reference conditions. This lack of large wood contributes significantly to the lack of instream habitat in the form of pools, cover, hydraulic complexity (fast, slow, deep, shallow water in close proximity), and sediment sorting. The channel banks through the project reach lack tress of sufficient size to remain stable once recruited into the channel. Trees estimated to be 60 in DBH and 100 ft long with rootwad attached would be required to remain stable in the channel, providing an initiation point to accumulate additional smaller wood in transport (Abbe and Montgomery 2003).

The absence of instream roughness from large wood also allows shear stress in the channel to increase, contributing to incision and coarsening of the channel substrate. This incision has isolated off-channel habitat by limiting the frequency and magnitude of overbank flooding and continues to further disconnect over time. The channel bed substrate has coarsened due to the incision and lack of instream roughness, reducing spawning opportunities within the project reach.

The current simplified single thread channel planform, due largely from the lack of stable large wood, suggests that the channel would likely plot toward anabranching under historic conditions (Figure 10). The formation of large logjams would have forced anabranch channel formation by splitting flow, as well as partition shear stress resulting in a finer channel substrate. Based on the reference condition of wood loading and current lack of wood, it is likely that the historic channel was more anabranching throughout the project reach, more so where less confined by alluvial fans.

4.5.2 Recent Channel Evolution

Historic air photos dating back to 1956 and the 1904 land survey map were georeferenced and reviewed to document the channel response to recent historic natural and human disturbances (Appendix F). The recent evolution of the channel and historic conditions serve to place the existing conditions in proper context. Current geomorphic processes are part of a sequence of events that have resulted from historic influences, both natural and anthropogenic. The assessment is limited by the accuracy of the georectification, resolution of the air photos, and shadows limiting view.

The earliest available maps for the project reach are land surveys from 1904. There are few reliable benchmarks suitable for precise rectification of the map, and the quality of these historic maps varies. As precise locations cannot be established with any certainty, some features depicted on the map can provide clues to the historic condition. The map shows the existing rail line on the northern side of the channel through the project reach, and the channel is clearly depicted as is White Pine Creek. Other than the rail line there does not appear to be significant development within the project reach by 1904. The alignment of the channel is off considerably in locations, and thus any evaluation of historic channel location changes cannot be made. It is of interest that the channel is depicted as a single thread channel with very few if any meanders within the project reach. Of additional interest is the depiction of wetlands on the 1904 map close to current beaver pond complex upstream of the Cascade Meadows Camp. This indicates that this off channel wetland feature has persisted on the landscape for over a century, continuing to provide valuable rearing habitat in the project reach.

Air photos from 1956 provide the earliest images of the project reach, with additional development within the valley apparent by this time (Appendix F). Whitepine Road is visible on the southern side of the channel, with the railroad on the northern side for the entire project reach. Forest clearing is visible at the current Cascade Meadows Camp. Just downstream of the Whitepine Creek confluence, a natural logjam on Nason Creek appears to have deflected the channel toward the left (near RM 16), creating a tight meander around the logjam through the left bank floodplain. In the subsequent air photos this site evolves as the channel begins to avulse around the right side of the logjam by 1963, and finally breaking through by 1974 (Appendix F). The long meandered abandoned channel to the left of the logjam is now currently perched 5-6 ft above the main channel.

Also visible in the 1956 air photo is what appears to be a low-head dam near RM 14.8, with a deep pool extending upstream. The structure is adjacent to the cleared land and buildings at the Cascade Meadows Camp. In the following air photo from 1963 the dam is no longer present, and the channel has avulsed downstream to the left into a new flow path adjacent to the rail line (Appendix F). The abandoned channel flow path, and a long side channel to the right, progressively become overgrow with vegetation over time. The main channel appears to widen and gravel bars become more pronounced over time downstream of RM 14.8, with the most significant channel migration between RM 14.5 and 14.25 from 1985-2006. It may be that this sub-reach downstream is in the process of transporting excess sediment stored behind the dam present in the 1956 air photo, responding by growing gravel bars and widening channel banks.

Logging in the proximity of the project reach occurs prior to the earliest air photo (1956), including much of the lower floodplain between RM 14 - 14.75, and the Cascade Meadows Camp between RM 14.75 – 15.2. Additional clearing occurs between 1963 and 1974 on the right bank floodplain between RM 15.4 – 15.7, with additional thinning along Whitepine Road upstream of RM 15.7 to 16.25. The removal of the floodplain trees during these logging events, likely the largest trees available to harvest, has diminished the supply of large trees available for future recruitment. This lack of large trees has contributed largely to the current lack of large wood in the channel as most trees recruited into the channel are not stable under normal flood conditions.

4.6 Reach-based Ecosystem Indicators

Reach-based ecosystem indicators (REI) were determined for the Upper Nason Reach based upon previous reach assessments and REI analyses in Nason Creek conducted by the U.S. Bureau of Reclamation (BOR) covering Nason from the mouth at the Wenatchee River up to the downstream extent of the Upper Nason Reach:

- Lower Nason (2011) RM 0 – 4.6
- Kahler (2009) RM 4.65 – 8.9
- Lower White Pine (2009) RM 9.45 – 11.55
- Upper White Pine (2009) 12.0 – 14.25

The indicators used in this analysis match those used in the previous Nason Creek REI assessments, which were originally developed by U.S. Fish and Wildlife Service in 1998, as published in Hillman and Giorgi (2002). The REI provide reach-scale ratings of function (i.e. adequate, at risk, or unacceptable), which allow comparison of functions between multiple reaches. The REI are also used to help establish restoration targets as used in the Restoration Strategy in Section 5 below. The complete REI summary can be found in Appendix B.

Table 5. Reach-Based Ecosystem Indicator Summary Results.

GENERAL CHARACTERISTIC	GENERAL INDICATOR		RATING
Watershed Condition	Effective Drainage Network and Watershed Road Density	Effective drainage network and watershed road density	At Risk

GENERAL CHARACTERISTIC	GENERAL INDICATOR		RATING
	Disturbance Regime	Disturbance Regime	At Risk
	Flow/Hydrology	Flow/hydrology	At Risk
	Habitat Access	Main channel physical barriers	Adequate
	Water Quantity and Quality	Quantity/ Temperature/ Chemical Contamination/ Nutrients	At Risk
Habitat Quality	Substrate	Dominant substrate/fine sediment	At Risk
	Large Woody Debris	Pieces per mile at bankfull	At Risk
	Pools	Pool frequency and quality	At Risk
	Pools	Large pools	At Risk
	Off-Channel Habitat	Connectivity with main channel	At Risk
Channel Condition	Floodplain Connectivity	Floodplain Connectivity	At Risk
	Bank Stability/Channel Migration	Bank Stability/Channel Migration	At Risk
	Vertical Channel Stability	Vertical Channel Stability	At Risk
	Vegetation Structure	Vegetation Structure	Adequate
	Vegetation Disturbance	Vegetation Disturbance	At Risk
	Canopy Cover	Canopy Cover	Not Assessed

5. RESTORATION STRATEGY

Development of the restoration strategy was guided by the habitat objectives set forth in the Upper Columbia Recovery Plan (UCSRB 2007), the ecological concerns for Nason Creek and recommended restoration actions from Upper Columbia Revised Biological Strategy (2014), and by field and analytical work conducted as part of this Reach Assessment. More analysis will still be necessary before projects are implemented; this may include topographic survey, hydraulic modeling, engineering analysis, and alternatives evaluation.

5.1 Existing and Target Habitat Conditions

An understanding of the current ecological concerns for Upper Nason Creek and a comparison of existing and target habitat conditions was used to identify action types and projects. Existing conditions were developed based directly on analyses and surveys performed as part of this Reach Assessment including habitat survey data and also the hydraulics and geomorphology assessments. Target habitat conditions have been developed based on the REI assessment in Appendix B, the Matrix of Diagnostics/Pathways and

Indicators (USFWS 1998), the NMFS Matrix of Pathways and Indicators (NMFS 1996), as well as more recent work conducted within the region by the USBR and their adaptation of these indicators (USBR 2012). Table 2 presents the existing and target habitat conditions.

Ecological concerns for Nason Creek and recommended restoration actions from Upper Columbia Revised Biological Strategy (2014) in priority order:

1. Peripheral and Transitional Habitat (Side Channel and Wetland Connections)
    - Reconnect side channels and off-channel habitat, where appropriate, from Whitepine Creek to the confluence with the Wenatchee River
2. Channel structure and form (Bed and Channel Form)
    - Increase large wood complexes from Whitepine Creek to the confluence with the Wenatchee River
    - Remove (or modify) levees, berms, and roads where feasible.
    - Restore channel structure and form to reduce sediment transport capacity and competency in order to counteract recent incision and confinement where it unnaturally occurs (i.e.: adjacent road and rail corridors).
3. Riparian Condition (Riparian Condition)
    - Focus riparian plantings in floodplain areas, residential developments, and side-channel reconnections from Whitepine Creek to the confluence with Nason Creek.
4. Channel structure and form (Instream Structural Complexity)
    - Restore instream habitat diversity by enhancing large wood recruitment, retention, and complexity.
5. Food (Altered Primary Productivity)
    - No new fertilization actions currently recommended
6. Sediment Conditions (Increased Sediment Quantity)
    - USFS road maintenance and actions
    - Decommission roads that are affecting sediment deliver to stream
7. Species Interaction (Competition)
    - No actions listed

Table 6. Existing and Target Conditions for the Upper Nason Creek Reach.

INDICATOR	EXISTING CONDITION	TARGET CONDITION 1	RESTORATION ACTION TYPE
Large Woody Debris	Current LWD frequency for pieces > 12 in diameter and > 35 ft length is 26 pieces/mile, meeting the requirement of at least 20 pieces/mile. Within the main channel however there were low amounts of LWD. Approximately 1/3 of the LWD for the entire reach is in a large off-channel area, including 34 small pieces, 22 medium pieces,	>20 pieces/mile with > 12 in diameter and > 35 ft length; and adequate sources of woody debris available for both long-term and short-term recruitment	Install Habitat Structures

INDICATOR	EXISTING CONDITION	TARGET CONDITION 1	RESTORATION ACTION TYPE
	and 3 large pieces. Wood recruitment within the reach also appears to be limited.		
Floodplain Connectivity	Due to the active incision in the upper 1.5 miles of the 2.5 mile long reach, and the disconnection of the upper floodplain in the lower section, floodplain connectivity is at risk in the Upper Nason Reach.	Floodplain areas are frequently hydrological links to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession	Floodplain Habitat Reconnection
Off-channel Habitat	Although manmade barriers are not a considerable issue, due to the lack of off-channel areas in the vast majority of the reach, off-channel habitat is in an at risk condition.	Reach has many ponds, oxbows, backwaters, and other off-channel areas with cover, and side channels are low energy areas. No manmade barriers present along the mainstem that prevent access to off-channel areas.	Floodplain Habitat Reconnection
Pools	Pool frequency is 10.2 pools/mile, meeting the criteria for adequate condition. Pools within the reach have good depth with 19 of the 26 pools meeting the large pool criteria of > 1 m (3.28 ft) deep. However, fish cover within pools is low at 6.7% on average. Fourteen pools within the reach had fish cover measured, of which three had no cover and eleven had between 5-15% cover. Fine sediment within the pools also appears to be a concern. Fines accounted for 22% of the substrate composition in pools on average with a range 10-60%.	Channel width (ft) 65-100 pools/mile 4 Pools have good cover and cool water, and only minor reduction of pool volume by fine sediment	Install Habitat Structures

[1] Target conditions was defined as the “adequate” condition for REI criteria.

5.2 Restoration Action Types and Project Opportunities

This section provides a description the overall actions types and the site-specific project opportunities identified during field surveys and further advanced based on the reach assessment results. A total of 15 specific project opportunities were identified and are presented in Table 7 below. All of the project opportunities are presented in maps located in Appendix C.

5.2.1 Protection

Protection and maintenance actions involve preservation of existing functional floodplain and riparian habitats. These actions may be accomplished through purchase of lands or acquisition of conservation easements from the landowners in areas containing existing functional habitat and/or physical processes. Areas identified for protection may have existing high quality and functioning habitat or may contain impaired habitat in need of restoration. In some cases, protection and maintenance objectives might be achieved through long-term management plans.

5.2.2 Floodplain Habitat Reconnection

The purpose of this action is to improve hydraulic connectivity between the main channel flows and those floodplain areas that include side-channels, off-channel habitat, and riparian wetlands. Prior to alteration of reach scale processes by removal of wood, bank armoring, and clearing of riparian forests, the channel was more frequently connected with these floodplain habitats that provide important ecological functions. The proposed actions increase floodplain capacity and provide access for aquatic organisms to move between floodplain and channel features. Site specific actions include the installation of large wood structures to deflect flows and targeted grading to increase connectivity with off channel areas.

5.2.3 Install Habitat Structures

Stable accumulations or “key” pieces of large woody material act as hard points in the floodplain that create backwater, promote sediment deposition and pool formation, decrease potential for channel incision, and provide essential cover habitat. Wood loading targets typically use reference reaches of “natural and unmanaged” forests in comparison to existing reach conditions. Fox and Bolton (2007) recommend a restoration target of >20 key pieces per mile for channels similar in size to Nason Creek. Current wood loading in Upper Nason Creek is 26 pieces per mile. The medium and large pieces in the off-channel area accounted for 37% of the total LWD number of medium and large pieces within the reach.

The addition of key pieces in the main channel and the stabilization of existing wood is recommended to increase wood stability and function in the main stem. The formation of stable wood jams in the channel relies upon recruitment or placement of key pieces that are large enough to resist hydraulic forces of flood flows. These key pieces are essential to the restoration of habitat-forming processes in Upper Nason Creek. Without key pieces, any wood recruited to the channel is likely to be quickly transported through the system and provide little, if any, geomorphic function.

Table 7. Upper Nason Creek Project Opportunities.

PROJECT LOCATION (RM/BANK)	PROJECT ID[1]	GROUP[2]	ACTION TYPE	CONDITION	ACTION	CONSIDERATIONS	PHOTO
RM 16.1/R	UN 1	G1	Install Habitat Structure Floodplain Habitat Reconnection	Location is immediately downstream of the Nason and Whitepine confluence. River left contains a narrow high flow channel. Surrounding floodplain is above the 2-year flood elevation.	Install LWM on river right downstream of the confluence pool to increase flow deflection and activation of the river left side channel.	Project can be combined with UN2 and UN3. Access through White Pine Road to support equipment access and construction.	River left side channel facing upstream. 

PROJECT LOCATION (RM/BANK)	PROJECT ID[1]	GROUP[2]	ACTION TYPE	CONDITION	ACTION	CONSIDERATIONS	PHOTO
RM 16.0/L	UN2a	G1	Protection	River left high flow floodplain terrace. Field assessment indicate that the floodplain surface is higher than the 10-year event.	No action proposed.	No action.	Mainstem near confluence with Whitepine Creek. 
RM 15.95/L and R	UN2	G1	Install Habitat Structure Floodplain Habitat Reconnection	Existing river left and river right side channels.	Install LWM on river left at downstream end of existing side channel to create scour pool and to deflect flows to river right to improve flow connectivity to existing side channel.	Combine action with LWM installation UN 1. Assess flow interaction with UN3 downstream. Access site from upstream and Whitepine Road.	Near location of proposed ELJ, facing downstream. Note side channel on river right. 

PROJECT LOCATION (RM/BANK)	PROJECT ID[1]	GROUP[2]	ACTION TYPE	CONDITION	ACTION	CONSIDERATIONS	PHOTO
RM 15.8/L	UN3	G1	Install Habitat Structure Floodplain Habitat Reconnection	Existing large LWM jam on river left associated with forced channel meander and perennial side channel.	Reinforce existing jam with large wood or posts to increase pool formation, channel migration to river right, and support of existing side channel.	Possible to combine action with UN 1 and UN2. Assess flow interaction with upstream treatments. No direct overland access to site. Use wide gravel bar immediately upstream to support construction/access. May require temporary bridges.	Existing large wood at RM 15.8. Incorporate into proposed ELJ structure. 

PROJECT LOCATION (RM/BANK)	PROJECT ID[1]	GROUP[2]	ACTION TYPE	CONDITION	ACTION	CONSIDERATIONS	PHOTO
RM 15.75/L	UN4	G2	Install Habitat Structure Floodplain Habitat Reconnection	Left bank low vegetated gravel bar with an existing side channel.	Install LWM at head up gravel bar to enhance flow split, improve side channel scour and connectivity, scour pool.	Difficult direct access. Consider helicopter construction to reduce access impacts.	Downstream end of river left side channel terminates at bedrock-scoured pool. 
RM 15.75/L	UN4a	G2	Protection	High floodplain on river left with historical evidence of overland flows. Floodplain above 10-year flood elevation.	Low opportunity for improving floodplain connectivity due to high floodplain elevation.	No Action.	High flow channel on river left. 

PROJECT LOCATION (RM/BANK)	PROJECT ID[1]	GROUP[2]	ACTION TYPE	CONDITION	ACTION	CONSIDERATIONS	PHOTO
Rm 15.50/L R	UN5	G3	Install Habitat Structure Floodplain Habitat Reconnect ion	River left low terrace with recent flood scour. Beaver ponds along downstream 300'. River right high-flow gravel bar with backbar side channel.	Add LWM structures on river right and left to improve flow deflection into existing side channels.	Difficult direct access. Consider helicopter construction to reduce access impacts	River left beaver ponds. 
RM 15.45	UN6	G3	Protection	Right bank floodplain is above 10-year flood elevation. A connection to the UN7 beaver pond complex Would require excavation through forested wetland to achieve greater surface water connection to large beaver pond complex.	No action.	An upstream connection channel would require deep excavation through high-quality forested floodplain and wetland habitats. Access is very limited with no existing area onside for staging or spoil materials.	High bank on river right. 

PROJECT LOCATION (RM/BANK)	PROJECT ID[1]	GROUP[2]	ACTION TYPE	CONDITION	ACTION	CONSIDERATIONS	PHOTO
RM 15.25/R	UN7	G3	Protection	Large beaver dam complex, ponded year-round with no direct upstream surface water inlet. High quality off channel habitat. Current beaver dams limit low flow fish access.	No action	Beaver complex is properly functioning.	Beaver dam complex. 
RM 15.10/L	UN7b	G3	Protection	Low forested floodplain with no existing side channel elements.	No action.	No action.	Forested floodplain. 

PROJECT LOCATION (RM/BANK)	PROJECT ID[1]	GROUP[2]	ACTION TYPE	CONDITION	ACTION	CONSIDERATIONS	PHOTO
RM14.75/R	UN8	G4	Install Habitat Structure Floodplain Habitat Reconnection	High floodplain terrace on river right; limited opportunity for floodplain connectivity enhancement.	Install LWM structure on river left to force migration to river left. Improve scour, LWM recruitment, possible improvement high flow connectivity.	Opportunity to construct in combination with UN9 and UN 10. Possible construction access through the camp and use of temporary bridges.	View downstream to right bank floodplain. 
RM14.77/L	UN9	G4	Install Habitat Structure Floodplain Habitat Reconnection	Low elevation gravel bar and side channel on river left.	Install LWM structure at the apex of the bar to split flow and improve side channel flow connectivity.	Opportunity to construct in combination with UN8 and UN10 downstream. Possible construction access through the camp and temporary bridges.	Open side channel on gravel bar. 

PROJECT LOCATION (RM/BANK)	PROJECT ID[1]	GROUP[2]	ACTION TYPE	CONDITION	ACTION	CONSIDERATIONS	PHOTO
RM 14.6/L	UN10	G4	Install Habitat Structure Floodplain Habitat Reconnect ion	Left bank bar and perennial side channel. High floodplain terrace on immediate left with evidence of debris from recent flow. Existing beaver-controlled channel at downstream end of large bar.	Install LWM structure on river left at head of mid-channel bar to emphasize flow split and connectivity to existing side channel.	Opportunity to construct in combination with UN9 and UN10 downstream. Difficult access for tracked equipment. Possible construction access through the camp and temporary bridges.	River right side channel. 
RM 14.25/L	UN11a	G5	Install Habitat Structure Floodplain Habitat Reconnect ion	Left bank gravel bar forming a mature meander bend. Existing large wood accumulated on gravel bar but mobile during high flows.	Install multiple LWM structures within the bar to stabilize existing wood and create flow splits across the bar. Emphasize channel migration to river right and improve flow connectivity to a flood channel on river right.	Difficult access for tracked equipment. Possible construction access through the camp and temporary bridges.	River left wood accumulation. 

PROJECT LOCATION (RM/BANK)	PROJECT ID[1]	GROUP[2]	ACTION TYPE	CONDITION	ACTION	CONSIDERATIONS	PHOTO
RM 14.1/R	UN11	G5	Protection	Right floodplain high terrace. Ponded at downstream end with large sand plug. Only connected at very high flow.	No action recommended. High risk area for deposition.		Sand deposition at outlet of alcove. 
RM 14.11/L	UN12	G5	Install Habitat Structure Floodplain Habitat Reconnect ion	Left bank inside meander high flow channel.	Install LWM to improve flow split through side channel while forcing flows to river right to improve scour at outlet of UN11 side channel.	Design should consider risk of avulsion through meander. Difficult construction access from Whitepine Rd.	River left avulsion path, facing downstream. 

1Project ID is indicated in Appendix C.

2Project groups were identified to indicated proposed project types that should be evaluated together for effect and construction feasibility. Single elements from each group can be constructed but the intent is to show opportunity for interrelated effect and construction efficiency.

Prioritization

Project prioritization was completed using a scoring matrix to rank the project groupings. Each grouping was evaluated and ranked based on the Yakama Nation Upper Columbia Habitat Restoration Project 2017 Project Ranking Methods. These methods rank projects based on the scoring of the following criteria:

- Benefit Score: Projects are scored according to 4 benefit categories, which include a "recovery gap" category and three additional categories. Scores for each category are summed to obtain the Benefit Score.
- Cost Score: Projects are given a Cost Score, which reflects the overall relative cost for the project based on techniques, access, and construction feasibility.
- Benefit-to-Cost Score: Total benefit score is divided by the cost score to obtain the Benefit-to-Cost Score.
- Feasibility Designation: Projects are given a Feasibility Designation based on the overall likely feasibility of being able to implement the project within a 10-year timeframe.

Table 1 in Appendix D presents the prioritization scoring for each of the project groupings.

6. REFERENCES

Abbe, T.B. and D.R. Montgomery. 2003b Patterns and processes of wood debris accumulation in the Queets River Basin, Washington. Geomorphology 51, 81-107.

Andonaegui, C. 2001. Salmon, Steelhead, and Bull Trout Habitat Limiting Factors for the Wenatchee Subbasin (Water Resource Inventory Area 45) and Portions of WRIA 40 within Chelan County (Squilchuck, Stemilt, and Colockum drainages). Washington State Conservation Commission, Olympia, WA. 347 p.

Beechie, T., H. Imaki, J. Greene, A. Wade, H. Wu, G. Pess, P. Roni, J. Kimball, J. Stanford, P. Kiffney, and N. Mantua. 2013. Restoring salmon habitat for a changing climate. River Research and Applications 29:939-960.

Columbia River Inter-Tribal Fish Commission (CRITFC). 2012. Coho Restoration in the Methow and Wenatchee Rivers: A tribal success story. Yakama Nation/CRITFC Brochure. http://www.critfc.org/wp-content/uploads/2012/11/success-wenatchee.pdf

Crandall, J.D. and E. Wittenbach. 2015. Pacific Lamprey Habitat Restoration Guide. Methow Salmon Recovery Foundation, Twisp, WA. First Edition, 54 p.

Department of Ecology (DOE), Washington State. 2007. Wenatchee River Watershed Temperature Total Maximum Daily Load: Water Quality Improvement Report. Washington State DOE Water Quality Program, Olympia, WA. 65 p.

Inter-Fluve, Inc. 2012. Upper Wenatchee River Stream Corridor Assessment and Habitat Restoration Strategy. Yakama Nation Fisheries, Toppenish, WA. 188 p.

Johnsen, A. and M.C. Nelson. 2012. Surveys of Pacific lamprey distribution in the Wenatchee River watershed 2010-2011. U.S. Fish and Wildlife Service, Leavenworth, WA. 15 p.

National Oceanic and Atmospheric Administration National Marine Fisheries Service (NOAA NMFS). 2016. Proposed ESA Recovery Plan for Snake River Spring/Summer Chinook Salmon (Oncorhynchus tshawytscha) & Snake River Steelhead (Oncorhynchus mykiss). NOAA West Coast Region, Portland, OR. 262 pp.

Natural Systems Design. 2018. Upper Chewuch Habitat Assessment: Habitat Conditions and Restoration Opportunities on the Upper Chewuch River, Boulder Creek, Twentymile Creek, Lake Creek, and Andrews Creek. Prepared for Yakama Nation Fisheries, Toppenish, WA.

Northwest Power and Conservation Council (NPCC). 2004a. Methow Subbasin Plan. Portland, OR. 814 p.

Northwest Power and Conservation Council (NPCC). 2004b. Wenatchee Subbasin Plan. Portland, OR. 394 p.

Tetra Tech. 2017. Beaver Creek Reach Assessment. Prepared for Yakama Nation Fisheries, Toppenish, WA. 87 p.

Upper Columbia Regional Technical Team (UCRTT). 2014. A biological strategy to protect and restore salmonid habitat in the Upper Columbia Region. Report to the Upper Columbia Salmon Recovery Board, Wenatchee, WA. 44 p.

Upper Columbia Salmon Recovery Board (UCSRB). 2007. Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan. Wenatchee, WA. 307 p.

United States Bureau of Reclamation (USBR) 2008. Nason Creek Tributary Assessment, Chelan County, WA. Pacific Northwest Region. Boise, ID.

United States Bureau of Reclamation (USBR) 2009a. Lower White Pine Reach Assessment, Nason Creek, Chelan County, WA. Pacific Northwest Region. Boise, ID. 357 p.

United States Bureau of Reclamation (USBR) 2009b. Upper White Pine Reach Assessment, Nason Creek, Chelan County, WA. Pacific Northwest Region. Boise, ID. 320 p.

United States Bureau of Reclamation (USBR) 2009c. Kahler Reach Assessment, Nason Creek, Chelan County, WA. Pacific Northwest Region. Boise, ID. 326 p.

United States Bureau of Reclamation (USBR) 2011. Lower Nason Assessment of Geomorphic and Ecologic Indicators, Nason Creek, Wenatchee Subbasin, Chelan County, WA. Pacific Northwest Region. Boise, ID. 202 p.

United States Forest Service (USFS). 1998. Biological assessment for steelhead, spring Chinook, bull trout and cutthroat trout in Nason Watershed, baseline condition and effects of ongoing activities, including recreation, effective December 1998: U.S. Department of Agriculture, Lake Wenatchee Ranger District, Wenatchee National Forest, Wenatchee, Washington, 47 pp.

United States Forest Service (USFS). 2003. Okanogan and Wenatchee National Forests Road Analysis: Wenatchee Sub-Basin. Okanogan-Wenatchee National Forest, Leavenworth Ranger District, Leavenworth, WA. 122 p.

United States Forest Service (USFS). 2012. Stream Inventory Handbook: Level I and Level II. Version 2.12. USFS Pacific Northwest Region (Region 6), Portland, OR. 89 p.

United States Fish and Wildlife Service (USFWS). 2010. Biological Opinion for the Buck Forest and Fuels Project. USFWS Central Washington Field Office, Wenatchee, WA. USFWS Reference Number: 13260-2010-F-0070

United States Geological Survey (USGS). 2018. Geospatial Multi-Agency Coordination (GeoMAC) Fire Perimeter Map. Accessed at https://www.geomac.gov/

Waitt, R. Jr. 1979. Late Cenozoic deposits, landforms, stratigraphy, and tectonism in Kittitas Valley, Washington. US Geological Survey Professional Paper 1127, 18p.

Washington Department of Fish and Wildlife (WDFW). 1993. Washington State Salmon and Steelhead Stock Inventory. Olympia, WA. 210 p.

Washington Department of Fish and Wildlife (WDFW). 1998. Washington State Salmonid Stock Inventory: Bull Trout and Dolly Varden. Olympia, WA. 441 p.

Washington State Conservation Commission (WSCC). 2006. Nason Creek Fish Periodicity Graph. Published in the Wenatchee Watershed Management Plan, Appendix B: Wenatchee River Instream Flow Studies. Wenatchee, WA.

Wenatchee Watershed Planning Unit (WWPU). 2006. Final Wenatchee Watershed Management Plan. Wenatchee, WA. 170 p.

Wydoski, R. and R. Whitney. 2003. Inland Fishes of Washington. Second edition. University of Washington Press, Seattle, WA.

Yakama Nation Fisheries (YNF). 2018. Pacific Lamprey Project Webpage. http://yakamafishnsn.gov/restore/projects/lamprey (Accessed March 2018).

Appendix A

USFS Reach Data

Natural Systems Design

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX A: USFS STREAM INVENTORY DATA

Geomorphology and Hydrology

Reach Boundaries: From the train bridge over Nason Creek at RM 14.1 to RM 16.6 (0.07 miles above the confluence with Whitepine Creek)

Reach Length: 2.5 river miles (2.57 miles measured)

Elevation: 2,235 feet to 2,320 feet (85 feet drop)

Orientation: Flows easterly

Valley Form: Wide, flat-floored

Average Valley Width Estimate: 500 feet

Sinuousity: 1.21

Gradient: 0.0063 (0.63%)

Average Bankfull Width: 87.0 feet

Average Width to Depth Ratio: 23.9

Average Floodprone Width: 252.0 feet

Rosgen Channel Type: C3

Substrate

Pebble Counts

D50: 75mm

D84: 157mm

Substrate Percentages:

- Fines: 5.5%
- Gravel: 39.0%
- Cobble: 49.0%
- Boulder: 6.5%
- Bedrock: 0%

Ocular Estimates

SUBSTRATE TYPE	REACH AVERAGE	POOL	FAST TURBULENT	FAST NON-TURBULENT
Fines	17.3%	22.5%	8.3%	12.5%
Gravel	41.5%	41.8%	38.3%	45.0%
Cobble	26.7%	22.5%	32.5%	32.5%
Boulder	14.0%	12.1%	20.8%	10.0%
Bedrock	0.6%	1.1%	0%	0%

Tributaries

TRIBUTARY NUMBER AND NAME	RIVER MILE	BANK	PERCENT OF FLOW	TRIBUTARY WATER TEMP (°C)	NASON WATER TEMP (°C)	DATE/TIME
T1: Unnamed Tributary	15.7	Left	1	3.0	2.0	November 14, 2017 2:22 PM
T2: Whitepine Creek	16.5	Right	40	0.5	1.5	November 15, 2017 10:09 AM

Large Woody Debris

LWD SIZE CLASS	LWD PIECES IN MAINSTEM	LWD PIECES IN SIDE CHANNELS	TOTAL LWD PIECES	LWD PIECES PER MILE
Large (>35' long, >20" diameter)	15	3	18	7.0
Medium (>35' long, >12" diameter)	24	25	49	19.1
Small (>20' long, >6" diameter)	42	46	88	34.2
Total LWD	81	74	155	60.3

Pool Habitat

Pools per Mile: 10.12

Pools >3 feet deep per Mile: 8.95

Pools >5 feet deep per Mile: 2.33

Average Maximum Depth of Survey Pools: 3.91 feet

Average Residual Depth of Survey Pools: 2.30

Sedimentation and Erosion

Percent of Pools Embedded: 14.3%

Linear Feet of Bank Erosion per Mile of Stream: 2301.9 feet

Percent Eroding Banks (Total of Both Banks): 17.0%

Habitat Summary

Percent Rapid (Fast Turbulent): 1.9%

Percent Riffle (Fast Turbulent): 47.9%

Percent Glide (Fast Non-Turbulent): 17.2%

Percent Pool: 23.9%

Percent Side Channel: 11.0%

Appendix B

REI Tables

Natural Systems Design

THIS PAGE INTENTIONALLY LEFT BLANK

Appendix B: Reach Based Ecosystem Indicators

1. INTRODUCTION

The reach-based ecosystem indicators (REI) analysis for the Upper Nason Reach builds upon previous reach assessments and REI analyses in Nason Creek conducted by the U.S. Bureau of Reclamation (BOR) covering Nason from the mouth at the Wenatchee River up to the downstream extent of the Upper Nason Reach:

- Lower Nason (2011) RM 0 – 4.6
- Kahler (2009) RM 4.65 – 8.9
- Lower White Pine (2009) RM 9.45 – 11.55
- Upper White Pine (2009) 12.0 – 14.25

The indicators used in this analysis match those used in the previous Nason Creek REI assessments, which were originally developed by U.S. Fish and Wildlife Service in 1998, as published in Hillman and Giorgi (2002).

2. WATERSHED CONDITION

2.1 Effective Drainage Network and Watershed Road Density

GENERAL INDICATORS	ADEQUATE CONDITION	AT RISK CONDITION	UNACCECPTABLE RISK CONDITION
Effective drainage network and watershed road density	Zero or minimum increases in active channel length correlated with human caused disturbance. Road density < 1 mi/mi²	Low to moderate increase in active channel length correlated with human caused disturbances. Road density 1-2.5 mi/mi²	Greater than moderate increase in active channel length correlated with human caused disturbances. Road density >2.5 mi/mi²

Watershed Condition: At Risk

Road density from the downstream extent of the reach at RM 14.1 to the headwaters of Nason Creek. is 0.95 mi/mi², which lies within the adequate condition. However, the density is an under-representation of total road length because some logging and forest service roads are not included, which can be seen in aerial imagery. In all likelihood, road density is within the 1-2.5 mi²/mi range, putting the condition into the at risk category.

A prior assessment of Nason Creek (USFS 1998) found significant increases in drainage network were only attributable to road and railroad grades. They concluded the indicator rating for effective drainage network in Nason Creek should reflect the road density rating, therefore the REI rating is at risk.

2.2 Disturbance Regime

GENERAL INDICATORS	ADEQUATE CONDITION	AT RISK CONDITION	UNACCECPTABLE RISK CONDITION
Disturbance Regime	Environmental disturbance is short lived; predictable hydrograph, high quality habitat and watershed complexity providing refuge and rearing	Scour events, debris torrents, or catastrophic fires are localized events that occur in several minor parts of the watershed. Resiliency of habitat to recover from	Frequent flood or drought producing highly variable and unpredictable flows, scour events, debris torrents, or high probability of catastrophic fire

GENERAL INDICATORS	ADEQUATE CONDITION	AT RISK CONDITION	UNACCECPTABLE RISK CONDITION
	space for all life stages or multiple life-history forms. Natural processes are stable.	environmental disturbances is moderate.	exists throughout a major part of the watershed. The channel is simplified, providing little hydraulic complexity in the form of pools or side channels. Natural processes are unstable.

Watershed Condition: At Risk

Logging, fires, railroad and highway impacts, climate change.

2.3 Flow/Hydrology

GENERAL INDICATORS	ADEQUATE CONDITION	AT RISK CONDITION	UNACCECPTABLE RISK CONDITION
Flow/hydrology	Magnitude, timing, duration, and frequency of peak flows within a watershed are not altered relative to natural conditions of an undisturbed watershed of similar size, geology, and geography.	Some evidence of altered magnitude, timing, duration, and/or frequency of peak flows relative to natural conditions or an undisturbed watershed of similar size, geology, and geography.	Pronounced changes in magnitude, timing, duration, and/or frequency of peak flows relative to natural conditions or an undisturbed watershed of similar size, geology, and geography.

Watershed Condition: At Risk

From logging, roads, climate change

2.4 Habitat Access

GENERAL INDICATORS	ADEQUATE CONDITION	AT RISK CONDITION	UNACCECPTABLE RISK CONDITION
Main channel physical barriers	No manmade barriers present in the mainstem that limit upstream or downstream migration at any flow.	Manmade barriers present in the mainstem that prevent upstream or downstream migration at some flows that are biologically significant.	Manmade barriers present in the mainstem that prevent upstream or downstream migration at multiple or all flows.

Watershed Condition: Adequate

Two natural barriers are present in Nason Creek Naturally occurring falls at RM 14.3 partially block upstream passage.

2.5 Water Quantity and Quality

GENERAL INDICATORS	ADEQUATE CONDITION	AT RISK CONDITION	UNACCECPTABLE RISK CONDITION
Quantity/ Temperature/ Chemical Contamination/ Nutrients	Adequate instream flows for habitat, low levels of water quality impairments from land use sources, no excessive nutrients, no CWA 303d designated reaches. Or, Washington State Department	Inadequate instream flows for habitat, moderate levels of water quality impairments from land use sources, some excess nutrients, CWA 303d designated reaches.	Inadequate instream flows for habitat, high levels of water quality impairments from land use sources, high levels of excess nutrients, CWA 303d designated reaches.

	of Ecology standards – 173-201A-200.		

Water quality assessment categories (https://ecology.wa.gov/Water-Shorelines/Water-quality/Water-improvement/Assessment-of-state-waters-303d/Assessment-categories)

- Category 1 – meets tested standards for clean waters.
- Category 2 – waters of concern.
- Category 3 – Insufficient data.
- Category 4 – Polluted waters that do not require a TMDL.
  - Category 4a – has a TMDL
  - Category 4b – has a pollution control program
  - Category 4c – is impaired by a non-pollutant
- Category 5 – polluted waters that require a TMDL.

Watershed Condition: At Risk

Nason Creek is classified by the Washington Department of Ecology (WA DOE) as a Category 4a water body for high water temperature, and is part of Wenatchee Watershed temperature TMDL program. WA DOE studied water temperature in 2003 using a logging station immediately downstream of the reach assessment boundary, and found between 6/25/2003 and 8/21/2003, the 7-day mean of daily maximum values (7DADmax) exceeded the criterion of 12°C on 52 of 58 days (90%). The maximum exceedance during this period was 18°C for the 7-day period centered on 7/29/2003 (WA DOE 2018). Additionally, the Columbia Habitat Monitoring Program had a temperature sensor within the reach, and in both 2014 and 2015 42 instances of 7DADmax exceeded 12°C during summer period. In 2015, there were also 40 instances where 7DADmax exceeded 16°C and 12 instances where 7DADmax exceeded 18°C.

3. HABITAT QUALITY

3.1 Substrate

SPECIFIC INDICATOR	ADEQUATE CONDITION	AT RISK CONDITION	UNACCECPTABLE RISK CONDITION
Dominant substrate/fine sediment	Gravels or small cobbles make-up >50% of bed materials in spawning areas. Reach Embeddedness in rearing areas <20%. ≤12% fines (<0.85 mm) in spawning gravel or 12% surface fines of ≤6 mm.	Gravels or small cobbles make-up 30-50% of bed materials in spawning areas. Reach embeddedness in rearing areas 20-30%. 12-17% fines (<0.85 mm) in spawning gravel or 12-20% surface fines of ≤6 mm.	Gravels or small cobbles make-up <30% of bed materials in spawning areas. Reach embeddedness in rearing areas >30%. >17% fines (0.85 mm) in spawning gravel or > 20% surface fines of ≤6 mm.

Reach Condition: At Risk

Gravels and cobbles make up 68% of the substrate within the reach, indicating in adequate condition for dominate substrate. However, surface fines comprise 17% of the substrate, which is too high for an adequate condition. Due to the presence of > 12% surface fines, the reach is at risk for substrate condition. Inputs of fine sediment are also exacerbated by timber harvest, logging roads, and runoff from Highway 2 (Reid et al 1981) (Bathurst and Iroume 2014).

Substrate composition results

SUBSTRATE SIZE	COMPOSITION
Fines (≤6 mm)	17.3%
Gravel (7 – 63 mm)	41.5%
Cobble (64 – 256 mm)	26.7%
Boulder (>256 mm)	14.0%
Bedrock	0.6%

3.2 Large Woody Debris

SPECIFIC INDICATOR	ADEQUATE CONDITION	AT RISK CONDITION	UNACCECPTABLE RISK CONDITION
Pieces per mile at bankfull	>20 pieces/mile with > 12 in diameter and > 35 ft length; and adequate sources of woody debris available for both long-term and short-term recruitment	Currently levels are being maintained at minimum levels for adequate condition, but potential sources for long-term woody debris recruitment is lacking to maintain minimum adequate condition.	< 20 pieces/mile with > 12 in diameter and > 35 ft length, and potential sources for both short and/or long-term recruitment are lacking.

Reach Condition: At risk

Current LWD frequency for pieces > 12 in diameter and > 35 ft length is 26 pieces/mile, meeting the requirement of at least 20 pieces/mile. Within the main channel however there were low amounts of LWD. Approximately 1/3 of the LWD for the entire reach is in a large off-channel area, including 34 small pieces, 22 medium pieces, and 3 large pieces. The medium and large pieces in the off-channel area accounted for 37% of the total LWD number of medium and large pieces within the reach.

Wood recruitment within the reach also appears to be limited. Most of the banks on either side of the channel are forested upstream of the Cascade Meadows Baptist Camp, with trees exceeding the LWD size threshold. Downstream of the camp the banks are more commonly lined with smaller deciduous species such as alder, willow, dogwood, and vine maple, with a few locations where the channel abuts large trees. The potential for LWD recruitment is tied to the availability of trees of sufficient size lining the channel banks, and bank erosion typically occurring during floods. The lack of large wood of sufficient size to remain stable during common flood events, forming large logjams that deflect flows, diminishes the potential for local bank erosion and LWD recruitment.

Large woody debris abundance and frequency

TOTAL NUMBER PIECES	
Small (6 in x 20 ft)	88
Medium (12 in x 35 ft)	49
Large (20 in by 35 ft)	18
NUMBER OF PIECES/MILE	
Small (6 in x 20 ft)	34.2
Medium (12 in x 35 ft)	19.1
Large (20 in by 35 ft)	7.0

3.3 Pools

SPECIFIC INDICATOR	ADEQUATE CONDITION	AT RISK CONDITION	UNACCECPTABLE RISK CONDITION
Pool frequency and quality	Channel width (ft) pools/mile 0-5 39 5-10 60 10-15 48 15-20 39 20-30 23 30-35 18 35-40 10 40-65 9 65-100 4 Pools have good cover and cool water, and only minor reduction of pool volume by fine sediment	Pool frequency is similar to adequate condition, but pools have inadequate cover/temperature, and/or there has been a moderate reduction of pool volume by fine sediment	Pool frequency is considerably lower than values for adequate condition, also cover/temperature is inadequate, and there has been a major reduction of pool volume by fine sediment
Large pools	Reach has many large pools >1 m deep	Reach has few large pools >1 m deep	Reach has no pools >1 m deep

Reach condition: At risk

Upper Nason has an average channel (BF) width of 88.7 ft, indicating there needs to be at least four pools per mile to meet adequate condition. Pool frequency is 10.2 pools/mile, meeting the criteria for adequate condition. Pools within the reach have good depth with 19 of the 26 pools meeting the large pool criteria of > 1 m (3.28 ft) deep. However, fish cover within pools is low at 6.7% on average. Fourteen pools within the reach had fish cover measured, of which three had no cover and eleven had between 5-15% cover. Fine sediment within the pools also appears to be a concern. Fines accounted for 22% of the substrate composition in pools on average with a range 10-60%. The depth of fines in pools was not measured, so the extent to which fines are filling in pools is not known, but the high presence of fines within pools suggests there is adequate fine sediment supply to create the potential for pools to be filled in.

Pool characteristics

POOL NUMBER	AVG WIDTH (FT)	MAX DEPTH (FT)	% FINES	% COVER
s1	44	5.5	15	0
s2	41	3.2	30	10
s3	44	3.4	-	-
s4	65	3.7	15	0
s5	47	3.1	-	-
s6	57	2.6	30	5
s7	45	2.6	-	-
s8	58	4	15	5
s9	50	2.5	-	-
s10	40	3	15	5

POOL NUMBER	AVG WIDTH (FT)	MAX DEPTH (FT)	% FINES	% COVER
s14	42	5	60	10
s15	36	5	-	-
s16	45	4	25	15
s17	68	3.6	-	-
s18	44	3	10	10
s19	76	4.3	-	-
s20	56	4.5	15	0
s21	44	5	-	-
s22	48	3.4	30	15
s23	38	3.4	-	-

POOL NUMBER	AVG WIDTH (FT)	MAX DEPTH (FT)	% FINES	% COVER
s11	54	4.5	-	-
s12	44	5	20	5
s13	58	4	-	-

POOL NUMBER	AVG WIDTH (FT)	MAX DEPTH (FT)	% FINES	% COVER
s24	27	3.9	25	5
s25	40	4.5	-	-
s26	48	5	10	10

3.4 Off-channel habitat

SPECIFIC INDICATOR	ADEQUATE CONDITION	AT RISK CONDITION	UNACCECPTABLE RISK CONDITION
Connectivity with main channel	Reach has many ponds, oxbows, backwaters, and other off-channel areas with cover, and side channels are low energy areas. No manmade barriers present along the mainstem that prevent access to off-channel areas.	Reach has some ponds, oxbows, backwaters, and other off-channel areas with cover, and side channels are generally high energy areas. Manmade barriers present that prevent access to off-channel habitat at some flows that are biologically significant.	Reach has few or no ponds, oxbows, backwaters, and other off-channel areas. Manmade barriers present that prevent access to off-channel habitat at multiple or all flows.

Reach condition: At risk

There are few manmade features preventing off-channel access. The railroad grade is cut and fill on hillslope that minorly reduces valley width, with largest impact at DS end of reach where channel is already naturally highly confined. Four side channels and one off-channel area are present in reach. Side and off-channel areas make up 11% of total area in the reach, however one large off channel area accounts for 30% of the total side and off-channel area. Additionally, the side channel habitat is not evenly distributed throughout the 2.5 mile long reach; all the side channels occur in a 0.3 mile stretch around RM 15.2, which equates to only 12% of the length of the reach with side channels.

Although manmade barriers are not a considerable issue, due to the lack of off-channel areas in the vast majority of the reach, off-channel habitat is in an at-risk condition.

4. CHANNEL CONDITION

4.1 Floodplain Connectivity

SPECIFIC INDICATOR	ADEQUATE CONDITION	AT RISK CONDITION	UNACCECPTABLE RISK CONDITION
Floodplain Connectivity	Floodplain areas are frequently hydrologically links to main channel; overbank flows occur and maintain wetland functions, riparian vegetation, and succession	Reduced linkage of wetland, floodplains, and riparian areas to main channel; overbank flows are reduced relative to historic frequency, as evidenced by moderate degradation of wetland function, riparian vegetation/succession.	Severe reduction in hydrologic connectivity between off-channel, wetland, floodplain, and riparian areas; wetland extent drastically reduced and riparian vegetation/succession altered significantly.

Reach condition: At risk

Floodplain connectivity in Upper Nason is a patchwork alternating from naturally confined, to connected, and disconnected floodplain. The lower 0.2 miles of the reach are naturally confined by hillslopes with a narrow valley bottom and floodplain width. The railroad grade and Whitepine Cr Rd run along the margin of the floodplain in the lower 0.2 mi, slightly further reducing the floodplain in this section. Upstream of the confined section, the valley and floodplain open up, Whitepine Cr Rd moves further away from the stream, and the stream enters the section with most connected floodplain in the reach. While there is moderate incision reducing connectivity to the upper floodplain, there is a fairly developed floodplain as Nason Cr meanders across the valley floor, forming gravel bars and shallow off channel areas on the inside of meander bends. The connected section extends up approximately 0.8 mi upstream to the Cascade Meadows Baptist Camp. Upstream of the camp to the top of the reach, the stream is more incised and less connected to the floodplain. Higher banks and more narrow meander bends provide evidence of incision and reduced floodplain function, and it appears flows less frequently engage the floodplain.

4.2 Bank Stability/Channel Migration

SPECIFIC INDICATOR	ADEQUATE CONDITION	AT RISK CONDITION	UNACCECPTABLE RISK CONDITION
Bank stability/channel migration	Channel is migrating at or near natural rates	Limited amount of channel migration is occurring at a faster/slower rate relative to natural rates, but significant change in channel width or planform is not detectable.	Little or no channel migration is occurring because of human actions preventing reworking of the floodplain; or channel migration is occurring at an accelerated rate such that channel width has at least doubled, possibly resulting in a channel planform change, and sediment supply has been noticeably increased from bank erosion.

Reach condition: At Risk

The loss of LWD has disrupted a primary mechanism for bank erosion. Naturally bank erosion was episodic with accumulations of LWD leading to rapid erosion events where large portions of banks around the LWD accumulations would dramatically erode. Currently, much of the Upper Nason reach is devoid of LWD, so this mechanism is not present and instead bank erosion is a steadier process where banks are more slowly but continuously eroded during high flows. The overall rate of bank erosion on a longer time scale (years) may be at or near natural rates, but the loss of LWD has removed the process for larger episodic erosion, resulting in less dynamic channel migration.

4.3 Vertical Channel Stability

SPECIFIC INDICATOR	ADEQUATE CONDITION	AT RISK CONDITION	UNACCECPTABLE RISK CONDITION
Vertical Channel Stability	No measurable or observable trend of aggradation or incision and no visible change in channel planform.	Measurable or observable trend of aggradation or incision that has the potential to, but has not yet caused, disconnect of the floodplain or a visible change in channel planform.	Enough incision that the floodplain and off-channel habitat areas have been disconnected; or enough aggradation that a visible change in channel planform as occurred.

Reach condition: At risk

Throughout the reach there is approximately 3 ft of channel incision. Field observations of side channel inlets and high flow channels in the floodplain showed these features were on average 5 to 6 ft above the current channel. In a natural condition we expect side channels would be 2 to 3 ft above the channel. The incision is primarily driven by two conditions: the loss of LWD and head cuts from channel straightening downstream of the Upper Nason Reach. LWD accumulations locally control the grade of the river, slowing vertical channel erosion and storing sediment upstream of the LWD. Removing LWD from the stream eliminates the grade control process, allowing the stream to more easily vertically erode (incise). Channel straightening has occurred extensively throughout Nason Creek, especially downstream of the White Pine Bridge. The channel has been straightened for development in the floodplain – infrastructure such as railroad lines, transmission lines, roads, and buildings. Channel straightening reduces the overall length of the channel, causing an increase in gradient due the change in elevation in the valley bottom occurring of a shorter river course. The higher gradient increases the erosional power of the river, causing the river to respond by head cutting upstream of the channel straightening, resulting in incision. Currently incision is moderate and the floodplain is still connected in some locations and disconnected in other through the Upper Nason reach. The factors of LWD loss and head cutting have caused some moderate incision leading to an at risk condition. Unless these causes of incision are addressed, the channel will likely continue to incise eventually leading to an unacceptable risk condition.

5. RIPARIAN/UPLAND VEGETATION

5.1 Vegetation Structure

SPECIFIC INDICATOR	ADEQUATE CONDITION	AT RISK CONDITION	UNACCECPTABLE RISK CONDITION
Vegetation structure	>80% of species composition, seral stage, and structural complexity are consistent with potential native community	50-80% species composition, seral stage, and structural complexity are consistent with potential native community.	<50% species composition, seral stage, and structural complexity are consistent with potential native community.

Reach condition: Adequate

The Nanson Creek floodplain is located at 2,200-3,000 foot elevation, east of the cascade crest. The creek along this reach is primarily single channel with a network of high flow side channels coursing through the adjacent floodplain and terraces. The floodplain varies in width from none along steep riparian embankments to over 900 feet in the more extensive floodplain areas. Associated with the floodplain side channel network are an array of beaver dam complexes, open floodplain water bodies, and emergent and scrub-shrub wetlands. The floodplain forest, which covers over 90% of the Nanson Creek reach floodplain surface area, is a mosaic of riparian forest patches of varying composition and age. Active floodplain surfaces are dominated by red alder *(Alnus rubra*) and black cottonwood (*Populus trichocarpa),* 21-32 inch DBH (diameter at breast height). The floodplain forest is dominated by mid-seral stage western red cedar (*Thuja plicata*), 21-32 inches DBH, and Douglas-fir (*Pseudotsuga menziesii*), 21 to >32 inches DBH, forest stands. Additional non dominant tree species include grand fir (*Abies grandis*), 9-21 inches DBH, with understory small tree and shrub community composed of red osier dogwood (*Cornus sericea*), vine maple (*Acer circinatum*), and willow species (*Salix spp*). The potential native plant community for this site most closely resembles the THPL/OPHO Association (*Thuja plicata/Oplopanax horridum;* western red cedar/devil's club) of the *Field Guide for Forested Plan associations of the Wenatchee National Forest* (Lillybridge et. Al., 1995).

The riparian/upland vegetation structure is in **adequate condition** for a mid-seral stage riparian plant community consistent with the potential native plant community (Lillybridge et. Al., 1995) for this elevation and floodplain geomorphic context.

5.2 Vegetation Disturbance

SPECIFIC INDICATOR	ADEQUATE CONDITION	AT RISK CONDITION	UNACCECPTABLE RISK CONDITION
Vegetation disturbance (natural/human)	>80% mature trees (medium-large) in the riparian buffer zone that are available for recruitment by the river via channel migration; <20% human disturbance in the floodplain; <2 mi/mi² road density in the floodplain	50-80% mature trees in the riparian buffer zone that are available for recruitment by the river via channel migration; 20-50% human disturbance in the floodplain; 2-3 mi/mi² road density in the floodplain.	<50% mature trees in the riparian buffer zone that are available for recruitment by the river via channel migration, >50% human disturbance in the floodplain; >3 mi/mi² road density in the floodplain.

Reach condition: At risk

71% mature trees, Whitepine Cr Rd is out of floodplain for nearly all of the reach, except for where it crosses at the downstream end of the reach, the effect of the road is minimal. However, the railroad grade is in floodplain – significant effect on channel for lower 1200 ft, and borders floodplain for 4834 ft. Floodplain area for reach is 0.18 mi², working out to 5.1 mi/mi²

5.3 Canopy Cover

SPECIFIC INDICATOR	ADEQUATE CONDITION	AT RISK CONDITION	UNACCECPTABLE RISK CONDITION
Canopy Cover	Trees and shrubs within one site potential tree height distance have >80% canopy cover that provides thermal shading to the river.	Trees and shrubs within one site potential tree height distance have 50-80% canopy cover that provides thermal shading to the river.	Trees and shrubs within one site potential tree height distance have <50% canopy cover that provides thermal shading to the river.

Reach condition: Not assessed

Data on canopy cover and tree height is not readily available, so no assessment on canopy cover condition was conducted. Riparian vegetation data for Upper Nason was collected using the USFS Level II protocol, but the measurements under the protocol do not provide adequate information to assess canopy cover. Although measurements on the seral stage and species types within the riparian zone are collected under the protocol, there is no measurement accounting for the amount of cover the canopy provides or tree heights. Canopy cover and tree height could potentially be calculated using LiDAR data, but LiDAR is only available for a small area in the lower portion of the reach.

6. REFERENCES

Bathurst, J. C., and A. Iroume. 2014. Quantitative generalizations for catchment sediment yield following forest logging. Water Resources Research. 50: 8383-8402.

Hillman, T.W. and A. E. Giorgi. 2002. Monitoring Protocols: Effectiveness Monitoring of Physical/Environmental Indicators in Tributary Habitats. BioAnalysts, Inc. Prepared for Bonneville Power Administration.

Lillybridge, T. R, B. L. Kovalchik, C. K. Williams, and B. G. Smith. 1995. Field guide for forested plant associations of the Wenatchee Forest. General Technical Report PNW-GTR-359. Portland, OR. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 335 pp.

Reid., L. M., T. Dunne, and C. J. Cederholm. 1981. Application of Sediment Budget Studies to the Evalution of Logging Road Impact. University of Washington, Seattle, WA.

U.S. Forest Service. 1998. Biological assessment for steelhead, spring Chinook, bull trout and cutthroat trout in Nason Watershed, baseline condition and effects of ongoing activities, including recreation, effective December 1998: U.S. Department of Agriculture, Lake Wenatchee Ranger District, Wenatchee National Forest, Wenatchee, Washington, 47 pp.

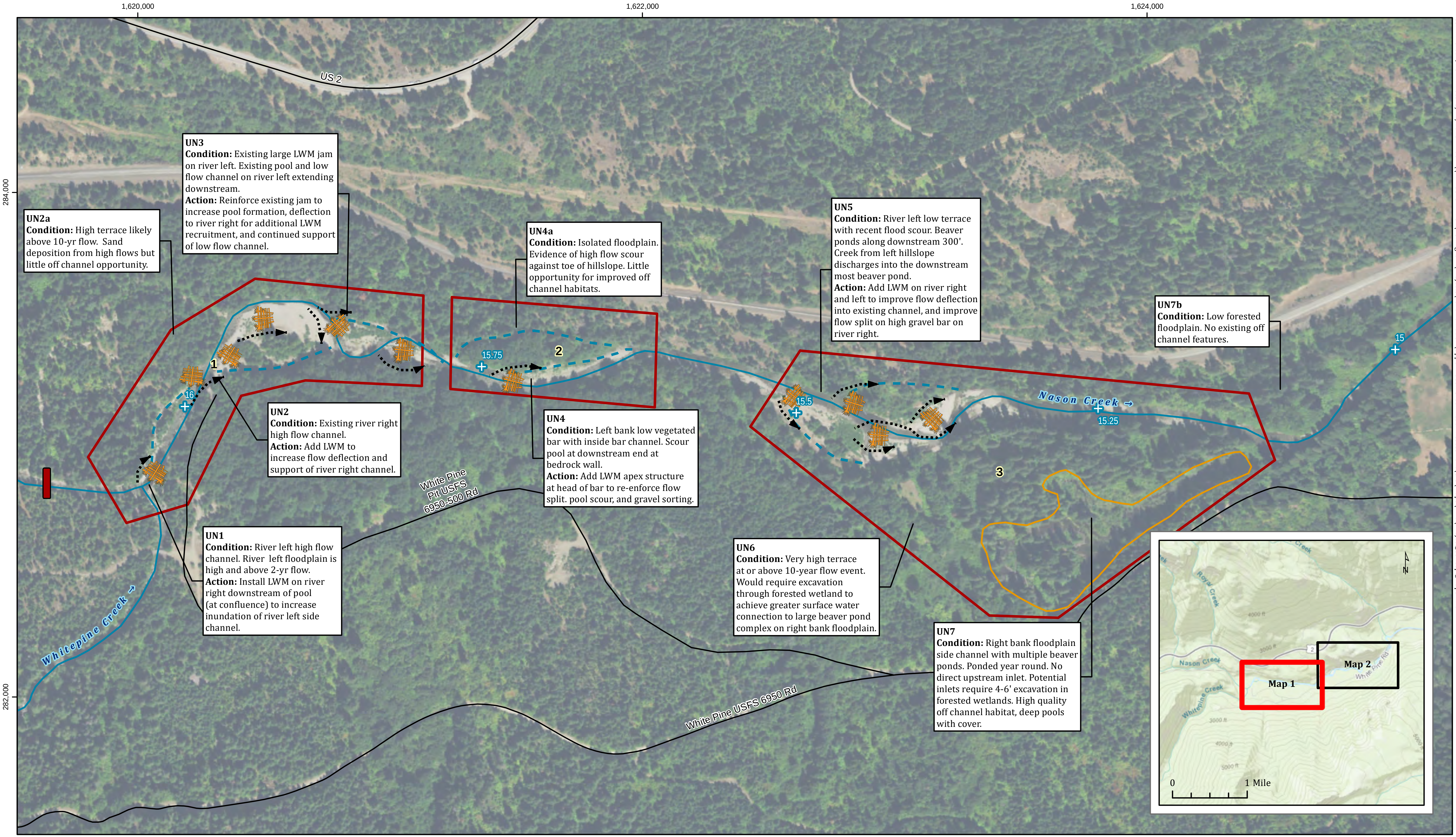
Washington Department of Ecology (WA DOE). 2018. Water quality listing ID: 42923. Accessed online 1/22/2018.

Appendix C

Restoration Project Concept Maps

Natural Systems Design

THIS PAGE INTENTIONALLY LEFT BLANK



Upper Nason Reach Assessment

Restoration Project Concepts - Map 1

Aerial Imagery Source: USDA NAIP (2015).
Other Data Sources: Streams from USGS National Hydrography Dataset.

N

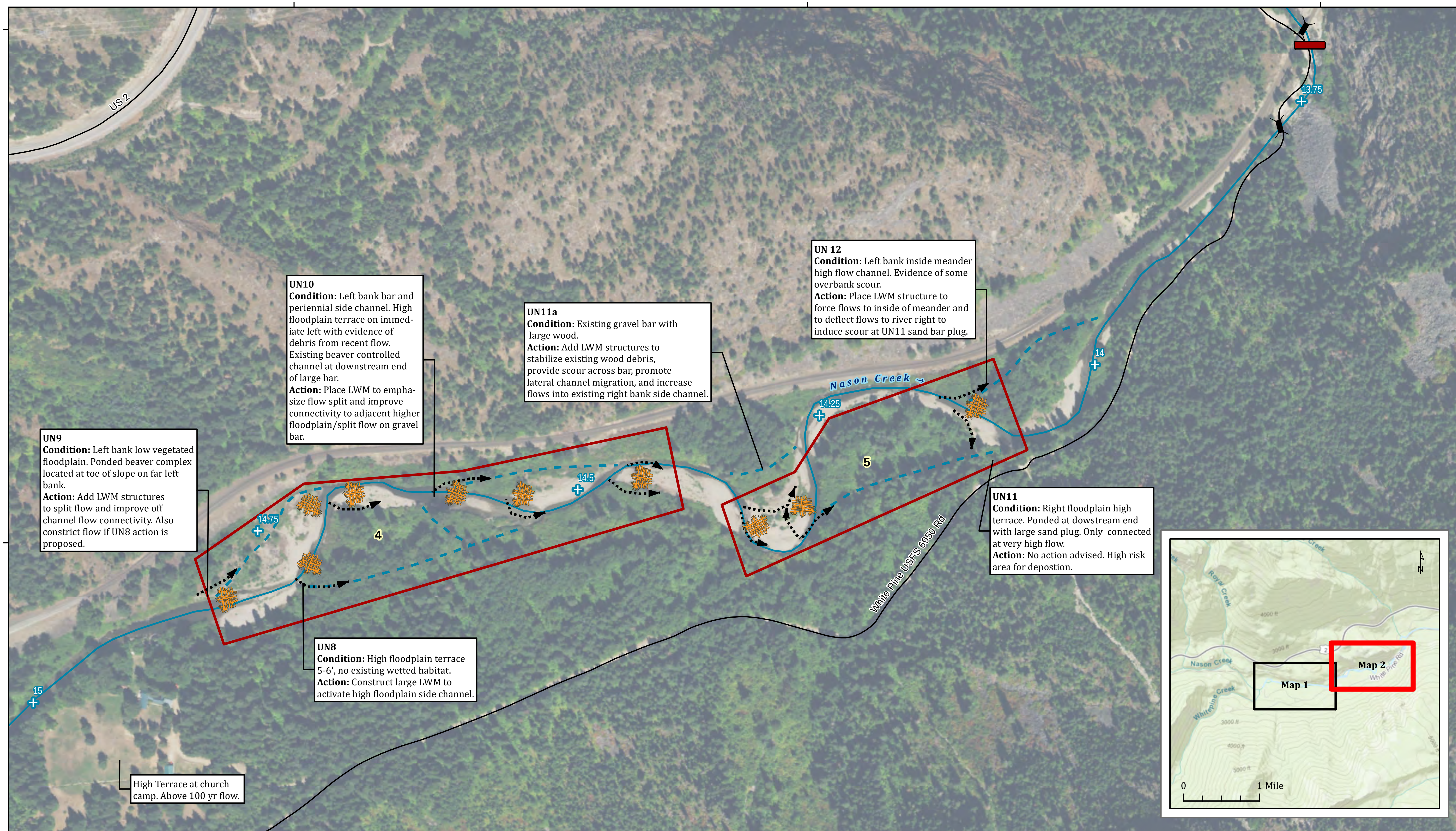
0 250 500 Feet

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)

Contour interval = 5 feet

Yakama Nation Fisheries

Natural Systems Design



Colin Riordan, NSD Date: 8/22/2018 Path: \\NATUSYST-NAS1\Bellingham\Projects\Yakama Nation\Upper Nason Creek Reach Assessment\GIS\maps\mxd\Project_Concept_maps.mxd

Upper Nason Reach Assessment

Restoration Project Concepts - Map 2

Aerial Imagery Source: USDA NAIP (2015).
Other Data Sources: Streams from USGS National Hydrography Dataset.

N

0 250 500 Feet

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)

Contour interval = 5 feet

Yakama Nation Fisheries

Natural Systems Design

Appendix D

Project Prioritization Matrix

THIS PAGE INTENTIONALLY LEFT BLANK

Appendix D. Project Prioritization Matrix

Project Information				Benefit Score													Cost Score		Cost Benefit	Feasibility Designation	
				Restoration Gap Analysis				Existing and Potential Fish Use		Root Causes		Ecological Concerns		Climate Change							
Project Group	Project ID	Project Location (RM - RM)	Total Length (mi)	Existing Condition (1-7)	Achievable Target (1-7)	Final Gap Score Target - Existing	Rationale/Assumptions	Score (1-3)	Rationale/Assumptions	Score (1-3)	Rationale/Assumptions	Score (1-3)	Rationale/Assumptions	Score (1-3)	Rationale/Assumptions	Total Benefits Score	Score (1-3)	Rationale/Assumptions	Benefit to Cost Score	Feasibility Designation	Rationale/Assumptions
G1	UN1; UN 2a; UN2; UN3	16.1 - 15.8	0.3	4	6	2	Group 1 plans to install multiple ELJs near the confluence area at Whitepine Creek. At risk pool, LWM, bed and habitat conditions due to human impacts within the reach and watershed. Improvement of wood quantity, pool cover, bed aggradation, and side channel connectivity will improve local conditions but greater watershed impairments remain.	3	Local reach intrinsic potential is High for both chinook and steelhead.	2	Restoration consists of mostly enhancement actions at confluence area (addition of wood, pool creation, side channel enhancement).	3	Restoration actions address high priority ecological concerns associated with Peripheral and Transitional Habitat and Channel Structure and Form.	2	Wood treatment will help to aggrade the channel and treat incision to improve floodplain connectivity.	12	2	Typical log jam structures.	6	High	In-channel work with adequate access; little infrastructure; USFS coordination.
G2	UN4; UN4a	15.75 - 15.75	0.1	4	5	1	Group 2 provides a local opportunity for wood placement and improving side channel hydrology. Little reach-scale improvement, and does not address greater watershed impairments.	3	Local reach intrinsic potential is High for both chinook and steelhead.	2	Addresses lack of wood loading and supports increased side channel hydrology.	3	Restoration actions address high priority ecological concerns associated with Peripheral and Transitional Habitat and Channel Structure and Form.	2	Wood treatment will help to aggrade the channel and treat incision to improve floodplain connectivity.	11	2	Typical log jam structure.	5.5	Moderate	In-channel work with remote access; little infrastructure; USFS coordination.
G3	UN5; UN6; UN7; UN7b	15.50 - 15.10	0.4	4	5	1	Group 3 provides a local opportunity for wood placement and improving side channel hydrology. Also includes preservation of extensive beaver dam complex. Little reach-scale improvement, and does not address greater watershed impairments	3	Local reach intrinsic potential is High for both chinook and steelhead.	2	Addresses lack of wood loading and supports increased side channel hydrology.	3	Restoration actions address high priority ecological concerns associated with Peripheral and Transitional Habitat and Channel Structure and Form.	2	Wood treatment will help to aggrade the channel and treat incision to improve floodplain connectivity.	11	2	Typical log jam structures.	5.5	Moderate	In-channel work with remote access; little infrastructure; USFS coordination.
G4	UN8; UN9; UN10	14.77 - 14.6	0.17	3	5	2	Group 4 includes the installation of multiple ELJs to improve wood loading, pool formation, channel bed aggradation, and side channel hydrology. Narrow floodplain corridor and degraded riparian conditions adjacent ot rail prism. Restoration action only addresses local conditions, and does not address greater watershed impairments.	3	Local reach intrinsic potential is High for both chinook and steelhead.	2	Addresses lack of wood loading and supports increased side channel hydrology.	3	Restoration actions address high priority ecological concerns associated with Peripheral and Transitional Habitat and Channel Structure and Form.	2	Wood treatment will help to aggrade the channel and treat incision to improve floodplain connectivity.	12	2	Typical log jam structures.	6	Moderate	In-channel work with remote access; little infrastructure; USFS coordination. Log structures would be immediately downstream of Church Camp.
G5	UN11; UN11a; UN12	14.25 - 14.10	0.15	3	4	1	Group 5 provides a local opportunity for wood placement and improving side channel hydrology. Little reach-scale improvement, and does not address greater watershed impairment	3	Local reach intrinsic potential is High for both chinook and steelhead.	2	Addresses lack of wood loading and supports increased side channel hydrology.	3	Restoration actions address high priority ecological concerns associated with Peripheral and Transitional Habitat and Channel Structure and Form.	2	Wood treatment will help to aggrade the channel and treat incision to improve floodplain connectivity.	11	2	Typical log jam structure.	5.5	Moderate	In-channel work with remote access; little infrastructure; USFS coordination.

Appendix E

Hydraulic Analysis

Natural Systems Design

THIS PAGE INTENTIONALLY LEFT BLANK

1. HYDRAULIC ANALYSIS

An analysis of existing conditions was conducted for the lower project reach of Nason Creek to characterize hydraulic parameters and current riverine conditions. Hydraulic modeling software developed by Hydronia, (RiverFlow2D GPU) and Aquaveo (SMS v12.3) was employed in this study. RiverFlow2D is a two-dimensional (2D) finite element computer model that calculates depth-averaged hydraulic parameters at discrete nodes within a triangular mesh domain. Hydraulic computations are resolved by the shallow water equations resulting from the integration of the Navier-Stokes equation. SMS is a GIS-based program that creates the triangular model mesh, model input files, and displays model results. For this project the computational mesh is composed of 104,973 triangular elements and 52,783 nodes.

The model begins at RM 14.5, 1.4 RM below the Whitepine Creek confluence, and extends to RM 13.5. Underlying topography is based on 2015 LiDAR (DOGAMI, 2016). Note that bed channel topography is limited to the water surface elevation at time of data collection, which was at low-flow conditions (30 cfs, September 26-27). Tributary inflows within this reach are not included in the model, nor are any bridges or culverts.

The simulation runs an unsteady state (variable discharge) and non-deformable bed (no adjustments for scour, sediment transport and deposition). The upstream boundary condition is an artificial hydrograph that gradually increases from 20 to 6,000 cfs (Figure 1) over a period of 20 hrs. The downstream boundary condition is defined as uniform outflow with a slope of 0.008. Manning's n values for this project were set for different roughness types using recent aerial photographs and in accordance with standard hydraulic reference manuals (Chow, 1959; Barnes, 1967; Hicks and Mason, 1998). Model roughness values are shown in Table 1. Data to calibrate the model was unavailable at the time of the analysis.

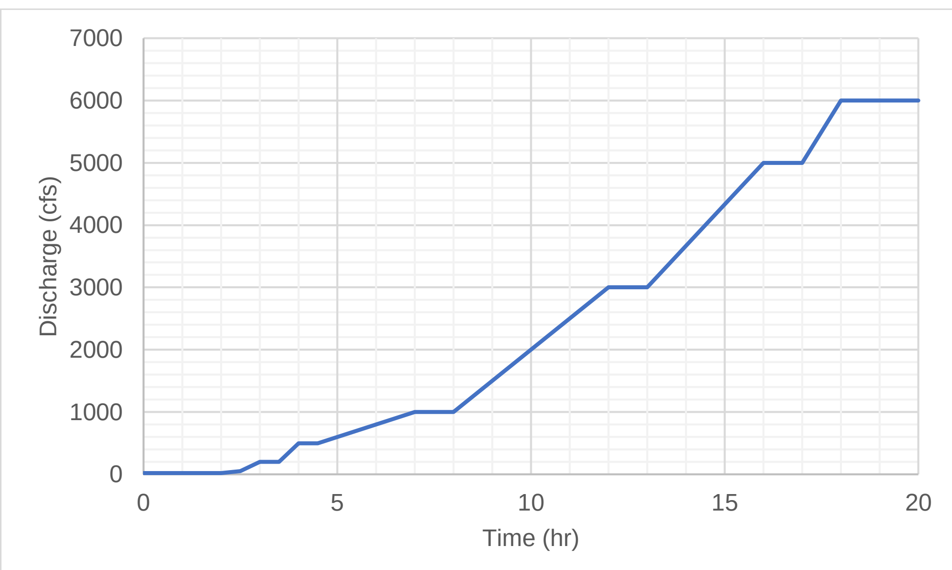


Figure 1. Inflow hydrograph for upstream boundary condition.

Table 1. Manning's n-value roughness definition for hydraulic model.

LAND COVER TYPE	MANNING'S N-VALUE
Main Channel	0.035
Gravel Bar	0.045
Forest	0.100
Road	0.020

Depth, velocity, and shear stress at select discharges are presented in Figure 2 through Figure 4. These result maps are representative of the 1-, 2-, and 100-year recurrence interval flows, respectively. Through RM 14, Nason Creek flows meanders through a 600 ft wide forested valley. Average channel width is approximately 75 ft in this reach, with bank heights ranging between 6 to 8 ft. Flow depths for the 1- and 2-year discharges range from 4 to 5 ft and 5 to 6 ft, respectively. Side channels connected with the main channel experience flow just above the 1-year recurrence discharge. The greater floodplain becomes engaged when flows exceed 2500 cfs, or the 5-year recurrence flow.

Beginning at RM 14 the valley constricts to a narrow, highly-confined canyon with a width of nearly 60 ft. At this point, channel gradient increases from 0.003 to 0.009. Channel velocity in the wider valley ranges from 5 to 8 ft/s, and increases to 10 to 15 ft/s in the canyon reach, for the 2-year flow. Significant infrastructure includes the White Pine Rd bridge (RM 13.8) and a railroad bridge (RM 13.7). Water surface elevation for the 100-year flow (2250 ft) is 2 to 3 ft below the abutment approach for the White Pine Rd bridge. The railroad bridge abutment approach is over 20 ft above the modeled 100-year water surface elevation.

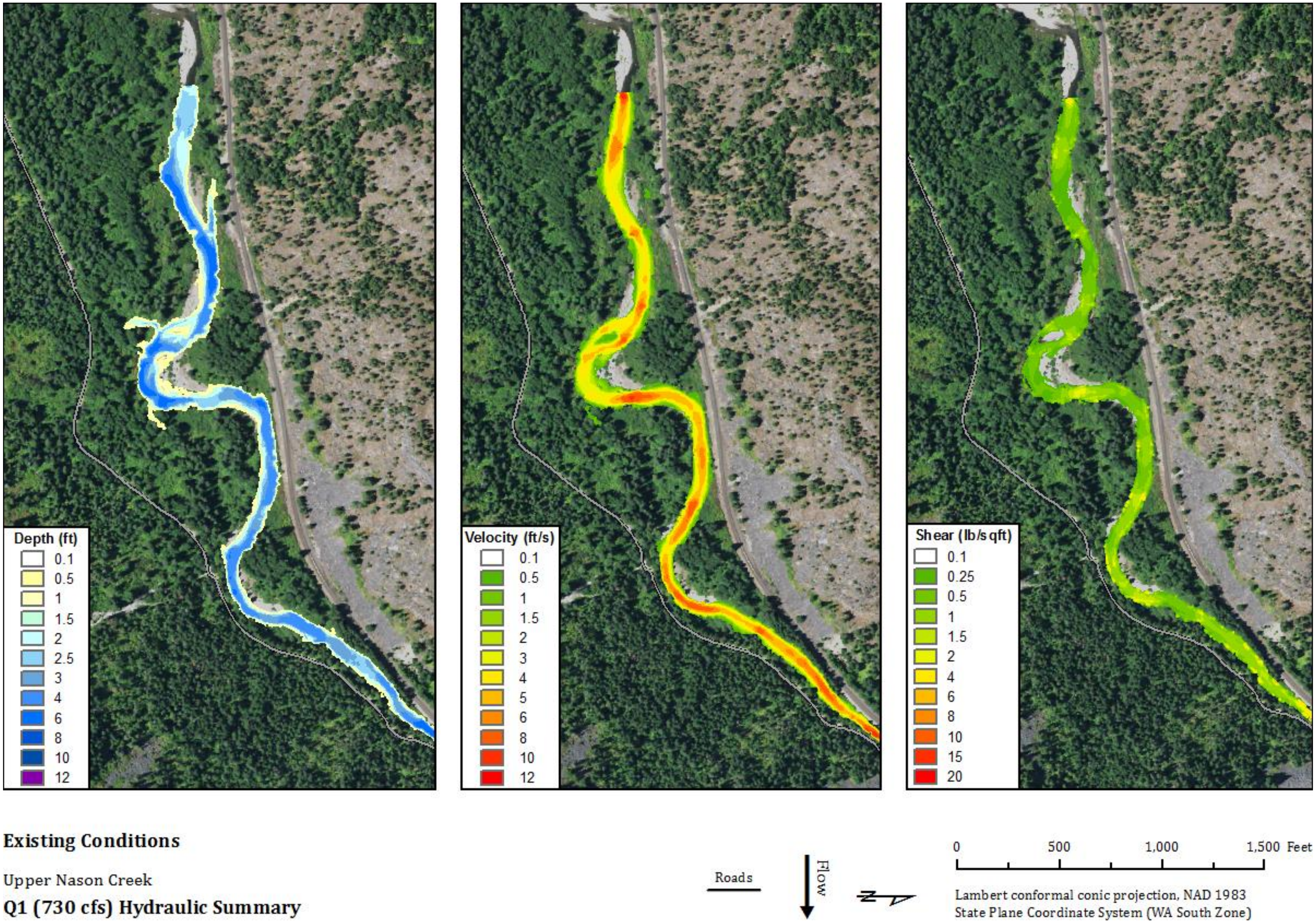


Figure 2. Hydraulic model results map for 1-year recurrence interval.

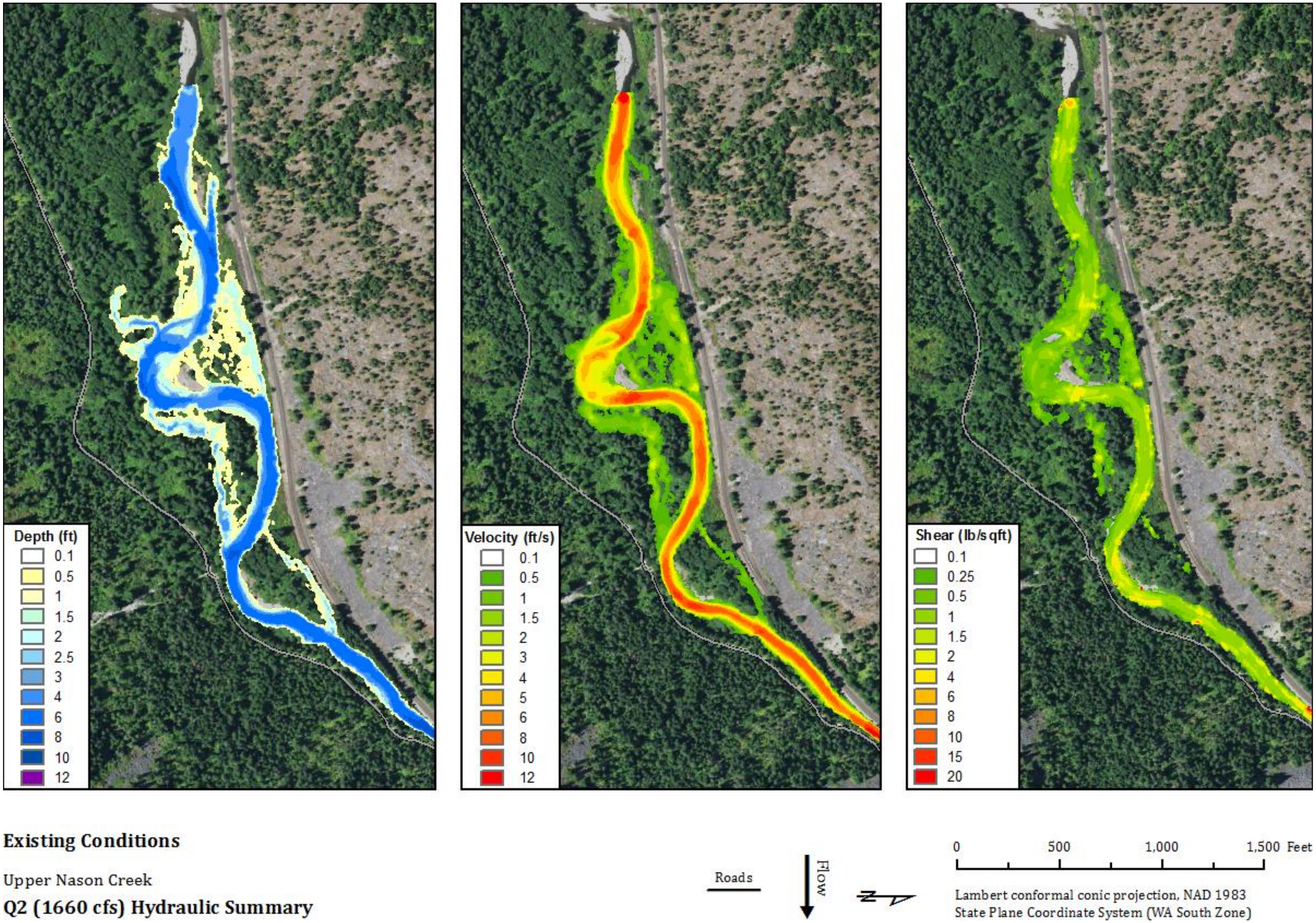
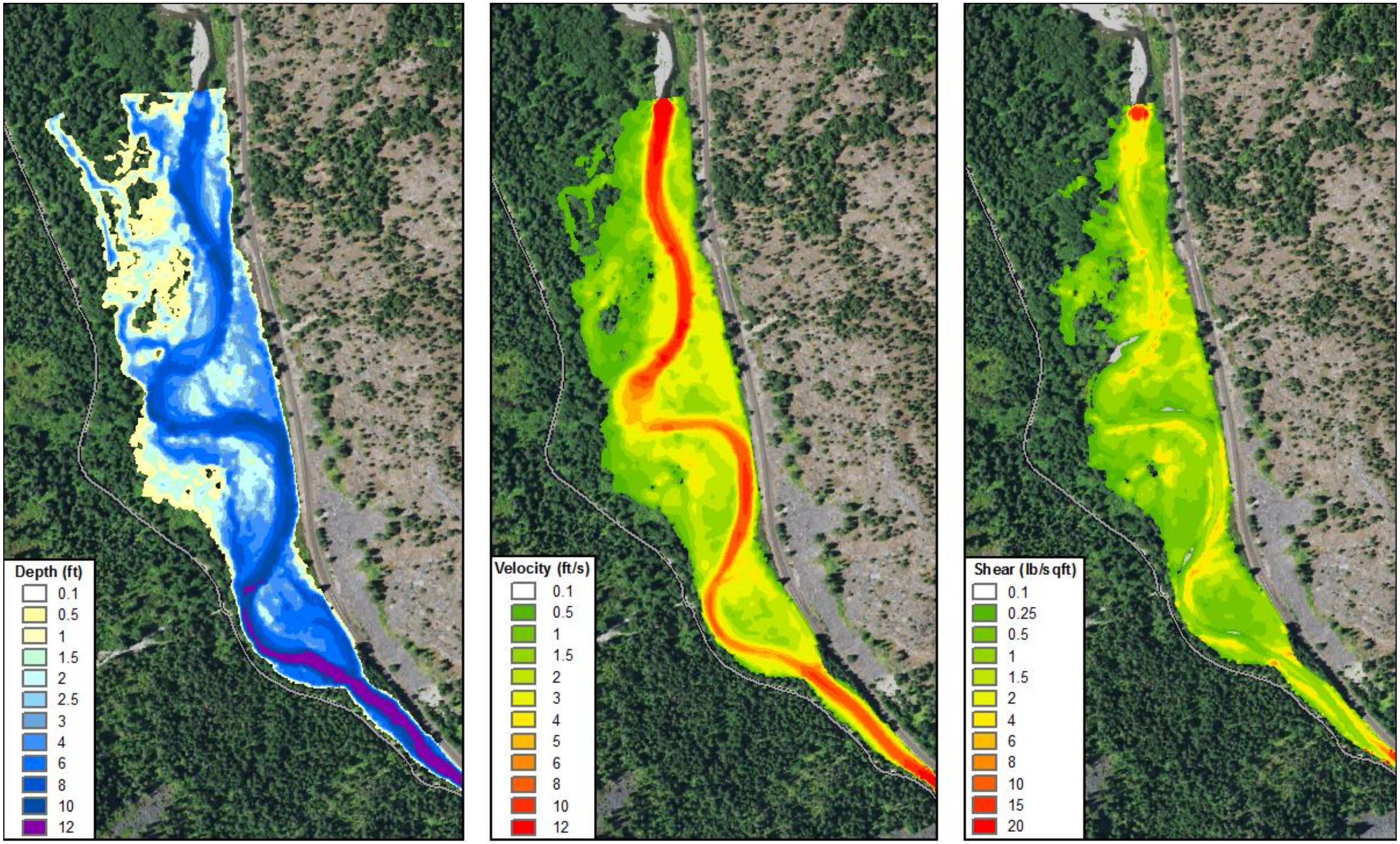


Figure 3. Hydraulic model results map for 2-year recurrence interval.



Existing Conditions

Upper Nason Creek

Q100 (5700 cfs) Hydraulic Summary

Roads

Flow

0 500 1,000 1,500 Feet

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA South Zone)

Figure 4. Hydraulic model results map for 100-year recurrence interval.

Appendix F

Historic Air Photos

Natural Systems Design

THIS PAGE INTENTIONALLY LEFT BLANK

Colin Riordan, NSD Date: 2/12/2019 Path: P:\Projects\Yakama Nation\Upper Nason Creek Reach Assessment\GIS\maps\mxd\Aerial.mxd

Upper Nason Reach Assessment

Aerial - 1956

Aerial Imagery Source: USGS

★ Reach Break

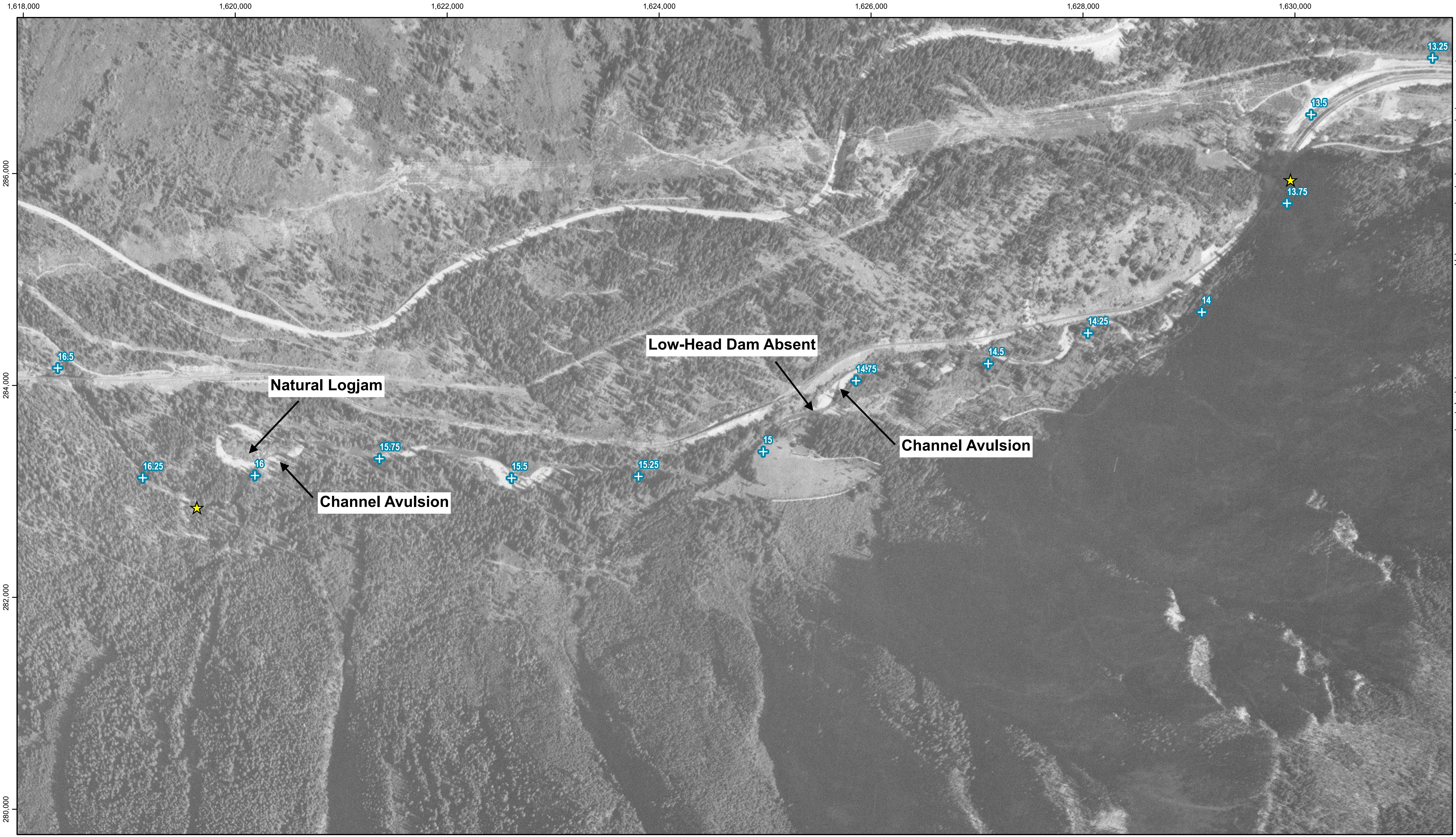
N

0 250 500 Feet

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)

Yakama Nation Fisheries

Natural Systems Design



Upper Nason Reach Assessment

Aerial - 1963

Aerial Imagery Source: USGS

Reach Break

N

0 250 500 Feet

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)

Yakama Nation Fisheries

Natural Systems Design

Upper Nason Reach Assessment

Aerial - 1974

Aerial Imagery Source: USGS

☆ Reach Break

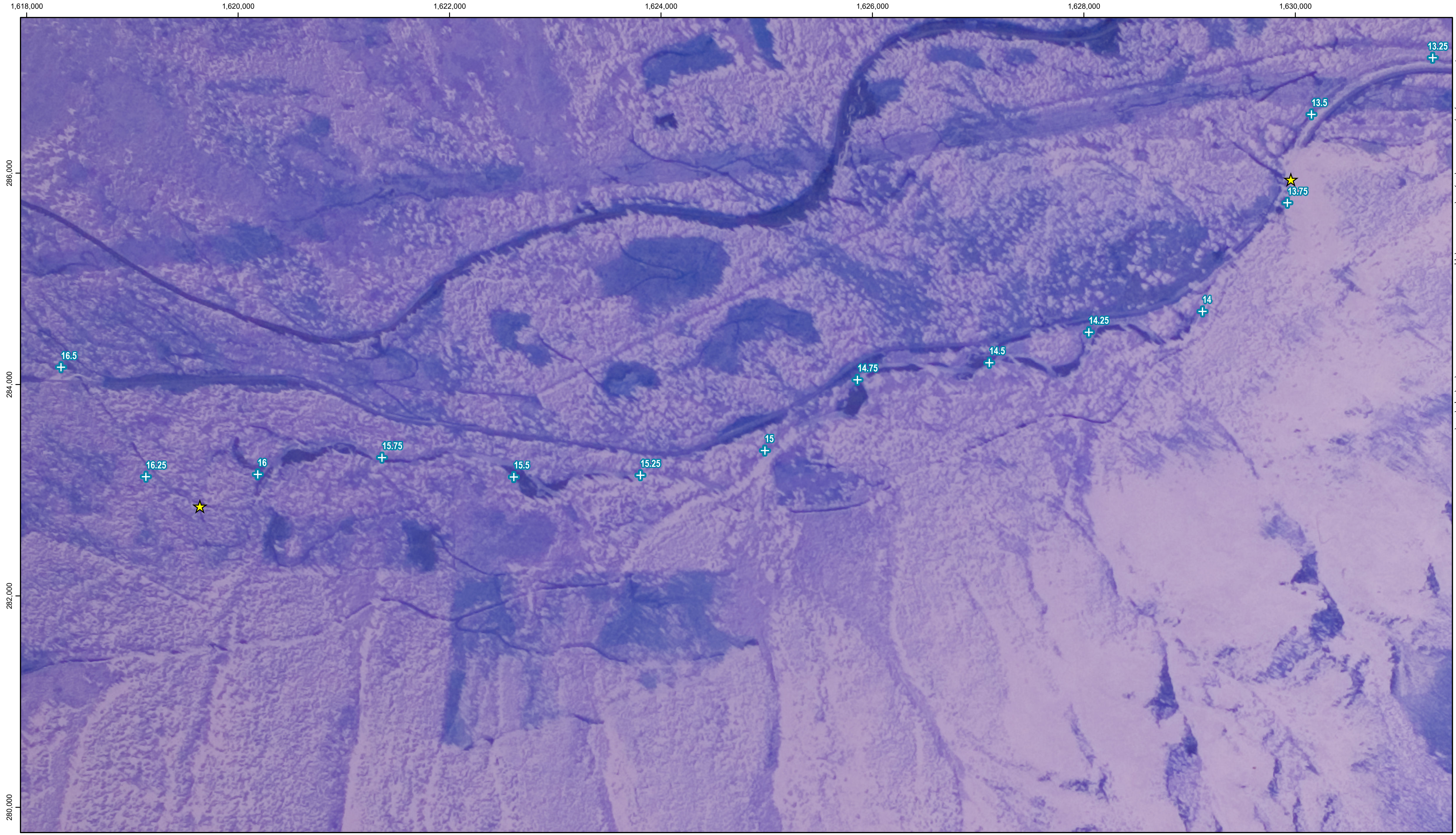
N

0 250 500 Feet

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)

Yakama Nation Fisheries

Natural Systems Design



Colin Riordan, NSD Date: 2/12/2019 Path: P:\Projects\Yakama Nation\Upper Nason Creek Reach Assessment\GIS\maps\mxd\Aerial.mxd

Upper Nason Reach Assessment

Aerial - 1985

Aerial Imagery Source: USGS

Reach Break

N

0 250 500 Feet

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)

Yakama Nation Fisheries

Natural Systems Design

Colin Riordan, NSD Date: 2/12/2019 Path: P:\Projects\Yakama Nation\Upper Nason Creek Reach Assessment\GIS\maps\mxd\Aerial.mxd

Upper Nason Reach Assessment

Aerial - 2006

Aerial Imagery Source: NAIP

☆ Reach Break

N

0 250 500 Feet

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)

Yakama Nation Fisheries

Natural Systems Design

Colin Riordan, NSD Date: 2/12/2019 Path: P:\Projects\Yakama Nation\Upper Nason Creek Reach Assessment\GIS\maps\mxd\Aerial.mxd

Upper Nason Reach Assessment

Aerial - 2011

Aerial Imagery Source: NAIP

★ Reach Break

N

0 250 500 Feet

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)

Yakama Nation Fisheries

Natural Systems Design

Colin Riordan, NSD Date: 2/12/2019 Path: P:\Projects\Yakama Nation\Upper Nason Creek Reach Assessment\GIS\maps\mxd\Aerial.mxd

Upper Nason Reach Assessment

Aerial - 2013

Aerial Imagery Source: NAIP

★ Reach Break

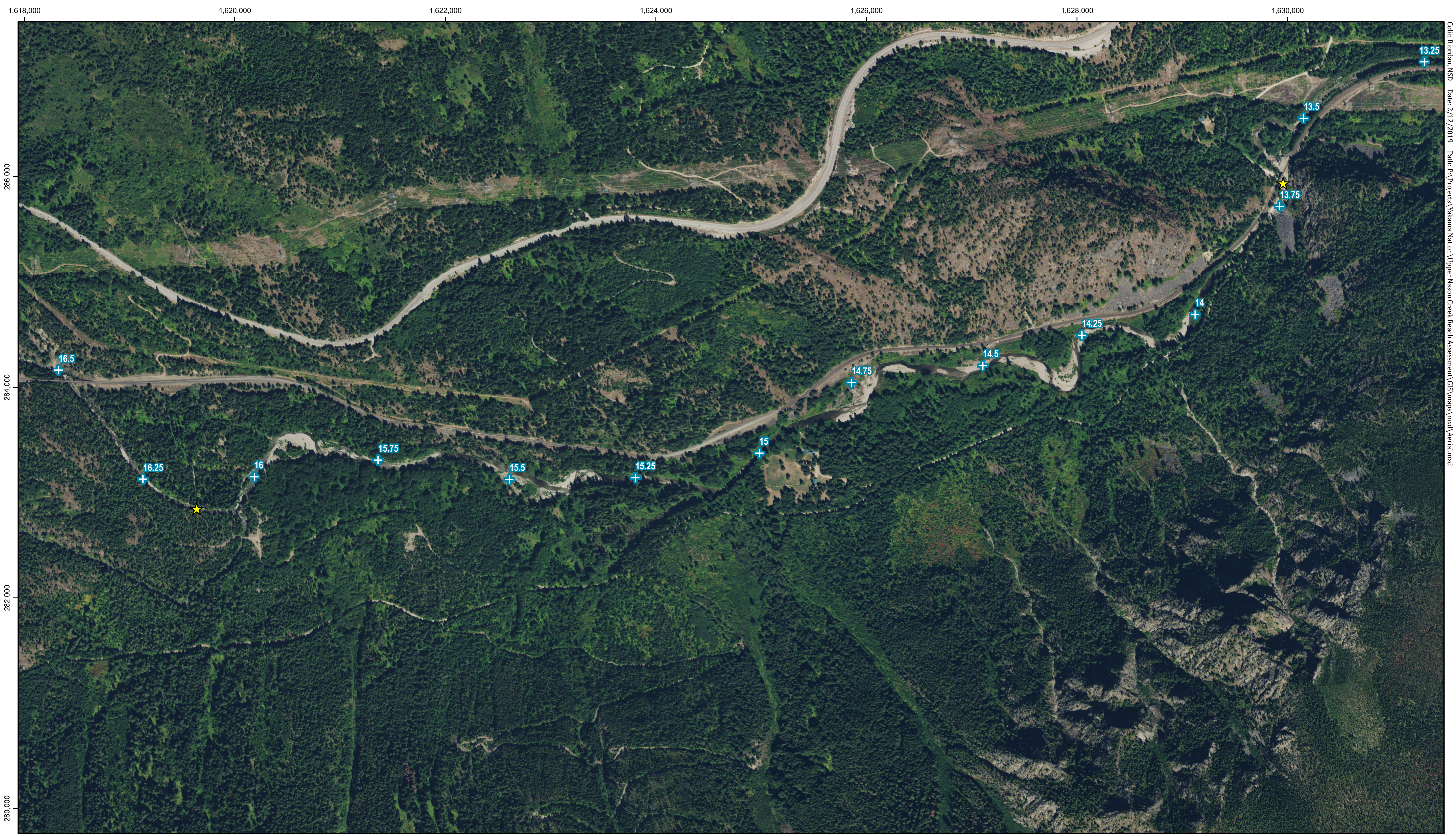
N

0 250 500 Feet

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)

Yakama Nation Fisheries

Natural Systems Design



Upper Nason Reach Assessment

Aerial - 2015

Aerial Imagery Source: NAIP

★ Reach Break

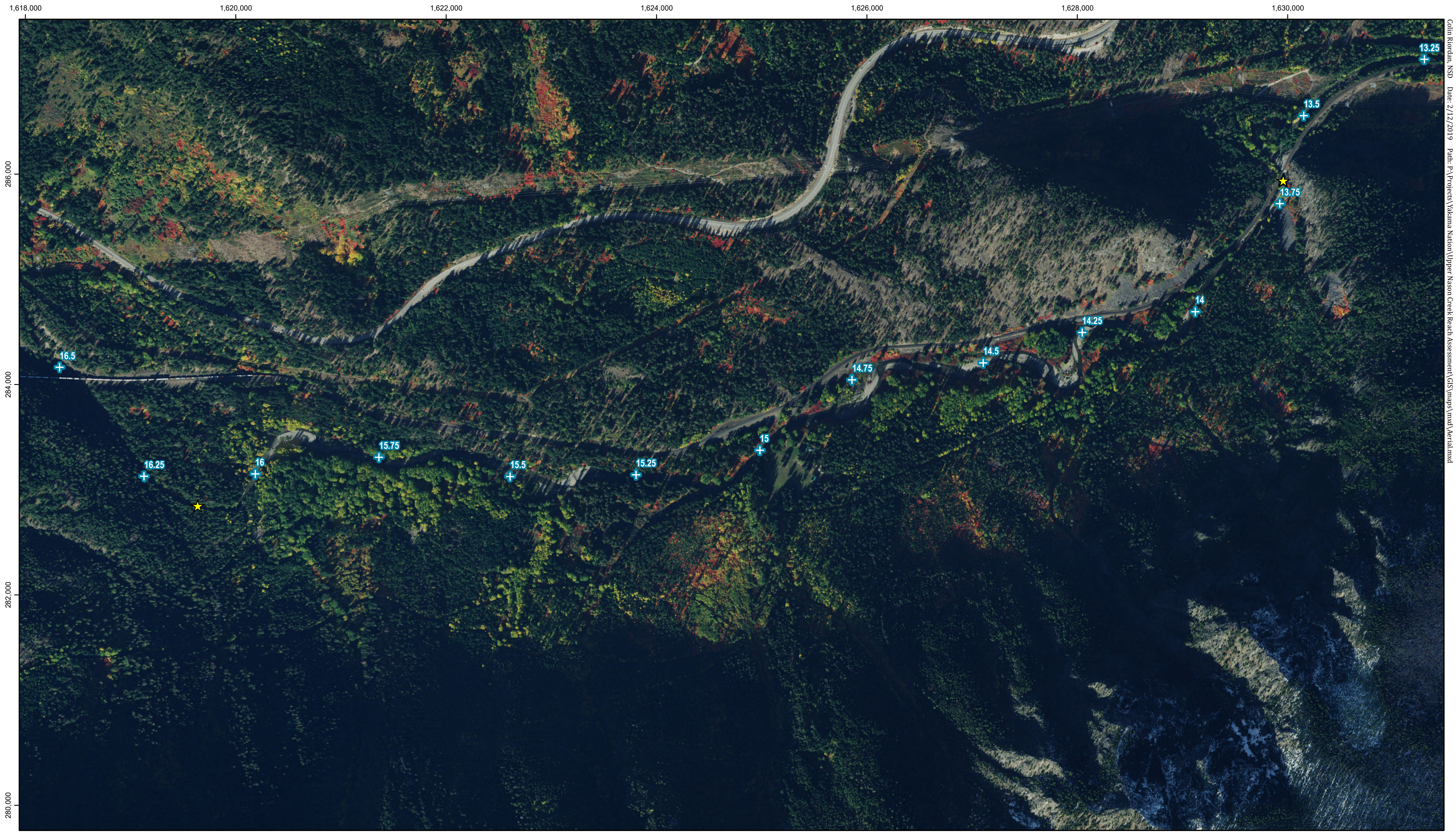
N

0 250 500 Feet

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)

Yakama Nation Fisheries

Natural Systems Design



Upper Nason Reach Assessment

Aerial - 2017

Aerial Imagery Source: NAIP

★ Reach Break

N

0 250 500 Feet

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)

Yakama Nation Fisheries

Natural Systems Design