Final

EAST FORK NOOKACHAMPS CREEK

Watershed Assessment and Management Plan

Prepared for
Upper Skagit Indian Tribe
Skagit County Public Works

May 2024

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Acronyms and Other Abbreviations

°C	degrees Celsius
°F	degrees Fahrenheit
AEP	Annual Exceedance Probability
AMSL	above mean sea level
BFW	bankfull width
BPA	Bonneville Power Administration
cfs	cubic feet per second
D50	median grain size
DD	Drainage District
DGER	Washington Division of Geology and Earth Resources
DIP	demographically independent populations
Ecology	Washington State Department of Ecology
EIS	Environmental Impact Statement
ESA	Endangered Species Act
ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration's
FPA	Forest Practice Application
GI	General Investigation
GIS	geographic information system
GLO	General Land Office
HEC-RAS 2D	Hydrologic Engineering Center-River Analysis System two-dimensional
LB	left bank
LiDAR	light detection and ranging
mg/L	milligrams per liter
NAVD 88	North American Vertical Datum of 1988
NLCD	National Land Cover Database
NMFS	National Marine Fisheries Service
NRCS	Natural Resources Conservation Service
NSD	Natural Systems Design
ORV	off-road vehicle
PRISM	Parameter-elevation Regressions on Independent Slopes Model
PUD	Public Utility District
RB	right bank
RM	river mile
SCSC	Skagit Climate Science Consortium
SFEG	Skagit Fisheries Enhancement Group
SRSC	Skagit River System Cooperative
SWC	Skagit Watershed Council
SWIFD	Statewide Integrated Fish Distribution
TFW	Timber Fish and Wildlife
TMDL	total maximum daily load
USACE	United States Army Corps of Engineers

USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
USIT	Upper Skagit Indian Tribe
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington Department of Natural Resources
WGS	Washington Geological Survey
WSC	Washington Stream Catalog
WSE	water surface elevation

1. INTRODUCTION

The Upper Skagit Indian Tribe and Skagit County partnered to develop a Watershed Assessment and Watershed Management Plan to improve salmonid habitat and reduce flooding issues in the East Fork Nookachamps Creek watershed (**Figure 1**). East Fork Nookachamps Creek is an important creek system in the lower portion of the Skagit River watershed. It supports all five species of anadromous salmon and steelhead. The Chinook salmon and steelhead populations are both listed as threatened under the federal Endangered Species Act (ESA). Nookachamps Creek supports an independent steelhead population that is part of the Puget Sound ESA listing. Chinook salmon from all six ESA-listed Skagit River populations use the lower portions of Nookachamps Creek and East Fork Nookachamps Creek for rearing. Other parts of the project area support salmonid spawning and rearing. The East Fork Nookachamps Creek project area includes Tier 1 and Tier 2 priority areas for Chinook salmon recovery in the Skagit River watershed based on providing the greatest potential to increase populations of Chinook salmon (SWC 2022).

The East Fork Nookachamps Creek watershed is also home to a vibrant community largely centered around agriculture and with long, multi-generational histories in the area. Since time immemorial, Skagit Indians inhabited the Skagit River watershed, and the Nookachamps villages of the Upper Skagit Indian Tribe fished, hunted, and gathered throughout the Nookachamps Creek watershed. Following European settlement and beginning in the late 1800s, the upper reaches of the watershed have been repeatedly logged. Such timber harvest is often associated with higher peak flows and increased sediment loads in downstream waterways. In recent years, salmon and steelhead returns to the creek have been declining while landowners have also been experiencing increased and longer duration flooding. It is expected that this Watershed Assessment and Watershed Management Plan will result in the identification and subsequent implementation of projects that benefit both human and aquatic communities.

The overall project goals include the following:

- Conduct a science-based evaluation of watershed conditions to identify strategic actions that will improve habitat conditions for salmonids and riparian-dependent species, restore natural hydrogeomorphic processes, and mitigate flood impacts on landowners, Skagit County roads, and Drainage District 21.
- Develop a Watershed Management Plan with recommended actions that can be conducted with willing landowners (i.e., entirely voluntary participation) with funding from public funding sources (e.g., grants). The recommended actions are expected to include some that can be designed and implemented soon after the completion of the plan as well as other actions that will require more time to plan due to their scale and complexity.

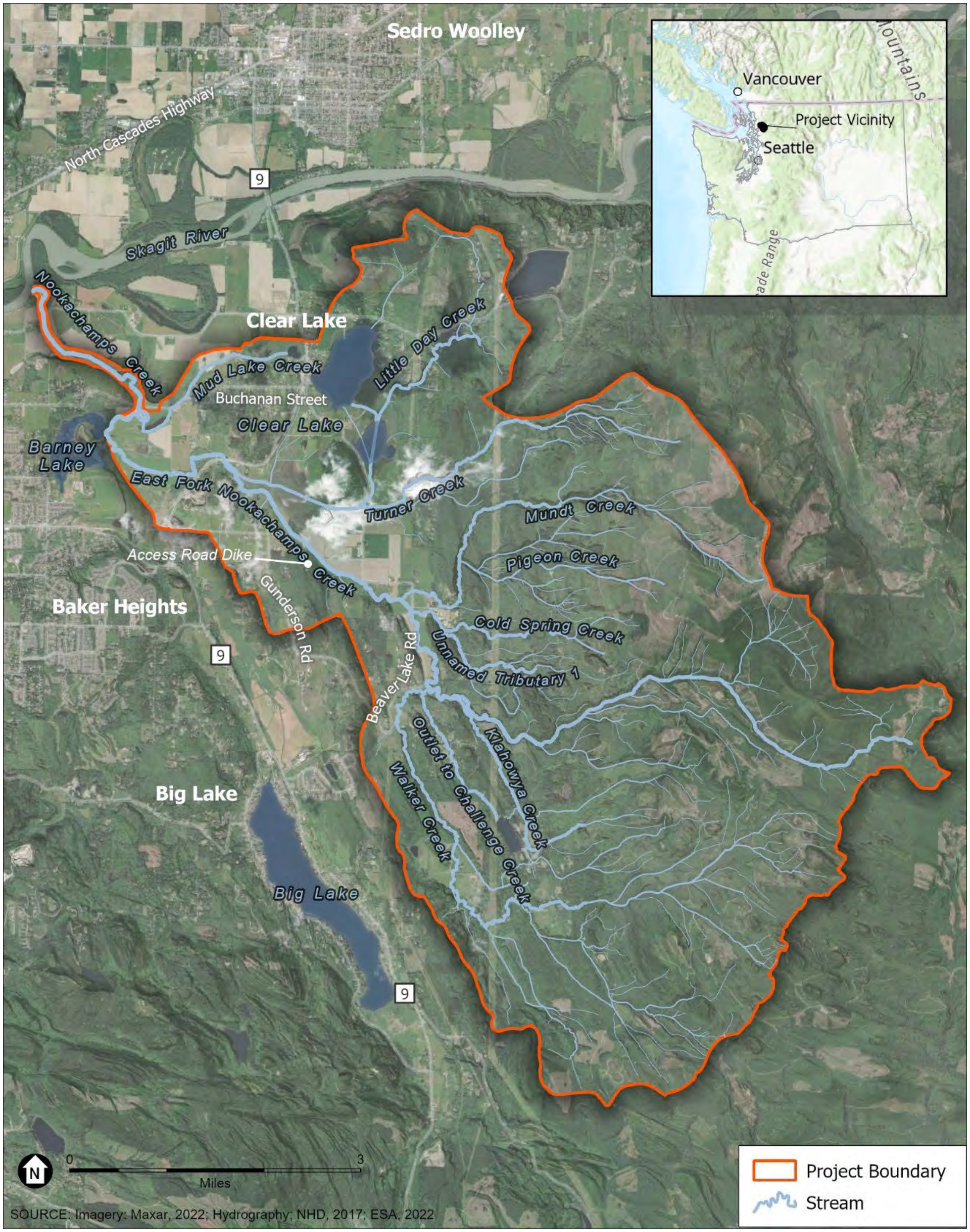


Figure 1.
East Fork Nookachamps Creek Project Area and Watershed Boundary

This Watershed Assessment and Management Plan presents an analysis of physical and biological conditions within the watershed and identifies contributing factors to those conditions. Informed by this analysis and with community and stakeholder input, the plan identifies recommended actions and strategies to address habitat and drainage deficiencies identified in the Watershed Assessment. The Watershed Management Plan includes specific, actionable objectives with watershed- and reach-scale strategies for achieving the multi-benefit goals. Actions and strategies are as specific as possible, with locations/reaches identified, desired implementation timeframes, and potential project sponsors.

2. WATERSHED SETTING

2.1 Watershed Overview

The East Fork Nookachamps Creek watershed encompasses 37.7 square miles from the Cultus Mountains in the east through a lowland valley and ultimately to its confluence with the Skagit River. The creek flows approximately 9.4 miles in a generally northwest direction from its eastern headwaters to Barney Lake where it joins the West Fork Nookachamps Creek. Downstream of Barney Lake, Nookachamps Creek conveys the water of both forks for approximately 2.9 miles before flowing into the Skagit River at river mile (RM) 18.8. There are several tributaries to the East Fork Nookachamps Creek consisting of approximately 50 additional stream miles (see **Figure 1**). The largest tributaries to East Fork Nookachamps Creek are Walker Creek, Turner Creek, Mundt Creek, and Little Day Creek. The tributaries of East Fork Nookachamps Creek with their Washington Department of Fish and Wildlife (WDFW) stream number, and location of its confluence with the East Fork Nookachamps Creek are listed in **Table 1**.

TABLE 1. CONTRIBUTING TRIBUTARIES IN EAST FORK NOOKACHAMPS CREEK

Stream	WDFW Stream Number	Location of Mouth along East Fork Nookachamps Creek
East Fork Nookachamps Creek	03.230	n/a
Mud Lake Creek	03.229	right bank (RB) of Nookachamps Creek at RM 2.15
Turner Creek	03.0231	RB at RM 2.1
Little Day Creek	03.0232	RB of Turner Creek RM 1.0
Mundt Creek	03.0235	RB at RM 4.1
Pigeon Creek	03.0236	LB of Mundt Creek at RM 1.0
Cold Spring Creek	03.0238	RB at RM 4.4
Unnamed Tributary 1	03.0237	LB of Cold Spring Creek at RM 0.4
Klahowya Creek	03.0248	LB at RM 5.75
Lake Challenge Outlet	03.0240	LB of Walker Creek at RM 0.1
Walker Creek	03.0239	left bank (LB) at RM 5.1

2.2 Geology

The geology of the watershed is important to consider because it dictates landform formation including topography, drainage courses, and sediment supply. The East Fork Nookachamps Creek watershed lies in the Puget Lowlands, a low-lying area stretching south from Centralia and north to Bellingham, bounded by the Olympic Mountains to the west and the Cascade Range to the east. The Puget Lowlands were shaped by the ice sheets of the Fraser Glaciation, which peaked around 14,500 years ago when glaciers reached as far south as Centralia. The most recent period of glacial advance, the Vashon Stade, occurred 15,000 to 12,000 years ago. As the region slowly warmed, the ice sheets retreated north, leaving a series of north-south trending valleys and ridges throughout the Puget Lowlands. In areas of the lower Skagit River Valley, ice sheets flowed in multiple directions over the course of the Fraser Glaciation, leaving unconsolidated sediments extending 1,300 to 2,000 feet beneath the valley floor (Heller 1980). In the early parts of the glaciation, 20,000 to 18,000 years ago, the Baker Valley glacier flowed westward down the valley. During the Vashon Stade, Cordilleran ice sheets then advanced eastward up the valley and eventually southeast as they overtopped higher ridges.

The Skagit River Valley, including the Nookachamps Valley, has also been shaped by lahars from Glacier Peak. Lahars are fast-moving mudflows consisting of mud, rock, and water that result from the eruptions of volcanoes, such as Glacier Peak, Mount Baker, Mount Rainier, or Mount St. Helens. Glacier Peak most recently erupted 13,100, 5,900, and 1,800 years ago, sending lahars down the Skagit River to Puget Sound. These lahars contributed to the growth of the Skagit River delta and left deposits of 10- to 50-foot-high terraces adjacent to the floodplain, primarily north of the Skagit River, between present-day Burlington and Sedro Woolley (Hodges 2005). During this time, the Skagit River delta was actively expanding; 11,000 years ago, the delta sat almost 25 miles to the northeast, near the town of Hamilton.

The geology of the project area records a complex history of accretion along the continental margin, mountain building, deposition of terrestrial and marine sediments, igneous intrusion, and the repeated advance and retreat of continental glaciers (Savoca et al. 2009). Elevations within the project area range from 4,000 feet above mean sea level (AMSL) at the top of Cultus Mountain on the eastern edge of the basin to 20 feet at the mouth of Nookachamps Creek. **Figure 2** uses data provided by the Washington Division of Geology and Earth Resources (DGER) to show the different geologic units associated with the project area, combined with information on landslide hazard areas from the Washington Geological Survey (WGS). Near the Skagit River and the valley bottoms, much of the geology is Quaternary Alluvium. Alluvium is loosely sorted sediments, including clay, silt, sand, or gravel, which is deposited by rivers, like the Skagit River. Upslope of the valley floor, glacial till from the Fraser Glaciation is the dominant geologic unit. Upland areas contain laterally discontinuous bodies of glacial and interglacial deposits that reflect both terrestrial and shallow marine depositional environments. Bedrock consisting of a complex assemblage of metamorphic rocks, sedimentary units, and igneous rocks underlies the alluvial valley and upland areas and crops out throughout the mountainous terrain (Savoca et al. 2009).

Large mass-wasting deposits associated with landslide hazard zones are in the upper reaches of the Cold Spring Creek, East Fork Nookachamps Creek, and Walker Creek sub-watersheds. Mass-wasting deposits occur when rock or soil travels downslope, driven by gravity. It may be caused by heavy soil saturation from an extreme precipitation event. Isolated areas of higher elevation within the East Fork Nookachamps Creek Valley (such as Buchanan Street Hill, directly southwest of Clear Lake, and Maple Hill, southwest of Beaver Lake) are deposits of Tokul gravelly medial loam, derived from volcanic ash mixed with loess, a wind-blown dust. These hills rise 200 feet above the valley floor.

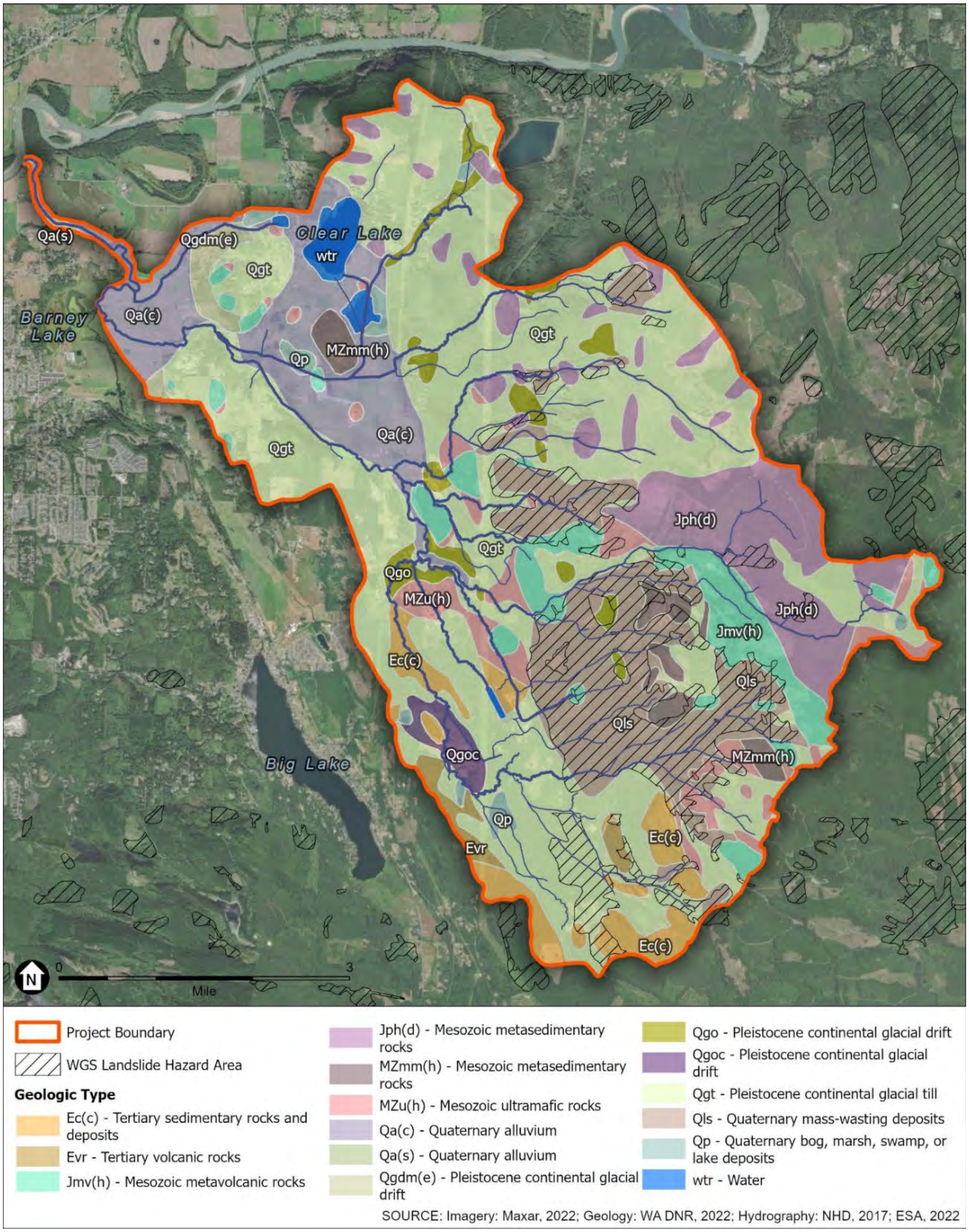


Figure 2.
Geologic Map of Project Area with East Fork Nookachamps Creek Watershed Boundary

2.2.1 Soils and Sediment Sources

In general, the geology of the project area records a complex history of accretion along the continental margin, mountain building, deposition of terrestrial and marine sediments, igneous intrusion, and the repeated advance and retreat of continental glaciers (Savoca et al. 2009). This geologic setting, along with significant mass wasting and the influence of historic Skagit River deposits, has resulted in watershed conditions with an abundance of available sediment for delivery from upland sources to lowland areas.

Figure 3, shows the soil types within the project area, sourced from the Washington Department of Natural Resources (WDNR). Nookachamps silt loam is a common soil in the valley bottom, consisting of very deep, poorly drained soils that formed in alluvium on floodplains. This alluvium is deposited during flood events by Nookachamps Creek or one of its tributaries or by the Skagit River. Many of the soils in the upper reaches of the East Fork Nookachamps Creek watershed are gravelly loam, which is a coarse-textured soil that is well drained and typical of glacial deposits. The mass-wasting deposits shown in **Figure 2** may be one source of sediment in the upper watershed. These deposits are loose and non-cohesive, easily eroded, and carried downslope by streams. Another potential source of sediment in the upper watershed is logging and road building associated with logging. Logging can expose large areas of soil that, without trees or vegetation to hold it in place, are more susceptible to erosion. These sources create a high sediment yield that corresponds with high sediment transport rates. Sediment transport is highest in the upper watersheds where mid-gradient streams have the capacity to transport typical gravel bedload. Sediment transport capacity greatly decreases within the low-gradient valley floor, which can cause transported sediment to deposit to the valley floor. During flood events, streams will overtop their banks and spill onto the floodplain, dropping sediment as they recede.

The Skagit River is also an extremely sediment-rich river, delivering on the order of 2.5 million metric tons, or approximately 40%, of the fluvial sediment that enters Puget Sound (Curran et al. 2016). Much of the fine sediment in the Skagit River comes from glaciers in its headwaters in North Cascades National Park and Glacier Peak. The Nookachamps Valley is in the Skagit River “Transport Zone,” where sediment is repeatedly carried and dropped by the river before being deposited in the river delta. Sand and gravel are gradually filling in the river channel; in Mount Vernon, the channel has risen approximately 10 feet between 1999 and 2012 (SCSC 2015). A 2014 United States Army Corps of Engineers (USACE) study found during flood events a large amount of deposition may occur in the river between RM 18 and 22, due to low channel velocities caused by floodwater diversions into the Nookachamps Creek area. This reach is also where the riverbed currently changes from gravel dominant to sand dominant. During flood events, the river will backwater the mainstem Nookachamps Creek and flood into the Nookachamps Valley, depositing sediments over the floodplain. Early mapping of the valley shows that the Skagit River occupied large portions of the current lower Nookachamps Creek valley, leaving behind deep deposits of alluvial material.

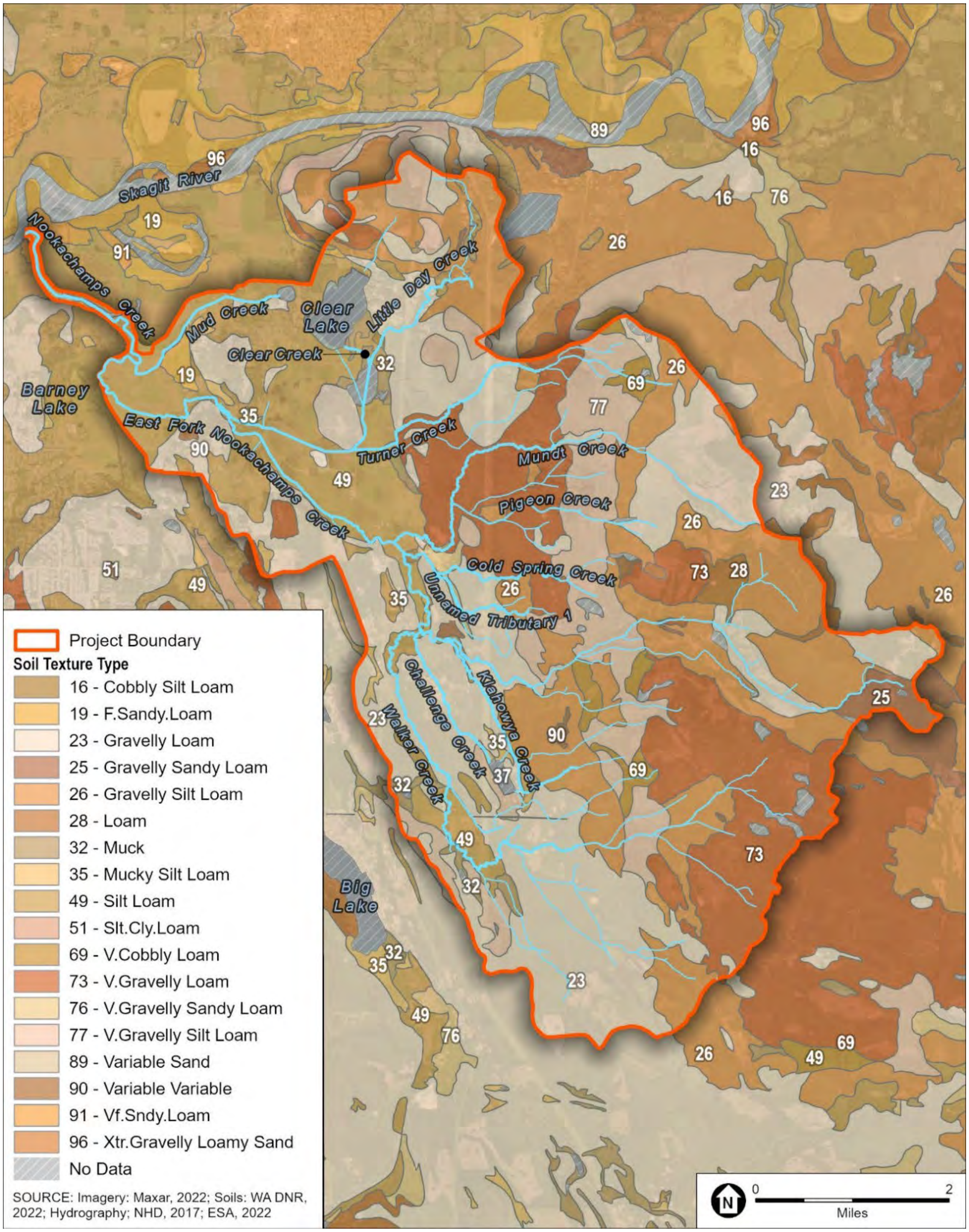


Figure 3.
Soils Map of the Project Area with East Fork Nookachamps Creek Watershed Boundary

A 2005 Cultural Resources Assessment conducted in the vicinity of the confluence of East Fork Nookachamps Creek and Mud Lake Creek with the mainstem Nookachamps Creek found that the upper 3 feet of the valley alluvium had been deposited relatively recently, potentially within the last century (Hodges 2005). Because the soils lacked woody debris, the alluvium was likely deposited after the land had been cleared of trees for agriculture. The study found glacial till near the soil surface at elevations above 40 feet AMSL, suggesting that this is the approximate flood stage for Nookachamps Creek.

Sediment aggradation has been a recognized and persistent condition on the East Fork Nookachamps Creek since the area was first settled. A newspaper article from 1944 states *"East Fork of Nookachamps creek is well known to local people because of the aggravated drainage problem present. Logs coming down stream during earlier logging days clogged up the stream and became compacted and then silted, until today the stream bed runs about three feet above the level of the surrounding territory"* (The Courier-Times 1944), The Courier-Times article documents several miles of planned ditch excavation lead by the Skagit Soil Conservation District in the East Fork Nookachamps Creek area, designed to benefit farmers and restore fish populations to the silted-in creek.

Finer sediments such as silty loam are dominant in areas closest to the Skagit River, extending to the East Fork Nookachamps Creek Valley and Mundt Creek. Silt is an intermediate-sized particle, larger than clay and smaller than sand, which is commonly deposited on valley floors by floodwaters. Loam is a mixture of sand, silt, and clay, with silty loam containing a greater amount of silt particles. Slightly higher in the watershed, outside of frequently flooded areas, gravelly loam is the most common soil type. This soil type contains coarser pieces of small rock and will drain faster than silt soils. Finally, gravelly silt loam is found in the uppermost reaches of the project area and contains a mixture of coarse gravel and finer silt particles. This pattern is fairly typical in that the dominant grain size of sediments starts coarse in the upper watershed and gradually becomes finer farther downstream as a reduction in stream power limits the ability of streams to move larger particle clasts.

2.3 Climate and Flora

The project area is located on the western slopes of the Cascade Mountains and has a temperate marine climate. The region has wet winters, with temperatures averaging around 40 degrees Fahrenheit (°F) and mild summers, averaging around 61°F (Hodges 2005). Mean annual precipitation within the watershed ranges from 43 to 94 inches, with a sharp orographic effect causing increased rainfall at higher elevations. Most precipitation falls during the rainy season from October through March. Higher elevations in the basin, like Cultus Mountain, likely see snow on an annual basis. In the drier summers, several weeks can pass with little or no precipitation.

The Puget Lowland region is covered with large stands of coniferous forest consisting of western hemlock, western redcedar, and the dominant Douglas-fir. Common shrubs include sword fern, salal, Oregon grape, oceanspray, blackberry, red huckleberry, and red elderberry (Franklin and Dyrness 1973). Common deciduous trees include bigleaf maple and red alder, both common in moist areas. Stream courses and floodplains are often dominated by red alder, black cottonwood, bigleaf maple, and other riparian plants. River valley wetlands typically support willow, alder, cranberries, cattail, reeds, wapato, nettles, and skunk cabbage.

2.4 Land Use

2.4.1 Historic Land Use

Since time immemorial, Skagit Indians inhabited the Skagit River watershed. This is known from local tribal history and is borne out by the oldest radiocarbon ages from two archaeological sites spanning Skagit Indian traditional territory: 13,800 years old (Orcas Island) and 9,800 years old (Cascade Pass). The Nookachamps villages of the Upper Skagit Indian Tribe historically occupied the Skagit River between Mount Vernon and Sedro Woolley, as well as along Nookachamps Creek. The four big lakes of the Nookachamps Creek watershed (Clear, Beaver, Big, and McMurray) were all important locations for Nookachamps villages and camps. This northern Lushootseed-speaking Salish group relied on stored foods, primarily salmon, roots and bulbs, and berries, and also hunted waterfowl, deer, and elk. They occupied summer fishing villages east of the mouth of Nookachamps Creek and a large winter house on Nookachamps Creek. The Nookachamps drainage was primarily used for hunting and gathering, and it was not until the arrival of white settlers in the 1870s that native land and waterscapes became heavily modified for homesteading and agriculture.

Prior to 1879, multiple large log jams on the Skagit River between Nookachamps Creek and Mount Vernon limited access and settlement in upstream areas. In 1879, a hand-hewn path was opened through the reportedly 30-foot-deep jam, allowing access to the interior of the basin. This led to the rapid growth of logging and expansion of railroads into the upstream reaches of the Skagit River. In the lower reaches of the Skagit Valley, including the Nookachamps Valley, farming became the primary industry. What was once likely a large complex of seasonal open water and forested wetlands in the EF Nookachamps valley was cleared for agriculture. Wetlands were channelized and converted to ditches to increase drainage and create drier fields. Oats, barley, hay, and potatoes were common crops, along with tulip bulbs by 1906 and vegetables by the 1920s (Hodges 2005). Dairy cattle became an important industry after creameries were introduced in 1895. The upper, forested portions of the East Fork Nookachamps Creek watershed were likely rapidly harvested in the late 1800s due to their proximity to Mount Vernon. However, there is little record of early logging activities.

Timber Harvest

Timber harvesting became a large part of the local economy around 1880, after the removal of the Skagit River log jam, peaking in the late 1800s and early 1900s. The more recent history of timber harvest in the East Fork Nookachamps Creek watershed was analyzed by reviewing Forest Practice Applications (FPAs) submitted after 1999. **Figure 4** shows all of the FPAs successfully submitted between 1999 and present day. A submitted FPA is not a guarantee that logging occurred as they are required for a variety of activities, including harvesting timber, salvaging standing and down wood, constructing forest roads, opening or expanding a rock pit on forest land for forestry use, operating in or over any typed water, and applying forest chemicals with an aircraft, but it is a strong indicator of some sort of intensive human activity.

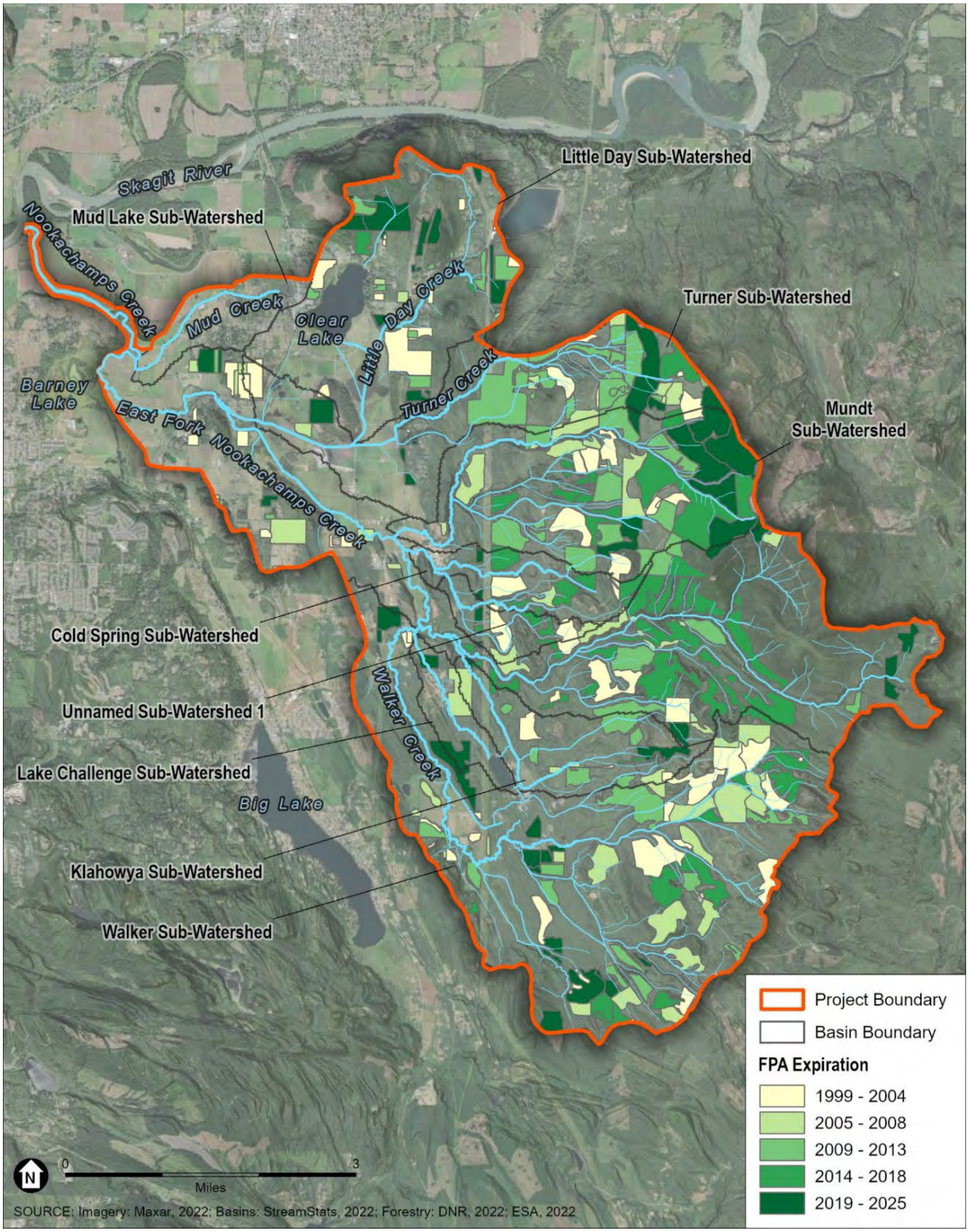


Figure 4.
Forest Practice Applications by Sub-watershed in the East Fork Nookachamps Creek Watershed (1999–present)

Table 2 presents the total FPA areas between 1999 and the present in each sub-watershed. Mud Lake has the lowest percentage of acreage, with a submitted FPA at only 0.3%, followed by Lake Challenge Outlet at 2%, Little Day Creek at 19%, Turner Creek at 28%, Walker Creek at 30%, Klahowya Creek at 31%, Cold Spring at 34%, Unnamed Tributary 1 at 36%, and Mundt Creek at 59%. Overall, 33% of the acreage in the East Fork Nookachamps Creek basin has had an FPA submitted in the 23 years, between 1999 and 2022.

TABLE 2. AREA OF SUBMITTED FOREST PRACTICE APPLICATIONS BY SUB-WATERSHED

Watershed	Watershed Area (Acres)	FPA Area (Acres)	Percentage
Project Area	24,399	7,612	33
Mud Lake Creek	508	1	0.3
East Fork Nookachamps Creek (excluding other sub-watersheds)	6,195	1,659	27
Turner Creek (excluding Little Day Creek sub-watershed)	2,443	922	28
Little Day Creek	3,055	577	19
Mundt Creek	2,932	1,729	59
Cold Spring Creek (excluding Unnamed Tributary 1 sub-watershed)	710	231	34
Unnamed Tributary 1	379	136	36
Klahowya Creek	1,086	335	31
Lake Challenge Outlet	412	95	23
Walker Creek (excluding Lake Challenge Outlet sub-watershed)	6,682	1,927	30

2.4.2 Current Land Use

Figure 5 shows current land cover in the watershed. The valley bottom is dominated by hay/ pasture uses and cultivated crops, with large wetlands in depressional areas surrounding creeks and lakes. Dairy farmland and grazing are the primary land uses in the lower watershed. There are also hazelnut farms and three quarries in the East Fork Nookachamps Creek watershed: Beaver Lake Quarry south of the confluence of Turner and Little Day Creeks on Beaver Lake Road, Skagit Aggregates southwest of the confluence of Turner and East Fork Nookachamps Creeks along Highway 9, and an unnamed quarry near Cold Spring Creek. The upper portion of the watershed is primarily deciduous and evergreen forest, with patches of shrub/scrub in recently logged areas. Much of the upper watershed is owned by the WDNR and private landowners.

The project area encompasses the town of Clear Lake, with an estimated population of 1,065 as of the 2020 Census. Clear Lake is situated between Clear and Mud Lakes, with Highway 9 running through its center. Most of the town lies within the 100-year flood zone of the Skagit River (FEMA 1985). Most of the residential homes and the population within the project area are situated around the town of Clear Lake.

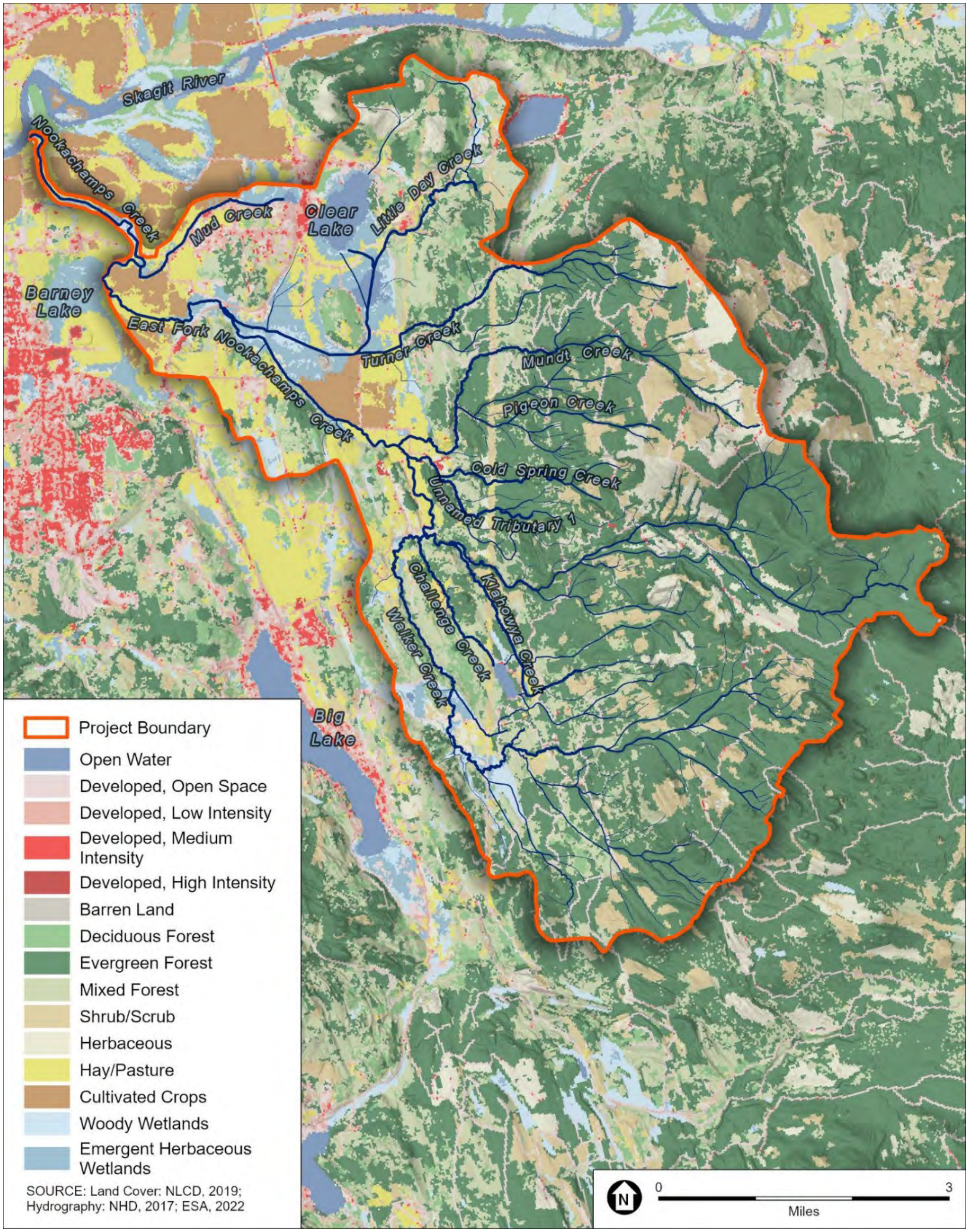


Figure 5.
National Land Cover Database (NLCD) Land Cover Map with East Fork Nookachamps Creek Watershed Boundary

2.5 Hydrography

2.5.1 Historic Channel Network

The Washington State General Land Office plat maps (GLO 1872) offer the opportunity to evaluate the East Fork Nookachamps Creek channel network prior to extensive human modification (**Figure 6**). Particularly noteworthy of the GLO mapping are the historical position of the Skagit River, the mouth of Nookachamps Creek, and the mid-watershed area near the current East Fork Nookachamps Creek river crossing of Beaver Lake Road.

The 1872 position of the Skagit River shows a still-active river meander at modern-day Debays Slough, and what appears to be a more historic meander cutoff just downstream. At the time of the survey, Nookachamps Creek was mapped emptying into this relict meander bend and then into the mainstem Skagit River. This reach of the modern-day Nookachamps Creek, generally located from Swan Road and northward, flows out to the Skagit River in this clearly oversized valley for the modern-day creek, which is in fact an abandoned section of the mainstem Skagit River channel. As the Skagit River abandoned this meander bend, and then also the meander bend of modern-day Debays Slough, thick deposits of alluvial material were left in place, providing rich soil for farming.

Farther up in the watershed, the GLO map depicts East Fork Nookachamps Creek originating from a wetland near the modern-day confluence of East Fork Nookachamps Creek and Turner Creek and flowing north, into another wetland area. Given that the mainstem Nookachamps Creek is mapped in detail several miles upstream, the isolated channel of the East Fork Nookachamps Creek and lack of upstream delineation indicate the possibility of a lack of defined channels to survey at the time. Most of the valley floor may have been a large wetland complex that lacked a single permanent channel. Given the steep tributaries entering the valley floor in this area to the south and west of both Clear Lake and Beaver Lake, the high volume of sediment delivered by these streams, and the extremely flat valley bottom, it is likely that a vast wetland marsh existed in this zone prior to human efforts to drain and farm the area. This is not to say that there may not have been episodic channel formation within the wetland, but that the dominant hydrologic feature was likely a wetland rather than the channel network as seen today.

By the 1937 aerial photo (**Figure 7**), Nookachamps Creek and much of the lower reaches of East Fork Nookachamps Creek are in the same general location as evident today, indicating large efforts to drain and develop cropland in the valley during the early portion of the 20^{th} century. Prior to modern dredging, the 1937 confluence of Turner Creek and East Fork Nookachamps Creek was located slightly upstream of the current location. The levee currently along the right bank of East Fork Nookachamps Creek, downstream of Cold Spring Creek and upstream of Turner Creek, is absent. The 1937 aerial photo indicates that most major modification of the channel network occurred in the 65years between 1872 and 1937.

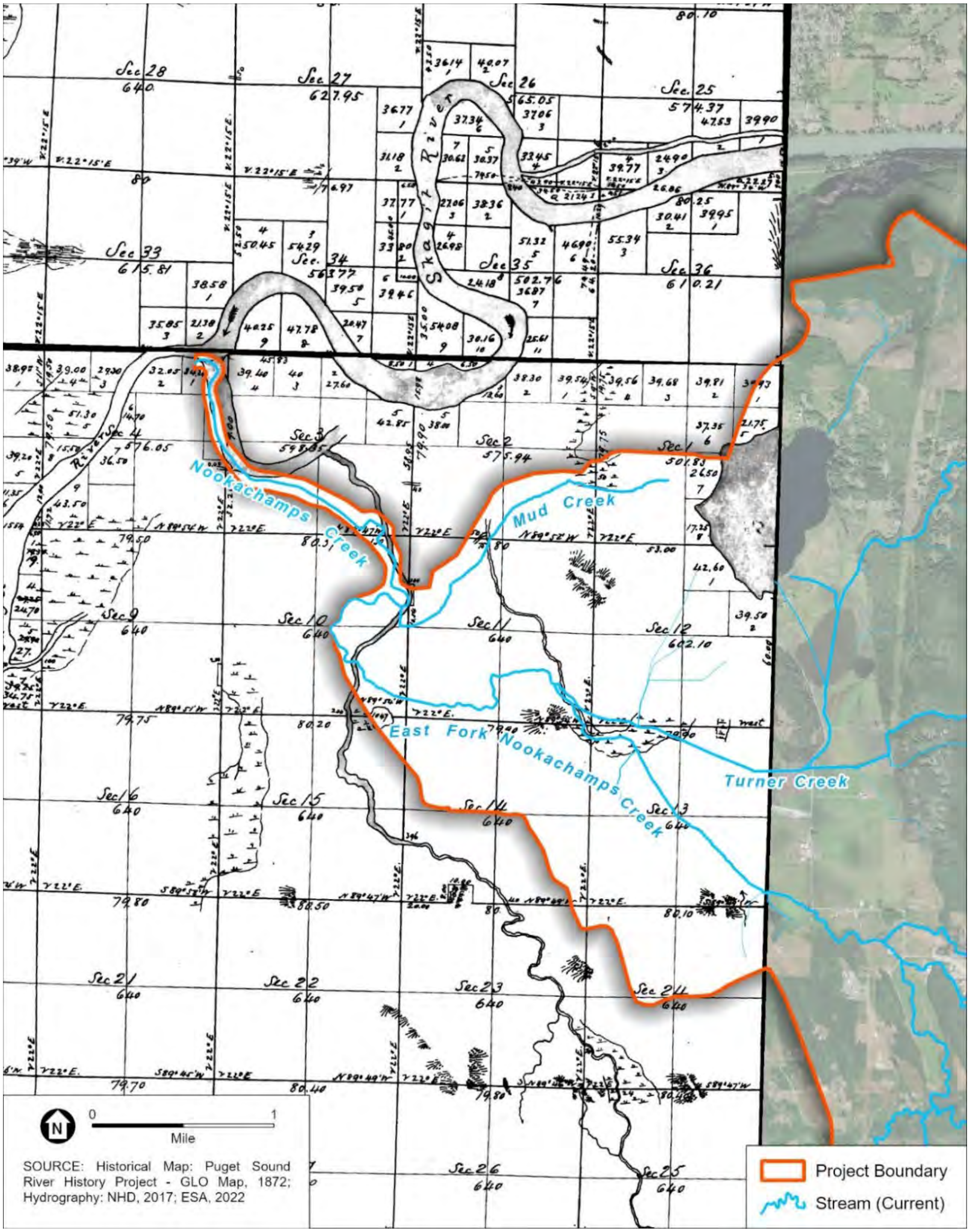


Figure 6.
Washington State General Land Office Map (1872) Showing Historic Position of Skagit River and Nookachamps Creek with Modern Channel Position Overlay

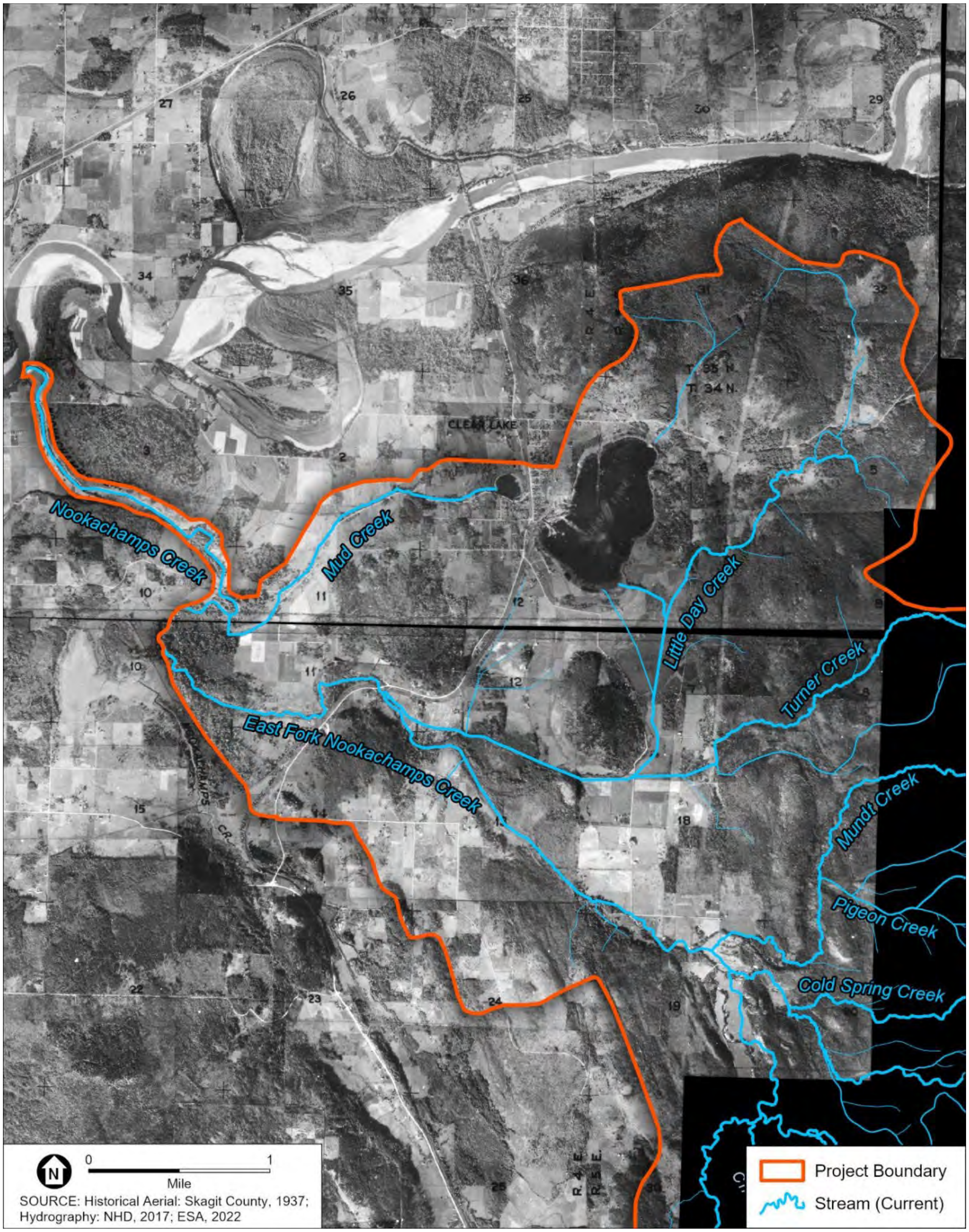


Figure 7.
1937 Aerial Photograph of Nookachamps Creek with Modern Channel Position Overlay

1969 aerial photos (**Figure 8**) show the levee running along the right bank of East Fork Nookachamps Creek, indicating it was built during the ~30 years between 1937 and 1969. The confluence of Turner Creek and East Fork Nookachamps Creek has moved downstream from its 1937 location, closer to its current position. Farther upstream, Turner Creek has not yet been routed to parallel Elk Drive. Conditions on the mainstem Nookachamps Creek and Mud Lake Creek are largely unchanged from today, except for an increase in riparian vegetation between 1969 and present day.

2.5.2 Existing Channel Network Modifications

The current channel network within the project area has been modified to accommodate human activities through levees, dredging, diking, drainage tiles, road crossings, and culverts.

Levees

Early farmers built the first dikes by hand to protect their farms. Organized efforts to build levees began in the 1890s, after a series of devastating Skagit River floods inundated Mount Vernon, Sedro-Woolley, and much of the Skagit River Valley. There is only one levee in the project area, running 1.8 miles along the right bank of East Fork Nookachamps Creek from approximately RM 3.5 downstream to the confluence of Turner Creek. This levee was constructed sometime after the 1937 aerial; there is no information on the exact year the levee was built. This levee protects agricultural fields north of the levee from floodwaters.

Downstream of Nookachamps Creek, levee improvements on the Skagit River have been associated with increased flood levels in Clear Lake and Nookachamps Valley. By increasing levee height and flood protection at the larger cities of Mount Vernon and Sedro-Woolley, backwatered upriver floodwaters would spill into unleveed areas, such as Clear Lake. In 1978, the USACE proposed the Skagit River Levee and Channel Improvements Flood Control Project, which would protect the downstream communities of Mount Vernon and Burlington from a 100-year flood. A USACE brochure stated that the project would increase water surface levels in the Clear Lake-Beaver Lake area by 0.9 to 1.4 feet (USACE 1979). Residents of Clear Lake and the Nookachamps Valley opposed this plan on the grounds that it would raise flood levels in the areas around Nookachamps Creek and Clear Lake. The plan was ultimately rejected by voters and never completed.

The Skagit County Dike, Drainage, and Irrigation District No. 12 maintains levees along the right bank of Skagit River, downstream of Nookachamps Creek. In 2013, they proposed expanding and raising their downstream levees by a maximum of 4 feet and predicted that the project would increase base flood elevations in the Nookachamps Creek basin by 0.1 foot. Although the Skagit Conservation District opposed this measure on the grounds that it would exacerbate flooding in Nookachamps Creek, the permit application was ultimately approved (Skagit County 2013).

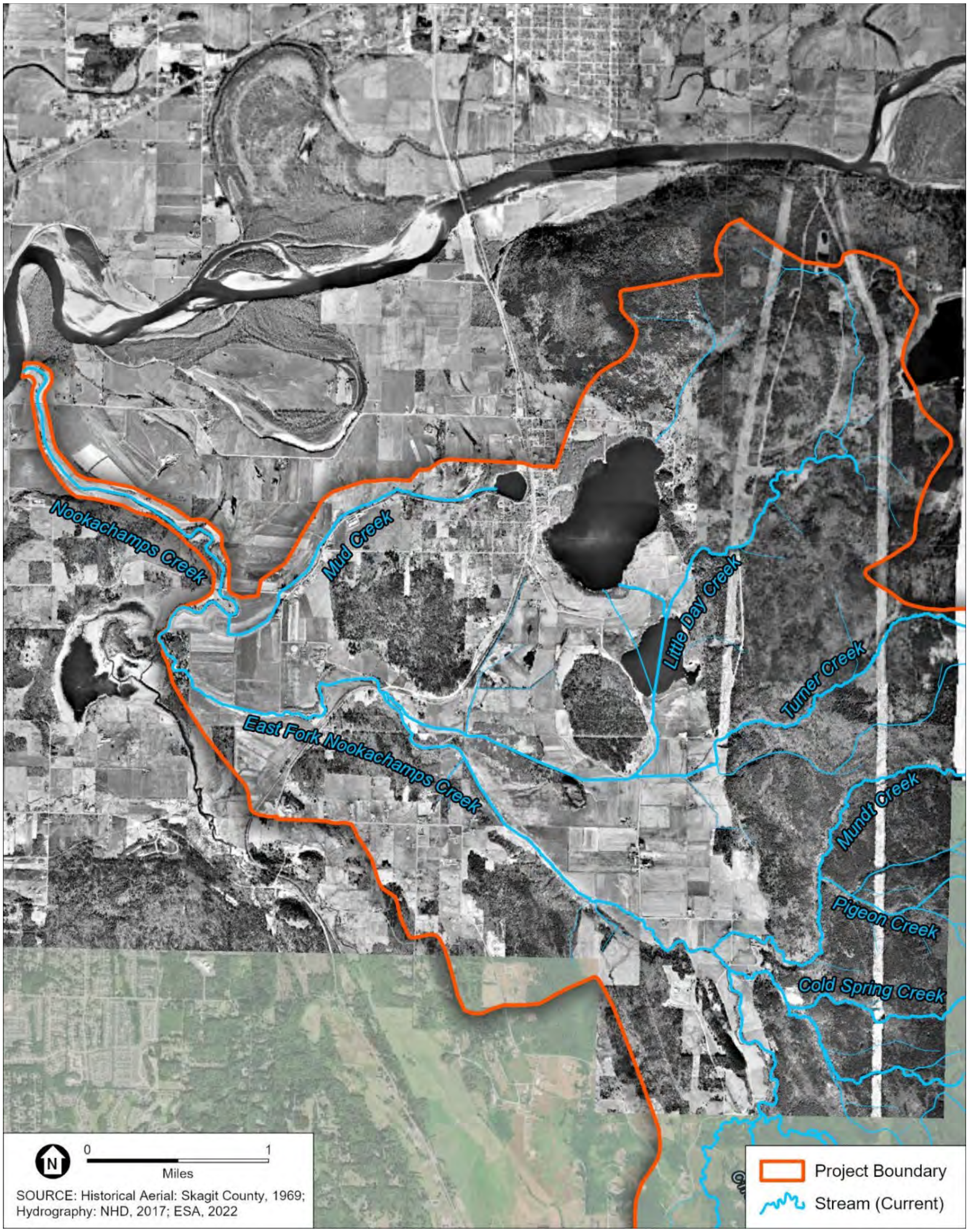


Figure 8.
1969 Aerial Photograph of Nookachamps Creek with Modern Channel Position Overlay

Drainage Districts

Two drainage districts include parts of the project area in their service area: Skagit County Drainage District (DD) 21 and DD 20. DD 21 serves the Beaver Lake area, including portions of the East Fork Nookachamps Creek east of Highway 9 and most of Turner Creek and maintains approximately 5 miles of ditches. In 2020, DD21 implemented multiple actions in Turner Creek and the East Fork Nookachamps Creek near the confluence of Turner Creek to improve drainage. In Turner Creek, DD21 dredged approximately 4 feet of sediment from three segments between Highway 9 and Beaver Lake Road. The segments included 1,800 feet of dredging upstream of RM 0.05, 500 feet of dredging at RM 0.85, and 1,600 feet of dredging between RM 1.1 and Beaver Lake Road. A short section of the downstream end of Little Day Creek (i.e., the portion downstream of Beaver Lake Road) was included in this work. As part of the dredging, DD21 installed six instream wood structures within Turner Creek to improve habitat for salmon and steelhead. This dredging realigned the confluence of Turner Creek and East Fork Nookachamps Creek 650 feet downstream of its previous location. As part of the Turner Creek work, DD21 also did a maintenance dredge of the sediment trap on Turner Creek at RM 1.8, just below Elk Drive to remove sediment approximately 4 feet deep in the trap. In a separate effort, DD21 also realigned the left bank of East Fork Nookachamps Creek just upstream of the Highway 9 crossing to improve drainage.

The DD20 service area includes a portion of Nookachamps Creek downstream of the East Fork Nookachamps Creek, but within the project area. No records of maintenance activities by DD20 in Nookachamps Creek were located in a search of permit applications to WDFW.

2.6 Hydrology

2.6.1 Surface Water

In 2014, the USACE prepared a Draft Feasibility Report and Environmental Impact Statement (EIS) for the Skagit River Flood Risk Management General Investigation (GI). It describes the Nookachamps Creek basin as flooding frequently and providing substantial natural flood storage. The study also states that water surface elevations (WSEs) at the debris-prone BNSF Bridge at RM 17.5 influence flood depths upstream in the Skagit River past the mouth of Nookachamps Creek. Because the Nookachamps Valley, including the project area, is one of the first unleveed areas on the mid-Skagit River, when downstream features such as the BNSF bridge and adjacent levees constrict floodwaters, they backwater and flow up Nookachamps Creek. Combined with flood flows from the creeks themselves, the East Fork Nookachamps Creek and its tributaries often overflow their banks and flood the low-lying areas of Nookachamps Valley and Clear Lake.

Typical Skagit River flooding, between a 2- and 5-year event, produces a WSE of 39.2 feet (North American Vertical Datum of 1988 [NAVD 88]) at the outlet of Nookachamps Creek. The November 2021 flooding was similar to a 20-year event and produced a WSE of 43.4 feet NAVD 88 (NSD 2022). **Figure 9** shows the Skagit River backwater extents up into the Nookachamps Valley for the flood scenarios described above, which were developed as part of a study funded by a Skagit County project at DeBay Slough and completed by Natural Systems Design (NSD 2022). The predicted backwater limits depicted in the figure are a simple elevation model and do not take into account the potential influence of drainage structures or levees within the Nookachamps Valley. A 2009 study conducted by the USACE estimates higher flood elevations from the Skagit River (USACE 2009) and lists the following flood stages on the Skagit River at Nookachamps Creek:

- 2-year flood elevation as 41.11 feet NAVD 88.
- 5-year flood elevation as 41.11 feet NAVD 88.
- 25-year flood elevation as 43.68 feet NAVD 88.

Climate change will likely cause changes in the hydrology and hydraulics of the Nookachamps Creek basin that may increase flood risks. The project area is far enough upstream on the Skagit River such that it will not be affected by projected sea level rise. The USACE GI study presents three sea level rise scenarios for the year 2070 at the mouth of the Skagit River: a low prediction of 0.37 feet, intermediate prediction of 0.79 feet, and a high prediction of 2.15 feet. With the highest projected sea level rise, the increase in water surface elevation would only carry up to RM 9.5 on the Skagit River (more than 9 miles downstream of the confluence with Nookachamps Creek). However, Nookachamps Creek is subject to backwater impacts from the Skagit River, which is predicted to experience peak flow increases resulting from climate change. The Skagit River Basin Climate Science Report (Lee and Hamlet 2011) studied the impacts of three different climate change scenarios on the Skagit River basin. The report predicted that by 2040, peak flood discharges will likely increase by an average of 23%, and by 2080 by an average of 40%. Larger peak floods along the Skagit River will increase backwater effects in the Nookachamps Creek basin.

Although no basin-specific climate change studies have been done on the Nookachamps Creek basin, similar increases in peak flood flows may be expected as seasonal climate patterns change, bringing wetter (more rain dominated and lower snowpack) winters and drier summers with extended periods of baseflow.

Stream Gages

There are three active gages and two historic gages in the East Fork Nookachamps Creek watershed. The Washington State Department of Ecology (Ecology) has operated gage 03G100 from 2000 to the present day. The gage is located just upstream of the Beaver Lake Road bridge, directly below the confluence of East Fork Nookachamps Creek and Cold Spring Creek. The gage measures flow, stage, water temperature, and air temperature at 15-minute increments. Previously, the U.S. Geological Survey (USGS) operated gage 12200000 at the same location, measuring mean daily discharge between 1943 and 1963. There is also an inactive USGS gage (12199800) on the upper reaches of East Fork Nookachamps Creek that recorded mean discharge between 1961 and 1972. **Figure 10** presents the locations of stream gages in the project area.

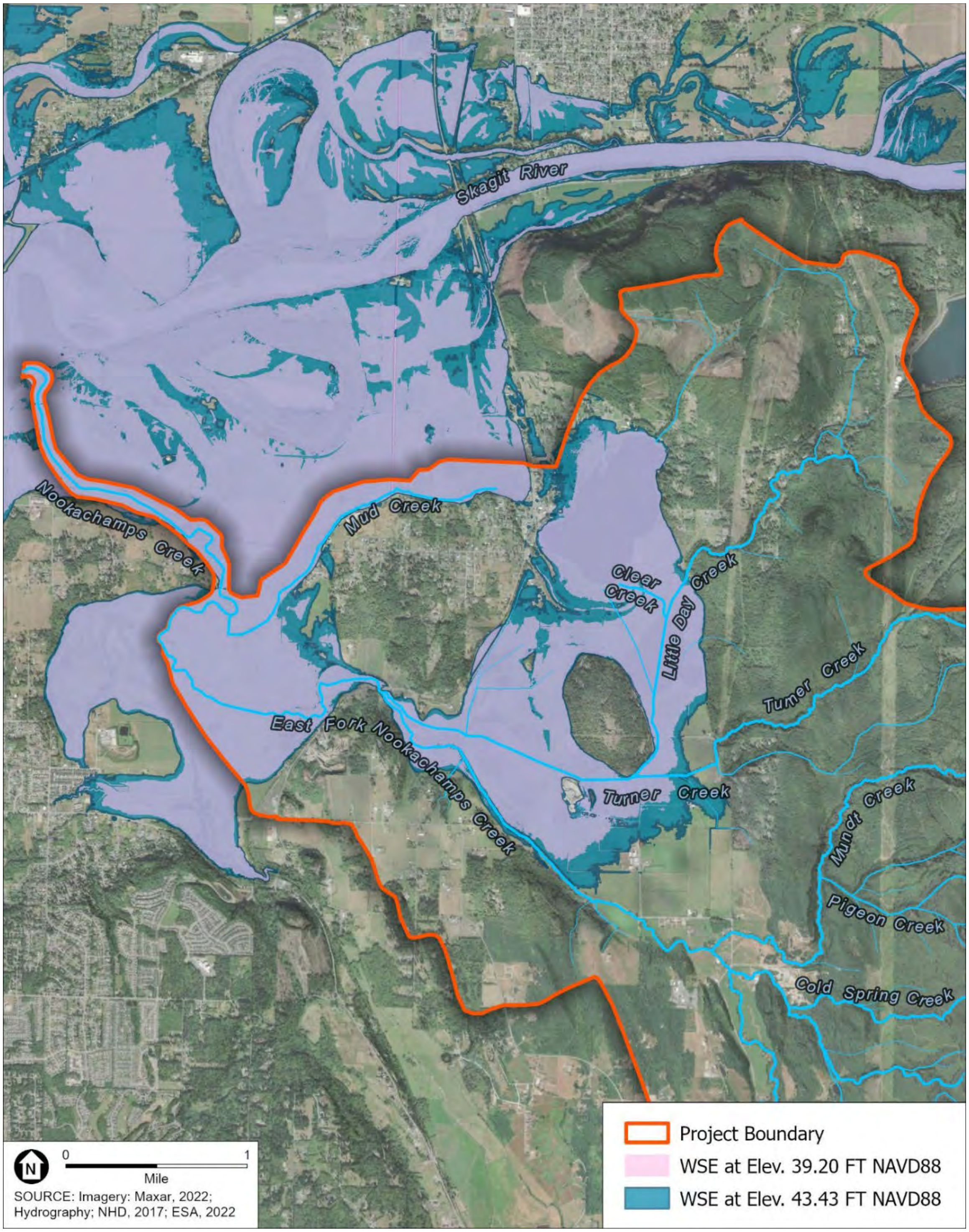


Figure 9.
Skagit River Backwater Potential for a "Typical" Flood Event in Pink (2- to 5-year flood) and a "Moderately High" (20-year flood) Flood Event in Blue

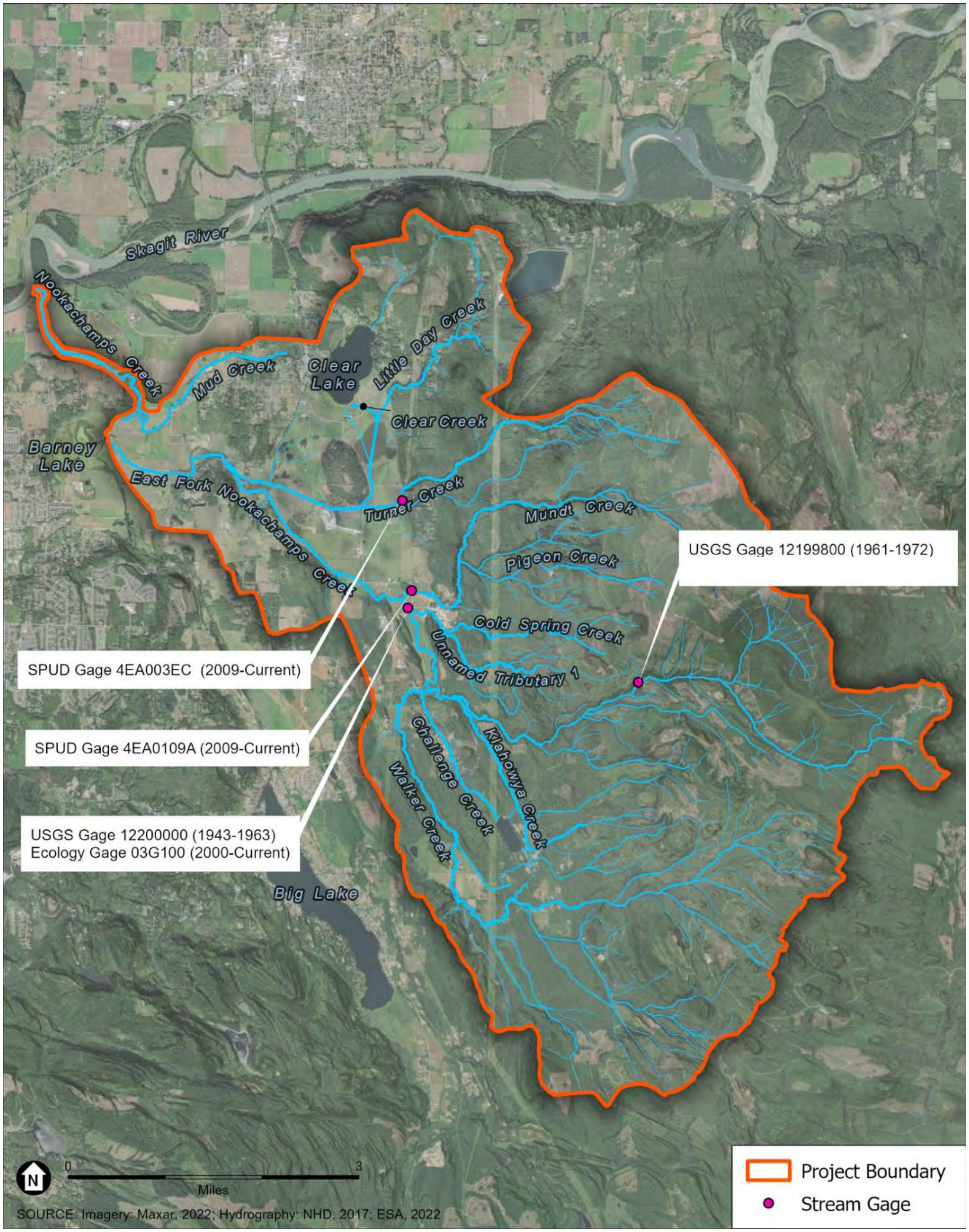


Figure 10.
Stream Gages in the East Fork Nookachamps Creek Watershed

Ecology has created rating curves and tables for Gage 03G100 for each year between 2000 and 2020. The rating curve compares the stage (measured from the channel bottom) associated with different discharges. At Gage 03G100, stage is increasing even as flows remain the same. The mean annual flow at the gage is 74.75 cubic feet per second (cfs) and the maximum daily mean discharge is 629.9 cfs. Between 2000 and 2020, the stage for 75 cfs increased by 1.19 feet (**Table 3**). This indicates that, at the location of the gage, the East Fork Nookachamps Creek stream bed is aggrading. At higher flows, the stage has remained consistent since 2005. Aggradation at this location appears to be increasing WSEs at average flows but not affecting WSEs during flood events.

TABLE 3. DISCHARGE VS. STAGE ON EAST FORK NOOKACHAMPS CREEK OVER TIME

Year	Stage (feet) at 75 cfs	Stage Change (feet) at 75 cfs Compared to Stage in 2000
2020	3.24	1.19
2015	3.05	1.00
2010	2.84	0.79
2005	2.10	0.05
2000	2.05	n/a

Skagit Public Utility District (PUD) operates two stream gages in the watershed: Gage 4EA003EC on Turner Creek and Gage 4EA0109A on Mundt Creek (see **Figure 10**). Both gages record discharge at 15-minute intervals, dating back to 2009. The gage on Turner Creek is located below the sediment trap at RM 1.8., while the gage on Mundt Creek is at the Beaver Lake Road crossing at approximately RM 0.1. Turner and Mundt Creeks are both sources of drinking water for the City of Mount Vernon. The primary purpose of these gages is to monitor flows below the drinking water diversion structures to ensure that instream flows are being met.

Sub-watershed Bankfull and Peak Flow Estimates

The USGS StreamStats tool (USGS 2019) was used to delineate watershed boundaries for the East Fork Nookachamps Creek and eight of its largest tributaries. Mean annual precipitation for each basin was generated from StreamStats using precipitation data for 1981 to 2010 pulled from the Parameter-elevation Regressions on Independent Slopes Model (PRISM). The area and precipitation values were entered into a USGS Flood Q Regression workbook. This workbook estimates flood discharge in Washington State at ungaged sites based on regional regression equations and user-determined basin characteristics. East Fork Nookachamps Creek is in Regression Region 3, which encompasses much of the Puget Sound region. **Table 4** shows the estimated discharges for each creek for selected reoccurrence intervals at the lowest portion of each creek. See **Appendix A** for estimated discharges for the full range of annual exceedance probabilities.

TABLE 4. ESTIMATED PEAK FLOWS BY SUB-WATERSHED FOR THE 1% AND 50% ANNUAL EXCEEDANCE PROBABILITY (AEP) FLOWS

Stream	Drainage Area (square miles)	50% AEP (2-year return period) peak flow (cfs)	1% AEP (100-year return period) peak flow (cfs)
Mud Lake Creek[a]	0.8	12	39
East Fork Nookachamps Creek Headwaters (excluding all sub-watersheds)	9.7	645	1,830
Turner Creek	8.6	244	776
Little Day Creek[a]	4.8	111	363
Mundt Creek	4.6	329	970
Cold Spring Creek	1.7	42	138
Unnamed Tributary 1[a]	0.6	16	53
Klahowya Creek	1.7	67	211
Walker Creek	10.4	407	1,260
Total East Fork Nookachamps Creek	**36.7**	**1,500[b]**	**4,570[b]**

NOTES:

a. Mud Lake Creek, Little Day Creek, and Unnamed Tributary 2 are excluded from the calculation of the total East Fork Nookachamps Drainage Area.

b. Peak flows for the total East Fork Nookachamps Creek are not cumulative.

2.6.2 Groundwater

No groundwater data were collected or analyzed prior to completion of this Watershed Assessment, but USIT has installed a series of monitoring wells in 2023 that will be used to characterize groundwater. Groundwater depths and durations are a crucial element driving drainage in the basin. A basin wide hydrogeologic study was completed for the Nookachamps Creek by the USGS in 2009 (Savoca et al. 2009). The study provides valuable information relative to the surficial and subsurface geology of the area, rates of hydraulic conductivity that drive groundwater movement in the basin, the various aquifers present in the area, and estimates of groundwater flow direction. Of particular note for this Watershed Assessment is the identification of much of the project area as a significant groundwater recharge zone. The area of the East Fork Nookachamps Creek and Turner Creek upstream of Highway 9 is among the highest identified recharge zones in the project area (**Figure 11**), indicating significant contributions of groundwater from precipitation, surface water, and upgradient groundwater resources. Persistent high groundwater and groundwater recharge zones makes drainage improvement in the project area a more difficult prospect, requiring a more holistic approach to river and land management that likely includes setting areas aside for conservation and restoration.

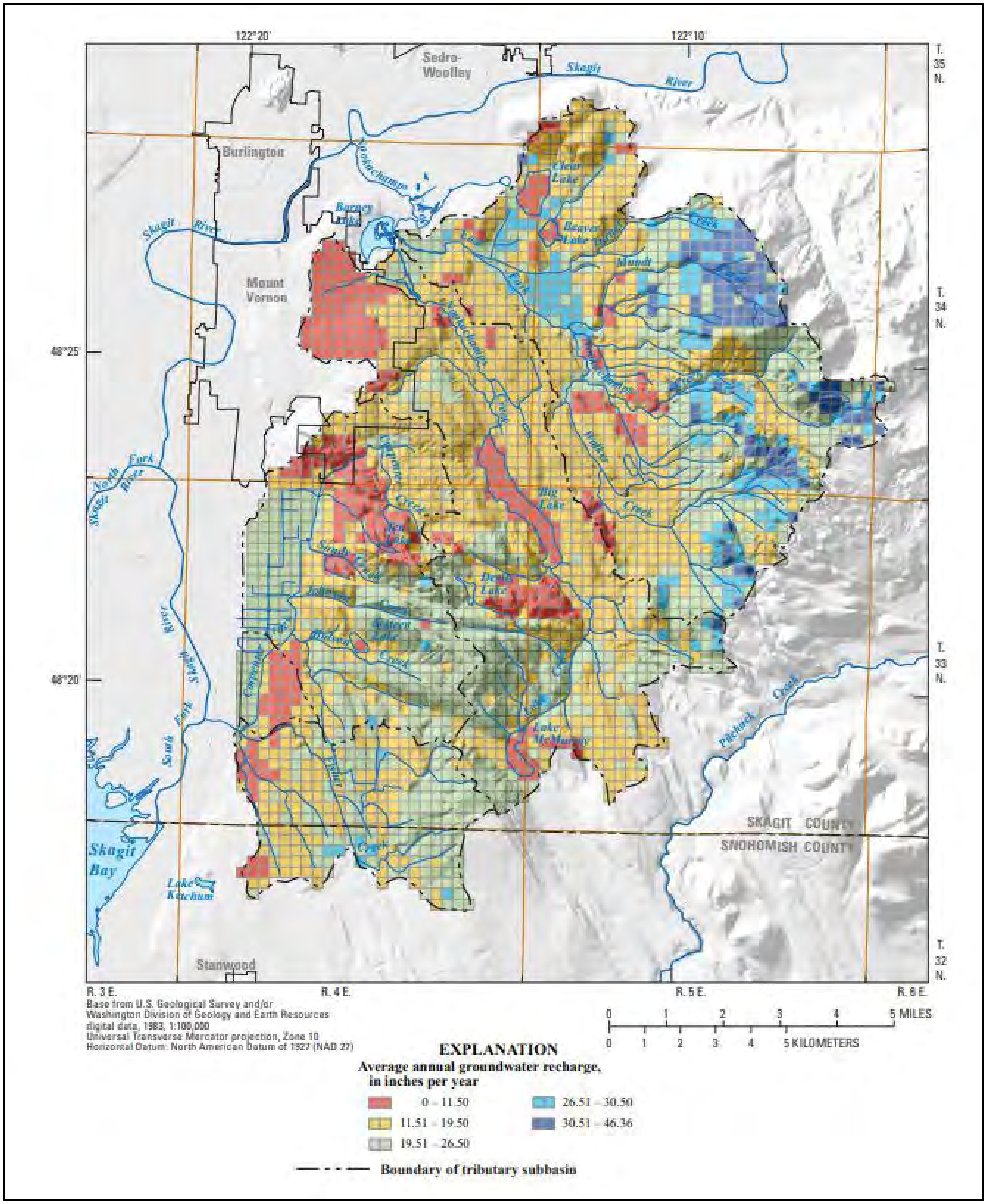


Figure 11.
Groundwater Recharge Rates (Source: Savoca et al. 2009)

3. SUB-WATERSHED DESCRIPTIONS AND REACH DELINEATION

East Fork Nookachamps Creek and each contributing tributary (see **Table 1**) were delineated into reaches to support the analysis of existing conditions and the identification of management recommendations. The reaches do not extend throughout the entire creek system; rather, the reaches encompass the portion of each creek that is accessible to anadromous salmonids. Each reach is identified to provide representative data for the broader tributary and sub-watershed; the reaches are a section of a stream where the geomorphic character (e.g., slope), habitat conditions, and salmonid distribution are similar based on a review of available data. The reaches were delineated through desktop analysis of stream slope, major infrastructure, historical fisheries surveys (e.g., WDFW 2016 steelhead spawner survey), riparian cover, and salmonid distributions in the project area.

A total of 28 reaches were delineated (**Table 5** and **Figure 12)**. A description of each sub-watershed in the project area and the reaches delineated is provided below.

TABLE 5. DELINEATED REACHES FOR THE FIELD DATA COLLECTION AND ANALYSIS

Stream	Reach	Drainage Area (square miles)	River Miles	Visited by Field Staff	Description
Nookachamps Creek	N1	69.0	0.0 – 1.6	Y	Relict Skagit River channel
	N2	68.0	1.6 – 2.8	Y	Relict channel to mouth of East Fork
Mud Lake Creek	Mud1	< 1.0	0.0 – 1.8+	Y	Outlet of Mud Lake
East Fork Nookachamps Creek	EF1	36.3	0.0 – 1.8	Y	Mouth to just downstream of Highway 9 bridge
	EF2	35.4	1.8 – 2.4	Y	Highway 9 bridge and confluence with Turner Creek
	EF3	25.8	2.4 – 3.5	Y	Leveed section
	EF4	25.4	3.5 – 5.0	N	Leveed section upstream to Walker Creek
	EF5	6.0	5.0+	Y	Above confluence with Walker Creek
Turner Creek	T1	8.2	0.0 – 1.0	Y	Dredged reach
	T2	7.8	1.0 - 1.9	Y	Beaver Lake Road to Elk Drive
	T3	2.4	1.9 – 2.5	Y	Elk Drive to BPA lines
	T4	1.3	2.5+	N	Above BPA lines
Little Day Creek	LD1	4.6	0.0 – 1.2	Y	Around Beaver Lake
	LD2	1.3	1.2+	Y	Above Beaver Lake
Mundt Creek	M1	4.6	0.0 – 0.9	Y	Mouth to passable falls
	M2	4.4	0.9+	Y	Upstream of falls
Cold Spring Creek	CS1	1.7	0.0 – 0.5	N	Below BPA lines
	CS2	0.6	0.5+	N	Above BPA lines

Stream	Reach	Drainage Area (square miles)	River Miles	Visited by Field Staff	Description
Unnamed Tributary 1	UNK1-1	0.6	0.0 – 1.0	N	Below private dam
	UNK1-2	0.3	1.0+	Y	Above private dam
Klahowya Creek	K1	1.7	0.0 – 0.8	Y	Below BPA lines
	K2	1.6	0.8 – 1.8	Y	Above BPA lines to Scout Camp
	K3	1.0	1.8+	N	Above Scout Camp
Lake Challenge Outlet	C1	0.7	0.0 – 2.0	N	Below Lake Challenge
Walker Creek	W1	9.8	0.0 – 0.5	Y	Centered around Taylor Road
	W2	9.2	0.5 – 2.0	N	Forested section
	W3	8.9	2.0 – 4.0	N	Upstream from W2 to BPA lines
	W4	5.9	4.0+	Y	Above BPA lines

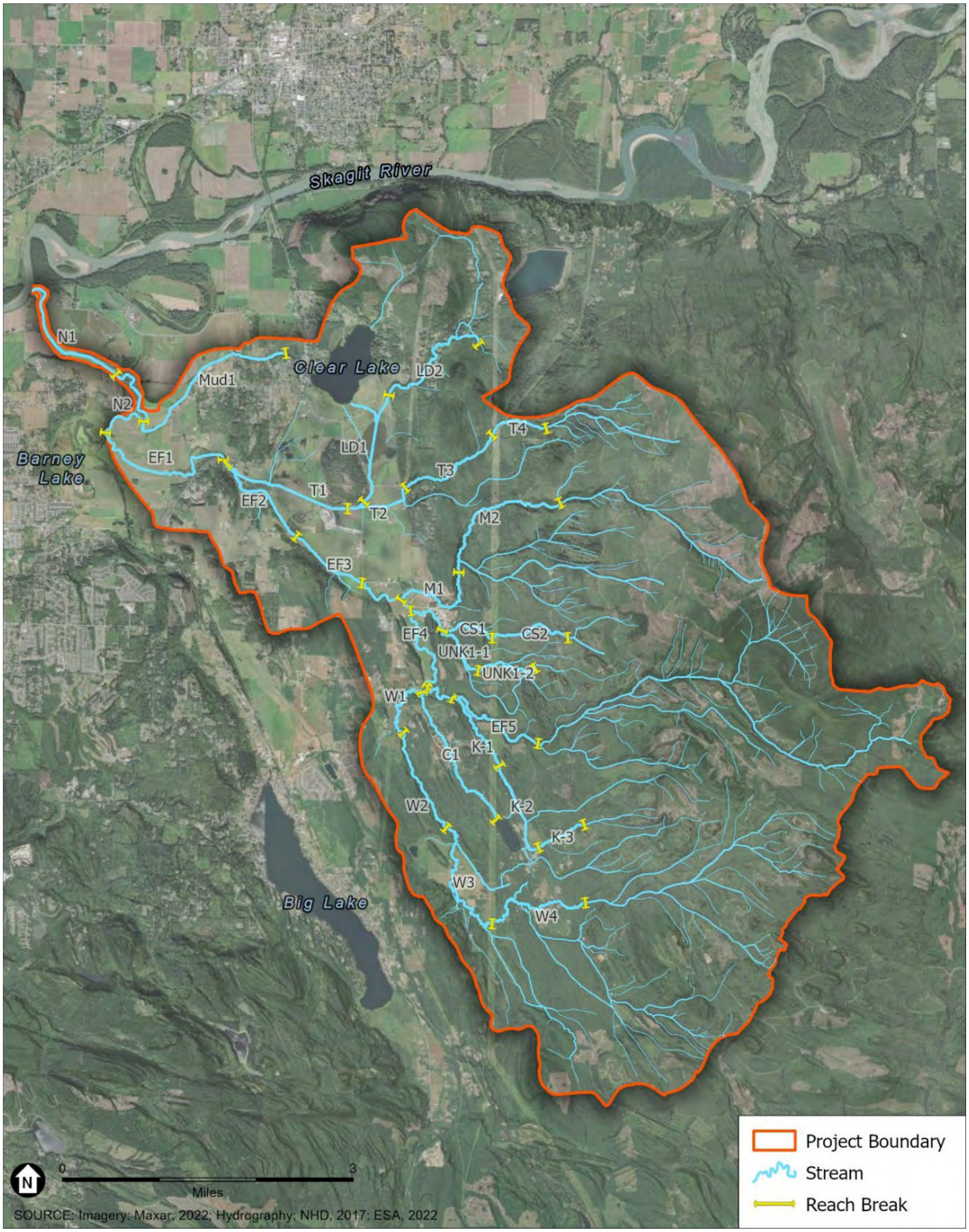


Figure 12.
Study Reaches within the Project Area

3.1.1 Nookachamps Creek

Nookachamps Creek is located on the lower Skagit River at RM 18.8, just upstream of the City of Mount Vernon. It drains approximately 69 square miles and is one of the largest tributaries on the Skagit River. The creek extends upstream more than 7 miles to its headwaters at Big Lake. The project area only encompasses the first 2.8 miles of Nookachamps Creek, below the confluence with East Fork Nookachamps Creek. This section of Nookachamps Creek is wide, deep, slow-moving, and has an extremely low gradient, less than 0.01%. Two major roads cross the lower Nookachamps Creek– the Francis Road bridge at RM 0.3 and the Swan Road bridge at RM 2.0. The creek is confined by its steep banks but overtops its banks during flood events, flooding both roads. The surrounding area is almost exclusively used for agricultural purposes, including corn, hazelnut, and dairy farms. There is little development other than the building associated with the farms.

Two reaches were delineated in Nookachamps Creek. The first reach, Reach N1, occupies a relict meander bend of the Skagit River, and extends from the confluence with the Skagit River upstream from RM 0.0 to 1.6. Because it is confined to the historic meander, Reach N1 displays less sinuosity than Reach N2. Reach N2 extends upstream from N1 to the confluence of the east and west forks of the creek (RM 1.6 to 2.8).

The portion of Nookachamps Creek included in this assessment is entirely within the floodplain of the Skagit River. During high flows in the Skagit River, this area is inundated well beyond the creek channel. The area has documented impairment for poor water quality, including high water temperatures and low dissolved oxygen (Ecology 2022). It is part of the Lower Skagit River Tributaries area identified as being impaired for high water temperatures, and an approved total maximum daily load (TMDL) plan is being implemented (Ecology 2020).

3.1.2 Mud Lake Creek

Mud Lake Creek is the primary outflow from Mud Lake and drains into the mainstem Nookachamps Creek at RM 2.2 during high flow events. The tributary ditch does not have a formal name but is referred to as Mud Lake Creek in this assessment. The creek runs upstream approximately 1.8 miles, paralleling Mud Lake Road, before its headwaters at Mud Lake and drains an area between 0.5 and 1 square mile. The creek functions more as a ditch, with a slope less than 0.01% and little observable flow. Agricultural land surrounds most of the lower portion of the creek; the upper portion of the creek near Mud Lakes forms the northwestern edge of the town of Clear Lake and has a higher density of residential structures. Other infrastructure includes the Swan Road culvert crossing at approximately RM 0.3. Several private crossings upstream of Swan Road provide access to adjacent fields from Mud Lake Road.

The creek was delineated as one single 1.8-mile-long reach (Mud1) from Nookachamps Creek upstream to Mud Lake. This was due to the lack of flow observed in the creek and its generally small size and drainage area. This reach displays very little sinuosity and has been artificially straightened for its entire length.

Mud Lake Creek is located within the floodplain of the Skagit River. During high flows in the Skagit River, this area is inundated well beyond one side (right bank) of the creek channel, while Mud Lake Road and land along the left bank are higher and less frequently inundated. The area has documented impairment for poor water quality and is part of the Lower Skagit River Tributaries area identified as being impaired for high water temperatures, and an approved TMDL plan is being implemented (Ecology 2020).

3.1.3 East Fork Nookachamps Creek

East Fork Nookachamps Creek flows approximately 11 miles from its headwaters on the south slope of Cultus Mountain to its confluence with Nookachamps Creek at RM 2.8. The creek drains 36 square miles of forested and agricultural land. The gradient of the creek varies from over 20% in the higher-elevation headwaters to less than 0.01% in its lowest reaches. Major road crossings include the Highway 9 bridge at RM 1.7 and the Beaver Lake Road culvert crossings at RM 4.2. Several other private driveway crossings span the creek. A private levee also runs along the right bank of the creek from RM 1.8 to

RM 4.2. Lower reaches of the creek are surrounded by agricultural fields, while much of the upper portion of the creek runs through forested timberland that has been periodically logged.

East Fork Nookachamps Creek was delineated into five reaches. East Fork Nookachamps Creek includes three reaches in the low gradient valley (EF1, EF2, and EF3); a transitional reach (EF4); and a higher gradient reach (EF5) into the mountains that form the headwaters of the creek. EF1 and EF2 both display low sinuosity and are artificially straightened. EF1 is distinct from EF2 in that it lies below the confluence with Turner Creek, while EF2 has a levee running along its right bank. EF3 is differentiated from EF1 and EF2 by its increase in sinuosity and more natural channel path. East Fork Nookachamps Creek is an important salmon creek due to the quality of its habitat and its strong production of salmon over the years; it provides habitat for salmon migrating to or from all other creeks in the sub-watershed.

Large portions of East Fork Nookachamps Creek are within the floodplain of the Skagit River, including upstream of the Highway 9 bridge. During high flows in the Skagit River, this area is inundated well beyond the creek channel. Given the additional water flowing from all contributing tributaries, flooding of the Skagit River creates a backwatering effect that expands the area and prolongs the duration of flooding along East Fork Nookachamps Creek. Two portions of the creek are part of the Lower Skagit River Tributaries area identified as being impaired for high water temperatures, and an approved TMDL plan is being implemented (Ecology 2020). This includes the entire reach (EF1) downstream of Highway 9 and a small portion between Cold Spring Creek and Mundt Creek where past monitoring documented water temperature impairment (Ecology 2020).

Land uses along East Fork Nookachamps Creek have altered the creek's natural connections with its floodplain and contributed to conditions that have required maintenance to manage sediment loads. Prior to the year 2000, truckloads of gravel were removed from the creek each year to retain channel conveyance capacity (i.e., how much water can flow in the channel before it hops its banks) (Janicki and Nilson, pers. comm.). Since the sediment management ended, the creek channel has risen several feet (Janicki and Nilson, pers. comm.). This has resulted in East Fork Nookachamps Creek being higher than Turner Creek near the confluence of the two creeks, which has negatively impacted the drainage of Turner Creek.

Farther upstream in the creek, WDFW and a private landowner have attempted to improve instream habitat for salmonids by placing large wood in the creek. The project did not perform as expected, which caused problems for the landowner; subsequent work to address the problems resulted in a dispute between the landowner and WDFW.

Farther upstream near Star View Road, the community has experienced erosion and drainage issues, which community members are working to identify how to address.

3.1.4 Turner Creek

Turner Creek is a 4.5-mile-long tributary that drains into East Fork Nookachamps Creek just upstream of the Highway 9 bridge. The Turner Creek watershed encompasses 8.2 square miles and includes portions of the town of Clear Lake east of Highway 9 and Clear Lake and Beaver Lake themselves. The northwestern portion of the basin near the town of Clear Lake contains the most development, with both residential dwellings and businesses. The lower watershed is primarily agricultural land, while the higher elevation eastern portion of the basin is forested. Major road crossings include the Beaver Lake Road culvert crossing at RM 1.1 and the Elk Drive culvert crossing at RM 1.4. The lower portion of the creek has a low gradient and lacks any sinuosity, having been artificially straightened and dredged. Above Elk Drive, the creek transitions into a higher gradient.

Turner Creek was delineated into four distinct reaches based on its current morphology. T1 extends from the confluence with East Fork Nookachamps Creek to the upstream end of a wide wetland near the gravel mine (RM 0.0 to 1.0). T2 continues upstream past Beaver Lake Road to the sediment trap next to Elk Drive (RM 1.0 to 1.9). T1 and T2 up to Beaver Lake Road were dredged in 2020 to alleviate flooding, install large woody debris, and plant trees in the riparian zone. T3 extends from the sediment trap upstream to a gradient break (RM 1.9 to 2.5). T4 extends above the gradient break at RM 2.5.

Large portions of Turner Creek are within the floodplain of the Skagit River. During high flows in the Skagit River, this area is inundated well beyond the creek channel. Given the additional water flowing from the contributing tributaries, flooding of the Skagit River creates a backwatering effect that expands the area and prolongs the duration of flooding along Turner Creek. A long portion of Turner Creek is part of the Lower Skagit River Tributaries area identified as being impaired for high water temperatures, and an approved TMDL plan is being implemented (Ecology 2020).

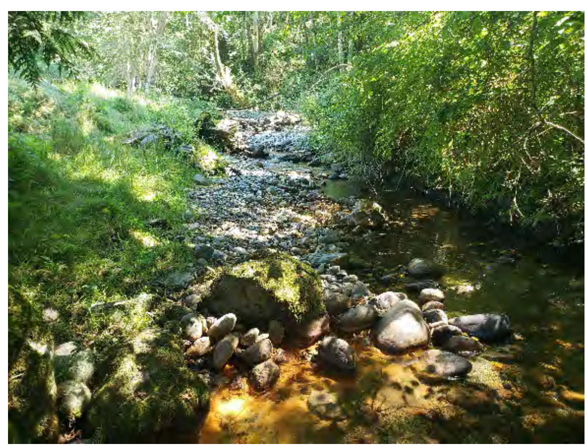
The valley portion of Turner Creek is a naturally wet area. Land uses along Turner Creek have led to channelizing the flow into a straight channel. The area has experienced increasing drainage problems associated with the rising levels of East Fork Nookachamps Creek. Flows from East Fork Nookachamps Creek flows drain into Turner Creek, which reduces the ability of Turner Creek to drain and in the summertime contributes to stagnant conditions (Janicki, pers. comm.). Efforts to improve drainage in Turner Creek include a sediment trap located along Elk Drive and dredging of the creek. In 2021, Drainage District 21 removed sediment from the sediment trap, dredged the creek downstream of Beaver Lake Road, and rerouted the outlet of the creek to enter East Fork Nookachamps Creek at a further downstream location. In 2022, DD21 dredged Turner Creek between Beaver Lake Road and the sediment trap.

3.1.5 Little Day Creek

Little Day Creek is a 3-mile-long tributary to Turner Creek with a drainage area of 4.55 square miles. Its confluence is just downstream of Beaver Lake Road near the gravel mine. Little Day Creek drains into and flows out of Beaver Lake. Clear Lake is connected to Beaver Lake by a channel under Fox Road. Little Day Creek was delineated into two reaches. Reach LD1 is extremely low gradient and extends from the confluence with Turner Creek up to Fox Road located upstream of Beaver Lake. The reach also includes the channel connecting Clear Lake to Beaver Lake. Reach LD2 extends from Fox Road upstream toward Old Day Creek Road and is distinctly higher gradient than Reach LD1.

Little Day Creek is warm and prone to stagnation during the summer. In winter, the area downstream of Fox Road is often inundated and far surpassing flows that can be conveyed through the culvert under Fonk Road. Given the warm water and connection to Clear Lake, the creek supports warmwater fish species that are predators of juvenile salmonids and can also move into Turner Creek if temperatures are satisfactory. Clear Lake is surrounded by multiple residences that have experienced increased flooding in recent years. This flooding was one motivation for the 2021 dredging in Turner Creek, and water levels are reportedly lower following that work (Janicki, pers. comm.).

3.1.6 Mundt Creek



Mundt Creek is a 4.7-mile-long tributary to East Fork Nookachamps Creek, which enters at RM 4.1. The Mundt Creek watershed is approximately 4.6 square miles and contains primarily forested timberland, with a few private residences surrounding the lower half-mile. Mundt Creek was delineated into two reaches. M1 extends from the confluence and continues upstream to RM 0.9, which is the upstream end of anadromous fish distribution (NWIFC and WDFW 2023) and a natural high gradient cascade (WDF 1975). M2 continues from RM 0.9 upstream past the overhead utility line right-of-way and into headwater forestland.

3.1.7 Cold Spring Creek and Unnamed Tributary 1

Cold Spring Creek joins East Fork Nookachamps Creek just above Beaver Lake Road at RM 4.3. Cold Spring Creek is approximately 2.5 miles long and drains 1.7 square miles. Most of the watershed is forested timberland, with a single residence and a quarry in the lower 0.2 mile of the creek. Unnamed Tributary 1 is a 1.7-mile-long tributary to Cold Spring Creek that drains 0.6 square mile and is identified by WDFW as Stream 3.0237. Unnamed Tributary 1 flows into Cold Spring Creek at RM 0.4. Like the Cold Spring Creek basin, the Unnamed Tributary 1 basin is mostly forested and has been periodically logged.

3.1.8 Klahowya Creek

Klahowya Creek is a 3.3-mile-long tributary to the East Fork Nookachamps Creek that has been given several different names in historical records. In WDFW 2016 surveys, it was labelled “Boy Scout Creek,” as the creek flows through Boy Scout owned property near Lake Challenge. The creek’s official designation in the Washington Stream Catalog is Stream 3.0248 (WDF 1975). Klahowya Creek joins East Fork Nookachamps Creek at RM 5.7 and drains 1.7 square miles. Much of the basin is rural timberland. The largest development within the watershed is the Fire Mountain Boy Scout Camp.

The creek was delineated into three reaches. K1 was from the confluence with East Fork Nookachamps Creek to the Bonneville Power Administration (BPA) power lines at RM 0.8. K2 extends from RM 0.8 to the Boy Scout Camp at RM 1.8. Reach K3 extends upstream from the Boy Scout Camp.

3.1.9 Lake Challenge Outlet

The outlet from Lake Challenge is a small drainage downstream from the lake. There was not an evident channel all the way up the approximately 1.9 miles to the lake despite hydrography maps indicating it does. There is a channel evident in the lower portions of the alignment to drain the approximately 0.7 square mile basin. The creek was delineated into one reach (C1).

3.1.10 Walker Creek

Walker Creek is a 7-mile-long tributary to East Fork Nookachamps Creek that drains approximately 9.8 square miles. Walker Creek joins East Fork Nookachamps Creek just above Star View Drive. The Walker Creek basin is situated in the southern portion of the East Fork Nookachamps Creek watershed and encompasses the Walker Valley Forest, a WDNR-managed working forest, as well as the Walker Valley Off-Road Vehicle (ORV) Area. Most of the surrounding land is forested, with small areas of agriculture and residential houses. Because the creek is higher in the watershed and outside of the Skagit River floodplain, it floods less frequently than other creeks in the project area.

Walker Creek is an important salmon creek due to the quality of its habitat, the long length of the creek, and its strong production of salmon over the years. Walker Creek has supported a large run of several species of salmon and steelhead. Walker Creek was separated into four reaches (W1–W4) that are fairly large due to the overall size of the tributary.

4. SALMONID LIFE HISTORIES AND DISTRIBUTION

East Fork Nookachamps Creek has documented presence of seven species of salmon and trout with sea-run life histories. These species include Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch)*, chum salmon (*O. keta*), pink salmon (*O. gorbuscha)*, steelhead (*O. mykiss)*, and coastal cutthroat trout (*O. clarkii)* (NWIFC and WDFW 2023). In addition, bull trout (*Salvelinus confluentus*) have been documented in Nookachamps Creek and West Fork Nookachamps Creek but are not documented or presumed to occur in East Fork Nookachamps Creek. Due to the risk of extinction, three species, Chinook salmon, steelhead, and bull trout are listed as threatened under the federal Endangered Species Act (ESA). Recovery efforts for these species and other anadromous salmonids are ongoing throughout the Skagit River watershed through restoration and protection of habitats.

Nookachamps Creek supports Chinook salmon in the Lower Skagit Fall Chinook population (SWC 2022). In addition, the portions of Nookachamps Creek that are within the Skagit River floodplain provide rearing habitat for all six populations of Chinook salmon in the Skagit River watershed. Nookachamps Creek includes Tier 1 and Tier 2 priority areas for the recovery of Chinook salmon populations in the Skagit (SWC 2022). Nookachamps Creek up to Barney Lake (N1, N2) and East Fork Nookachamps Creek (EF1) downstream of the Highway 9 bridge is a Tier 1 priority area due to its importance in the mainstem Skagit River floodplain, thus providing productive floodplain habitats for all Chinook salmon populations in the watershed. East Fork Nookachamps Creek (EF2–EF5) is a Tier 2 priority area as a major tributary providing productive floodplain habitats for Lower Skagit Fall Chinook salmon. Nookachamps Creek supports an independent population of steelhead (SWC 2016).

The life cycle and habitat requirements of each species differ, but important commonalities apply to all species. Following is a summary of the life cycle and habitat requirements of salmonids. Details on the life history, distribution, and available abundance data of each salmonid species in East Fork Nookachamps Creek are provided in **Appendix B**.

All of the species spend part of their life cycle in freshwater and the rest in the estuary or ocean. The species are anadromous, which means that they lay their eggs in freshwater, spend a portion of their early life cycle rearing in freshwater, then outmigrate to the ocean to grow, before returning as adults to start the cycle again. Almost all salmonid species do this cycle once and die after depositing eggs. The species *O. mykiss* and *O. clarkii* are outliers to the general life history cycle described above. For *O. mykiss* and *O. clarkii,* a portion of their population exhibits a "resident" life cycle that does not include outmigration to the estuary and ocean. Also, a portion of the *O. mykiss* and *O. clarkii* populations can spawn in multiple years (rather than dying after spawning).

The amount of time young salmonids (termed juveniles) spend in freshwater varies from a few days or weeks to months or even one or more years. Likewise, there is tremendous variability in the amount of time each species spends in estuaries or the ocean. A species like pink salmon exhibits a very consistent 2-year life cycle. Other species exhibit substantial variations in the number of years spent in freshwater and saltwater environments. Importantly, these variations occur in the same species such that different individuals are completing very different life cycles.

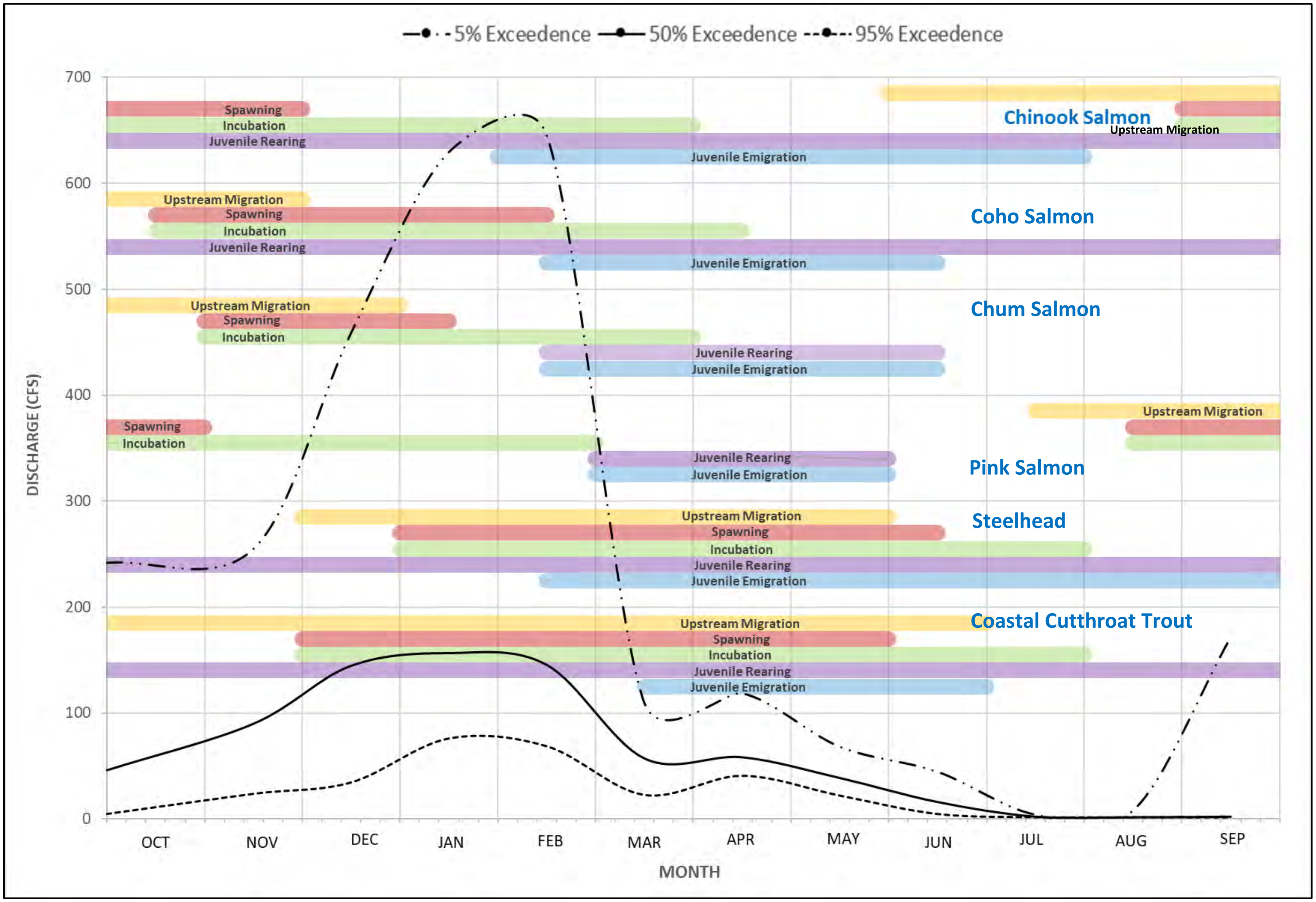
Due to the multiple species of salmonids and the variability of life cycles, salmon and trout are found in the East Fork Nookachamps Creek and the smaller creeks throughout all months of the year. Therefore, suitable habitat conditions need to be provided during all conditions, including during warm summer days and the powerful flows that more often occur during winter months.

The quantity and quality of freshwater habitats are vital factors for the survival of all salmonids. Growth in freshwater as juveniles can affect their likelihood of survival through the marine portion of their life cycle (Thompson and Beauchamp 2014). As noted above, the habitat requirements of adult and juvenile salmon vary between species, but all salmonid species have shared habitat needs. A salmon recovery planning document for a nearby watershed summarizes the habitat requirements termed the “5 Cs” (Sound Salmon Solutions 2017). Salmon need water that is:

- **Clean**: Pollution and other contaminants can harm salmon and other aquatic life.
- **Clear**: Water that is too turbid, or has too many suspended solids, is detrimental to salmon, particularly juveniles.
- **Cold**: Salmon are cold-blooded and need cold water to function properly; water that is too warm will kill them.
- **Connected**: Fish passage barriers, like culverts, dams, poorly made bridges, and other human infrastructure, can prevent salmon from reaching their spawning streams.
- **Complex**: Properly functioning riparian habitats have diverse native tree and shrub species; natural river meanders, side channels, wetlands, and oxbows; and contain rocks and log jams to provide instream habitat for salmon during all stages of their life cycle.

Figure 13 presents an overview of the salmonid life history and timing in the East Fork Nookachamps Creek. Life history information is overlaid on monthly flow statistics to relate salmonid life stages present to the creek flows encountered during the year.[1] Upstream migration and spawning by salmonids occur in fall and winter when the rainy season starts and creek flows are increasing. Egg incubation of all salmon and trout includes the mid-winter months when the highest flows tend to occur. In this way, the eggs of all salmon and trout are susceptible to being scoured away during high flows, and the risk can be exacerbated by watershed alterations affecting creek velocities (e.g., channel narrowing, bank armor, or water crossings) and flow delivery (e.g., cleared vegetation). Juvenile rearing for all species occurs during spring months as flows tend to be lower than mid-winter. Juvenile salmonids who rear throughout the year, including Chinook and coho salmon, steelhead, and cutthroat trout, remain in the creek during the summer months when flows are the lowest.

[1] The monthly flow statistics are based on data from Ecology gage 03G100 for the 2021 Water Year. The 50% exceedance is the median flow rate, meaning that over the period evaluated, half the flows were higher than this rate and half were lower. The 5% exceedance rate is the flow at which only 5% of flows during the period evaluated were higher than this rate (i.e., 95% were lower). The 95% exceedance rate is the flow at which 95% of flows during the period evaluated were higher than this rate (i.e., only 5% were lower).



Sources: WDFW (1975) and Washington State Conservation Commission (2003)

Figure 13.
Salmon Life History Timing Relative to Streamflow in the East Fork Nookachamps Creek

The distribution of the seven salmon and trout species in the East Fork Nookachamps Creek project area based on the Statewide Washington Integrated Fish Distribution (SWIFD) database (NWIFC and WDFW 2023) is shown in **Figure 14**. To understand how and when salmon use the different creeks and reaches of the project area, species life stage and distribution information was compiled. This compilation focused on Chinook, coho, chum salmon and steelhead. Data sources included:

- SWIFD (NWIFC and WDFW 2023).
- Habitat Limiting Factor Analysis of Anadromous and Resident Salmonid Distribution (Cutler 2001).
- Salmon and Steelhead Habitat Inventory and Assessment Project (NWIFC).
- WDFW and Upper Skagit Indian Tribe (USIT) Steelhead Spawning Survey (Fowler and Turnbull 2016).
- WDFW biologist field observations (Moran, pers. comm.).

These data sources provide information on documented/known occurrences by life stage as well as presumed presence. Spawning indicates that returning adults are in the reach, followed by incubating eggs, and at least some juvenile presence. Rearing indicates no known or presumed spawning, but the reach supports juvenile salmonids using the habitats for growth and survival. Rearing reaches also support migration by juveniles and, depending on location relative to spawning grounds, also support upstream migration of returning adult salmonids. The composite information on distribution by species and life stage is presented in **Table 6** and **Figure 15**.

The figures and tables show the broad distribution of salmon and trout throughout the East Fork Nookachamps Creek and their requirements for suitable conditions throughout every month of the year. The compiled information may underestimate distributions because salmonids will move into any accessible habitats to seek food and refuge from undesirable conditions (e.g., high temperatures or fast water).

All creeks that are accessible to salmonids are important. In addition, portions of watersheds that are inaccessible to salmonids that effect salmon habitat quantity and quality in accessible reaches downstream (e.g., through water temperatures and fine sediment amounts in the water flowing into downstream reaches). To characterize the relative importance of reaches in the project area, information on the presence of Chinook, coho, chum salmon and steelhead as well as the life stages documented as present was used to identify a “Salmon Use Category.” The Salmon Use Category assignments are based on the data in **Table 6** and the rules identified in **Table 7**. The Salmon Use Category assignments are presented in **Table 8**.

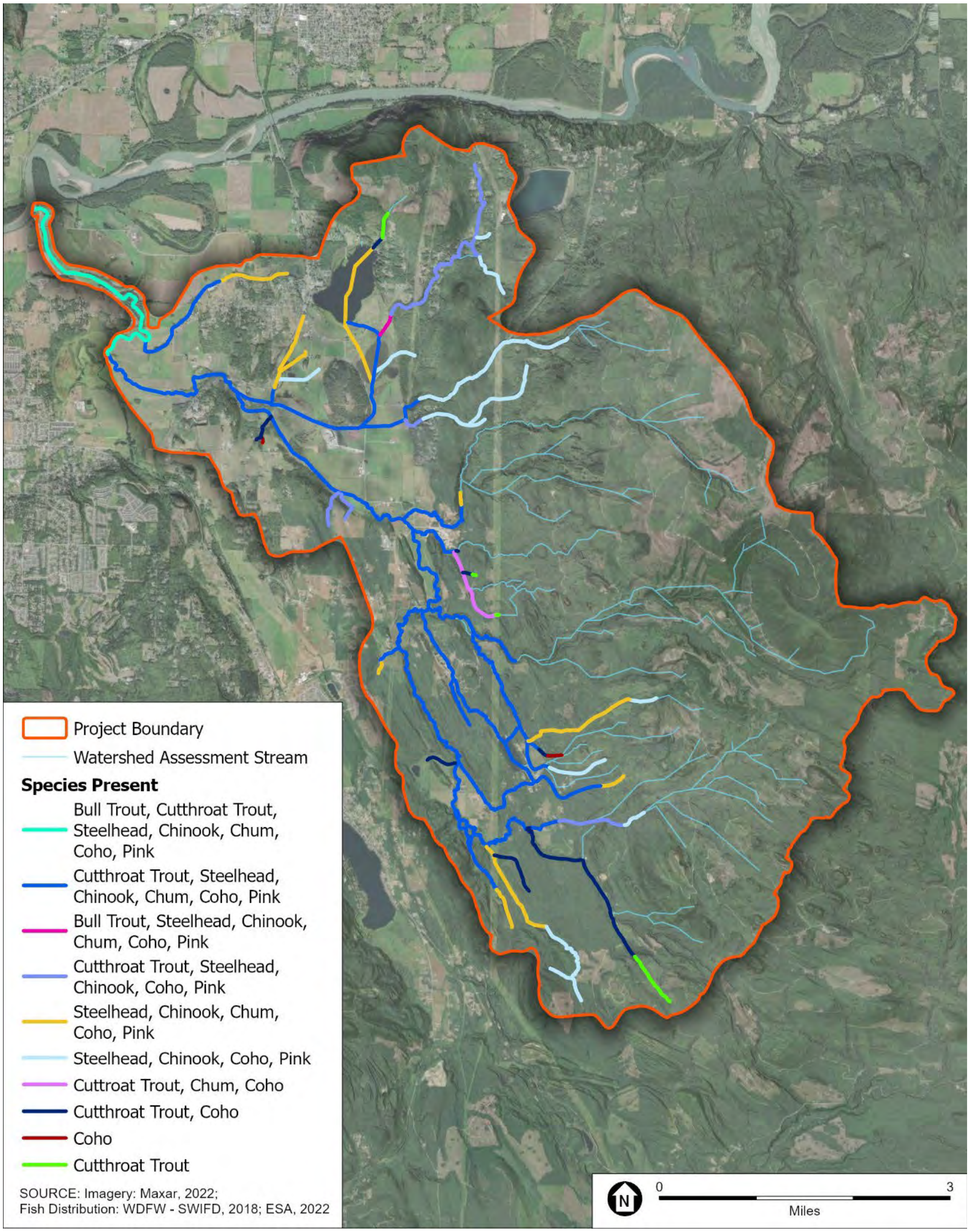


Figure 14.
Fish Distribution in the East Fork Nookachamps Creek Watershed

TABLE 6. CHINOOK, COHO, CHUM SALMON, AND STEELHEAD DISTRIBUTIONS BY LIFE STAGE

Stream	Reach	Chinook Salmon	Steelhead	Coho Salmon	Chum Salmon
Nookachamps Creek	N1	rearing - known	rearing - known	rearing - known	rearing - known
	N2	rearing - known	rearing - known	rearing - known	rearing - known
East Fork Nookachamps Creek	EF1	rearing - known	spawning & rearing - known	rearing - known	spawning & rearing - known
	EF2	spawning & rearing - known	spawning & rearing - known	spawning & rearing - known	spawning & rearing - known
	EF3	spawning & rearing - known	spawning & rearing - known	spawning & rearing - known	spawning & rearing - known
	EF4	spawning & rearing - known	spawning & rearing - known	spawning & rearing - known	spawning & rearing - known
	EF5	spawning & rearing - presumed	spawning & rearing - known	spawning & rearing - known	spawning & rearing - known
Mud Lake Creek	Mud1	rearing - presumed	rearing - presumed	rearing - known	rearing - presumed
Turner Creek	T1	rearing - presumed	rearing - known	rearing - known	spawning & rearing - known
	T2	rearing - presumed	spawning & rearing - known	spawning & rearing - known	spawning & rearing - known
	T3	rearing - presumed	spawning & rearing - presumed	spawning & rearing - known	spawning & rearing - known
	T4	rearing - presumed	rearing - presumed	rearing - presumed	no
Little Day Creek	LD1	rearing - presumed	rearing - presumed	spawning & rearing - known	rearing - presumed
	LD2	rearing - presumed	rearing - presumed	spawning & rearing - known	no
Mundt Creek	M1	rearing - known	spawning & rearing - known	spawning & rearing - known	spawning & rearing - known
	M2	no	no	no	no
Cold Spring Creek	CS1	rearing - presumed	spawning & rearing - known	spawning & rearing - known	rearing - presumed
	CS2	no	no	no	no
Unnamed Tributary 1	UNK1-1	no	no	rearing - known	rearing - presumed
	UNK1-2	no	no	rearing - known	rearing - presumed
Klahowya Creek	K1	rearing - presumed	rearing - known	spawning & rearing - known	rearing - presumed
	K2	rearing - presumed	rearing - known	rearing - known	rearing - presumed
	K3	rearing - presumed	rearing - presumed	rearing - known	rearing - presumed
Lake Challenge Outlet	C1	rearing - known	rearing - known	rearing - presumed	rearing - presumed
Walker Creek	W1	spawning & rearing - known	spawning & rearing - known	spawning & rearing - known	spawning & rearing - known
	W2	spawning & rearing - known	spawning & rearing - known	spawning & rearing - known	spawning & rearing - known
	W3	spawning & rearing - known	spawning & rearing - known	spawning & rearing - known	spawning & rearing - known
	W4	spawning & rearing - known	spawning & rearing - known	spawning & rearing - known	spawning & rearing - known

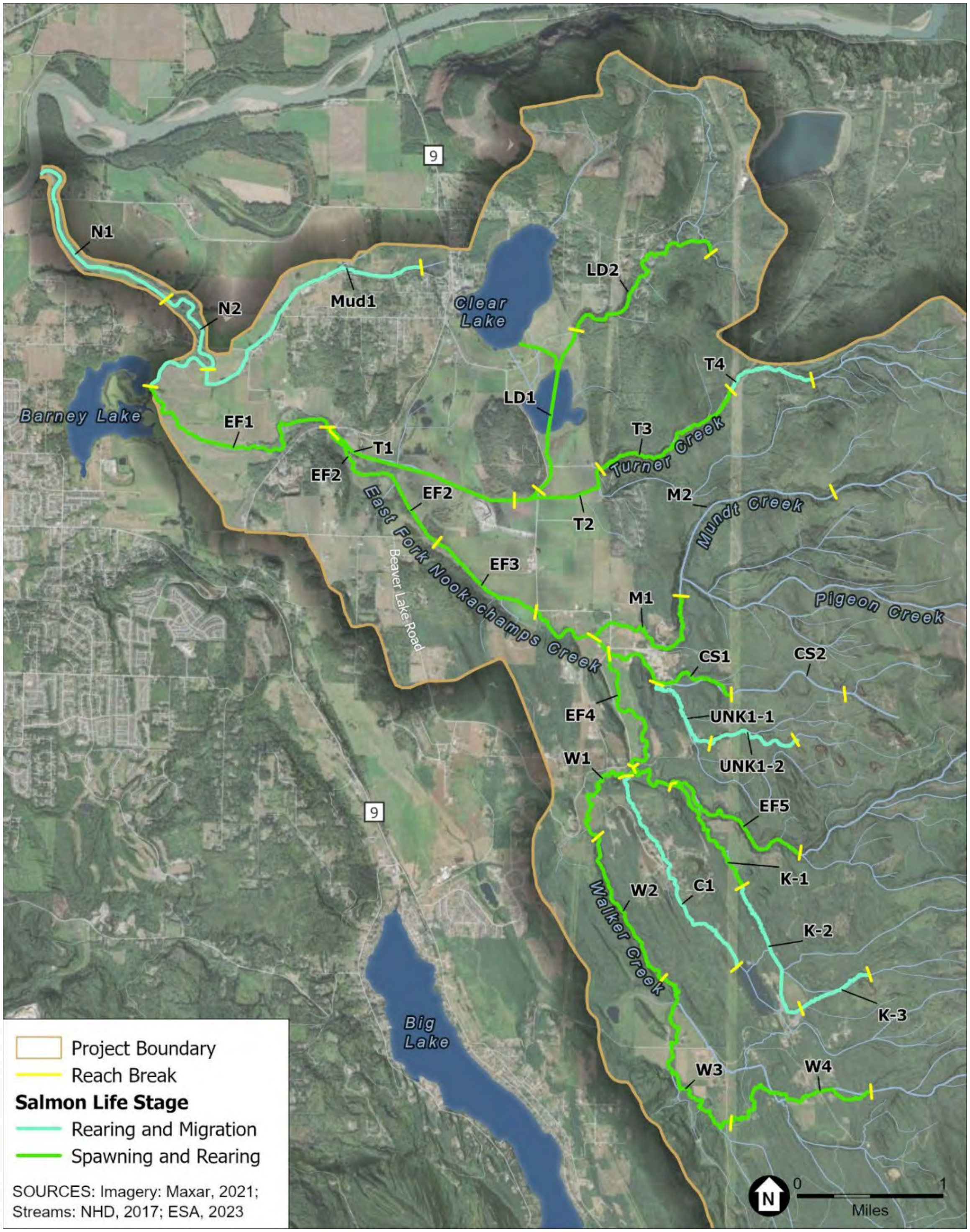


Figure 15.
Salmonid Life Stages Present in Each Reach

Table 7. Salmon Use Category Assignment Rules

Salmon Use Category	Rules Based on Individual Impairment Categories
High Use	Tier 1 or Tier 2 Priority Area in Skagit Chinook Recovery Plan (SWC 2022) or known spawning by at least three of the salmonid species evaluated.
Moderate Use	Known spawning by one or two of the salmonid species evaluated.
Low Use	No known spawning by the salmonid species evaluated, but known or presumed rearing.
None	No salmonid distribution.

Table 8. Salmon Use Categories By Reach

Stream	Reach	Salmon Use Category
Nookachamps Creek	N1	high use
	N2	high use
East Fork Nookachamps Creek	EF1	high use
	EF2	high use
	EF3	high use
	EF4	high use
	EF5	high use
Mud Lake Creek	Mud1	low use
Turner Creek	T1	moderate use
	T2	high use
	T3	moderate use
	T4	low use
Little Day Creek	LD1	moderate use
	LD2	moderate use
Mundt Creek	M1	high use
	M2	none
Cold Spring Creek	CS1	moderate use
	CS2	none
Unnamed Tributary 1	UNK1-1	low use
	UNK1-2	low use
Klahowya Creek	K1	moderate use
	K2	low use
	K3	low use
Lake Challenge Outlet	C1	low use
Walker Creek	W1	high use
	W2	high use
	W3	high use
	W4	high use

The reaches of highest use and dependence by salmonids are all reaches in Nookachamps Creek N1–N2), East Fork Nookachamps Creek (EF1–EF5), and Walker Creek (W1–W4). The downstream Mundt Creek reach (M1) that is accessible to salmonids and Turner Creek between Beaver Lake Road and just upstream of Elk Drive (T2) are also high use reaches. All high use reaches either support much of the salmonid spawning in the project area or are important migratory corridors for salmonids in the project area. The moderate salmonid use reaches are T1 and T3, which are upstream and downstream of the high-use T2 reach; both reaches of Little Day Creek (LD1, LD2) in Beaver Lake area; the downstream-most reach of Cold Spring Creek (CS1); and the downstream-most reach of Klahowya Creek (K1). The low salmonid use reaches are Mud Lake Creek; the upstream-most reach of Turner Creek (T4); both reaches of Unnamed Tributary 1 (UNK1-1, UNK1-2), the two upper reaches of Klahowya Creek (K2, K3), and the outlet creek from Lake Challenge (referred to as Lake Challenge Outlet; C1). While designated as low salmonid use relative to other reaches in the project area, these are still salmon streams providing important rearing habitat for one or more salmonid species.

5. EXISTING CONDITIONS

5.1 Habitat Limiting Factors

An analysis was conducted to understand and describe the existing conditions in the East Fork Nookachamps Creek project area that are contributing to the decline of adult salmon and steelhead returns as well as the flooding problems that the community is encountering. The existing conditions analysis focused on the salmonid habitat limiting factors in addition to a drainage limiting factors analysis.

As part of salmon recovery planning work in the Skagit River watershed, a habitat limiting factors analysis was prepared by the Washington State Conservation Commission (2003). As a watershed-wide report, the analysis was necessarily conducted at a relative broad spatial scale, and Nookachamps Creek was evaluated as part of a Lower Skagit River sub-watershed area. This analysis in this Watershed Assessment and Management Plan focuses entirely on the East Fork Nookachamps Creek project area.

5.1.1 Methods

The habitat limiting factors analysis was conducted using compiled information from available sources and supplemented by a limited field effort. To be used in the analysis, each data source needed to have information on the entire project area (i.e., East Fork Nookachamps Creek and the tributaries that flow into it). The habitat limiting factors analysis in Washington State Conservation Commission (2003) was a starting point upon which more recent and more spatially focused data sources were added. **Appendix B** includes an excerpt from Washington State Conservation Commission (2003), which provides an excellent overview of the importance of habitat for salmonids and the impacts of modifications on habitats.

Limited information was available to document habitat conditions in the East Fork Nookachamps Creek. To supplement available information, field data were collected. The project area was delineated into 28 reaches based on fish distribution and geomorphic conditions. A representative 200-foot-long section within each reach was surveyed to inform a geomorphic assessment and fish habitat assessment. As part of the characterization of each reach, an office-based assessment of bridge and culvert crossings and channel conveyance capacity was conducted. The methods and results of the field survey and crossing analysis are presented in **Appendix C**. The channel conveyance capacity analysis is presented in **Appendix D**. The methods and results of the fish habitat field survey are presented in **Appendix E**.

Habitat limiting factors identified in the analysis include those for which there is a clear link to salmonid habitat quality and sufficient data to support the analysis throughout the project area. The suite of habitat limiting factors evaluated is not exhaustive; rather, it is intended to inform an evaluation of locations within the watershed where more modifications affect salmon populations relative to other areas. In this way, the habitat limiting factors evaluated are intended to indicate the relative quality of habitats in the project area.

Habitat Limiting Factors Evaluated

The three habitat limiting factors evaluated were fish access, hydromodifications, and water quality (temperature and dissolved oxygen). Each habitat limiting factor is defined below, including its importance to salmonid habitat, and the data source for the evaluation identified.

Fish Access

The ability for salmonid species to access habitats that would naturally be accessible to them is fundamentally important for the survival and health of the populations. Manmade water crossings can restrict salmonid access if they are not properly sized and designed for the creek size, range of flow conditions throughout the year, and other key site factors such as creek slope. The swimming and jumping abilities of salmonids contribute to their ability to migrate upstream and downstream through river systems and especially past water crossings. The swimming and jumping abilities vary between species and life stages (e.g., adult salmonids can swim upstream in conditions that prevent juvenile salmonids from moving upstream).

This habitat limiting factor analysis focuses on the fish passage conditions provided by water crossings such as road culverts and bridges. WDFW (2019) includes a protocol for evaluating whether a water crossing creates a fish passage barrier. The protocol is based on the swimming abilities of an adult trout that is assumed to be 6-inches long. The protocol also characterizes the severity of the fish passage barrier into categories of 0% passable (total barrier), 33% passable (partial barrier, severely limiting), 67% passable (partial barrier), and 100% passable (not a barrier). While the protocol likely underestimates the passage conditions for juvenile salmonids that are <6 inches long, a strength of the protocol is that it provides a standardized approach that is used throughout Washington State.

Partial and total barriers impair conditions for salmonids by restricting their access to naturally available habitats. While clearly problematic in limiting the upstream migration of adult salmonids to spawning grounds, the impacts on juvenile salmonids can be equally problematic. As described above and summarized in **Figure 13**, juvenile salmonids of several species are present in the creeks throughout the year. These juvenile salmonids may naturally move upstream in creeks to access rearing habitat, and this may be especially important for overwinter rearing in areas upstream of the highest and fastest flows.

Fish access in the East Fork Nookachamps Creek was evaluated based on information on the location of fish passage barriers in WDFW's Fish Passage and Diversion Screening Inventory (WDFW 2023) and the length of anadromous salmon habitat upstream based on WDFW's SalmonScape Database. SalmonScape provides fish distribution data comparable to the SWIFD dataset (NWIFC and WDFW 2023) but includes stream length data to inform calculation of the length of upstream anadromous habitat.

Hydromodifications

Hydromodifications can include structures that harden the banks of creeks and rivers to prevent erosion and channel migration and also maintenance activities such as dredging to maintain modified channel planform over time. Hydromodifications negatively affect salmonids by impairing the habitats of the streambank and by preventing channel-forming processes that connect, form, and maintain floodplain (off-channel) habitats (SRSC and WDFW 2005). Hydromodifications in East Fork Nookachamps Creek interrupt the natural tendency of the channel to migrate freely across its native floodplain, thereby simplifying channel structure and habitat forming processes. The habitat impacts along the streambank can include reduced shallow edge habitat, disconnection of terrestrial-to-aquatic connections through a loss of riparian vegetation (e.g., shade, insect production, and small and large woody debris inputs) (SRSC and WDFW 2005). In this way, hydromodifications reduce the quality of edge habitats that are used by rearing and outmigrating juvenile salmon (Hartson and Shannahan 2015).

The impacts of hydromodifications on river processes greatly reduce the quantity and quality of floodplain habitats by limiting connectivity and altering the geomorphic processes that create complex off-channel features such as side channels and backwaters (SRSC and WDFW 2005). Access to floodplain habitats is critical for salmonids, especially given that the project area includes floodplains of the Skagit River as well as floodplains of the contributing creeks in the East Fork Nookachamps Creek watershed. The area is prone to frequent and prolonged flooding beyond the main channels; therefore, floodplain habitats are important refuge and rearing habitats for salmonids.

The distribution of hydromodifications in the East Fork Nookachamps Creek was evaluated based on an inventory of hydromodified bank structures in Chinook-bearing streams throughout the Skagit River watershed by the Upper Skagit Indian Tribe (Hartson and Shannahan 2015). The survey extent of Hartson and Shannahan (2015) in the East Fork Nookachamps Creek project area includes Nookachamps Creek, East Fork Nookachamps Creek, Walker Creek, and a portion of the lower reach of Mundt Creek. To supplement this inventory, field observations were noted for large hydromodifications such as a levee armoring a bank or dredging/ditching to expand channel size. The presence of hydromodifications, particularly those occurring over a relatively long portion of creek bank, is an indicator of impairment to floodplain habitat connectivity and formation. Hydromodifications in known locations of erosion act to work against habitat-forming changes that bank erosion can provide, such as side channel creation.

Water Quality

Good water quality is a fundamental element of productive creeks and rivers. This evaluation focused on two key parameters: water temperature and dissolved oxygen. High water temperatures can have lethal, sublethal, and behavioral effects on salmonids, which are cold water fish species. High water temperatures put stress on Chinook and reduce their survival and their growth rates, as well as create thermal barriers that salmonids avoid, thereby restricting access to potential habitat (SRSC and WDFW 2005). In the Skagit River tributaries, high water temperatures are generally caused by removal of riparian trees and reductions in streamflow (SRSC and WDFW 2005).

Adequate concentrations of dissolved oxygen in streams are critical for the survival of salmonids (Carter 2005). Reduced levels of dissolved oxygen can impact growth, development, and survival of different life stages of salmonids (Carter 2005).

Sources of water quality information focused on stream temperature and dissolved oxygen. Information on the 303(d)-category water quality impairment of the waterbody was compiled (Ecology 2022). Stream temperatures from the U.S. Forest Service's NorWeST database provides modeled estimates of mean August stream temperatures between 1993 and 2011 (Chandler et al. 2016). Field data collection in reaches included dissolved oxygen point measurements. This limited dataset was used to conservatively identify reaches where dissolved oxygen is considered likely to be impaired (i.e., below the Washington State standard for salmonid rearing and migration reaches [6.5 mg/L]) if sufficient data were available.

Habitat Limiting Factors Not Evaluated

A comprehensive habitat limiting factors analysis was beyond the scope of the current project. The evaluated habitat limiting factors are considered reasonable indicators of where in the project area stream habitat conditions are more or less suitable to support salmon spawning, rearing, and migration. Additional factors potentially affecting salmon and salmon habitat in the project area include instream habitat conditions (e.g., large woody debris quantities, pool frequency, and fine sediment amounts), floodplain refuge habitats, riparian vegetation, water quantity, additional water quality parameters (e.g., 6PPD-quinone, metals, and nutrients), warmwater fish predation, and coastal cutthroat hybridization with steelhead/rainbow trout. There are also multiple potential changes that may result through climate change, including lower summer low flows, higher winter peak flows, higher summer water temperatures, and altered timing of seasonal patterns (e.g., salmon eggs developing faster than historically due to higher water temperatures).

Impairment Categories of Habitat Limiting Factors

The condition of each habitat limiting factor was evaluated for each reach using the data sources identified above. Impairment categories of high, moderate, low, or none were assigned according to evaluation rules established to characterize the existing condition. The impairment categories were informed by conditions observed in the project area. **Table 9** identifies the impairment category rules for each habitat limiting factor.

TABLE 9. HABITAT LIMITING FACTORS IMPAIRMENT CATEGORIES

Habitat Limiting Factor	High Impairment	Moderate Impairment	Low Impairment	No Impairment	Data Confidence
Fish Access	More than 1 mile of upstream anadromous habitat blocked by barrier(s)	0.5 to 1 mile of upstream anadromous habitat blocked by barrier(s)	Less than 0.5 mile of upstream anadromous habitat blocked by barrier(s)	No barriers	High confidence in the WDFW fish passage barrier data.
Hydromodifications	>25% of stream length with a hydromodification or substantial additional hydromodification observed	10% – 25% of stream length with a hydromodification	0.1% – 10% of stream length with a hydromodification	No hydromodifications	High confidence in the locations with angular rock (e.g., riprap) in reaches surveyed by USIT (Hartson and Shannahan 2015). High confidence in the observation of large hydromodifications (e.g., long levee or dredged reaches. Low confidence in reaches not surveyed by USIT due to lack of complete survey).

Habitat Limiting Factor	High Impairment	Moderate Impairment	Low Impairment	No Impairment	Data Confidence
Water Quality	303(d) Category 4A or 5 for temperature or dissolved oxygen or NorWeST modeled temperatures >16ºC, or dissolved oxygen <6.5 mg/L in field data collection			Undetermined impairment for all other reaches based on limited data availability.	High confidence in the reaches with 303(d) listings. Moderate confidence in the NorWeST water temperature modeling estimates due to regional modeling being applied to differentiate among small scale reaches.

The impairment ratings of the five habitat limiting factors were combined to arrive at a composite impairment category for the reach**. Table 10** identifies the composite impairment category rules based on the impairment assignments for each habitat limiting factor.

TABLE 10. COMPOSITE HABITAT LIMITING FACTOR IMPAIRMENT CATEGORIES

Composite Impairment Category	Rules Based on Individual Impairment Categories
High	Two or more high impairment habitat limiting factors
Moderate	One high impairment habitat limiting factors
Low	One or more moderate low impairment habitat limiting factors
None	No impairment

5.1.2 Results

Habitat limiting factors were assigned an impairment rating for each limiting factor and then assigned a composite impairment category. In this analysis, high impairment indicates poor habitat conditions, moderate impairment indicates fair habitat conditions, low impairment indicates good habitat conditions, and no impairment indicates excellent habitat conditions.

Fish Access

The WDFW (2023) database identifies 14 partial or total barriers and two additional crossings that are considered barriers of unknown severity (**Table 11**). However, the WDFW database is known to be incomplete by not having a full inventory of private crossings. It is expected that there are additional fish passage barriers on private property that have not been evaluated.

All but one of the known barriers in the WDFW database are located on smaller tributaries or the uppermost extent of anadromy on a larger creek. The outlier is an unknown barrier on Turner Creek in reach T2 at Beaver Lake Road. There are four total barriers in the project area: two on the lower reach of Unnamed Tributary 1 (UNK1-1), one on the Lake Challenge Outlet (C1), and one on the upstream-most reach of Walker Creek (W4).

TABLE 11. FISH ACCESS IMPAIRMENT ANALYSIS

Stream	Reach	Number of Total Barriers	Number of Partial or Unknown Barriers	Upstream Length of Anadromous Habitat in Miles	Fish Passage Impairment Category
Nookachamps Creek	N1				none
	N2				none
East Fork Nookachamps Creek	EF1				none
	EF2				none
	EF3				none
	EF4				none
	EF5				none
Mud Lake Creek	Mud1				none
Turner Creek	T1				none
	T2		1	2.10	high
	T3				none
	T4				none
Little Day Creek	LD1				none
	LD2		2	1.01	high
Mundt Creek	M1				none
	M2				none
Cold Spring Creek	CS1		2	0.65 and 0.54	moderate
	CS2				none
Unnamed Tributary 1	UNK1-1	2		0.20 and 0.20	low
	UNK1-2				none
Klahowya Creek	K1		2	1.85 and 0.72	high
	K2				none
	K3				none
Lake Challenge Outlet	C1	1	3	1.10, 1.00, 0.90	high
Walker Creek	W1				none
	W2				none
	W3				none
	W4	1		0.51	moderate

Each of the documented barriers block access to between 0.2 mile and 2.1 miles of salmonid habitat based on stream length data in the WDFW SalmonScape database. Four creeks have barriers blocking more than 1 mile of habitat. These are Turner Creek (2.1 miles), Little Day Creek (1.01 miles), Klahowya Creek (1.85 miles), and the Lake Challenge Outlet (1.1 miles).

Hydromodifications

Hartson and Shannahan (2015) inventoried hydromodifications in 12 of the reaches evaluated in this project. These included all reaches of Nookachamps Creek, East Fork Nookachamps Creek, and Walker Creek, plus the downstream reach in Mundt Creek (M1). **Table 12** presents the hydromodifications impairment analysis.

TABLE 12. HYDROMODIFICATIONS IMPAIRMENT ANALYSIS

Creek	Reach	Percent Reach Length with Hydromodifications[a]	Additional Hydromodification Observations	Hydromodifications Impairment Category
Nookachamps Creek	N1	0%		none
	N2	2%		low
East Fork Nookachamps Creek	EF1	3%		low
	EF2	13%	earthen levee lining much of right bank	high
	EF3	9%	earthen levee lining much of right bank	high
	EF4	42%		high
	EF5	1%		low
Mud Lake Creek	Mud1	ns		none/data gap
Turner Creek	T1	ns	dredging throughout reach	high
	T2	ns	dredging throughout reach	high
	T3	ns		none/data gap
	T4	ns		none/data gap
Little Day Creek	LD1	ns	ditched throughout reach	high
	LD2	ns	ditched in lower portion up to road	high
Mundt Creek	M1	20%		moderate
	M2	ns		none/data gap
Cold Spring Creek	CS1	ns		none/data gap
	CS2	ns		none/data gap
Unnamed Tributary 1	UNK1-1	ns		none/data gap
	UNK1-2	ns		none/data gap
Klahowya Creek	K1	ns		none/data gap
	K2	ns		none/data gap
	K3	ns		none/data gap
Lake Challenge Outlet	C1	ns		none/data gap
Walker Creek	W1	13%		moderate
	W2	0%		none/data gap
	W3	13%		moderate
	W4	2%		low

NOTES:
a. Hydromodification data from Hartson and Shannahan (2015)
ns Indicates not surveyed

Hartson and Shannahan (2015) documented hydromodifications such as riprap and bridge abutments in 10 of the 12 surveyed reaches inventoried, as the lower reach of Nookachamps (N1) and a Walker Creek reach (W2) did not have hydromodifications. The longest extent of hydromodifications was documented in reach EF4 as more than 4,000 feet of hydromodifications or roughly 42% of the reach length were observed. The second highest amount of hydromodifications occurred in the downstream portion of Mundt Creek (M1), with more than 1,000 feet and 20% of the reach length with hydromodifications. Three reaches, EF2 (i.e., from the Highway 9 crossing to the private crossing at the big bend on Beaver Lake Road), W1 (i.e., the lowermost reach on Walker Creek), and W3, all had 13% of their stream length with modifications. Reach EF3 (i.e., downstream of Beaver Lake Road to along the DD21 levee) had hydromodifications documented along 9% of the stream length. The remaining reaches (N2, EF1, EF5, and W4) had 3% or less of their stream length with modifications.

During the field data collection portion of this project, additional major modifications to the stream channel and its connection to the floodplain were observed. These included the earthen levee along reaches EF2 and EF3, the channel widening and deepening in reaches T1 and T2, and the ditching and channelization of reaches LD1 and LD2 upstream and downstream of Beaver Lake.

Water Quality

Several of the largest creeks in the project area have impaired water temperatures (too high) or dissolved oxygen (too low) (**Table 13**). The impaired reaches include both Nookachamps Creek reaches (N1, N2); four East Fork Nookachamps Creek reaches (EF1–EF4) downstream of Walker Creek; Mud Lake Creek (Mud1); all four Turner Creek reaches (T1–T4); both reaches of Little Day Creek (LD1, LD2); and the Lake Challenge Outlet. Most of these reaches were in the Lower Skagit River Tributaries temperature TMDL implementation area and therefore designated by Ecology as impairment category 4A (Ecology 2008). Both Nookachamps Creek reaches (N1, N2) and the East Fork Nookachamps Creek reach (EF1) downstream of Highway 9 are listed as impaired (Category 5) for low dissolved oxygen (Ecology 2022). Several additional reaches were identified as being highly impaired based on modeled water temperatures between 1993–2011 exceeding 16ºC.

TABLE 13. WATER QUALITY IMPAIRMENT ANALYSIS

Creek	Reach	Water Quality Assessment Impairment for Water Temperature[a]	Water Quality Assessment Impairment for Dissolved Oxygen	1993 – 2011 Modeled Water Temperature[b]	Dissolved Oxygen (mg/L) in July 2022 Point Sampling	Water Quality Impairment Category
Nookachamps Creek	N1	4a	5	16ºC-18ºC		Impaired
	N2	4a	5	16ºC-18ºC		Impaired
East Fork Nookachamps Creek	EF1	4a	5	16ºC-18ºC	6.0	Impaired
	EF2			16ºC-18ºC	8.1	Impaired
	EF3			16ºC-18ºC	9.1	Impaired
	EF4	4a	2	14ºC-16ºC	10.5	Impaired
	EF5			14ºC-16ºC	9.6	Undetermined
Mud Lake Creek	Mud1	4a		14ºC-16ºC	1.1	Impaired
Turner Creek	T1			16ºC-18ºC	4.4	Impaired
	T2	4a		14ºC-16ºC	8.7	Impaired
	T3	4a		14ºC-16ºC	8.9	Impaired
	T4	4a		12ºC-14ºC	9.7	Impaired
Little Day Creek	LD1			18ºC-20ºC	1.4	Impaired
	LD2			16ºC-18ºC	9.5	Impaired
Mundt Creek	M1			14ºC-16ºC	9.8	Undetermined
	M2			14ºC-16ºC	8.9	Undetermined
Cold Spring Creek	CS1	2		14ºC-16ºC		Undetermined
	CS2			14ºC-16ºC		Undetermined

Creek	Reach	Water Quality Assessment Impairment for Water Temperature[a]	Water Quality Assessment Impairment for Dissolved Oxygen	1993 – 2011 Modeled Water Temperature[b]	Dissolved Oxygen (mg/L) in July 2022 Point Sampling	Water Quality Impairment Category
Unnamed Tributary 1	UNK1-1			14ºC-16ºC		Undetermined
	UNK1-2			14ºC-16ºC		Undetermined
Klahowya Creek	K1			14ºC-16ºC	9.7	Undetermined
	K2			14ºC-16ºC	9.8	Undetermined
	K3			12ºC-14ºC		Undetermined
Lake Challenge Outlet	C1			16ºC-18ºC		Impaired
Walker Creek	W1			14ºC-16ºC		Undetermined
	W2			14ºC-16ºC		Undetermined
	W3			14ºC-16ºC		Undetermined
	W4			14ºC-16ºC		Undetermined

NOTES:

a. Data from Ecology (2022) 2018 Water Quality Assessment.
Category definitions:
Category 5 = polluted water that requires a water improvement project.
Category 4a = already has a U.S. Environmental Protection Agency-approved Total Maximum Daily Load (TMDL) plan in place and implemented.
Category 4b = has a pollution control program, similar to a TMDL plan, that is expected to solve the pollution problems.
Category 4c = is impaired by causes that cannot be addressed through a TMDL plan.
Category 3 = insufficient data.
Category 2 = water of concern.
Category 1 = meets tested standards for clean water.

b. Data from U.S. Forest Service NorWeST modeling (Chandler et al. 2016)

The remaining reaches in the project area are considered undetermined for water quality impairment. This reflects there being insufficient data to adequately assess water quality conditions relative to Washington State standards.

Composite Habitat Limiting Factors Impairment

Based on the findings of the three habitat limiting factors evaluated, eight reaches were identified as being highly impaired for salmon habitat conditions (**Table 14**). The high impairment reaches include three East Fork Nookachamps Creek reaches (EF2–EF4) between the Highway 9 bridge and downstream of Walker Creek; two Turner Creek reaches (T1, T2) downstream of Elk Drive; both reaches of Little Day Creek (LD1, LD2); and the Lake Challenge Outlet (C1).

Seven reaches had a moderate composite habitat impairment rating. These reaches included both reaches in Nookachamps Creek (N1, N2); the lowermost reach of East Fork Nookachamps Creek (EF1); Mud Lake Creek (Mud1); two Turner Creek reaches (T3, T4) upstream of Elk Drive; and the lowermost reach of Klahowya Creek (K1).

Seven reaches had low impairment, including East Fork Nookachamps Creek (EF5) upstream of the confluence with Walker Creek; the lowermost reaches of Mundt Creek (M1); the lowermost reach of Cold Spring Creek (CS1); and the Unnamed Tributary (UNK1-1) to Cold Spring Creek; and three Walker Creek reaches (W1, W3, W4).

Six reaches were found to have no impairment. These reaches included the upstream reaches of Mundt Creek (M2); Cold Spring Creek (CS2); the Unnamed Tributary (UNK1-2) to Cold Spring Creek; the two upper reaches of Klahowya Creek (K2, K3); and Walker Creek reach W2.

TABLE 14. HABITAT LIMITING FACTORS RESULTS BY REACH

Creek	Reach	Fish Access	Hydromodifications	Water Quality	Composite Impairment
Nookachamps Creek	N1	No impairment	No impairment	Impaired	Moderate impairment
	N2	No impairment	Low impairment	Impaired	Moderate impairment
East Fork Nookachamps Creek	EF1	No impairment	Low impairment	Impaired	Moderate impairment
	EF2	No impairment	High impairment	Impaired	High impairment
	EF3	No impairment	High impairment	Impaired	High impairment
	EF4	No impairment	High impairment	Impaired	High impairment
	EF5	No impairment	Low impairment	Undetermined	Low impairment
Mud Lake Creek	Mud1	No impairment	No impairment	Impaired	Moderate impairment
Turner Creek	T1	No impairment	High impairment	Impaired	High impairment
	T2	High impairment	High impairment	Impaired	High impairment
	T3	No impairment	No impairment	Impaired	Moderate impairment
	T4	No impairment	No impairment	Impaired	Moderate impairment
Little Day Creek	LD1	No impairment	High impairment	Impaired	High impairment
	LD2	High impairment	High impairment	Impaired	High impairment
Mundt Creek	M1	No impairment	Moderate impairment	Undetermined	Low impairment
	M2	No impairment	No impairment	Undetermined	No impairment
Cold Spring Creek	CS1	Moderate impairment	No impairment	Undetermined	Low impairment
	CS2	No impairment	No impairment	Undetermined	No impairment
Unnamed Tributary 1	UNK 1-1	Low impairment	No impairment	Undetermined	Low impairment
	UNK 1-2	No impairment	No impairment	Undetermined	No impairment
Klahowya Creek	K1	High impairment	No impairment	Undetermined	Moderate impairment
	K2	No impairment	No impairment	Undetermined	No impairment
	K3	No impairment	No impairment	Undetermined	No impairment
Lake Challenge Outlet	C1	High impairment	No impairment	Impaired	High impairment
Walker Creek	W1	No impairment	Moderate impairment	Undetermined	Low impairment
	W2	No impairment	No impairment	Undetermined	No impairment
	W3	No impairment	Moderate impairment	Undetermined	Low impairment
	W4	Moderate impairment	Low impairment	Undetermined	Low impairment

5.1.3 Key Findings of Habitat Conditions

East Fork Nookachamps Creek and its contributing tributaries provide areas with good habitat to support salmonid populations. Generally, high quality habitat is available in the tributaries flowing from Cultus Mountain and the uppermost reach in East Fork Nookachamps Creek (EF5). Lower in the East Fork Nookachamps Creek and in the creeks flowing through the low elevation and low gradient portion of the watershed, the habitats are generally in poor condition. Since the lower reaches are vital for juvenile and adult salmonid migrations between the Skagit River and the upper portions of the watershed, the poor habitat conditions are a significant limiting factor for salmonid populations. The low-gradient areas with generally poor salmonid habitat include East Fork Nookachamps Creek from the DD21 levee downstream to Barney Lake, Nookachamps

Creek, Mud Lake Creek, Turner Creek below the sediment trap near Elk Drive, and Little Day Creek from the Fox Road crossing to its confluence with Turner Creek. These lower watershed areas contain highly modified and simplified habitats comprised of generally straight stream routes with impaired floodplain connectivity, lack of instream wood for habitat structure, and limited canopy cover from non-invasive trees and shrubs. In the summer, these poor habitat conditions are greatly exacerbated by high water temperatures and low dissolved oxygen that are inhospitable to salmonids, which are cold water dependent. The poor water quality in the summer likely causes salmonids to avoid the areas if they can and exposes those salmonids that do enter the area to predation from warmwater fish and birds, reduced fitness, or reduced survival. The low flows that occur in the summer contribute to the impaired water quality, as well as further reduce habitat quality by reducing available aquatic habitat and the ability of juvenile salmonids to move more freely throughout the watershed. In the winter, the poor habitat conditions are also exacerbated by the flooding that is common in the watershed, as salmonids are either displaced by rapidly moving water with limited off-channel habitat due to manmade modifications to seek refuge, or move with flood flows out of the creek channels and into farm fields where stranding is a concern.

The higher quality habitats noted above occur in the upper portions of creeks with downstream impairments (e.g., East Fork Nookachamps Creek and Turner Creek), larger creek systems (e.g., Walker Creek and Mundt Creek), as well as in smaller creek systems that often are unnamed. These areas generally had abundant spawning gravels and cobbles, and more complex habitats including pools. Upstream of the reaches surveyed, the creeks often became quite steep, thereby resulting in substrates too large for spawning. As a result of the steep slopes upstream and the poor habitats downstream, the higher quality habitats described above are particularly important as they are the only areas favorable for salmonids.

Even within portions of the watershed identified with higher quality habitats, there are still zones of degraded habitat such as areas of excessive fine sediment, lower than desired amounts of instream wood, and degraded riparian vegetation. There are opportunities for improvement on each of these habitat parameters. Fine sediment levels in spawning areas can have a negative effect on the survival of incubating eggs in redds. High amounts of fine sediments can reduce water flow and oxygen exchange to eggs, which can lead to suffocation and egg mortality. The reduced survival rate of salmonid eggs with increased amounts of fine sediments in redds is well documented (e.g., Chapman 1988). The input of fine sediment and the availability of areas with well-sorted gravels with lower fines is to some degree related to a lack of instream wood and riparian vegetation noted above. Instream wood serves as a sediment storage and sorting mechanism, influencing fine sediment amounts by changing scour and deposition patterns, which can help transport fine sediments from spawning gravels, especially at pool tailouts. Riparian vegetation conditions affect fine sediment inputs as the root structure of riparian vegetation helps stabilize streambanks, which reduces bank erosion and associated fine sediment inputs. Another major contributing factor for fine sediment loads is the condition upstream all the way to the headwaters. Land use alterations in upper watersheds, particularly timber harvest, can result in bank and hillside erosion which contributes fine sediments that get transported downstream to spawning areas. Road building for timber harvest access is also a potentially large contributor to fine sediment in watersheds with active and historical logging.

Manmade barriers at road crossings are a common stream modification that impacts the movements of juvenile and adult salmonids. Access for adult salmonids is necessary for the fish to reach upstream spawning reaches. Aquatic habitat connectivity is also highly important for juvenile salmonids who move upstream and downstream in creek systems during their rearing. This is especially true for species like steelhead and coho that remain in creeks for one full year or more before outmigrating. These fish need access to habitats for rearing during all seasons of the year. Given the smaller body size and lesser swimming abilities of juvenile salmon compared to adults, juvenile salmonid access to habitats often becomes restricted before adult salmonid access. Properly sized crossings also provide better conditions for drainage, sediment transport, wood transport, and natural stream processes.

WDFW maintains a WDFW Fish Passage Database (WDFW 2023), which has the most complete inventory available of crossings, but it is known to be incomplete (especially in documenting private crossings that may impact fish passage). WDFW (2019) fish passage barrier assessment protocols distinguish between total barrier (i.e., no fish passage) and partial barrier (i.e., fish can pass under some conditions). Recovery efforts in the Skagit River watershed have focused on restoring fish passage at all sites found to impact fish movements, regardless of whether defined as a partial or total barrier. Since the WDFW categorization informs the level of severity of the barrier, the following summary distinguishes between total and partial barriers. The WDFW database documents four total barriers and several partial barriers in the project area.

5.2 Drainage and Flooding Limiting Factors

A drainage factors analysis was conducted for the East Fork Nookachamps Creek project area to identify and evaluate conditions affecting flooding. The following sections describe the methods and results of the analysis. In addition, a hydraulic model was developed to assess the potential performance of some flood reduction alternatives around the Highway 9 bridge crossing, which is considered a potential flow constriction affecting upstream drainage.

5.2.1 Methods

The drainage factor analysis focused on watershed conditions affecting the ability for water to drain from the area, especially during high flows. Drainage factors include natural conditions and manmade modifications affecting drainage.

Drainage Factors Evaluated

Five drainage factors were identified and evaluated. The five drainage limiting factors evaluated were undersized water crossings, channel capacity, road prisms, stream slope, and Skagit River backwatering. Each drainage factor is defined below.

Undersized Water Crossings

This analysis evaluated the capacity of water crossings such as culverts and bridges to convey flows. The analysis focused on characterizing the degree to which an undersized crossing impairs the effective flow of water in the reach during various flood events.

Five culvert crossings within the East Fork Nookachamps Creek project area were evaluated using the Federal Highway Administration's (FHWA) HY-8 Culvert Hydraulic Analysis Program as documented in **Appendix E**. As the HY-8 modeling is partially based on observations and measurements collected by a field crew, primarily from public roads and rights-of-way, not all existing crossings (specifically those located on private property) were modeled. Additionally, HY-8 does not evaluate bridges, and a separate method was used to evaluate bridge crossings and at culvert crossings where field measurements were not available. The bankfull width, as measured in the field or, where measurements were not taken, estimated from aerial imagery, was compared to the culvert or bridge span to calculate the contraction ratio. The contraction ratio is the culvert or bridge span divided by the bankfull width. A contraction ratio of less than 1 indicates that the crossing is restricting flow during the bankfull flow.

For the crossings evaluated with HY-8, a rating of "high" indicates that the crossing cannot convey the entirety of the 2-year flow event (i.e., typical flow event) without overtopping the roadway (USGS 2019). A rating of "moderate" indicates that the crossing cannot convey the entirety of the 10-year flood. A rating of "low" indicates that the crossing cannot convey the entirety of the 100-year flood. The 100-year flood is used by the Federal Emergency Management Agency (FEMA) as their Base Flood and is considered an extreme event. A rating of "not impaired" indicates that the culvert adequately conveys all floods or that the crossings are bridges that do not restrict flow.

For the crossings evaluated by bankfull width, a rating of "high" indicates that the crossing span is less than 50% of the bankfull width, and a rating of "moderate" indicates that the crossing span is between 50% and 99% of the bankfull width. A rating of "low" indicates that the crossing span is equal to or greater than the bankfull width. With multiple crossings present in many of the reaches, each reach is assigned a ranking of "high," "moderate," "low," or "not impaired," based on the highest level of impairment of an individual crossing.

Channel Capacity

The channel capacity analysis assessed the degree to which the ability of the channel to convey "typical" floods within a natural channel and floodplain has been reduced through channel simplification, confinement, and/or dredging.

"Predicted" bankfull widths were generated using StreamStats. These bankfull widths are calculated by the StreamStats application using regional regression equations to predict bankfull width as a function of drainage area (USGS 2019). These predicted bankfull widths were compared to the actual bankfull widths, as measured in the field, or estimated by aerial photographs. In much of the project area, stream channels have been modified, bermed, and artificially channelized and narrowed. A measured bankfull width that is significantly less than the predicted bankfull width indicates that the channel has been modified and is likely undersized for the amount of flow generated by its watershed.

A rating of "high" indicates that the measured bankfull width is less than 75% of the predicted bankfull width. A rating of "moderate" indicates that the measured bankfull width is between 75% and 90% of the predicted bankfull width. A rating of "low" indicates that the measured bankfull width is between 90% and 99% of the predicted bankfull width. A rating of “not impaired” indicates that the measure bankfull width is greater than the predicted bankfull width. If multiple channel cross sections are evaluated within a single reach, the reach is rated based on the channel with the highest level of impairment.

Road Prism

The road prism analysis characterizes whether road fill prisms occupy portions of the natural floodplain within the reach. When placed within the floodway, fill from road prisms can reduce the amount of flood storage capacity and increase water levels during a flood event. A rating of “yes” indicates that there is at least one instance of significant road fill or other artificial fill, such as a levee, occupying the floodplain, while a rating of “no” indicates there are no instances of road fill occupying the floodplain. A road crossing within a reach does not guarantee a rating of “yes;” if the stream has a steep gradient or a narrow floodplain that is not significantly impacted by adjacent fill, it may be given a rating of “no.” For the purposes of this exercise, floodplains in the upper reaches of the watershed are defined as flood prone width (2 X bankfull height); while in the lower reaches this metric can also be used and also reference to known extents of flooding or results from the hydraulic analysis.

Slopes

The slopes analysis assessed the degree to which slope transitions and channel slope within the reach contribute to excessive sediment deposition and reduced drainage. This was done in two parts: identifying if the reach or the reach directly upstream of it contains a slope break and evaluating the channel slope of the reach itself. Sediments are often deposited when a stream loses transport capacity as it exits a high-gradient environment and enters a low-slope valley floor. To identify such locations of slope transition, channel gradient was calculated by manually drawing stream centerlines in geographic information system (GIS) and sampling elevations from a 2017 light detection and ranging (LiDAR) surface every 100 feet along the centerline (WDNR 2017). Slope was then calculated along 500 feet intervals to ensure that the calculations were capturing the true gradient of the stream channel, rather than local stream features such as drops or pools.

Each 500-foot section of stream was then assigned a rating of “low,” “moderate,” or “high.” A rating of “low” is automatically given to any section with a slope of less than 1%; while a transition from a 0.1% to 0.5% slope would be a 400% increase in slope, at such low slope, this is not considered significant or likely to contribute to sediment deposition. At slopes above 1%, a rating of “low” indicates that the slope increases or decreases up to 50%; a rating of “moderate” indicates that the slope increases or decreases by between 50% and 100%; and a rating of “high” indicates that the slope increases or decreases by more than 100%. A second rating was assigned based on the actual channel slope, with a rating of “high” indicating an average slope of less than 0.1%, a rating of “moderate” indicating an average slope between 0.1% and 4%, and a rating of “high” indicating an average slope greater than 4%. The two ratings were combined to form a composite rating. These ratings do not necessarily indicate the presence of excessive sediment deposition, but instead identify the potential for deposition and channel aggradation.

Skagit River Backwatering

The East Fork Nookachamps Creek project area includes multiple reaches in the floodplain of the Skagit River mainstem. High flows in the mainstem contribute to backwatering up the mainstem of Nookachamps Creek and into the project area. This analysis characterized whether each reach is subject to backwatering or ponding associated with flooding of the mainstem Skagit River.

Flood water elevations from a hydraulic model created by Natural Systems Design (NSD 2022) were used to evaluate the extent of Skagit River backwatering within the East Fork Nookachamps Creek project area during "typical flooding," defined as between a 2-year and 5-year event. A rating of "yes" indicates that some portion of the reach is impacted by backwatering, while a rating of "no" indicates that no portion of the reach is impacted by backwatering.

Flooding Risk

Flooding risk is an additional metric that was qualitatively evaluated based on input received during a community meeting, a review of aerial imagery, field observations, and input from Skagit County. Flooding risk was characterized as high, moderate, low, or undetermined. The latter category reflects no reports or observations of flooding.

Drainage Factors Impairment Categories

The condition of each drainage factor was evaluated for each reach using the data sources identified above. Impairment categories of high, moderate, low, or none were assigned according to evaluation rules established to characterize the existing condition. The impairment categories were informed by conditions observed in the project area. **Table 15** summarizes the impairment category rules for each drainage factor.

TABLE 15. IMPAIRMENT CATEGORIES FOR DRAINAGE FACTORS

Drainage Factor	High Impairment	Moderate Impairment	Low Impairment	No Impairment	Data Confidence
Undersized Water Crossings	Crossing cannot convey the entirety of the 2-year flow event (i.e., typical flow event) (USGS 2019) without overtopping the roadway OR crossing span is less than 50% of the bankfull width (BFW).	Crossing cannot convey the entirety of the 10-year flood OR crossing span is between 50% and 99% of the BFW.	Crossing cannot convey the entirety of the 100-year flood OR crossing span is equal to or greater than the BFW.	Culvert adequately conveys all floods or there are no crossings.	Moderate confidence in correlation between contraction ratio and presence of undersized crossings.
Channel Capacity	Measured BFW is less than 75% of predicted BFW.	Measured BFW is between 75% and 90% of the predicted BFW.	Measured BFW is between 90% and 99% of predicted BFW.	Measured BFW is equal to or greater than predicted BFW.	Moderate confidence in StreamStats regression equations to generate "predicted" bankfull widths and the correlation between impaired channel capacities.
Road Prism	At least one instance of significant road fill or other artificial fill, such as a levee, occupying the floodplain.	n/a	n/a	No instances of road fill occupying the floodplain.	High confidence in presence or absence of roads in project area.

Drainage Factor	High Impairment	Moderate Impairment	Low Impairment	No Impairment	Data Confidence
Slopes	At slopes above 1%, where the slope increases or decreases by more than 100%.	At slopes above 1%, where the slope increases or decreases between 50% and 100%.	Any section with a slope of less than 1%. At slopes above 1%, where the slope increases or decreases up to 50%.	n/a	High confidence in LiDAR data and generated slope data.
Skagit River backwatering	A portion of the reach is inundated by backwatering up to a 5-year flow recurrence event.	n/a	n/a	No portion of the reach is inundated by backwatering up to a 5-year flow recurrence event.	High confidence in NSD modeling and presence of Skagit River backwatering in project area.

NOTES:
a. D_{50} is the substrate particle size that half is larger than and half is smaller than.

The impairment ratings of the five drainage factors were combined to arrive at a composite impairment category for each reach. **Table 16** identifies the composite impairment category rules based on the impairment assignments for each habitat limiting factor.

TABLE 16. COMPOSITE IMPAIRMENT CATEGORIES FOR DRAINAGE LIMITING FACTORS

Composite Impairment Category	Rules Based on Individual Impairment Categories
High	Two or more high impairment habitat limiting factors.
Moderate	One high impairment or two or more moderate impairment habitat limiting factors.
Low	One moderate impairment or two or more low impairment habitat limiting factors.
None	No impairment or one low impairment habitat limiting factors.

The composite drainage factor impairment and the additional flood risk category were used to identify priority areas for drainage improvement and flood reduction.

Hydraulic Analysis of the Highway 9 Crossing

An existing conditions HEC-RAS 2D model was developed to assess drainage conditions upstream of and as a result of the Highway 9 crossing of East Fork Nookachamps Creek. Three proposed conditions models were also completed to evaluate if modifications to the crossing and a downstream feature could meaningfully improve drainage patterns upstream of Highway 9. The full discussion of the modeling approach and results is presented in **Appendix F**.

5.2.2 Results

Drainage factors were evaluated by reach for each of the five parameters evaluated and assigned a composite impairment category. In this analysis, high impairment indicates poor drainage conditions, moderate impairment indicates fair drainage conditions, low impairment indicates good drainage conditions, and no impairment indicates natural drainage conditions.

Undersized Water Crossings

Table 17 presents the results of the water crossings impairment analysis. Nine reaches (EF2, Mud1, T2, LD1, LD2, CS1, K1, C1, and W4) have the highest level of drainage impairment due to crossings like culverts or bridges. Reaches with a high ranking generally correspond with a greater number of culverts, as these are more likely to be undersized and impound flow than bridges. Of the evaluated reaches, Mud1 has the most crossings, with five culvert crossings. EF4, C1, and W1 each have four crossings. Reaches ranked as “not impaired” (EF1, EF3, EF5, T1, T4, UNK 1-1, K3, and W2) do not have any documented crossings.

Channel Capacity

Table 18 presents the results of the channel capacity impairment analysis. Eleven reaches (N2, EF1, EF2, EF3, EF4, T2, T3, T4, LD1, K1, and K2) have the highest level of channel capacity impairment. These reaches generally correspond with the areas that have high levels of channel modification. In many reaches along the valley floor, the channel network may have originally consisted of multiple smaller channels that have now been reduced to a single channel. As the channel aggrades with sediment, its capacity to convey flood flows is reduced. For example, EF2 and EF3 have been confined by the continuous levee running along the right bank and have aggraded to be higher than the agricultural fields to the northeast.

Road Prism

Table 19 presents the results of the road prism impairment analysis. Thirteen reaches(N1, N2, EF1, EF2, EF3, EF4, Mud1, T1, T2, LD1, M1, CS1, and C1) have road prisms present in the floodplain that may limit drainage. For example, in N1, Francis Road is built at a higher elevation than the surrounding floodplain and acts as a berm that limits drainage when water levels recede after a large flood. Swan Road has a similar effect in reach N2, as does Mud Lake Road in Mud1, Highway 9 in EF2, the levee fill prism in EF3, Beaver Lake Road in EF4, the levee fill prism in T1, Beaver Lake Road in T2, Fonk Road and Fox Road in LD1, Beaver Lake Road in M1, and Benham Road in CS1. The remaining reaches do not have roads with significant fill prisms.

Channel Slope

Eight reaches (EF3, EF4, T1, T2, LD1, W1, W2, and W3) are rated as highly impacted by slope. The intention of the slope rating is to identify reaches that are subject to sediment deposition response resulting from low slopes; in some cases this is merely a result of valley position which has no remedy, whereas other reaches may be impaired sue to local modification and can be evaluated further to identify treatments to resolve both the habitat and drainage limitations created by excessive sediment deposition.

Table 17. Undersized Water Crossing Impairment Analysis

Creek	Reach	Crossing Name	Crossing Type	Rating (Modeling Assessment)	Bankfull Width (feet)	Crossing Span (feet)	Contraction Ratio	Undersized Crossing Impairment Category
Nookachamps Creek	N1	Francis Road	bridge	---	60[a]	130	2.17	Low
	N2	Swan Road	bridge	---	50[a]	126	2.52	Low
East Fork Nookachamps Creek	EF1	no crossings	n/a	n/a	23.8	n/a	n/a	Not Impaired
	EF2	Highway 9	bridge	Moderate, (HEC-RAS 2D)	38.6	143	3.70	High
	EF3	no crossings	n/a	n/a	32.1	n/a	n/a	Not Impaired
	EF4	Driveway 1	bridge	---	33.3	60	1.80	Low
		Driveway 2	bridge	---	33.3	50	1.50	Low
		Beaver Lake Road	bridge	---	33.3	73	2.19	Low
		Star View Drive	bridge	---	33.3	60	1.80	Low
	EF5	no crossings	n/a	n/a	30.5	n/a	n/a	Not Impaired
Mud Lake Creek	Mud1	Swan Road	culvert		10.0	10.2	1.02	Low
		Private Road 1	culvert	---	10.0	3	0.30	High
		Private Road 2	culvert	---	10.0	4	0.40	High
		Private Road 3	culvert	---	10.0	12	1.20	Low
		Private Road 4	culvert	---	10.0	7.9	0.79	Moderate
Turner Creek	T1	no crossings	n/a	n/a	39.0	n/a	n/a	Not Impaired
	T2	Beaver Lake Road	culvert	High (HY-8)	20.1	4	0.20	High
		Elk Drive	culvert	High (HY-8)	20.1	8	0.40	High
	T3	Janicki Road/BPA Road	culvert	---	11.1	8	0.72	Moderate
	T4	no crossings	n/a	n/a	9.5	n/a	n/a	Not Impaired
Little Day Creek	LD1	Beaver Lake Road	culvert	Low (HY-8)	16.0[a]	7.9	0.49	High
		Fonk Road	culvert	Low (HY-8)	16.0[a]	8.00	0.50	High
	LD2	Fox Road	culvert	---	12.8	5.4	0.42	High
		Wayward Way	bridge	---	12.8	36	2.81	Low
		Private Road	culvert	---	12.8	4	0.31	High
Mundt Creek	M1	Beaver Lake Road	culvert (2)	---	19.3	19	0.98	Moderate
		Private Driveway	bridge	---	19.3	37.4	1.94	Low
	M2	BPA Access Road	bridge	---	16.1[b]	40	2.48	Low

Creek	Reach	Crossing Name	Crossing Type	Rating (Modeling Assessment)	Bankfull Width (feet)	Crossing Span (feet)	Contraction Ratio	Undersized Crossing Impairment Category
Cold Spring Creek	CS1	Private Road	culvert (2)	---	15.6[b]	5	0.32	High
		Abandoned Road	culvert	---	15.6[b]	4	0.26	High
	CS2	BPA Access Road	culvert	---	9.8[b]	Unknown	NA	Low
Unnamed Tributary 1	UNK1-1	no crossings	n/a	n/a	10.7[b]	n/a	n/a	Not Impaired
	UNK1-2	Private Dam	dam	---	6.7[b]	0	NA	Not Impaired
		BPA Access Road	culvert	---	6.7[b]	Unknown	NA	Low
Klahowya Creek	K1	Private Road	culvert	---	10.4	3	0.29	High
		BPA Access Road	culvert	---	10.4	8.5	0.82	Moderate
	K2	Swinomish Lane	bridge	---	7.5	16.4	2.19	Low
		Klahowya Lane	culvert	---	7.5	4	0.53	Moderate
	K3	no crossings	n/a	n/a	12.3[b]	n/a	n/a	Not Impaired
Lake Challenge Outlet	C1	Wood Bridge	bridge	---	10.4[b]	16.4	1.58	Low
		Private Road	culvert	---	10.4[b]	2	0.19	High
		Private Road	culvert	---	10.4[b]	4	0.38	High
		Private Road	culvert	---	10.4[b]	3.3	0.32	High
Walker Creek	W1	Private Road	bridge	---	31.5	62	1.97	Low
		Private Road	bridge	---	31.5	66	2.10	Low
		Footpath	bridge	---	31.5	NA	NA	Low
		Taylor Road	bridge	---	31.5	39.4	1.25	Low
	W2	no crossings	n/a	n/a	32.2	n/a	n/a	Not Impaired
	W3	Walker Valley Road	culvert	---	30.3	16.4	0.54	Moderate
		BPA Access Road	bridge	---	30.3	32.8	1.08	Low
	W4	Peter Burns Road	culvert	---	28.0	9	0.32	High

NOTES: Modeling assessment “---” indicates not evaluated.

n/a Indicates not applicable because there is no crossing to evaluate.
a. Indicates bankfull width estimated using aerial imagery.
b. Indicates bankfull width estimated using StreamStats because tree cover in aerial imagery blocks view of creek.

TABLE 18. CHANNEL CAPACITY IMPAIRMENT ANALYSIS

Stream	Reach	StreamStats Calculation of Bankfull Width (feet) Based on Watershed Size	Measured Bankfull Width (feet)	Measured / Calculated Bankfull Width	Channel Capacity Impairment Category
Nookachamps Creek	N1	76.5	60	78.4%	Moderate
	N2	76.0	50	65.8%	High
East Fork Nookachamps Creek	EF1	58.1	23.8	41.0%	High
	EF2	57.4	38.6	67.2%	High
	EF3	50.1	32.1	64.1%	High
	EF4	49.8	33.3	66.9%	High
	EF5	26.8	30.5	113.8%	Not Impaired
Mud Lake Creek	Mud1	9.2	10.0	108.7%	Not Impaired
Turner Creek	T1	30.9	39.0	126.2%	Not Impaired
	T2	30.0	20.1	67.0%	High
	T3	18.0	11.1	61.7%	High
	T4	14.0	9.5	67.9%	High
Little Day Creek	LD1	23.8	16.0	67.2%	High
	LD2	13.8	12.8	92.8%	Low
Mundt Creek	M1	23.8	19.3	81.1%	Moderate
	M2	16.1	16.7	103.7%	Not Impaired
Cold Spring Creek	CS1	15.6	Not measured	n/a	Not Evaluated
	CS2	9.8	Not measured	n/a	Not Evaluated
Unnamed Tributary 1	UNK1-1	10.7	Not measured	n/a	Not Evaluated
	UNK1-2	6.7	Not measured	n/a	Not Evaluated
Klahowya Creek	K1	15.6	10.4	66.7%	High
	K2	15.0	7.5	50.0%	High
	K3	12.3	Not measured	n/a	Not Evaluated
Lake Challenge Outlet	C1	10.4	Not measured	n/a	Not Evaluated
Walker Creek	W1	34.0	31.5	92.6%	Low
	W2	32.2	Not measured	n/a	Not Evaluated
	W3	30.3	Not measured	n/a	Not Evaluated
	W4	26.5	28.0	105.7%	Not Impaired

TABLE 19. ROAD PRISM IMPAIRMENT ANALYSIS

Stream	Reach	Road Prism Present Bisecting Floodplain?	Road Name	Road Prism Impairment Category
Nookachamps Creek	N1	Yes	Francis Road, Thillburg Road	Impaired
	N2	Yes	Swan Road	Impaired
East Fork Nookachamps Creek	EF1	Yes	Derelict bridge abutments and road approach	Impaired
	EF2	Yes	Highway 9, Levee fill prism	Impaired
	EF3	Yes	Levee fill prism	Impaired
	EF4	Yes	Beaver Lake Road, Star View Road	Impaired
	EF5	No		Not Impaired
Mud Lake Creek	Mud1	Yes	Mud Lake Road, Swan Road	Impaired
Turner Creek	T1	Yes	Levee prism, gravel mining operations	Impaired
	T2	Yes	Beaver Lake Road, Elk Drive	Impaired
	T3	No		Not Impaired
	T4	No		Not Impaired
Little Day Creek	LD1	Yes	Fonk Road, Fox Road, Beaver Lake Road	Impaired
	LD2	No		Not Impaired
Mundt Creek	M1	Yes	Beaver Lake Road	Impaired
	M2	No		Not Impaired
Cold Spring Creek	CS1	Yes	Benham Road, Beaver Lake Road	Impaired
	CS2	No		Not Impaired
Unnamed Tributary 1	UNK1-1	No		Not Impaired
	UNK1-2	No		Not Impaired
Klahowya Creek	K1	No		Not Impaired
	K2	No		Not Impaired
	K3	No		Not Impaired
Lake Challenge Outlet	C1	Yes	Artificial impoundments and driveway fill on private property viewed from aerial	Impaired
Walker Creek	W1	No		Not Impaired
	W2	No		Not Impaired
	W3	No		Not Impaired
	W4	No		Not Impaired

Table 20 presents the results of the channel slope impairment analysis. These reaches with a highly impaired slope rating typically have both a low reach-wide average channel slope and a significant slope break either within the reach or directly upstream of it. These results generally match areas of known excessive sediment deposition, including the lower reaches of Turner Creek (T1 and T2) where dredging has occurred, and the middle reaches of east Fork Nookachamps Creek (EF3 and EF4) where landowners have reported significant sediment deposition near at a private bridge crossing near Beaver Lake Road. Ten reaches have moderate drainage impairment (N1, N2, EF1, EF2, Mud1, T1, T2, LD1, and W1–W3). These reaches typically have either a low reach-wide average channel slope or a significant slope break within the reach or directly upstream. The remaining reaches are rated as having low impairment or as not impaired.

TABLE 20. SLOPE IMPAIRMENT ANALYSIS

Stream	Reach	Slope Break in Reach	Upstream Slope Break	Average Reach Slope	Reach Slope Category	Overall Slope Impairment Category
Nookachamps Creek	N1	Low	No	0.01%	High	Moderate
	N2	Low	No	0.02%	High	Moderate
East Fork Nookachamps Creek	EF1	Low	No	0.1%	High	Moderate
	EF2	Low	No	0.1%	High	Moderate
	EF3	Low	Yes	0.2%	High	High
	EF4	Moderate	Yes	0.5%	High	High
	EF5	Moderate	No	3.4%	Moderate	Low
Mud Lake Creek	Mud1	Low	No	0.1%	High	Moderate
Turner Creek	T1	Low	Yes	0.02%	High	High
	T2	High	Yes	0.7%	High	High
	T3	High	Yes	8.4%	Low	Moderate
	T4	Moderate	No	6.8%	Low	Not Impaired
Little Day Creek	LD1	High	Yes	0.2%	High	High
	LD2	High	No	4.7%	Low	Low
Mundt Creek	M1	Moderate	Yes	1.7%	Moderate	Moderate
	M2	Moderate	No	9.6%	Low	Low
Cold Spring Creek	CS1	Moderate	Yes	6.1%	Low	Moderate
	CS2	High	No	13.6%	Low	Low
Unnamed Tributary 1	UNK1-1	Low	Yes	3.8%	Low	Low
	UNK1-2	Moderate	No	12.9%	Low	Not Impaired
Klahowya Creek	K1	Moderate	No	3.7%	Moderate	Low
	K2	Low	Yes	1.7%	Moderate	Moderate
	K3	High	No	12.1%	Low	Low
Lake Challenge Outlet	C1	High	No	2.9%	Moderate	Moderate
Walker Creek	W1	Low	Yes	0.5%	High	High
	W2	High	Yes	1.4%	Moderate	High
	W3	Moderate	Yes	0.7%	High	High
	W4	High	No	4.6%	Low	Low

Skagit River Backwatering

Backwatering from the Skagit River impacts most of the lower reaches of the project area, including N1, N2, EF1, EF2, EF3, Mud1, T1, T2, and LD1. Backwater from the Skagit is not proposed to be addressed through any treatments but it is useful to understand which reaches are subject to the condition when considering other proposals to improve drainage. **Table 21** presents the results of the Skagit River backwatering impairment analysis. The remaining reaches are located at a higher elevation in the watershed and are not impacted when the Skagit River floods.

TABLE 21. SKAGIT BACKWATERING IMPAIRMENT ANALYSIS

Stream	Reach	Model Indicates Skagit Backwatering in Reach	Skagit Backwatering Impairment Category
Nookachamps Creek	N1	Yes	Impaired
	N2	Yes	Impaired
East Fork Nookachamps Creek	EF1	Yes	Impaired
	EF2	Yes	Impaired
	EF3	Yes	Impaired
	EF4	No	Not Impaired
	EF5	No	Not Impaired
Mud Lake Creek	Mud1	Yes	Impaired
Turner Creek	T1	Yes	Impaired
	T2	Yes	Impaired
	T3	No	Not Impaired
	T4	No	Not Impaired
Little Day Creek	LD1	Yes	Impaired
	LD2	No	Not Impaired
Mundt Creek	M1	No	Not Impaired
	M2	No	Not Impaired
Cold Spring Creek	CS1	No	Not Impaired
	CS2	No	Not Impaired
Unnamed Tributary 1	UNK1-1	No	Not Impaired
	UNK1-2	No	Not Impaired
Klahowya Creek	K1	No	Not Impaired
	K2	No	Not Impaired
	K3	No	Not Impaired
Lake Challenge Outlet	C1	No	Not Impaired
Walker Creek	W1	No	Not Impaired
	W2	No	Not Impaired
	W3	No	Not Impaired
	W4	No	Not Impaired

Highway 9 Bridge Crossing

An evaluation of the effects that the Highway 9 crossing has on impairing downstream flow and drainage out of the EFNC and Turner Creek valleys was completed to determine if modifications to that crossing could improve drainage. A full description of the hydraulic modeling exercise is presented in Appendix F. The analysis demonstrates that the valley construction located at and downstream of the SR9 bridge crossing creates a drainage constriction, one made slightly worse through further narrowing of the construction with the earthen fill road prism and bridge abutment of SR9. A model simulation depicting widening the Highway 9 crossing and the valley widening both showed a slight flood benefit for Nookachamps Creek and tributary-related flooding, but caused an adverse flood impact when backwater flooding from the Skagit River was modeled. Drainage of flood flows was faster under the Highway 9 widening and valley widening scenarios for both the with and without Skagit River backwater conditions, but only on the order of several hours. It is unclear at this time whether widening of the Highway crossing or valley would provide a net flood benefit for the area upstream of Highway 9 due to the complex interplay between the East Fork Nookachamps Creek and tributary flooding and Skagit River backwater-caused flooding.

5.2.3 Composite Drainage Factors Impairment

Based on the findings of the five drainage limiting factors evaluated, eight reaches were identified as being highly impaired for drainage (**Table 24**). The high impairment reaches include both reaches of Nookachamps Creek (N1, N2) and two East Fork Nookachamps Creek reaches (EF2, EF3). It also includes Mud Lake Creek (Mud1), two Turner Creek reaches (T1, T2), and one reach of Little Day Creek (LD1).

Eight reaches had a moderate composite habitat impairment rating. These reaches include two East Fork Nookachamps Creek reaches (EF1, EF4); one Turner Creek reach (T3); the lowermost reaches of Mundt Creek (M1), Cold Spring Creek (CS1), two reaches of Klahowya Creek (K1, K2); and the Lake Challenge Outlet (C1).

Twelve reaches had low impairment, including East Fork Nookachamps Creek (EF5) upstream of the confluence with Walker Creek, the upper reach of Turner Creek (T4), the upper reach of Little Day Creek (LD2), the upper reach of Mundt Creek (M2), the upper reach of Cold Spring Creek (CS2), both reaches of the unnamed tributary (UNK1-1, UNK1-2) to Cold Spring Creek, the upper reach of Klahowya Creek (K3), and all reaches of Walker Creek (W1–W4).

5.2.4 Drainage Improvement and Flood Reduction Needs

The composite drainage factors ratings presented in **Table 22** were combined with the flooding risk to prioritize the drainage improvement and flood reduction needs of each reach. These priorities are provided in **Table 23**.

5.2.5 Key Findings of Drainage Analysis

The East Fork Nookachamps Creek watershed originates from mountainous terrain underlain by complex geology, producing variable size and high volumes of sediment. The tributary creeks contributing flows to East Fork Nookachamps Creek transition rapidly from the steeper slopes of the Cultus Mountains to the low-gradient alluvial valley created by the Skagit River. Although the Skagit River has since moved northward of its prior position in the modern-day lower Nookachamps Valley, it still maintains a strong hydrologic and geomorphic influence over conditions in the East Fork Nookachamps Creek system in the form of base level control and also due to backwatering during flood events, which extend a significant distance upstream along the Nookachamps Creek water courses.

Table 22. Composite Drainage Factors Results By Reach

Creek	Reach	Undersized Water Crossings	Channel Capacity	Road Prisms	Slopes	Skagit River Backwatering	Drainage Factors Composite Impairment
Nookachamps Creek	N1	Low	High	Yes	Moderate	Yes	High
	N2	Low	Moderate	Yes	Moderate	Yes	High
East Fork Nookachamps Creek	EF1	Not Impaired	Moderate	No	Moderate	Yes	Moderate
	EF2	Low	High	Yes	Moderate	Yes	High
	EF3	Not Impaired	High	Yes	High	Yes	High
	EF4	Low	Moderate	Yes	High	No	Moderate
	EF5	Not Impaired	Not Impaired	No	Low	No	Low
Mud Lake Creek	Mud1	High	Not Impaired	Yes	Moderate	Yes	High
Turner Creek	T1	Not Impaired	Moderate	Yes	High	Yes	High
	T2	High	High	Yes	High	Yes	High
	T3	Moderate	Moderate	No	Moderate	No	Moderate
	T4	Not Impaired	Moderate	No	Not Impaired	No	Low
Little Day Creek	LD1	High	High	Yes	High	Yes	High
	LD2	High	Low	No	Low	No	Low
Mundt Creek	M1	Moderate	Low	Yes	Moderate	No	Moderate
	M2	Low	Not Impaired	No	Low	No	Low
Cold Spring Creek	CS1	High	Not Impaired	Yes	Moderate	No	Moderate
	CS2	Low	Not Impaired	No	Low	No	Low
Unnamed Tributary 1	UNK1-1	Not Impaired	Not Impaired	No	Low	No	Low
	UNK1-2	Low	Not Impaired	No	Not Impaired	No	Low
Klahowya Creek	K1	High	Moderate	No	Low	No	Moderate
	K2	Moderate	Moderate	No	Moderate	No	Moderate
	K3	Not Impaired	Not Impaired	No	Low	No	Low
Lake Challenge Outlet	C1	High	Not Evaluated	Yes	Moderate	No	Moderate
Walker Creek	W1	Low	Low	No	High	No	Low
	W2	Not Impaired	Not Evaluated	No	High	No	Low
	W3	Moderate	Not Evaluated	No	High	No	Low
	W4	High	Not Impaired	No	Low	No	Low

TABLE 23. DRAINAGE IMPROVEMENT AND FLOOD REDUCTION PRIORITIES

Stream	Reach	Drainage Factors Composite Impairment	Flood Risk Level	Flood Risk Notes	Drainage Improvement and Flood Reduction Priority Categories
Nookachamps Creek	N1	High	High	Francis Road overtops and surrounding area floods, limits access.	High
	N2	High	High	Swan Road overtops and surrounding area floods, limits access.	High
East Fork Nookachamps Creek	EF1	Moderate	Moderate	Area may flood, but surrounding area is just ag fields, no roads.	Moderate
	EF2	High	High	Area known to flood, may threaten houses to north.	High
	EF3	High	Moderate	Area may flood but is largely confined by levee.	High
	EF4	Moderate	Moderate	Area may flood, but no reports of significant flooding or road overtopping.	Moderate
	EF5	Low	Low	Potential for flooding near Walker Creek, surrounding land is timberland.	Low
Mud Lake Creek	Mud1	High	High	Swan Road floods and overtops, limiting access.	High
Turner Creek	T1	High	High	Area known to flood, may threaten houses to north.	High
	T2	High	High	Beaver Lake Road and Fonk Road known to flood and limit access.	High
	T3	Moderate	None known	No reports of flooding.	Low
	T4	Low	None known	No reports of flooding, surrounding land is timberland.	Low
Little Day Creek	LD1	High	High	Fonk Road is known to flood and limit access.	High
	LD2	Low	None known	No reports of flooding, surrounding land is timberland.	Low
Mundt Creek	M1	Moderate	Low	Potential for some flooding near outlet but no known reports.	Moderate
	M2	Low	None known	No reports of flooding, surrounding land is timberland.	Low
Cold Spring Creek	CS1	Moderate	Low	Potential for some flooding near outlet but no known reports.	Moderate
	CS2	Low	None known	No reports of flooding, surrounding land is timberland.	Low
Unnamed Tributary 1	UNK1-1	Low	None known	No reports of flooding, surrounding land is timberland.	Low
	UNK1-2	Low	None known	No reports of flooding, surrounding land is timberland.	Low
Klahowya Creek	K1	Moderate	None known	No reports of flooding, surrounding land is timberland.	Low
	K2	Moderate	None known	No reports of flooding, surrounding land is timberland, some Boy Scout Camp property.	Low
	K3	Low	None known	No reports of flooding, surrounding land is timberland.	Low
Lake Challenge Outlet	C1	Moderate	None known	No reports of flooding.	Low
Walker Creek	W1	Low	Low	Potential for some flooding near outlet but no known reports.	Low
	W2	Low	None known	No reports of flooding, surrounding land is timberland.	Low
	W3	Low	None known	No reports of flooding, surrounding land is timberland and some ag.	Low
	W4	Low	None known	No reports of flooding, surrounding land is timberland.	Low

As a result of this high sediment load and rapid topographical transition, streams that cross the valley floor, including East Fork Nookachamps Creek, Mud Lake Creek, Turner Creek, and Little Day Creek, are very low energy with little capacity to carry sediments. Combined with large sediment loads from upstream mass wasting deposits and fluvial deposits from the sediment-rich floodwater of the Skagit River, the stream bed channels are highly aggradational. Prior to settlement, the valley floor was likely characterized by an alluvial fan and a large wetland complex adjacent to the Skagit River, crossed by multi-thread stream channels that frequently migrated across the valley, as old channels filled with sediments and new ones formed through episodic avulsions.

Following the arrival of European settlers to the area, several streams were channelized to drain the surrounding land and open it up for agriculture. These channels were likely similar to what is observed today: deep, artificially straight, and with little connection to their floodplains. While these channels do help convey flood flows downstream, they are subject to increased rates of sediment deposits, which are now confined to a narrow reach of channel rather than spread out over a wider floodplain. The efficacy of drainage ditches is also muted by the presence of high groundwater throughout the lower valley, a noted recharge zone for regional groundwater.

A major geomorphic “pinch point” exists just below the confluence of East Fork Nookachamps Creek and Turner Creek, near the Highway 9 bridge. At this location, East Fork Nookachamps Creek is confined between two higher-elevation hills to the northeast and southwest. The entire East Fork Nookachamps Creek watershed, including Clear Lake and Beaver Lake, must drain through this narrow point, making this area highly aggradational. Field crews observed evidence of aggradation, including large deposits of sediment and an upstream channel avulsion on East Fork Nookachamps Creek. Before Highway 9 and the community of Clear Lake was developed, flow may have been able to drain northwest out of Clear Lake and toward Debays Slough and the Skagit River.

Overall, of the five culverts hydraulically evaluated, only the Beaver Lake Road crossing of Turner Creek is unable to pass the 2-year flow, partially due to its smaller, 4-foot diameter. The four other culverts (including Elk Drive at Turner Creek, Beaver Lake Road at Little Day Creek, Fonk Road at Little Day Creek, and Swan Road at Mud Lake Creek) are all larger in size, with diameters greater than 6 feet, and adequately sized to convey the estimated flood flows. Because these areas, with the exception of Elk Drive, are known to frequently flood and have overtopped as recently as February 2020, as in the case of Fonk Road, it is likely that there are other factors, such as downstream channel capacity, groundwater elevations, or backwatering contributing to flooding. In the lower sections of East Fork Nookachamps Creek, those subject to Skagit River backwatering, depressional topography, saturated ground conditions, and inefficient drainage pathways contribute to longer duration effects from backwatering than residents have experienced historically.

The channel capacity analysis of these reaches indicates that most channel reaches do not have the capacity to pass the 2-year flow without overtopping their banks. Reach EF1 has an average channel capacity of 1,840 cfs, adequate to pass the estimated 2-year discharge of 1,420. EF2 has an average channel capacity of 50 cfs, above which flow will start overtopping the banks. Reach

EF3 has an average channel capacity of 985 cfs compared to a predicted 2-year flow of 1,260 cfs. Near the confluence with East Fork Nookachamps Creek, Turner Creek has a channel capacity of 144 cfs and a 2-year discharge of 243 cfs. Just below Beaver Lake Road at Reach T2, the average channel capacity is 287 cfs, which is only slightly greater than the 2-year flow of 234 cfs. The average channel capacity of Little Day Creek is 87 cfs, compared to the 2-year discharge of 109 cfs. Because of its small drainage area and proportionally small flood flows, the Mud Lake Creek channel and all its crossings are adequately sized to convey the estimated flood flows.

6. SALMON-FOCUSED AND MULTI-BENEFIT RESTORATION PRIORITIES

Reaches in the East Fork Nookachamps Creek project area were assigned to restoration priority tiers based on the existing conditions analysis. Three approaches were taken to identify restoration priorities (salmon-focused restoration, drainage improvements and flood reduction, and multi-benefit restoration), as described below.

A salmon-focused restoration framework was conducted to prioritize the reaches in which restoration to benefit salmon is most needed. Prioritization tiers were assigned based on information from the salmon distribution analysis and the habitat limiting factors analysis. A two-axis approach was implemented to interpret the results of each component such that the highest priority was assigned to those reaches with the highest salmon use and highest impairment. **Table 24** presents the prioritization tier assignments based on salmon use and habitat limiting factors impairment. Similarly, reaches were also prioritized based on the benefits of habitat protection per the priority tier assignment rules in **Table 25**.

TABLE 24. PRIORITY ASSIGNMENT CATEGORIES FOR SALMON-BASED RESTORATION

		Salmon Use			
		High	**Moderate**	**Low**	**No**
Habitat Limiting Factors Composite Impairment	**High**	Restore High	Restore High	Restore Low	Restore Low
	Moderate	Restore High	Restore Moderate	Restore Low	Restore Low
	Low	Restore Moderate	Restore Moderate	Restore Low	Restore Low
	No	Restore Low	Restore Low	Restore Low	Restore Low

TABLE 25. PRIORITY ASSIGNMENT CATEGORIES FOR SALMON-BASED PROTECTION

		Salmon Use			
		High	**Moderate**	**Low**	**No**
Habitat Limiting Factors Composite Impairment	**High**	Protect Low	Protect Low	Protect Low	Protect Low
	Moderate	Protect Moderate	Protect Moderate	Protect Low	Protect Low
	Low	Protect High	Protect Moderate	Protect Moderate	Protect Low
	No	Protect High	Protect High	Protect Moderate	Protect Low

A second framework was developed to prioritize reaches for drainage improvements and flood reduction. For this flood reduction prioritization, tiers were assigned based on information from the drainage factors analysis and the flooding risk characterization. As in the salmon-focused prioritization, a two-axis approach was implemented to interpret the results of each component such that the highest priority was assigned to those reaches with the highest need to address drainage factor impairments and flooding risk. **Table 26** presents the drainage improvements and flood reduction prioritization tier assignments.

TABLE 26. PRIORITY ASSIGNMENT CATEGORIES FOR DRAINAGE IMPROVEMENTS AND FLOOD REDUCTION

		Flood Risk Category			
		High	**Moderate**	**Low**	**No**
Drainage Factor Impairment Category	**High**	High Need	High Need	High Need	Moderate Need
	Moderate	High Need	Moderate Need	Moderate Need	Low Need
	Low	High Need	Moderate Need	Low Need	Low Need
	No	Moderate Need	Low Need	Low Need	Low Need

A third framework was developed to prioritize reaches for multi-benefit restoration projects that improve habitat for salmon and reduce the risk of flooding. For this multi-benefit prioritization, prioritization tiers were assigned based on information from the salmon distribution analysis and the drainage factors analysis. As in the salmon-focused prioritization, a two-axis approach was implemented to interpret the results of each component such that the highest priority was assigned to those reaches with the highest salmon use and highest priority for drainage improvements and flood reduction. **Table 27** presents the multi-benefit prioritization tier assignments based on salmon use and drainage factors impairment.

TABLE 27. PRIORITY ASSIGNMENT CATEGORIES FOR MULTI-BENEFIT RESTORATION

		Salmon Use Priority Category		
		High	**Moderate**	**Low**
Drainage Improvement and Flood Reduction Priority Category	**High**	Restore High	Restore High	Restore Moderate
	Moderate	Restore High	Restore Moderate	Restore Moderate
	Low	Restore Moderate	Restore Moderate	Restore Low

6.1 Salmon-Focused Restoration and Protection Priorities

The salmon-focused restoration priorities are presented in **Table 28** and **Figure 16**. These priorities reflect where restoration can improve highly used reaches for salmonids where human alterations have impaired habitat conditions. The rankings are intended to guide where to prioritize working first, if possible, but do not mean that no restoration should be done in low priority reaches. All salmon habitats are important and merit restoration where and how possible. In addition, upstream reaches can substantially influence the quality of habitats downstream, notably through water temperature control (e.g., shading to prevent solar heating benefits all downstream reaches) and fine sediment inputs (e.g., naturally stable banks such as through the root structure of riparian vegetation deliver fewer fine sediments to the creek, benefitting all downstream reaches).

TABLE 28. PRIORITY ASSIGNMENT CATEGORIES FOR SALMON-BASED RESTORATION

Salmon-Based Restoration Priority Category	Creek Name: Reach(es)
High	Nookachamps Creek: N1–N2 East Fork Nookachamps Creek: EF1–EF4 Turner Creek: T1–T2
Moderate	East Fork Nookachamps Creek: EF5 Turner Creek: T3 Mundt Creek: M1 Cold Spring Creek: CS1 Walker Creek: W1, W3, W4
Low	Mud Lake Creek: Mud1 Turner Creek: T4 Little Day Creek: LD1, LD2 Mundt Creek: M2 Cold Spring Creek: CS2 Unnamed Tributary: UNK1-1, UNK1-2 Klahowya Creek: K1–K3 Lake Challenge Outlet: C1 Walker Creek: W2

Eight reaches were categorized as high priority for salmon-focused restoration based on high salmon use (see **Table 8**) coupled with either high or moderate impairment of habitat limiting factors (see **Table 16**). The high priority reaches include both Nookachamps Creek reaches (N1, N2) downstream of Barney Lake, the four East Fork Nookachamps Creek reaches (EF1–EF4) between confluence with Walker Creek and downstream to Barney Lake, and the lower two Turner Creek reaches (T1–T2) upstream to Elk Drive.

Seven moderate priority reaches were identified. These include the upstream-most reach of East Fork Nookachamps Creek (EF5), Turner Creek Reach T3, the lowermost reach of both Mundt Creek (M1) and Cold Spring Creek (CS1), and three Walker Creek reaches (W1, W3, W4).

The remaining reaches were categorized as low priority. The low priority reaches include Mud Lake Creek (Mud1), the upstream reach of Turner Creek (T4); both reaches of Little Day Creek (LD1, LD2) near Beaver Lake; the upstream reach of Mundt Creek (M2); the upstream reach of Cold Spring Creek (CS2); both reaches of Unnamed Tributary 1 (UNK1-1, UNK1-2) to Cold Spring Creek; all three reaches of Klahowya Creek (K1, K2, K3); the Lake Challenge Outlet (C1); and Walker Creek Reach W2.

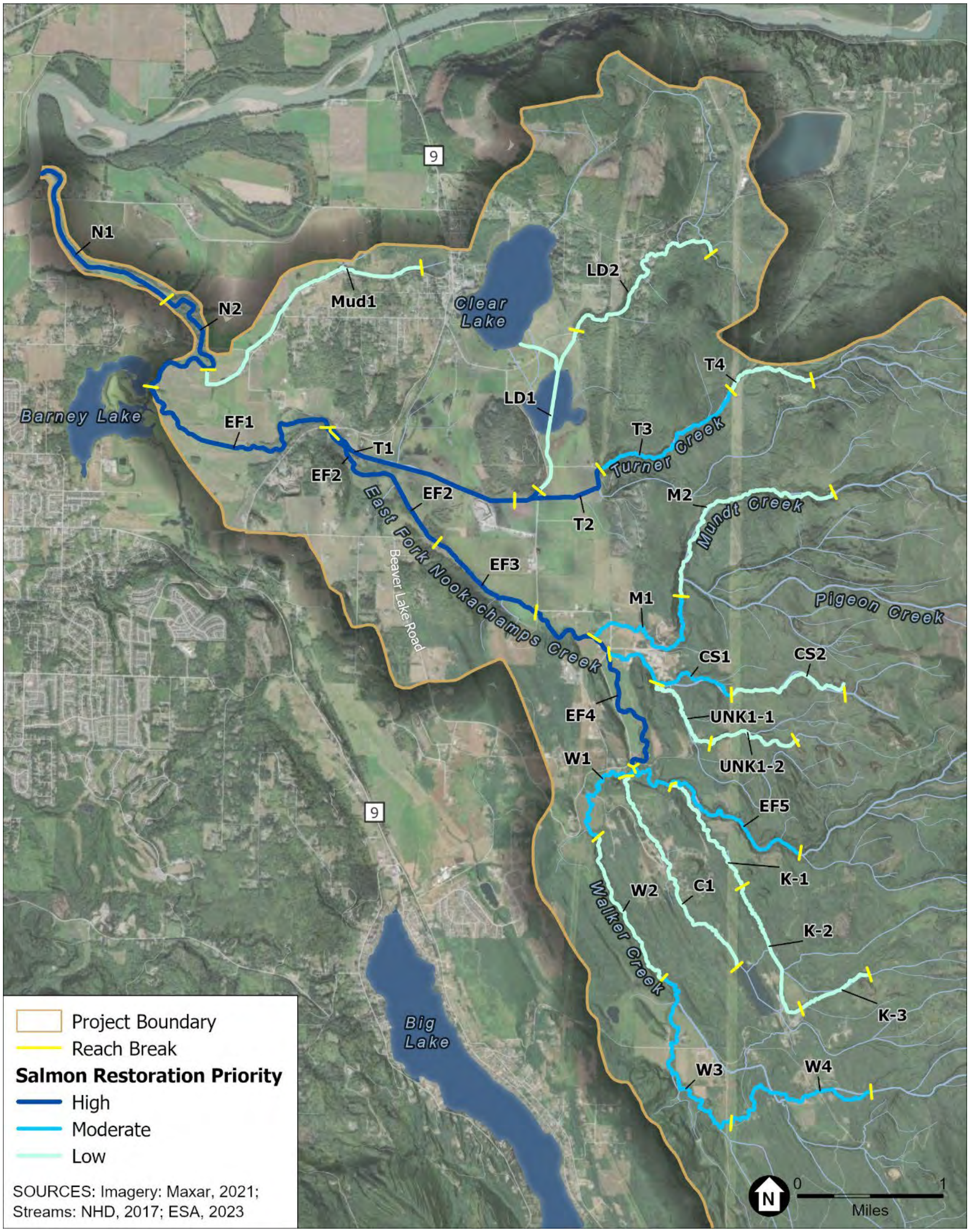


Figure 16.
Reach Restoration Priorities for Salmon Based on Salmon Use and Habitat Needs

The salmon-focused protection priorities are presented in **Table 29** and **Figure 17**. The rankings are intended to guide where to prioritize working first, if possible, but do not mean that no protection should be done in low priority reaches. All salmon habitats are important and merit protection where and how possible.

TABLE 29. PRIORITY ASSIGNMENT CATEGORIES FOR SALMON-BASED PROTECTION

Salmon-Based Protection Priority Category	Creek Name: Reach(es)
High	East Fork Nookachamps Creek: EF5 Mundt Creek: M1 Walker Creek: W1–W4
Moderate	Nookachamps Creek: N1, N2 East Fork Nookachamps Creek: EF1 Turner Creek: T3 Cold Spring Creek: CS1 Unnamed Tributary: UNK1-1, UNK1-2 Klahowya Creek: K2, K3
Low	East Fork Nookachamps Creek: EF2–EF4 Mud Lake Creek: Mud1 Turner Creek: T1, T2, T4 Little Day Creek: LD1, LD2 Mundt Creek: M2 Cold Spring Creek: CS2 Klahowya Creek: K1 Lake Challenge Outlet: C1

Six reaches were categorized as high priority for salmon-focused protection based on high salmon use (see **Table 8**) coupled with no or low impairment of habitat limiting factors (see **Table 14**). The high priority reaches include the upstream-most reach of East Fork Nookachamps Creek (EF5), all four Walker Creek reaches (W1–W4), and the lowermost reach of Mundt Creek (M1).

Nine moderate priority reaches for protection were identified. These include both Nookachamps Creek reaches (N1, N2) downstream of Barney Lake; the lowest reach of East Fork Nookachamps Creek (EF1) downstream of Highway 9; Turner Creek Reach T3 upstream from Elk Drive; the lower reach of Cold Spring Creek (CS1); both reaches of Unnamed Tributary 1 (UNK1-1, UNK1-2) to Cold Spring Creek; and the two upstream reaches of Klahowya Creek (K2, K3).

The remaining reaches were categorized as low priority. The low priority reaches include East Fork Nookachamps Creek Reaches EF2–EF4; Mud Lake Creek (Mud1); Turner Creek Reaches T1, T2, and T4; both reaches of Little Day Creek (LD1, LD2) near Beaver Lake; the upstream reach of Mundt Creek (M2); the upstream reach of Cold Spring Creek (CS2); the lower reach of Klahowya Creek (K1); and the Lake Challenge Outlet (C1).

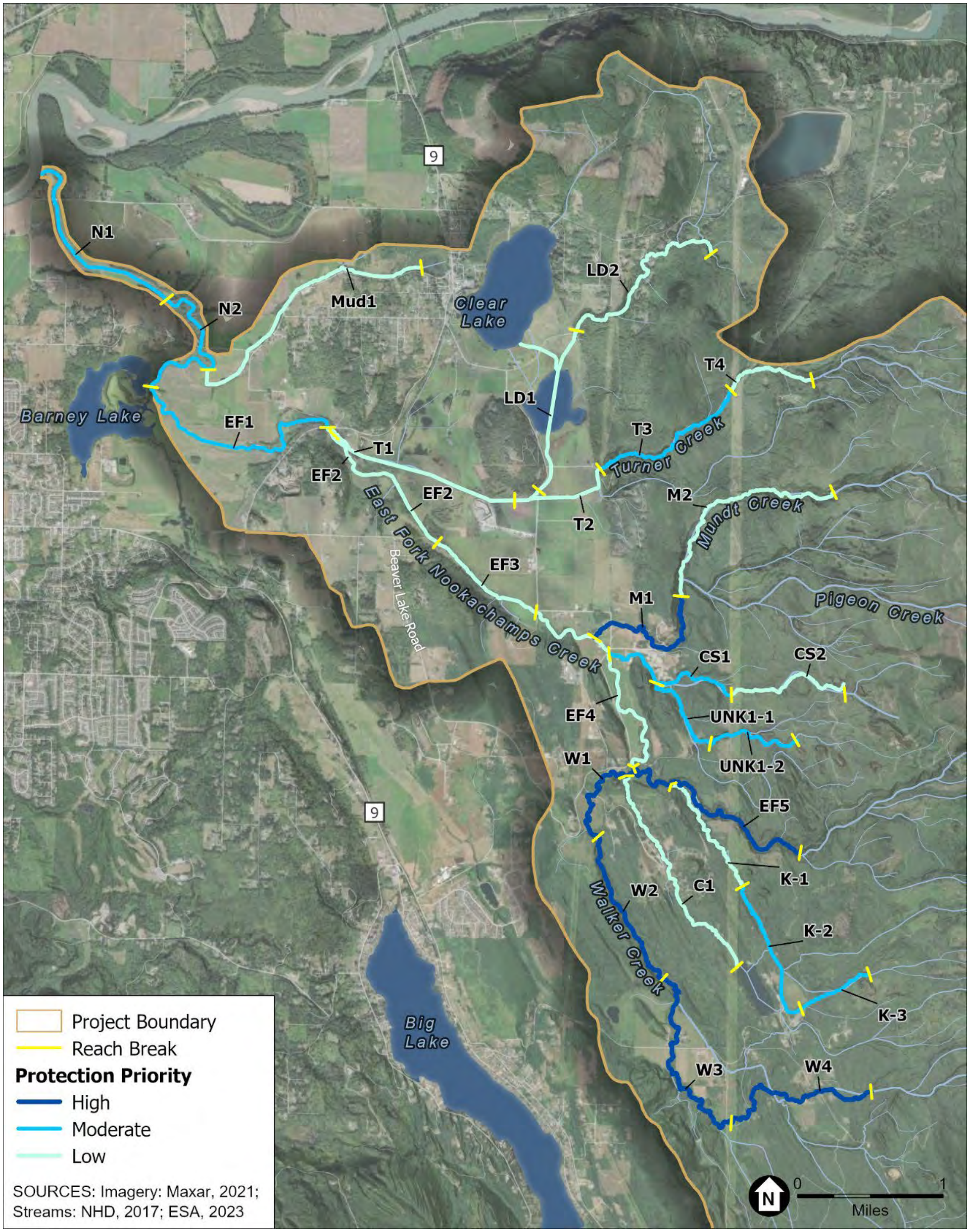


Figure 17.
Reach Protection Priorities for Salmon Based on Salmon Use and Habitat Needs

The drainage improvement priority category assignments are presented in **Table 30**. The rankings are intended to guide where to prioritize working first, if possible, but do not mean that no drainage improvements should be done in low priority reaches.

TABLE 30. PRIORITY ASSIGNMENT CATEGORIES FOR DRAINAGE IMPROVEMENTS AND FLOOD REDUCTION

Drainage Improvement and Flood Reduction Priority Category	Creek Name: Reach(es)
High	Nookachamps Creek: N1, N2 East Fork Nookachamps Creek: EF2, EF3 Mud Lake Creek: Mud1 Turner Creek: T1, T2 Little Day Creek: LD1
Moderate	East Fork Nookachamps Creek: EF1, EF4 Mundt Creek: M1 Cold Spring Creek: CS1
Low	East Fork Nookachamps Creek: EF5 Turner Creek: T3, T4 Little Day Creek: LD2 Mundt Creek: M2 Cold Spring Creek: CS2 Unnamed Tributary: UNK1-1, UNK1-2 Klahowya Creek: K1, K3 Lake Challenge Outlet: C1 Walker Creek: W1, W4

Eight reaches were categorized as high priority for drainage improvements and flood reduction based on drainage factor impairment and flooding risk (see **Table 23**). The high priority reaches include both Nookachamps Creek reaches (N1, N2) downstream of Barney Lake; the two East Fork Nookachamps Creek reaches (EF2, EF3) between Highway 9 and Beaver Lake Road; Mud Lake Creek (Mud1); the two Turner Creek reaches (T1, T2) downstream of Elk Drive; and the lower reach of Little Day Creek (LD1).

Four moderate priority reaches were identified. These include two East Fork Nookachamps Creek reaches (EF1, EF4), and the lowermost reaches of both Mundt Creek (M1) and Cold Spring Creek (CS1).

The remaining reaches were categorized as low priority. The low priority reaches include the upstream most reach of East Fork Nookachamps Creek (EF5); the two upstream most Turner Creek reaches (T3, T4); the upstream reaches of Little Day Creek (LD2), Mundt Creek (M2), and Cold Spring Creek (CS2); both reaches of Unnamed Tributary 1 (UNK1-1, UNK1-2) to Cold Spring Creek; all three reaches of Klahowya Creek (K1–K3); the Lake Challenge Outlet (C1); and all four Walker Creek reaches (W1–W4).

6.2 Multi-Benefit Restoration Priorities

The multi-benefit restoration priorities are presented in **Table 31** and **Figure 18**. These priorities reflect where restoration can address habitat needs for salmon and drainage issues for the community. The rankings are intended to guide where to prioritize working first, if possible, but do not mean that no restoration should be done in low priority reaches.

TABLE 31. PRIORITY ASSIGNMENT CATEGORIES FOR MULTI-BENEFIT RESTORATION

Multi-Benefit Restoration Priority Category	Creek Name: Reach(es)
High	Nookachamps Creek: N1, N2 East Fork Nookachamps Creek: EF1–EF4 Turner Creek: T1, T2
Moderate	East Fork Nookachamps Creek: EF5 Mud Lake Creek: Mud1 Turner Creek: T3 Little Day Creek: LD1 Mundt Creek: M1 Cold Spring Creek: CS1 Walker Creek: W1, W3, W4
Low	Turner Creek: T4 Little Day Creek: LD2 Mundt Creek: M2 Cold Spring Creek: CS2 Unnamed Tributary: UNK1-1, UNK1-2 Klahowya Creek: K1–K3 Lake Challenge Outlet: C1 Walker Creek: W2

Eight reaches were categorized as high priority for multi-benefit restoration based on salmon restoration priority and drainage restoration priority. The high priority reaches include both Nookachamps Creek reaches (N1, N2) downstream of Barney Lake, four reaches of East Fork Nookachamps Creek (EF1–EF4), and the two lowermost Turner Creek reaches (T1, T2).

Nine moderate priority reaches were identified. These include the upstream-most reach of East Fork Nookachamps Creek (EF5); Mud Lake Creek (Mud1); Turner Creek Reach T3; the lower reach of Little Day Creek (LD1); the lowermost reaches of both Mundt Creek (M1) and Cold Spring Creek (CS1); and three Walker Creek reaches (W1, W3, W4).

The remaining reaches were categorized as low priority. The low priority reaches include the upstream-most reach of Turner Creek (T4); the upstream reach of Little Day Creek (LD2) near Beaver Lake; the upstream reach of Mundt Creek (M2); the upstream reach of Cold Spring Creek (CS2); both reaches of Unnamed Tributary 1 (UNK1-1, UNK1-2) to Cold Spring Creek; all three reaches of Klahowya Creek (K1-K3); the Lake Challenge Outlet (C1); and Walker Creek Reach W2.

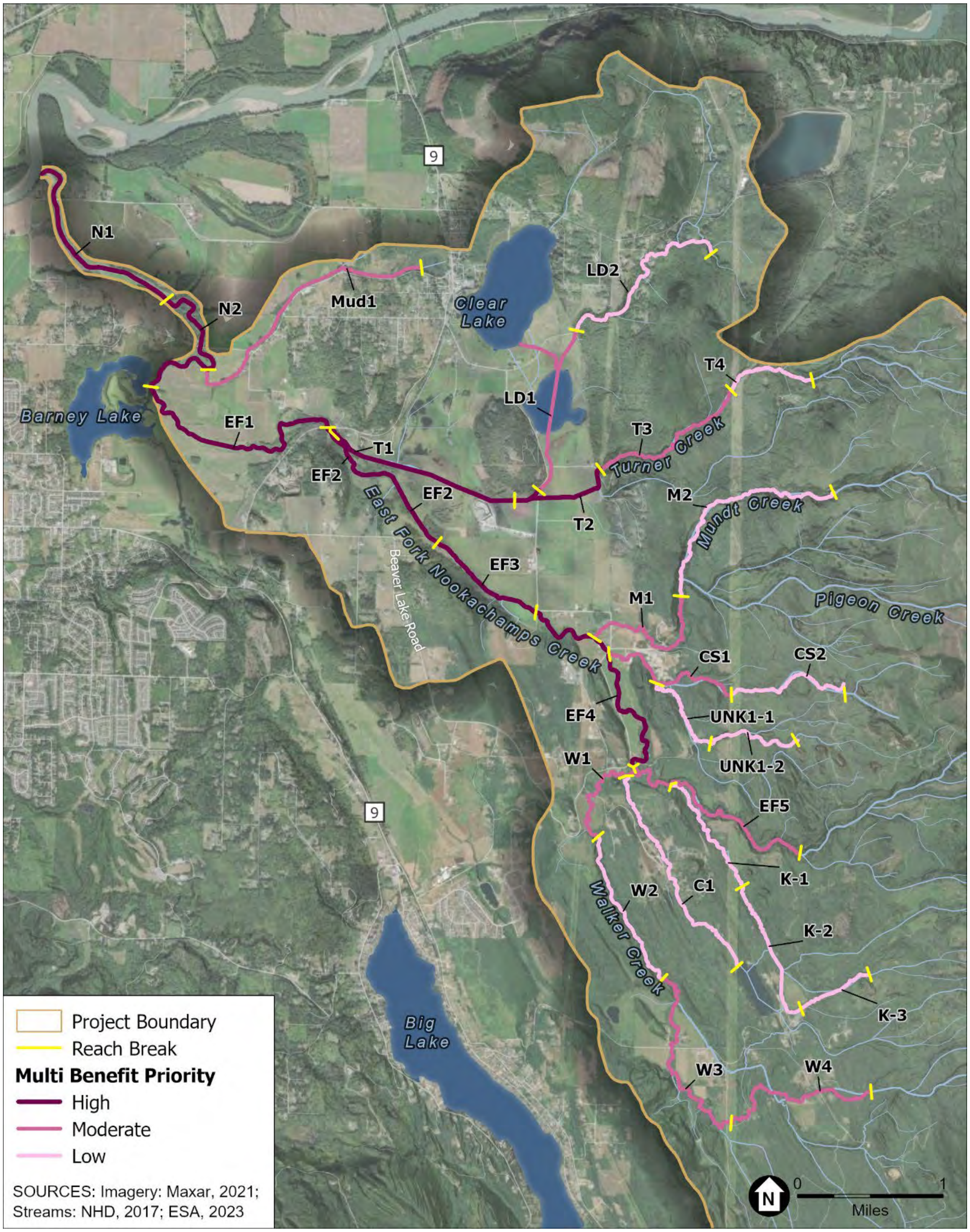


Figure 18.
Reach Multi-Benefit Priorities for Improving Salmon Habitat and Drainage Conditions

7. MANAGEMENT ACTION RECOMMENDATIONS

This section of the report represents a shift from the Watershed Assessment portion of the work into proposed actions to address the known physical and biological limiting factors affecting salmon recovery in the East Fork Nookachamps watershed. The approach described in the following sections is based on prioritizing specific treatments within specific reaches to offset or repair the issues standing in the way of improved physical and biological function within the watershed. Actions are primarily focused on those that will improve salmon and steelhead recovery with the expectation that many will also provide drainage improvements.

The East Fork Nookachamps Creek watershed was historically productive for salmonids, but changes in the fluvial environment since European settlement have degraded the supporting habitat. The Skagit Chinook Recovery Plan (SRSC 2005) emphasizes protection and restoration of Chinook rearing habitats, including mainstem river floodplains. Large tributaries and alluvial fans are also identified for their importance to Chinook spawning and rearing. Nookachamps Creek includes Tier 1 and Tier 2 priority areas for the recovery of Chinook salmon populations in the Skagit (SWC 2022). Nookachamps Creek up to Barney Lake (N1, N2) and East Fork Nookachamps Creek (EF1) downstream of Highway 9 are a Tier 1 priority area due to its association with mainstem Skagit River reaches that have high rearing potential and provide habitat for all six Skagit Chinook populations. East Fork Nookachamps Creek (EF2–EF5) is a Tier 2 priority area as a large tributary providing productive spawning and rearing habitats for Lower Skagit Fall Chinook salmon. This plan recognizes these Tier 1 and Tier 2 areas as high priority for habitat restoration. Additionally, the Nookachamps Creek basin encompasses one of the four demographically independent populations (DIP) of ESA-listed steelhead. No Skagit River-specific recovery plan exists for steelhead, and the Chinook Recovery Plan has made no attempt to prioritize reaches specifically for steelhead recovery. However, the vast majority of steelhead spawning in the Nookachamps Creek basin has been documented in East Fork Nookachamps Creek and its tributaries (Fowler and Turnbull 2016); hence, the actions described in this plan will benefit steelhead and will achieve progress toward recovery. This plan also emphasizes multi-species benefits, including actions that will support coho salmon and chum salmon.

Salmonid habitat restoration is needed to address impaired habitats and contribute to the recovery of salmon, steelhead, and trout populations in the East Fork Nookachamps Creek project area. As described in this Watershed Assessment, many of the highest priority areas and habitat needs for salmonids occur in areas where there is a need to improve drainage to reduce flooding. Many of the types of actions that would reduce flooding could be done in a way that also improves habitat for salmonids. Likewise, many of the types of actions that would improve habitat for salmonids could be done in a way that also reduces flooding.

The ability to implement restoration for salmonid habitat and/or improved drainage depends on the willingness of landowners. The actions described in this chapter will be most likely to proceed with the willingness and support of the landowners.

Given the importance of the salmonid populations and the drainage needs, multiple potential funding sources are available that can pay for the restoration actions. Many of the funding sources are state and federal grant funding programs with annual grant competitions to fund projects benefiting the resources targeted by the programs. There are currently many state and federal grant programs focused on restoring fish passage and salmon habitat. As competitive funding programs, the likelihood of receiving funding from them depends on the merits of the proposed project. In this way, restoration projects that provide substantial improvements to salmonid habitats, especially for Chinook salmon and steelhead, will be highly competitive to receive funding.

7.1 Types of Restoration Actions

Different types of restoration actions have been identified to improve salmon habitat and drainage in the project area. Ten types of location-specific restoration actions were identified with a subset of four also identified for reach scale application. Location-specific restoration actions are those recommended at specified sites within the project area (e.g., at a road crossing). Reach scale restoration actions are recommended to be applied wherever feasible within the reach. Part of the reason for identification of restoration actions is incomplete information on specific sites within reaches where there are opportunities to do the restoration work (e.g., major fine sediment source locations have not been inventoried, but restoration to address fine sediment inputs is recommended). These restoration action types are described below, followed by a description of actions needed in each reach. The restoration action types and associated symbols are presented in **Figure 19**.

All restoration actions require the willingness of landowners and would not occur without landowner approval. Landowners supporting restoration on their land can often receive compensation if a protective easement is established for the restoration area. Purchase of the land included in the restoration is another way landowners can be compensated for supporting restoration work.

Figure 19.
Restoration Action Categories to Improve Salmonid Habitat and Drainage

7.1.1 Fix Fish Passage Barriers

Manmade water crossings can restrict salmonid access if they are not properly sized and designed for the creek size, range of flow conditions throughout the year, and other key site factors (such as creek slope). Fish passage can be restored by replacing the culverts (pipes) with structures such as bridges or larger culverts. The design of a new crossing needs to be sized based on consideration of both the magnitude of high flows and the geomorphic setting of the site.

7.1.2 Address Roads Limiting Drainage and Habitat-Forming Process

Roads and roadway prisms can impact drainage when culverts are unable of fully convey creek flows. When road prisms extend into the floodway and are higher than surrounding areas, they act as berms, impounding water during flood events. Installing larger culverts or bridges at existing crossings and/or installing additional culvert crossings to allow more drainage across a road prism can reduce the impacts of roads on drainage. If feasible, more significant actions such as removing a road would provide greater drainage benefits. Roads also interrupt natural processes that create and maintain floodplain habitats, including those used by rearing Chinook salmon. Removing road fill, expanding existing stream crossings, and installing new crossings can alleviate these habitat impacts.

7.1.3 Remove Bank Armoring or Levees

Several types of hydromodifications function as bank armoring (e.g., riprap, rubble, manmade debris) or levees. These structures impact stream habitat and prevent channel-forming processes that connect, form, and maintain floodplain (off-channel) habitats (SRSC and WDFW 2005). The removal or replacement of bank armoring or levee structures can increase habitat complexity. Where needed, replacement of bank armoring with bank treatments that incorporate large wood can provide the desired bank protection in a manner that also provides beneficial edge habitat and wood structure for salmonids.

7.1.4 Reconnect Stream and Floodplain Processes

Floodplain habitats provide important refuge for salmonids to escape the fast water in channels during high flows that can carry juvenile salmonids downstream and out of the creek system. Connected floodplains allow river processes to connect and form important habitats, such as side channel and off-channel habitats, which are also accessible during lower flow conditions. In addition to the removal of bank armoring and levees and roads (described above separately), floodplain reconnection can include the recontouring of streambanks to increase channel widths and access to floodplain habitats. If needed, floodplain reconnection projects can include features setback from the channel to prevent flooding of adjacent properties outside of the reconnection area.

7.1.5 Increase In-Channel Complexity

Creek systems with a variety of aquatic habitats, multiple channels, and instream structure are more complex and offer habitat for all freshwater life stages of salmonids. Habitat restoration through actions such as adding channel length, creating side channels or off-channel habitats, and installing large wood all provide substantial improvements to salmon habitats.

7.1.6 Restore Native Riparian Commuities

Native riparian vegetation (i.e., trees and shrubs adjacent to streams) provides many beneficial functions for salmonid habitat and drainage. Riparian vegetation can keep stream temperatures cooler by decreasing solar exposure to the water (Ecology 2008). The shading benefits of riparian vegetation are critical to keeping water as cool as possible for cold water fish species such as salmonids. Large woody debris input from mature riparian zones provides habitat structure used by juvenile and adult salmonids and is key to pool-formation and habitat complexity (SRSC and WDFW 2005). Riparian vegetation contributes to good salmon habitat by providing bank stability, organic matter providing nutrients, insect production, and small and large woody debris (Washington State Conservation Commission 2003; SRSC and WDFW 2005). Riparian vegetation, especially in headwater areas, can increase the infiltration of rainwater and slow the delivery of precipitation to the stream channel. Both of these functions can reduce flooding of downstream areas.

Wide riparian buffers provide the range of functions described above and are the most beneficial condition for the health of the stream and salmonid populations. In areas where the opportunity for a wide riparian buffer is compromised by adjacent land uses, a narrower vegetation buffer would provide some benefit to the creek. Most notably, riparian vegetation that shades the stream channel can provide important benefits by reducing water temperatures (or reducing their potential to increase).

7.1.7 Reduce Fine Sediment Inputs

Excessive amounts of fine sediments can lower the survival rate of eggs deposited in the gravel due to decreased oxygen supply or blocked emergence of hatched salmonid fry (Washington State Conservation Commission 2003; SRSC and WDFW 2005; Jensen et al. 2009). Numerous studies have shown a strong negative relationship between fine sediment and salmonid egg survival to emergence, such that small increases in fine sediment amounts lead to large decreases in egg survival (Chapman 1988; Bash et al. 2001). Excessive sediment and suspended sediments also have multiple detrimental effects on salmon rearing and spawning (Newcombe and MacDonald 1991; Bash et al. 2001). Large amounts of sediment can fill in the interstitial spaces of larger substrates, called embeddedness, and fill pools, which reduces benthic invertebrate production and reduces juvenile salmon access to hiding places among cobbles, large wood, and in pools (SRSC and WDFW 2005). Suspended sediment has lethal, sublethal, and behavioral impacts through mechanisms such as gill clogging and reduced foraging and prey detection (Newcombe and MacDonald 1991; Bash et al. 2001).

Sedimentation derived from land use activities is a major cause of habitat degradation (Bash et al. 2001). Land use practices can alter the delivery of fine and coarse sediments to streams, through alteration of vegetation, hydrology, and soil structure. Residential development, logging, grazing, agriculture, and stream channelization all affect upslope and instream conditions, contributing to sediment loads (Berman 1998). Given the connectivity of creek reaches as water and sediment flows downstream, this is a habitat limiting factor in which habitat quality in one reach is often related to the conditions upstream (e.g., logging and removal of vegetation in upper watershed areas can increase sediment loads to downstream portions of the creek).

Actions to reduce the input of fine sediment can be highly beneficial to salmonids. This can be achieved through actions that address bank erosion using fish-friendly techniques, such as using large wood with interstitial spaces in log jams. This restoration action is shown as a reach scale application in most reaches, as a detailed sediment source investigation was not part of this study and therefore location specific sediment sources will be identified through future efforts and likely as part of broader restoration treatment designs.

7.1.8 Forest Road Maintenance

While commercial forestry practices have improved over time to reduce stream impacts and are now regulated with creek systems in mind, there are several ways to further reduce the impact of forestry operations, including forest road and road crossing maintenance, and wider vegetated corridors along creeks. If feasible, decommissioning forest roads can reduce the number of water crossings and the potential for fine sediment inputs and allow for revegetation throughout the road corridor. Adding vegetation in riparian areas (described separately) and in areas beyond the riparian zone can slow water and erosion that also deliver sediments to creek systems.

7.1.9 Manage Excessive Sediment Loads

Sediment transport and deposition throughout the project area affect both drainage and habitat conditions. The deposition of large quantities of sediment from upstream areas can form large gravel bars and over time, raise the channel bed, and create barriers to ide channels. This reduces channel conveyance capacity and limits the amount of flow a channel can convey before overtopping its banks. It can also widen channels and fill in pools, resulting in simplified channels, shallower depths, and disconnection from groundwater, leading to increased summer water temperature and decreased summer flows. The delivery of large quantities of sediment during winter storms can also bury salmon redds and suffocate incubating eggs. Actions to manage excessive sediment volumes outside of the wetted channel can reduce sediment deposition in low gradient downstream reaches, thus retaining channel conveyance capacity.

We recognize that sediment deposition is a natural geomorphic process in the watershed, even though volumes and timing of delivery have been altered via upper watershed logging and lower watershed development and hydromodification. Sediment management is considered a viable action only where it is combined with other, process-based solutions such as levee setbacks and stream and floodplain connectivity. Any removal of sediment from the system will be done in a manner to minimize impacts and will be appropriately mitigated. Even if the maximum potential for process-based restoration could be implemented in the EFNC, it must be considered that the sediment loads are so high that negative consequences to fish habitat could result regardless, and therefore sediment management may be a viable strategy in concert with other restoration approaches.

7.1.10 Modify Lake Connections

Clear Lake and Beaver Lake contain warm water during summer months that flows into and raises water temperatures in Little Day Creek and Turner Creek. As cold water species, salmonids require cooler water, and the warmer temperatures can have behavioral (e.g., avoidance), sublethal (e.g., reduced fitness), and lethal effects on salmonids. Clear Lake also supports warmwater fish species known to be predators of juvenile salmonids, such as largemouth bass and yellow perch. These warmwater fish may migrate out of the lakes to prey on juvenile salmonids in the creeks. The water quality relationship between the lakes and Turner Creek needs to be investigated further.

7.1.11 Examples of Each Action Types and Linkages to Habitat Limiting Factors and Drainage Factors

Table 32 provides examples of more specific actions within each category and the linkages to the habitat and drainage limiting factors.

TABLE 32. MANAGEMENT ACTIONS LINKAGES AND TARGET CONDITIONS

Management Action	Example Action Elements
Fix Fish Passage Barriers	• Replace undersized culvert with larger culvert or bridge that complies with state requirement to ensure stream function. • Remove crossing structure.
Address Roads Limiting Drainage	• Replace undersized culvert with larger culvert or bridge. • Remove crossing structure. • Add new crossings through road prism. • Remove or relocate road prism.
Remove Bank Armoring or Levees	• Remove bank armoring. • Remove levee. • Replace bank armoring (e.g., riprap, rubble, manmade debris) with fish-friendly designs incorporating wood to provide fish habitat. • Setback levee to allow wider channel and increased floodplain connectivity and incorporate wood to provide fish habitat.
Reconnect Stream Channel and Floodplain Processes	• Recontour (set back) streambanks to increase conveyance capacity and floodplain inundation when channel capacity is exceeded. • Other management actions such as removing bank armoring or levees and addressing road prisms will also help reconnect floodplains.
Increase Instream Habitat Complexity	• Add channel length through re-meandering. • Add edge habitat, pools, and riffles through re-meandering, side channel creation/activation, off-channel creation, and large wood installation. • Install large woody debris for salmon cover and refuge.
Restore Riparian Vegetation	• Plant riparian corridors of native trees that will cast shade on stream channel, slow runoff, and provide long-term source of large woody debris.
Reduce Fine Sediment Inputs	• Recontour (set back) streambanks to reduce bank erosion. • Use fish-friendly bank treatments with large wood to reduce bank erosion contributing fine sediment to the creek.
Forest Road Maintenance	• Maintain forest roads and water crossings to reduce erosion and washouts.

Management Action	Example Action Elements
Manage Excessive Sediment Loads	• In combination with habitat restoration actions, remove sediment from floodplain and unwetted depositional areas to reduce sediment loads. Requires regular monitoring to evaluate effects to inform whether continuation of action is an effective component of restoration in project area.
Modify Lake Connections	• Block connection of Clear Lake to Beaver Lake during summer months to reduce input of warm water and warmwater fish species into Little Day Creek and Turner Creek. • Block connection of Clear Lake and Beaver Lake to Little Day Creek and Turner Creek during summer months to reduce input of warm water and warmwater fish species.

7.2 Conservation and Protection Actions

In addition to the restoration actions, there are several types of conservation actions that can protect salmon habitat in the East Fork Nookachamps Creek project area. Protection actions can include purchase of land outright or through conservation easements that limit the types of changes a landowner can make on the land. Example conservation easements include payment to establish a vegetated riparian corridor. Protection of water resources, especially those contributing cold water, would be especially beneficial given the lowland setting of the project area. Currently and even more so in the future with expected changes, cold water resources are highly important for salmonids. Water protection through water rights and water use conservation are effective tools for preserving limited streamflow during summer months.

All protection actions require the willingness of landowners and would not occur without landowner approval. Landowners supporting restoration on their land can often receive compensation if a protective easement is established for the restoration area. Purchase of the land included in the restoration is another way landowners can be compensated for supporting restoration work.

7.3 Management Action Recommendations by Sub-watershed

To address the salmon habitat and drainage needs in the East Fork Nookachamps Creek project area, potential locations for implementing the restoration actions were identified and organized geographically by sub-watershed. Recommendations for each reach are presented in a map series (**Figure 20, Sheets A through H**) and described in the following sections by location.

None of the actions shown would occur without willing landowners. An action on the map does not imply landowner willingness. It is expected that some potential restoration actions have been identified in locations that do not have landowner support at this time. The actions are shown to identify the type and location of where beneficial projects to address salmonid habitat and drainage deficiencies are recommended if landowners are willing.

Evaluating the feasibility of these actions is a crucial first step, along with the identification of willing landowners. There may be site constraints, such as public/private safety, property rights, and project costs, which make an identified action infeasible or less feasible.

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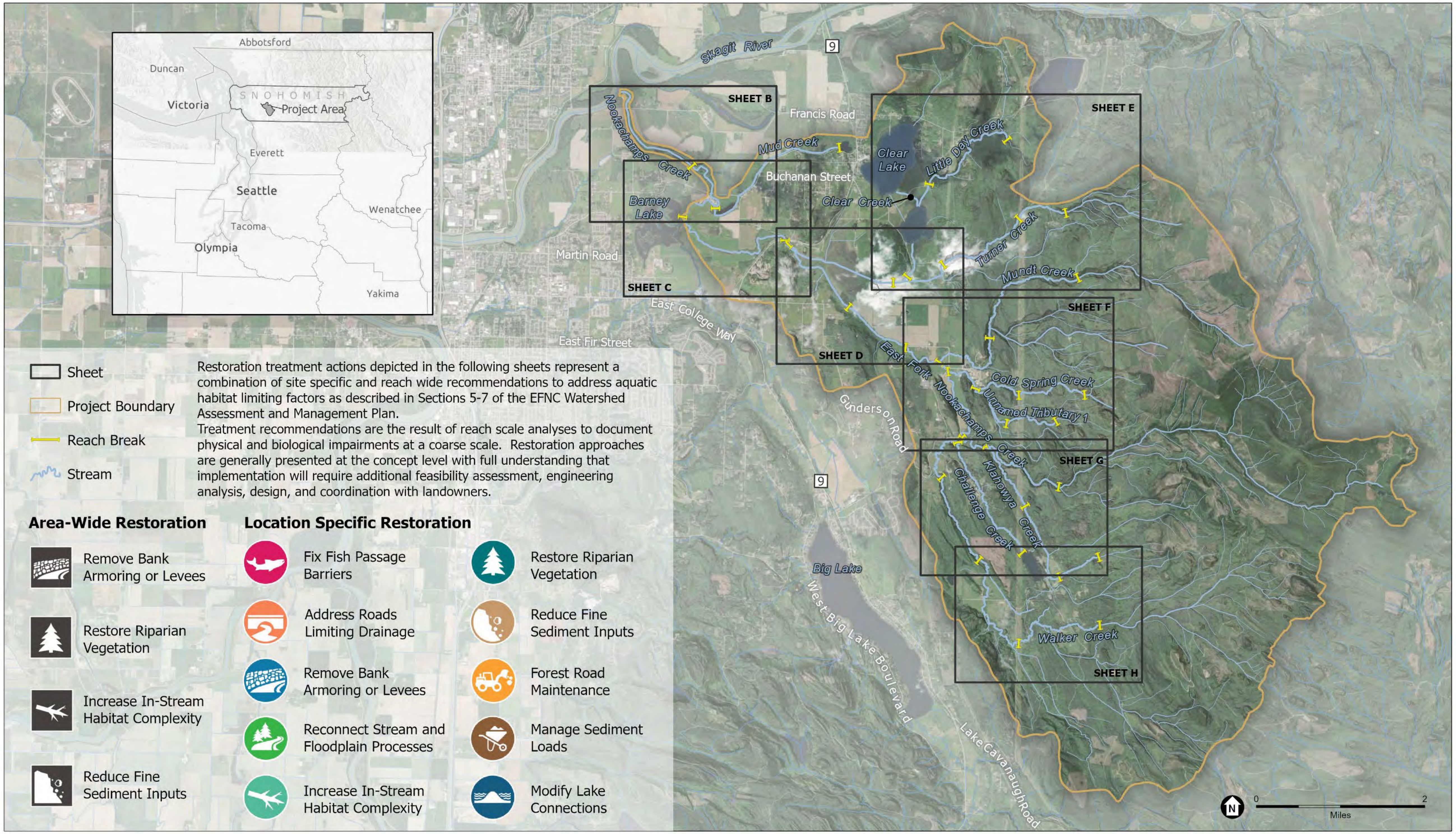


SOURCES: Imagery: Maxar, 2021; Streams, ESA, 2023

East Fork Nookachamps Watershed Assessment

Figure 20
Map Series of Recommended Restoration Actions in East Fork Nookachamps Creek Watershed

Sheet A of H

ESA

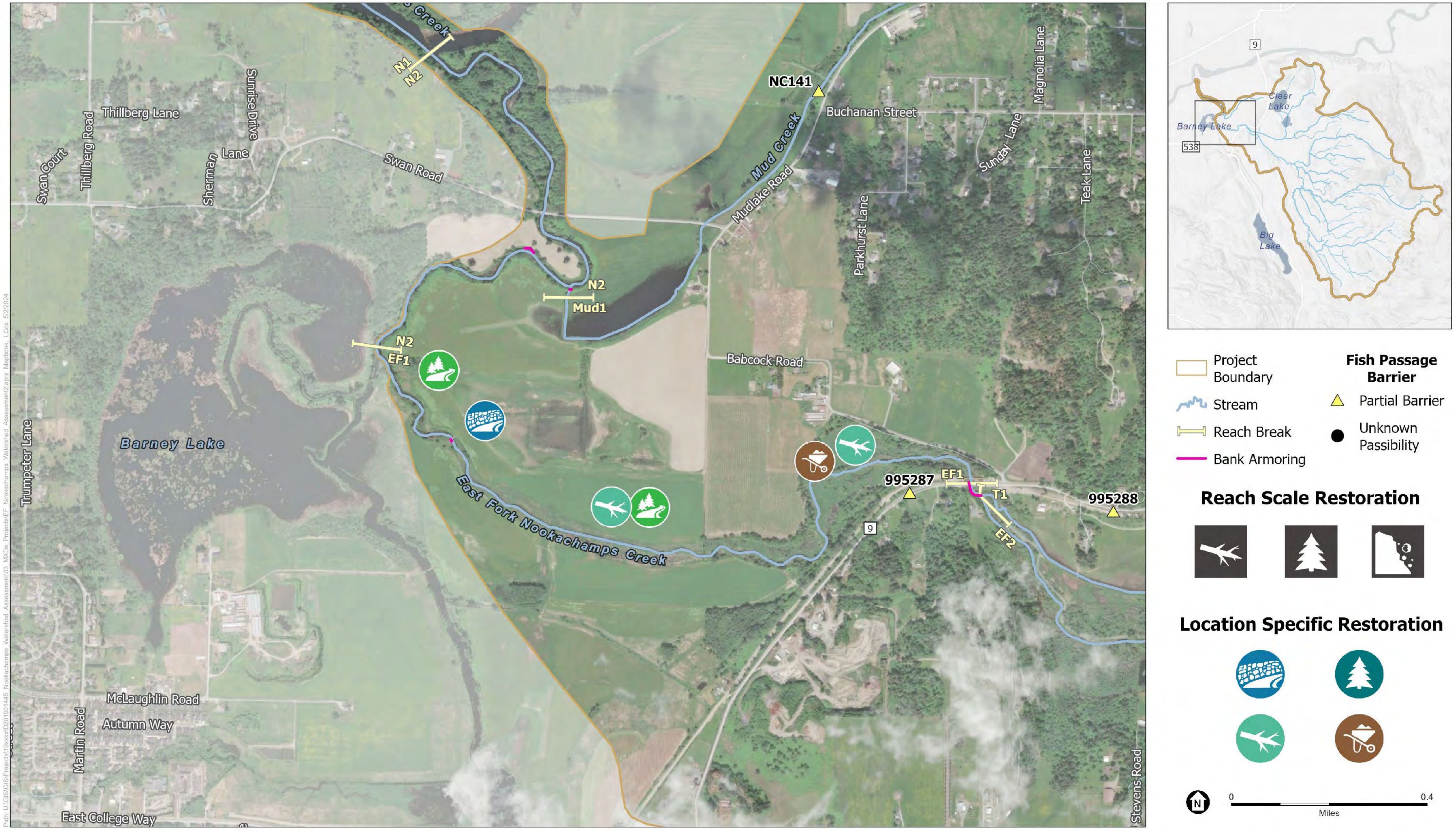
SOURCES: Imagery: Maxar, 2021; Bank Armoring: Upper Skagit Indian Tribe, 2015; Streams, ESA, 2023

East Fork Nookachamps Watershed Assessment

Figure 20
Nookachamps Creek (N1, N2) and Mud Lake Creek (Mud1)

Sheet B of H

ESA



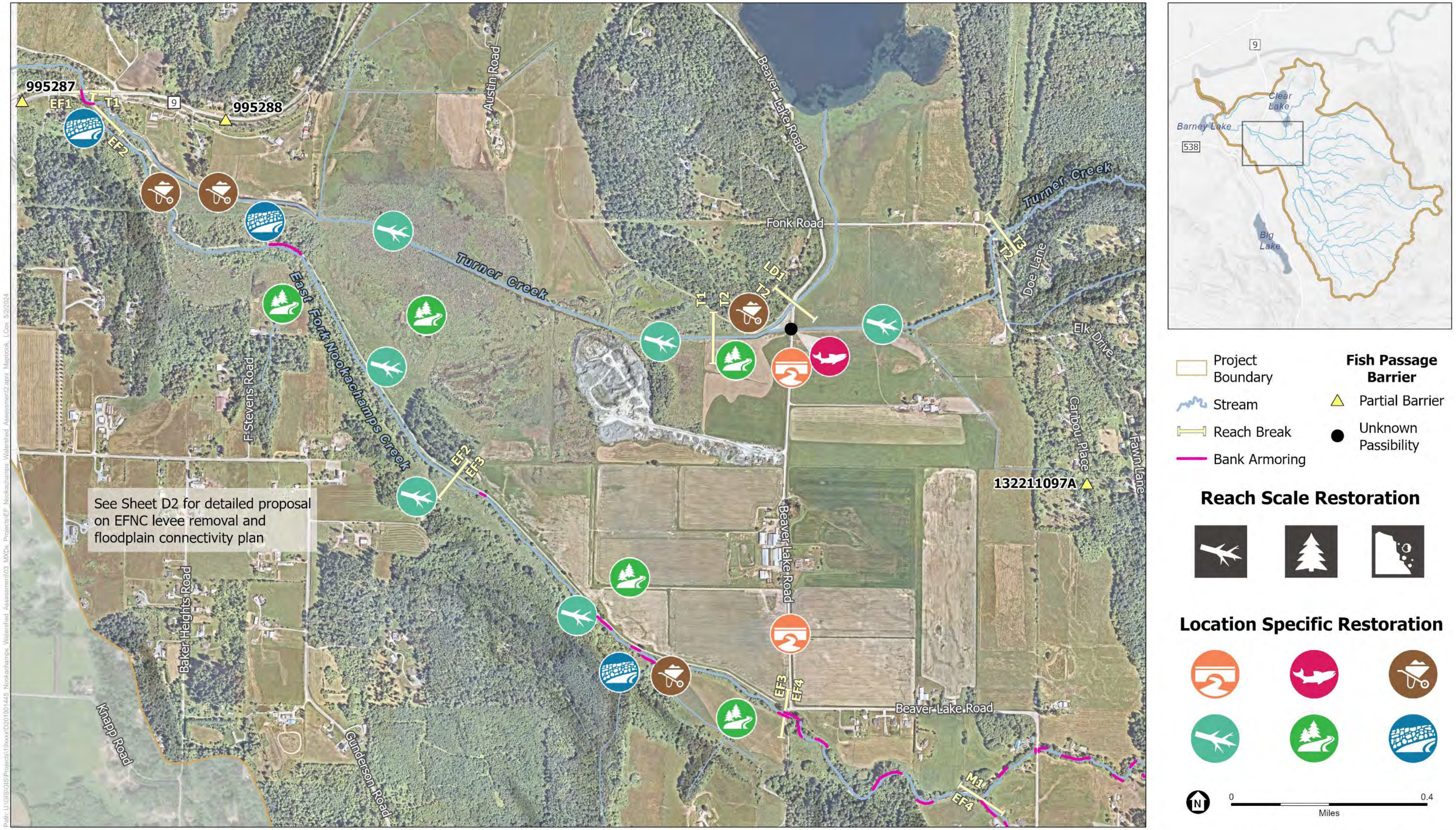
SOURCES: Imagery: Maxar, 2021; Bank Armoring: Upper Skagit Indian Tribe, 2015; Streams, ESA, 2023

East Fork Nookachamps Watershed Assessment

Figure 20
East Fork Nookachamps Creek (EF1)

Sheet C of H

ESA



SOURCES: Imagery: Nearmap, 2022; Bank Armoring: Upper Skagit Indian Tribe, 2015; Streams, ESA, 2023

East Fork Nookachamps Watershed Assessment

Figure 20
East Fork Nookachamps Creek (EF2, EF3) and Turner Creek (T1, T2)

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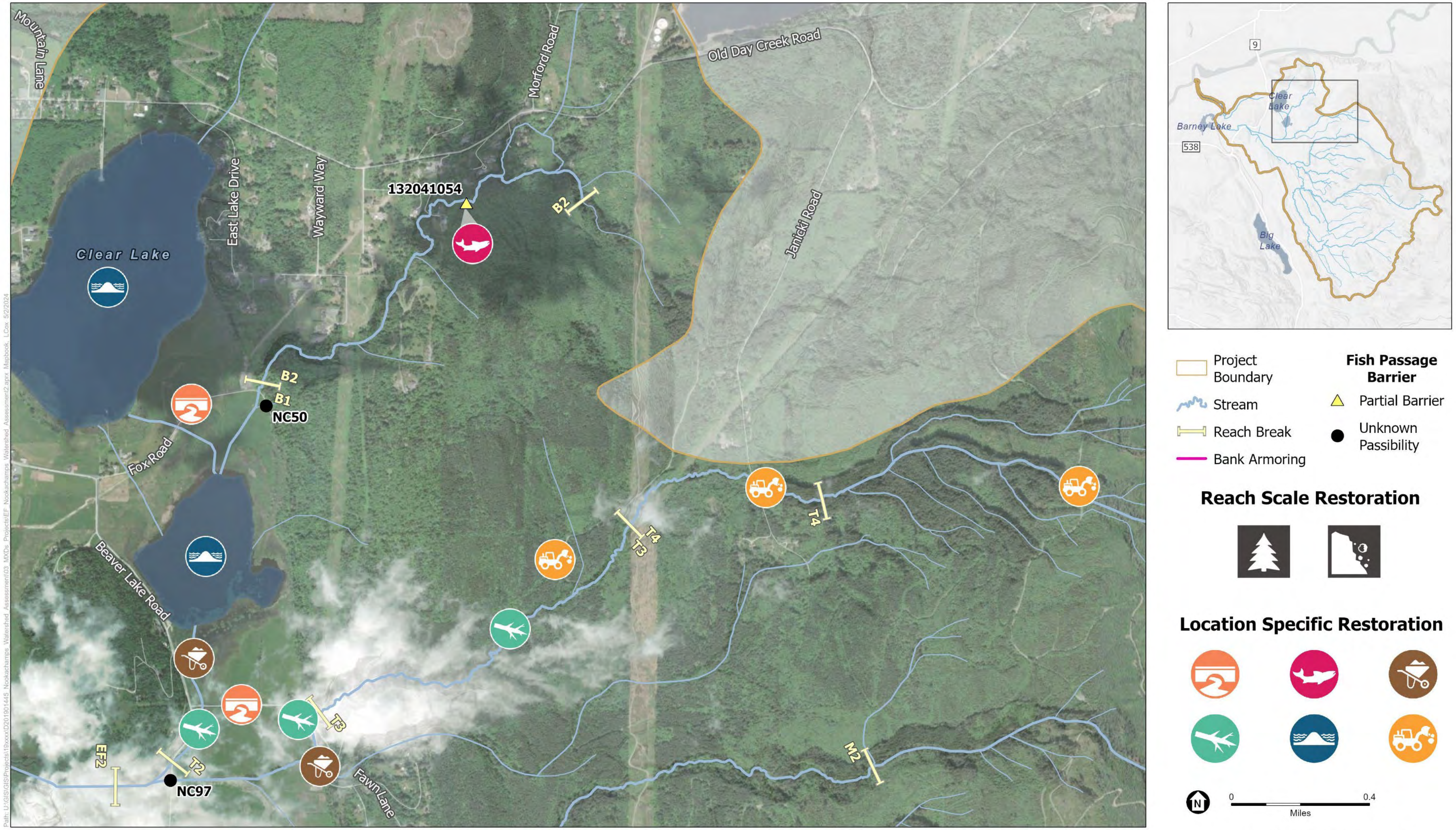

SOURCES: Imagery: Maxar, 2021; Bank Armoring: Upper Skagit Indian Tribe, 2015; Streams, ESA, 2023

East Fork Nookachamps Watershed Assessment

Figure 20
Little Day Creek (L1, L2) and Turner Creek (T3, T4)

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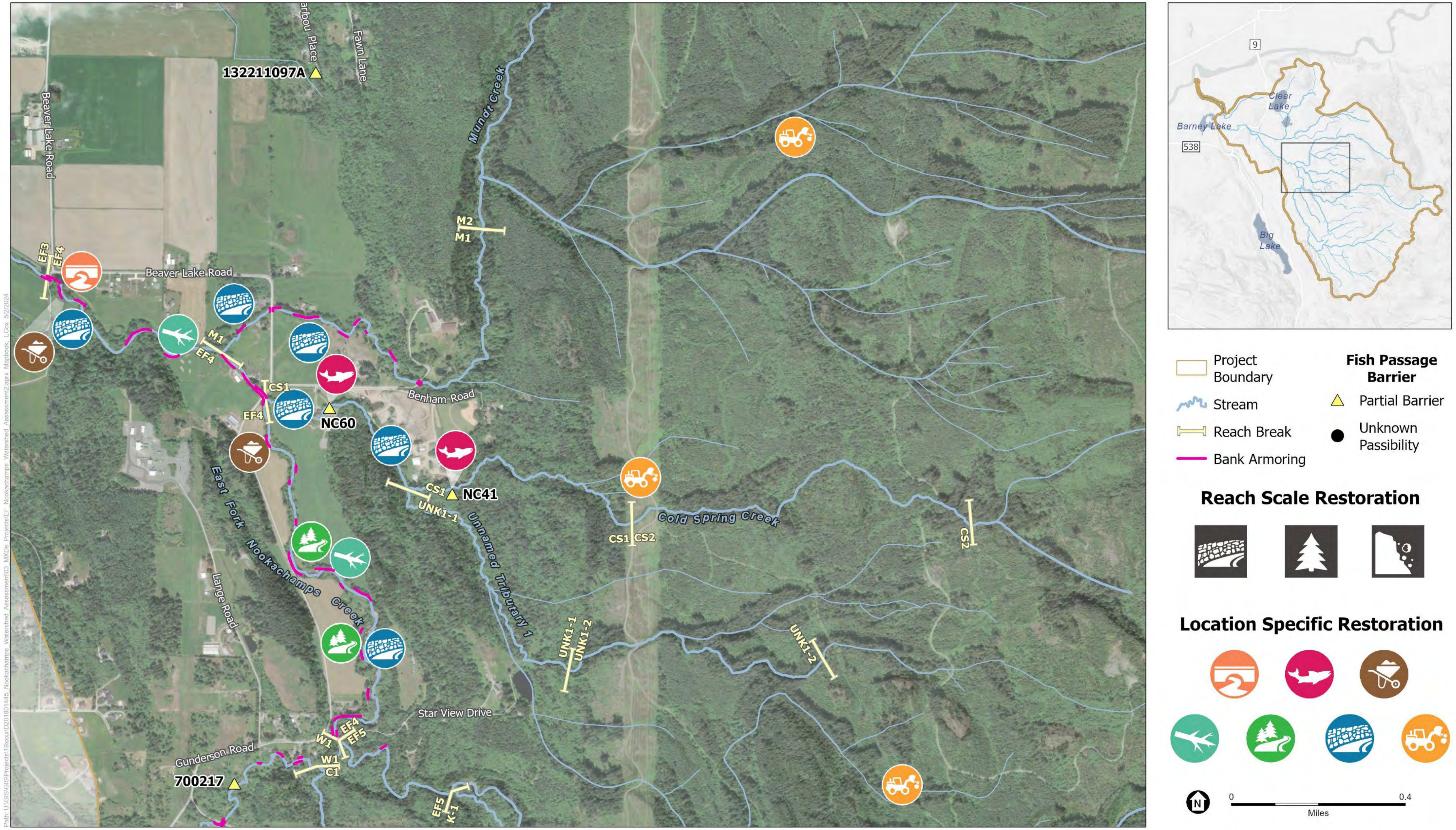

SOURCES: Imagery: Maxar, 2021; Bank Armoring: Upper Skagit Indian Tribe, 2015; Streams, ESA, 2023

East Fork Nookachamps Watershed Assessment

Figure 20
East Fork Nookachamps Creek (EF4), Mundt Creek (M1, M2), Cold Spring Creek (CS1, CS2), and Unnamed Tributary (UNK1-1, UNK1-2)

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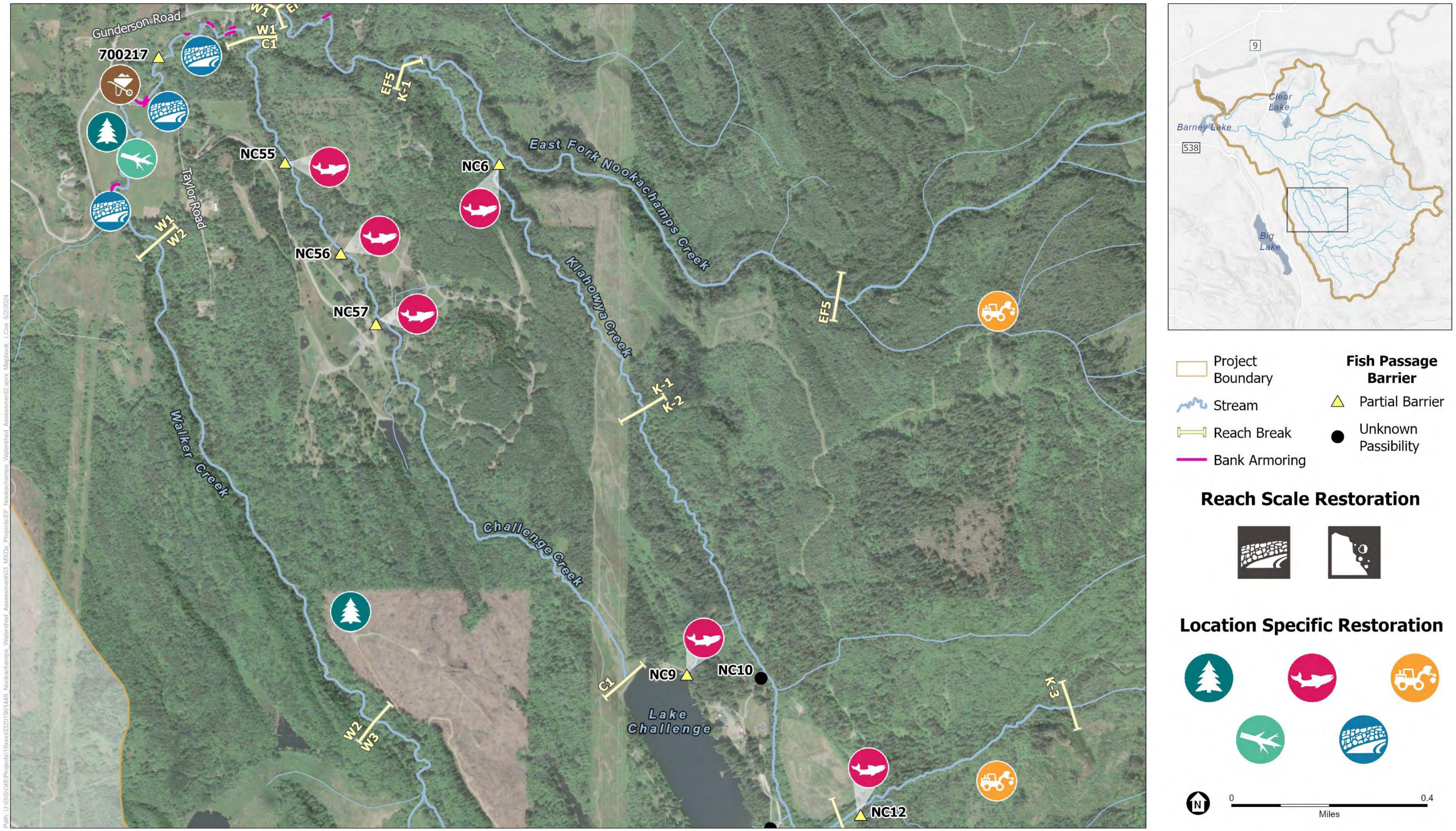

SOURCES: Imagery: Maxar, 2021; Bank Armoring: Upper Skagit Indian Tribe, 2015; Streams, ESA, 2023

East Fork Nookachamps Watershed Assessment

Figure 20
East Fork Nookachamps Creek (EF5), Klahowya Creek (K1, K2, K3), Outlet to Lake Challenge (C1), and Walker Creek (W1, W2)

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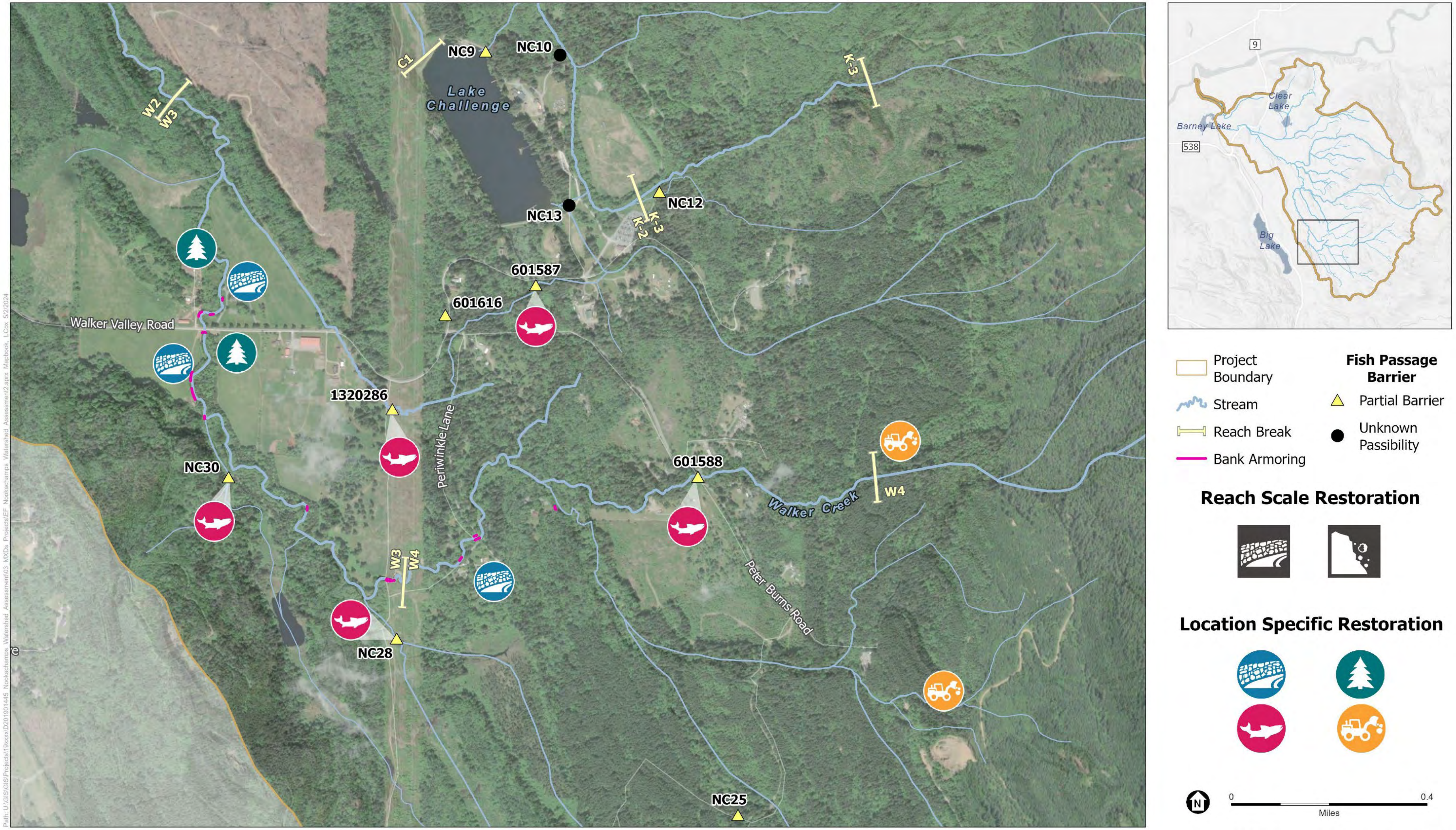

SOURCES: Imagery: Maxar, 2021; Bank Armoring: Upper Skagit Indian Tribe, 2015; Streams, ESA, 2023

East Fork Nookachamps Watershed Assessment

Figure 20
Walker Creek (W3, W4)

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ESA

7.3.1 Nookachamps Creek (N1, N2) and Mud Lake Creek (Mud1)

Level of Priority by Reach

Stream	Reach	Salmon Habitat Restoration Priority	Salmon Habitat Protection Priority	Drainage Improvement and Flood Reduction Priority	Multi-Benefit Priority
Nookachamps Creek	N1	high	moderate	high	high
	N2	high	moderate	high	high
Mud Lake Creek	Mud1	low	low	high	moderate

Restoration Actions

Reach Scale Needs

Location-specific Needs

Strategy

These reaches are within the Skagit River floodplain and are especially susceptible to backwatering from the Skagit River. Actions focusing on improving drainage to reduce the length of time of backwater-related flooding occurs would be most beneficial. Road prisms and culverts should be evaluated to better understand their impact on flooding and the feasibility of making drainage improvements through modification, replacement, or removal actions.

As the lowest reaches in the project area, this area is the most likely to be used by salmon and steelhead originating from other parts of the watershed, as well as those originating in the East Fork Nookachamps Creek project area. The importance of these habitats for other salmonid stocks is reflected in these reaches being identified as a Chinook salmon recovery Tier 1 priority area as floodplain areas benefiting multiple stocks (SWC 2022). Tributaries flowing through mainstem floodplain habitats are priority areas for salmon recovery.

0- to 10-Year Goals

Develop and implement two habitat restoration projects focusing on installing large wood, removing bank armoring, and restoring the riparian corridor.

Replace the fish passage barrier with a fish-passable structure.

Evaluate the effectiveness and feasibility of potential road prism and water crossing changes to improve drainage.

10- to 20-Year Goals

Develop and implement a drainage improvement project to reduce the impacts of the road prism and/or water crossings.

Develop and implement floodplain reconnection project to improve connectivity to off-channel habitats

Near-term habitat restoration work in these reaches should focus on identifying willing landowners and feasible opportunities to install large wood for aquatic habitat structure, improve connectivity to off-channel habitat, and expand work-to-date restoring riparian habitats. In addition, there are discrete locations in these reaches to remove bank armoring and address a partial fish passage barrier. Longer term and where possible, projects should attempt to combine multiple action types to achieve multiple improvements to salmonid habitat, including floodplain reconnection and levee setback. Also, a bank armor removal site may also be a good location to install large wood to provide comparable bank stabilization benefits to reduce fine sediment inputs and improve habitat complexity, as well as plant native riparian vegetation.

7.3.2 East Fork Nookachamps Creek (EF1)

Level of Priority by Reach

Stream	Reach	Salmon Habitat Restoration Priority	Salmon Habitat Protection Priority	Drainage Improvement and Flood Reduction Priority	Multi-Benefit Priority
East Fork Nookachamps Creek	EF1	high	moderate	moderate	high

Restoration Actions

Reach Scale Needs

Location-specific Needs

Strategy

This reach is within the Skagit River floodplain and is especially susceptible to backwatering from the Skagit River. There are no road prisms in the reach, but two former bridge abutments constrict the channel in one location. Drainage could be improved throughout the reach by expanding the channel capacity and increasing floodplain connectivity through setting back streambanks.

Near-term habitat restoration work in this reach should focus on identifying willing landowners and feasible opportunities to reconnect the floodplain, install large wood for aquatic habitat structure, expand work-to-date restoring riparian

0- to 10-Year Goals

Remove the former bridge abutments.

Develop and implement one habitat restoration project focusing on installing large wood and restoring the riparian corridor near the upstream end of the reach.

Develop and implement one habitat restoration project focusing on creating a high flow side channel with large woody debris and native vegetation in a wide riparian corridor.

10- to 20-Year Goals

Develop and implement a second habitat restoration project focusing on creating a high flow side channel with large woody debris and native vegetation in a wide riparian corridor.

habitats, and expand channel capacity and floodplain connectivity. Where possible, projects should combine multiple action types to achieve multiple improvements to salmon habitat and drainage. For example, a project to create a side channel and improve floodplain connectivity could also include the installation of large wood and the planting of native riparian vegetation.

7.3.3 East Fork Nookachamps Creek (EF2, EF3) and Turner Creek (T1, T2)

Level of Priority by Reach

Stream	Reach	Salmon Habitat Restoration Priority	Salmon Habitat Protection Priority	Drainage Improvement and Flood Reduction Priority	Multi-Benefit Priority
East Fork Nookachamps Creek	EF2	high	low	high	high
	EF3	high	low	high	high
Turner Creek	T1	high	low	high	high
	T2	high	low	high	high

Restoration Actions

Reach Scale Needs

Location-specific Needs

Strategy

These reaches are extremely important for salmonid populations and drainage conditions in the East Fork Nookachamps Creek project area. These reaches provide spawning and rearing habitat for all salmonid species in the area, including Chinook salmon and steelhead. This is also a low-gradient reach in which land uses have reduced the natural capacity of the area to function and floodplain wetland habitat able to accommodate fluctuating water levels throughout the year.

Any opportunity to implement both reach scale and location specific actions would be especially beneficial. Decades of land uses and modifications to reduce floodplain connectivity have contributed to very different stream profiles in East Fork Nookachamps Creek (higher channel elevation) and Turner Creek (lower channel elevation). This situation needs to be remedied to allow for management actions that benefit both creek systems. Currently, the channel bed of East Fork Nookachamps Creek is multiple feet higher than Turner Creek and the surrounding fields, due to sediment aggradation in the confined channel. Ideally for habitat and drainage benefits, channel networks in the floodplain between the creeks could be formed and maintained through natural processes. This requires increasing sediment transportation within the reaches, allowing sediment to move through the system or not deposit in this portion of the creek. A single action to engineer a solution is not sustainable without aggressive maintenance and is therefore not recommended. Instead, multiple actions are recommended to improve salmonid habitat and manage excessive sediment to lower the stream profile of East Fork Nookachamps Creek.

Figure 21 presents a multi-phase strategy for this area. This strategy is described below. Actions to increase salmonid habitat by creating side channels with large wood for habitat complexity and a native riparian vegetation canopy over the channels, removing bank armoring and replacing with fish-friendly structures using large wood, and setting back the streambanks to increase channel capacity. These actions would deliver more sediment bedload to floodplain habitats while also increasing salmonid habitat. A complementary action to reduce the sediment bedload that, based on reach aggradation, has exceeded the sediment transport capacity through the reach, is to selectively remove sediment from the system. Any such action would need to be carefully planned and implemented to avoid or minimize potential effects to salmonids and salmonid habitat (e.g., removing sediment from the system from a floodplain area or depositional area during low-flow periods such that the work could be completed entirely in dry conditions disconnected from the surface and groundwater connections to the stream channel).

The purpose of these combined habitat and sediment management actions would be to improve the reaches' response to natural fluvial processes such that the stream profile of East Fork Nookachamps Creek is lowered over time. Each aspect of the project will need to be monitored over time to evaluate the contribution of the action and the overall effectiveness of the entire suite of actions. Most critically, monitoring is recommended for the action and the stream profile throughout the reaches to evaluate whether sediment management is functioning as intended and whether additional actions should be implemented.

<u>0- to 10-Year Goals</u>

Develop and implement one habitat restoration project in East Fork Nookachamps Creek focusing on creating side channels with large woody debris and native vegetation in a wide riparian corridor, as well as including sediment management to remove sediment bedload and lower the stream profile over time.

Develop and implement one habitat restoration project in Turner Creek focusing on installing large woody debris, recontouring the channel to create complex edge habitat, and establishing native vegetation in a wide riparian corridor.

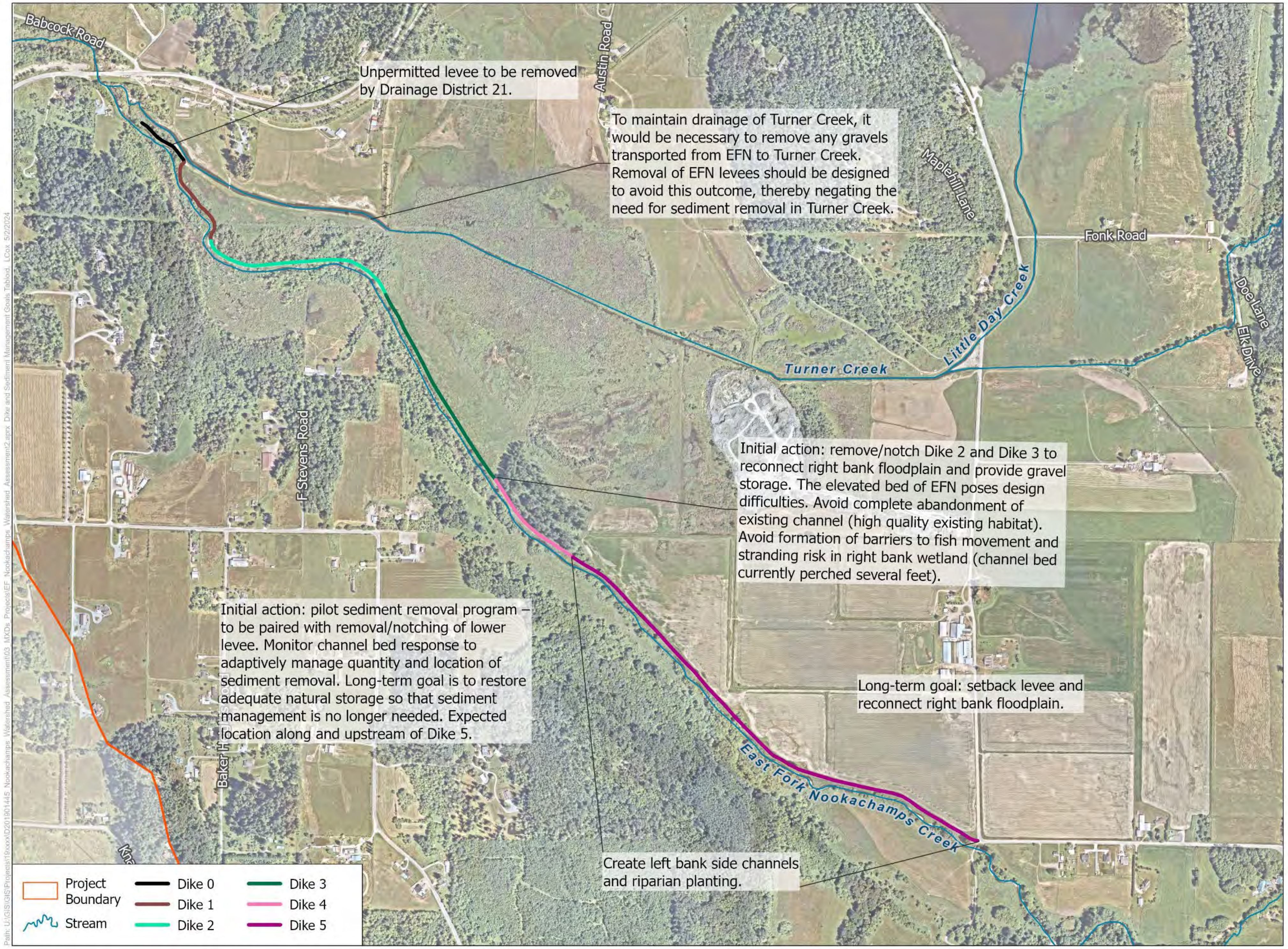
Evaluate the effectiveness and feasibility of potential changes to the road prism and/or culverts along Beaver Lake Road to improve drainage.

Plant native riparian vegetation and control invasive vegetation to entirely shade Turner Creek in as wide a corridor as feasible.

<u>10- to 20-Year Goals</u>

Develop and implement a second habitat restoration project in East Fork Nookachamps Creek focusing on creating side channels with large woody debris and native vegetation in a wide riparian corridor, as well as including sediment management to remove sediment bedload and lower the stream profile over time.

Evaluate the effectiveness and feasibility of potential changes to the DD21 levee and reconnection of the right bank floodplain for drainage and habitat improvements.



SOURCE: Imagery: Nearmap, 2022; Streams: ESA, 2023

Near-term actions in reach 2 and 3 of EFN must be designed with existing land-use patterns in mind.

We propose a phased approach with initial actions focused on the lower levee and a long-term goal of full levee removal/setback. Due to the severe aggradation in the channel and present opportunity to reconnect floodplain storage areas, initial actions should include sediment management along and upstream of Dike 5.

Monitoring will inform the success of initial actions and inform the need for additional levee setbacks and sediment management.

We propose the follow sequence:

I. Remove downstream end of dike
- This should be done strategically.
- There is a considerable amount of sediment storage space between the Dike 2/Dike 3 and Turner creek.

II. Begin a sediment management program
- Includes natural and mechanical removal.
- Track quantity sediment mechanically removed.
- Track streambed elevation response.
- Adjust program as needed.

III. Plan and implement additional restoration projects
- Create opportunity for natural sediment storage.
- Riparian planting.
- Channel habitat complexity.
- Channel sinuosity.

IV. Continue to monitor flooding, Turner creek flow and lake levels

V. Long-term goal of full levee setback/ removal

N 0 1,000 Feet

East Fork Nookachamps Watershed Assessment

Figure 21
Details and Phasing of Recommended Actions in East Fork Nookachamps Creek and Turner Creek

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ESA

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7.3.4 Little Day Creek (LD1, LD2) and Turner Creek (T3, T4)

Level of Priority by Reach

Stream	Reach	Salmon Habitat Restoration Priority	Salmon Habitat Protection Priority	Drainage Improvement and Flood Reduction Priority	Multi-Benefit Priority
Turner Creek	T3	moderate	moderate	low	moderate
	T4	low	low	low	low
Little Day Creek	LD1	low	low	high	moderate
	LD2	low	low	low	low

Restoration Actions

Reach Scale Needs

Location-specific Needs

Strategy

Near-term habitat restoration should focus on improving habitat complexity in the channel downstream of Beaver Lake by adding channel length, improving edge habitat, installing large wood, and planting native riparian vegetation. Farther upstream in Little Day Creek, a partial fish passage barrier should be removed.

In Turner Creek, the upper reaches are almost entirely state-owned forest land. If feasible based on site access, installing large wood would improve instream habitat and potentially sediment retention. Upstream of the anadromous zone, actions to reduce fine sediment inputs from forest roads would benefit downstream reaches.

Actions to change the connectivity of Little Day Creek to Turner Creek should be evaluated for their potential benefits to salmonid habitat in Turner Creek where low flows and poor water quality make most of the area uninhabitable by salmonids during summer months. This type of action would require careful consideration with input from tribes, agencies,

0- to 10-Year Goals

Develop and implement one habitat restoration project focusing on adding channel length, improving edge habitat, installing large wood, and restoring the riparian corridor downstream of Beaver Lake.

Replace the fish passage barrier with a fish passable structure.

Evaluate the effectiveness and feasibility of potential modifications to the connections between Beaver Lake and/or Clear Lake and Turner Creek to improve summer water quality in downstream reaches.

10- to 20-Year Goals

If feasible and effective, develop and implement a project to modify the connections between Beaver Lake and/or Clear Lake and Turner Creek.

and many stakeholders especially because the timing of flow and water quality impairment have not been fully evaluated. This type of action could create a seasonal barrier to stream reaches with known salmonid use, although it would be during a least-used time of year and where water temperatures may already create a thermal barrier limiting salmonid movements into and out of the area

7.3.5 East Fork Nookachamps Creek (EF4), Mundt Creek (M1, M2), Cold Spring Creek (CS1, CS2), and Unnamed Tributary 1 (UNK1-1, UNK1-2)

Level of Priority by Reach

Stream	Reach	Salmon Habitat Restoration Priority	Salmon Habitat Protection Priority	Drainage Improvement and Flood Reduction Priority	Multi-Benefit Priority
East Fork Nookachamps Creek	EF4	high	low	moderate	high
Mundt Creek	M1	moderate	high	moderate	moderate
	M2	low	low	low	low
Cold Spring Creek	CS1	moderate	moderate	moderate	moderate
	CS2	low	low	low	low
Unnamed Tributary 1	UNK1-1	low	moderate	low	low
	UNK1-2	low	moderate	low	low

Restoration Actions

Reach Scale Needs

Location-specific Needs

Strategy

This East Fork Nookachamps Creek reach (EF-4) and the lower reaches of contributing tributaries provides important spawning and rearing habitats for salmonids. Near-term habitat restoration work in these reaches should focus on identifying willing landowners and feasible opportunities to remove or replace bank armoring with fish-friendly actions including large wood for habitat complexity. Additional actions to increase floodplain connectivity and side channels with large wood and native riparian vegetation would be highly beneficial for salmonids and drainage.

If feasible, sediment management is a potential complementary action to reduce the sediment bedload upstream of Beaver Lake Road to benefit downstream reaches. Any such action would need to be carefully planned and implemented to avoid or minimize potential effects to salmonids and salmonid habitat (e.g., removing sediment from the system from a floodplain area or depositional area during low-flow periods such that the work could be completed entirely in dry conditions disconnected from the surface and groundwater connections to the stream channel).

the two total barriers on Unnamed Tributary 1 to Cold Spring Creek should be replaced with structures allowing full fish passage.

The headwater reaches of these creeks are in commercial forestry lands. Where needed, actions should be taken to reduce possible fine sediment inputs from forest roads, thereby providing benefits to downstream reaches. These headwaters are especially important given the salmonid spawning in the lower reaches.

0- to 10-Year Goals

Develop and implement one habitat restoration project focusing on removing bank armoring and replacement with a fish-friendly large wood structure, improved edge habitat, and a restored riparian corridor.

Replace the two fish passage barriers with fish-passable structures.

10- to 20-Year Goals

Develop and implement a second habitat restoration project focusing on removing bank armoring and replacement with a fish-friendly large wood structure, improved edge habitat, and a restored riparian corridor.

Develop and implement one habitat restoration project in East Fork Nookachamps Creek focusing on improving floodplain connectivity and creating side channels with large woody debris and native vegetation in a wide riparian corridor, as well as including sediment management to remove sediment bedload and lower the stream profile over time.

7.3.6 East Fork Nookachamps Creek (EF5), Klahowya Creek (K1, K2, K3), Lake Challenge Outlet (C1), and Walker Creek (W1, W2)

Level of Priority by Reach

Stream	Reach	Salmon Habitat Restoration Priority	Salmon Habitat Protection Priority	Drainage Improvement and Flood Reduction Priority	Multi-Benefit Priority
East Fork Nookachamps Creek	EF5	moderate	high	low	moderate
Klahowya Creek	K1	low	low	low	low
	K2	low	moderate	low	low
	K3	low	moderate	low	low
Lake Challenge Outlet	C1	low	low	low	low
Walker Creek	W1	moderate	high	low	moderate
	W2	low	high	low	low

Restoration Actions

Reach Scale Needs


Location-specific Needs



Strategy

This East Fork Nookachamps Creek reach (EF5) and the lower reaches of Walker Creek (W1, W2) provide important spawning and rearing habitats for salmonids. Near-term habitat restoration work in these reaches should focus on identifying willing landowners and feasible opportunities to remove or replace bank armoring with fish-friendly actions including large wood for habitat complexity. Additional restoration by creating side channels with large wood and native riparian vegetation would benefit salmonids. If feasible, sediment management is a potential complementary action to reduce the sediment bedload delivered to downstream reaches that are experiencing problematic aggradation. Any such action would need to be carefully planned and implemented to avoid or minimize potential effects to salmonids and salmonid habitat (e.g., removing sediment from the system from a floodplain area or depositional area during low-flow periods such that the work could be completed entirely in dry conditions disconnected from the surface and groundwater connections to the stream channel).

Several barriers on the smaller tributaries should be replaced with structures allowing full fish passage.

The headwater reaches of these creeks are in commercial forestry lands. Actions should be taken to reduce fine sediment inputs from forest roads, thereby providing benefits to downstream reaches.

0- to 10-Year Goals

Develop and implement one habitat restoration project focusing on removing bank armoring and replacement with a fish-friendly large wood structure, improved edge habitat, and a restored riparian corridor.

Replace two fish-passage barriers with fish passable structures.

Develop and implement a large native riparian vegetation project in a wide corridor along Walker Creek.

10- to 20-Year Goals

Develop and implement a second habitat restoration project focusing on removing bank armoring and replacement with a fish-friendly large wood structure, improved edge habitat, and a restored riparian corridor.

Replace all remaining fish passage barriers with fish-passable structures.

Evaluate the effectiveness and feasibility of a combined bank armoring removal, side channel restoration, and sediment management project on Walker Creek.

If feasible, develop and implement a combined bank armoring removal, side channel restoration, and sediment management project on Walker Creek.

7.3.7 Walker Creek (W3, W4)

Level of Priority by Reach

Stream	Reach	Salmon Habitat Restoration Priority	Salmon Habitat Protection Priority	Drainage Improvement and Flood Reduction Priority	Multi-Benefit Priority
Walker Creek	W3	moderate	high	low	moderate
	W4	moderate	high	low	moderate

Restoration Actions

Reach Scale Needs

Location-specific Needs

Strategy

Walker Creek reaches W3 and W4 provide important spawning and rearing habitats for salmonids. Near-term habitat restoration work in these reaches should focus on identifying willing landowners and feasible opportunities to remove or replace bank armoring with fish-friendly actions including large wood for habitat complexity and further improving the riparian corridor. Three fish passage barriers should be replaced with structures allowing full fish passage.

The headwater reach of this creek is in commercial forestry lands. Actions should be taken to reduce fine sediment inputs from forest roads, thereby providing benefits to downstream reaches. These headwaters are especially important given the salmonid spawning in the lower reaches.

0- to 10-Year Goals

Develop and implement one habitat restoration project focusing on removing bank armoring and replacement with a fish-friendly large wood structure, improved edge habitat, and a restored riparian corridor.

Replace three fish passage barriers with fish-passable structures.

10- to 20-Year Goals

Develop and implement a second habitat restoration project focusing on removing bank armoring and replacement with a fish-friendly large wood structure, improved edge habitat, and a restored riparian corridor.

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Appendix A.
Estimated Flood Discharges

TABLE A1. ESTIMATED FLOOD DISCHARGES USING REGIONAL REGRESSION EQUATIONS, CFS

Creek	AEP:	0.5	0.2	0.1	0.04	0.02	0.01	0.005	0.002
		2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
East Fork Nookachamps		1,500	2,280	2,820	3,510	4,010	4,570	5,110	5,850
Mud Lake Creek		11.7	18.7	23.5	29.7	34.3	39.3	44.2	51.2
Turner Creek		244	379	471	591	679	776	871	1,000
Beaver Lake Creek		111	175	218	275	317	363	408	471
Mundt Creek		329	501	614	756	858	970	1,080	1,220
Cold Spring Creek		42.1	66.5	83.1	105	121	138	155	180
Unnamed Trib. 1		16	25.3	31.7	40	46	52.7	59.2	68.3
Klahowya Creek		67.1	105	130	162	186	211	236	271
Walker Creek		407	626	775	966	1,110	1,260	1,410	1,610

Appendix B.
Salmonid Life Histories, Distributions, and Habitat Needs

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Appendix B. Salmonid Life Histories, Distribution, and Habitat Needs

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1.0 Salmonid Life Histories, Distribution, and Abundance

East Fork Nookachamps Creek has documented presence of seven species of salmon and trout with sea-run life histories. These species include Chinook salmon (*Oncorhynchus tshawytscha*), Coho salmon (*O. kisutch)*, chum salmon (*O. keta*), pink salmon (*O. gorbuscha)*, steelhead (*O. mykiss)*, and coastal cutthroat trout (*O. clarkii)* (NWIFC and WDFW 2023). In addition, bull trout (*Salvelinus confluentus*) have been documented in Nookachamps Creek and West Fork Nookachamps Creek but are not documented or presumed to occur in East Fork Nookachamps Creek. Due to the risk of extinction, three species, Chinook salmon, steelhead, and bull trout are listed as threatened under the Endangered Species Act (ESA). Recovery efforts for these species are ongoing throughout the Skagit River watershed through restoration and protection of habitats.

Nookachamps Creek supports Chinook salmon in the Lower Skagit Fall Chinook population (Skagit Watershed Council 2022). Nookachamps Creek includes Tier 1 and Tier 2 priority areas for the recovery of Chinook salmon populations in the Skagit (Skagit Watershed Council 2022). Nookachamps Creek up to Barney Lake (N1, N2) and East Fork Nookachamps Creek (EF1) downstream of Highway 9 is a Tier 1 priority area due to its importance in the mainstem Skagit River floodplain, thus providing productive floodplain habitats for all Chinook salmon populations in the watershed. East Fork Nookachamps Creek (EF2-EF5) is a Tier 2 priority area as a major tributary providing productive floodplain habitats for Lower Skagit Fall Chinook salmon. Nookachamps Creek supports an independent population of Steelhead (Skagit Watershed Council 2016). This is one of five Steelhead populations in the watershed. The interim Steelhead Strategy for recovery in the Skagit Watershed applied that same tier designations as developed for Chinook salmon. As a result, East Fork Nookachamps Creek includes Tier 1 and Tier 2 priority areas for the recovery of Steelhead populations in the Skagit (Skagit Watershed Council 2016).

This section describes an overview of the life history of each of the documented salmon and steelhead species in the East Fork Nookachamps Creek watershed.

1.1 Chinook Salmon

1.1.1 Species Description

Chinook salmon in EF Nookachamps Creek and the Skagit River watershed are part of the Puget Sound Chinook salmon evolutionarily significant unit (ESU) which is listed as threatened under the ESA (NMFS 1999). This listing is based on the determination that Puget Sound Chinook salmon are threatened to go extinct in the foreseeable future if protections are not put in place and active recovery efforts undertaken.

Adult Chinook salmon spawn in freshwater streams in the late summer and fall. Fry emerge from the gravel in late winter and early spring. Juvenile Chinook salmon rear in the lower mainstem of rivers and tributaries before entering the estuary and salt marshes (Myers et al. 1998). Rearing in the Skagit River can range from days to months with a relatively small number remaining for a full year (Beamer 2014). Chinook salmon generally outmigrate to estuaries and saltwater in the spring and summer. After outmigration to estuarine and saltwater habitats, Chinook salmon utilize estuaries and coastal areas for rearing (Wydoski and Whitney 1979; Healey 1991). Most individuals spend from 2 to 4 years feeding in the North Pacific Ocean before returning to spawn. Adult Chinook salmon return to spawn in their natal streams from mid-May through October (Myers et al. 1998) and die after spawning.

During the summer and fall, juvenile Chinook salmon commonly rear in river and stream habitats with cover provided by woody debris. In winter, juvenile Chinook salmon frequently use boulder pockets along stream margins for cover. Spawning habitat for Chinook salmon typically consists of riffles and pool tailouts with clean substrates dominated by cobbles. These habitats are located in the mainstem of rivers and large tributaries.

1.1.2 Distribution

The Skagit River is home to three separate Chinook salmon life histories including spring-run, summer run, and fall-run (WDFW 2022b). Fall-run Chinook salmon are the only life history found in the EF Nookachamps Creek drainage and have been documented by historical spawning in the mainstem Nookachamps Creek, EF Nookachamps Creek, Mundt Creek, Walker Creek, and an East Fork Walker Creek to EF Nookachamps Creek Washington Stream Catalog (WDF 1975). Additionally, Beaver Creek, Mud Lake Creek, Turner Creek, Cold Spring Creek, and several unnamed tributaries to Walker Creek have been identified as Chinook salmon habitat based on their accessible gradient (SWIFD 2022).

1.1.3 Spawning Abundance

WDFW has conducted Chinook spawning salmon surveys since 1984 and has documented Chinook salmon in EF Nookachamps Creek, Mundt Creek, Walker Creek, and an (3.0241). Surveys were not conducted every year and the number of surveys conducted per year varied. Over 80% of Chinook salmon documented during the spawner surveys were in the EF Nookachamps Creek. Low numbers of Chinook salmon have been historically observed during spawning surveys. From 1984-2009 the highest number of Chinook salmon seen was 12 (in 1999). There were 68 Chinook salmon seen during the 2010 surveys, which accounted for 65% of the historical records. The most recent survey year for Chinook salmon was in 2020 when three individuals were observed in EF Nookachamps Creek.

Salmon spawner surveys were conducted on the Nookachamps Creek watershed from October through January, beginning in 1998 through 2006 by the Skagit Fisheries Enhancement Group (SFEG) at previously restored habitat reaches. Both live fish and carcasses were counted, and redds (gravel nests excavated by spawning females) were located and identified to species. The surveys were done on a lower reach in the EF Nookachamps Creek and a lower reach in Turner Creek, although higher quality habitat existed upstream. It is presumed the number of fish present in the East Fork and in Turner Creeks was higher than recorded.

Low numbers of Chinook salmon were observed in EF Nookachamps Creek and Mundt Creek from 1998-2006. The peak number of Chinook salmon observed during the survey period was in the 2001-2002 surveys when 10 total Chinook salmon were counted (8 live and 2 carcasses) and 4 redds were observed (SFEG 2007).

1.2 Steelhead

1.2.1 Species Description

Steelhead in the EF Nookachamps Creek and the Skagit River watershed are part of the Puget Sound Steelhead distinct population segment (DPS) that was listed as threatened under the ESA in 2007 (72 Federal Register 91). This listing is based on the determination that Puget Sound steelhead are threatened to go extinct in the foreseeable future if protections are not put in place and active recovery efforts undertaken.

Steelhead exhibit one of the most complex suites of life history traits of any salmonid species. Steelhead may be anadromous or freshwater residents (which are usually referred to as rainbow or redband trout). Biologically, steelhead can be divided into two reproductive ecotypes: “stream maturing” and “ocean maturing.” Stream-maturing, or summer-run steelhead enter fresh water in a sexually immature condition and require several months to mature and spawn. Ocean maturing, or winter-run steelhead enter fresh water with well-developed gonads and spawn shortly after river entry. Steelhead adults typically spawn between December and June. Depending on water temperature, steelhead eggs may incubate in redds for 1.5 to 4 months before hatching. Puget Sound DPS of steelhead typically smolt after 2 years, although they may spend 1 to 4 years in fresh water. They then reside in marine waters for typically 2 or 3 years prior to returning to their natal stream to spawn. Steelhead are iteroparous, but rarely spawn more than twice before dying; most that do so are females.

1.2.2 Distribution

The Skagit River supports both summer-run and winter-run life histories of steelhead. Winter-run steelhead were documented by spawning surveys in Nookachamps Creek, EF Nookachamps Creek, Cold Spring Creek, Turner Creek, Mundt Creek, Walker Creek and East Fork Walker Creek (SWIFD 2022). Juvenile summer-run steelhead from the Skagit River may use Nookachamps Creek as rearing habitat (SWIFD 2022).

1.2.3 Spawning Abundance

Few steelhead were counted during the 1998-2006 SFEG spawning surveys because the surveys were conducted from October-January, and winter-run steelhead spawn from late January-May depending on run timing and flows. The greatest number of steelhead observed during any of the monitoring years was eight in Mundt Creek in 2004-2005 (SFEG 2007).

WDFW steelhead spawner surveys did not occur until 2011 and have been conducted annually since. From 2015-2016 WDFW conducted a detailed spawning steelhead assessment beginning in January and continuing through May, surveying bi-weekly. Steelhead abundance was highest in the EF Nookachamps Creek, followed by Walker Creek, then Mundt Creek (WDFW 2016). A total of 123 redds were recorded during the surveys in 2015/2016, with 61 counted in EF Nookachamps Creek, 30 in Walker Creek, and 17 in Mundt Creek. Redds were also recorded in

Turner Creek, Cold Spring Creek, East Fork Walker Creek, and multiple upstream tributaries. Steelhead were last recorded in 2019 with 10 observed in East Fork Nookachamps and 1 in Mundt Creek.

1.3 Coho Salmon

1.3.1 Species Description

Coho salmon are an anadromous fish species that generally exhibits a relatively simple 3-year life cycle. Adults typically begin their freshwater spawning migration in the late summer and fall, spawn by mid-winter, and then die. Depending on river temperatures, eggs incubate in redds for 1.5 to 4 months before hatching as alevins (a larval life stage dependent on food stored in a yolk sac). Coho salmon fry typically transition to the juvenile stage by about mid-June when they are about 50 to 60 mm, and both stages are collectively referred to as young of the year juveniles (Quinn 2005). Juveniles rear in fresh water for up to 15 months, then migrate to the ocean as smolts in the spring. Coho salmon typically spend 2 growing seasons in the ocean before returning to their natal stream to spawn as 3 year-olds. Some precocious males, called ‘‘jacks,’’ return to spawn after only 6 months at sea.

Coho salmon generally choose spawning sites near the head of a riffle, just below a pool where there is abundant small- to medium-size gravel (NMFS 2016). After emergence fry seek out shallow water along stream margins. Juvenile rearing usually occurs in tributary streams with a gradient of 3% or less, although they may move up streams with as much as 5% gradient. Typical juvenile rearing habitat consists of slow moving, complex pool habitat commonly found within small, heavily forested tributary streams.

1.3.2 Distribution

Records of coho salmon from historical spawning surveys include Nookachamps Creek, EF Nookachamps Creek, Turner Creek, Mundt Creek, Walker Creek, and East Fork Walker Creek. Additionally, Beaver Creek, Cold Spring Creek, and several unnamed tributaries have been identified as coho salmon habitat based on their accessible gradient (SWIFD 2022).

1.3.3 Spawning Abundance

Spawning coho salmon data have been collected by WDFW started in 1952 and surveys were conducted almost yearly through 2021. The number of surveys each year was not standardized and varied. Coho salmon are historically the most abundant salmonid in the EF Nookachamps Creek watershed and have been documented in Mundt Creek since 1952, Walker Creek since 1976, sporadically documented in Turner Creek beginning in 1977, and sporadically documented in EF Nookachamps Creek beginning in 1974.

Coho salmon were the most abundant salmonid observed during surveys from 1998-2006. In 2001-2002, 549 live Coho salmon were counted in Mundt Creek, and 137 redds were counted for the season (SFEG 2007).

1.4 Chum Salmon

1.4.1 Species Description

Chum salmon spawn in small to medium, slow-flowing, spring-fed side channels but can spawn in a wide variety of habitats including large muddy rivers, cold, clear headwater streams, and in the mouths of rivers below the high-tide line. As with other Pacific salmon, a female chum salmon excavates depressions (redds) in the gravel and deposits her eggs as one or more males simultaneously releases their sperm resulting in fertilization. The female then covers the fertilized eggs with gravel and guards the redd until she eventually becomes too weak to hold position in the stream. Chum salmon embryos hatch from eggs after 3–4 months, depending on water temperature. Hatchlings (alevin) remain in the gravel while continuing to absorb nutrients from the egg yolk for an additional 60–90 days before emerging. Chum salmon fry begin their migration to the sea within days or weeks and do not rear in freshwater.

1.4.2 Distribution

Fall-run chum salmon are present in the Skagit River drainage and EF Nookachamps Creek watershed. Chum salmon have been documented by historical spawning surveys in the mainstem Nookachamps, EF Nookachamps Creek, Mundt Creek, Walker Creek, and East Fork Walker Creek. Additionally, Beaver Creek, Mud Lake Creek, Turner Creek, Cold Spring Creek, and several unnamed tributaries to Walker Creek have been identified as Chum salmon habitat based on their accessible gradient (SWIFD 2022).

1.4.3 Spawning Abundance

Based on historical records Mundt Creek is the primary spawning tributary for chum salmon. The highest number of fish recorded was in 1997 when 117 individual chum salmon were counted. Thirty-six individuals were recorded in EF Nookachamps Creek in 2006, which was the largest return of chum salmon recorded outside of Mundt Creek. Only six chum salmon have been recorded in Turner Creek since surveys began in 1976. Minimal numbers of chum salmon have been recorded in Walker Creek and its tributaries.

Chum salmon returns showed high variability during the surveys from 1998-2006. In Mundt Creek zero fish were recorded in the 2000-2001 season, versus a high of 121 live fish recorded in the 2003-2004 season (SFEG 2007).

1.5 Pink Salmon

1.5.1 Species Description

Pink salmon have the shortest lifespan of all the Pacific salmon found in North America. They mature and complete their entire life cycle in 2 years. This predictable 2-year life cycle has created genetically distinct odd-year and even-year populations of pink salmon. Pink salmon spawn in odd-number years in Puget Sound, numbering in the tens of thousands to over a million in the Skagit River. Pinks spawn in September–October then immediately outmigrate to saltwater upon fry emergence, usually in March–April (WDFW 2022c). Since young pink salmon migrate immediately to the ocean, they generally do not eat as they leave freshwater.

1.5.2 Distribution

Odd-year pink salmon are present in the Skagit River drainage and have only been recorded in the Nookachamps Creek, EF Nookachamps Creek, and Mundt Creek. Additionally, Beaver Creek, Mud Lake Creek, Turner Creek, Cold Spring Creek, and Walker Creek have been identified as pink salmon habitat based on their accessible gradient (SWIFD 2022).

1.5.3 Spawning Abundance

Pink salmon have only been recorded in EF Nookachamps Creek and Mundt Creek based on WDFW historical surveys. The highest number of pink salmon counted during the surveys was 1,749 in Mundt Creek in 2009. Only 35 individuals were counted in 2011. Pink salmon were only counted in Mundt Creek in the 2001/2002 and the 2003/2004 seasons, with 51 live and 20 redds counted in the 2003/2004 year (SFEG 2007). The most recent year with documented pink salmon was 2013 when 10 pink salmon were counted in Mundt Creek.

1.6 Sockeye Salmon

1.6.1 Species Description

Sockeye salmon are unique in that they almost always require a lake to rear in as fry, so the river they choose to spawn in must have a lake in the system. Juvenile sockeye rear for 1 or 2 years in a lake, although they are also found in the inlet and outlet streams of the lake. In the spring. they emerge from the gravel as fry and move to rearing areas. In systems with lakes, juveniles usually spend 1 to 3 years in fresh water, feeding on zooplankton and small crustaceans, before migrating to the ocean in the spring as smolts. However, in systems without lakes, many juveniles migrate to the ocean soon after emerging from the gravel.

Sockeye salmon are not present in the EF Nookachamps Creek watershed. Sockeye salmon are present in the Skagit River, where WDFW traps and trucks spawning adults upstream to Baker Lake where they spawn in the lake’s tributaries each year.

1.7 Coastal Cutthroat Trout

1.7.1 Species Description

Adult sea-run cutthroat trout begin to congregate in the estuary and tidal waters of their spawning streams in July to prepare for their upstream migration to freshwater. Unlike salmon and steelhead which spend two or more winters in salt water, sea-run cutthroat trout return to fresh water only 4 to 6 months after they have migrated to the ocean. Not all coastal cutthroat trout returning from the sea for the first time spawn that same year. Sexually immature fish return to the sea the next spring and migrate to fresh water a second time before spawning. This trait is inherited in individual populations, and the percentage of fish exhibiting this behavior varies by geographical area. Details of overwintering periods for adult cutthroat that have returned to fresh water from the ocean are not documented. Their movements are probably like those of the older juveniles that move throughout the upper reaches to the pools and side channels which are sheltered from the high water flows of winter. Coastal cutthroat with access to the Pacific Ocean will often spend their summers feeding along the coast and inside saltwater bays before ascending rivers and streams to spawn in the fall. Most juvenile cutthroat trout that migrate to the ocean for the first time (smolts) do so after their third winter. However, this varies considerably. They follow the tides into shallow areas where they forage on scuds, sand fleas, shrimp, crab megalops and the occasional stickleback, sculpin, sand lance or small baitfish. They stay close inshore and avoid crossing bodies of deep, open water.

1.7.2 Distribution

Coastal cutthroat trout are present in the Skagit River and its tributaries, and mapped in Nookachamps Creek, EF Nookachamps Creek, Turner Creek, Mundt Creek, Walker Creek and their tributaries, Little Day Creek, Cold Spring Creek, and several unnamed tributaries have been identified as cutthroat habitat based on their accessible gradient (SWIFD 2022).

1.7.3 Spawning Abundance

Targeted coastal cutthroat trout surveys have not been conducted in the EF Nookachamps Creek basin. A few cutthroat trout were observed during the 1998-2006 spawning surveys, and over 100 “trout redds” were identified during the 2016 WDFW steelhead surveys, however, it is unknown whether any of these redds were cutthroat versus stream type rainbow trout.

1.8 Bull Trout

1.8.1 Species Description

Bull trout have a complex life history that includes a resident form and a migratory form. The individuals of the migratory form may be stream dwelling (fluvial), lake dwelling (adfluvial), or ocean/estuarine dwelling (anadromous) (USFWS 1998). Individuals of each form may be represented in a single population; however, migratory populations may dominate where migration corridors and subadult rearing habitats are in good condition (USFWS 1998).

Bull trout spawn in streams with clean gravel substrates and cold water temperatures (less than 9ºC/48ºF) (USFWS 1998). Spawn timing is relatively short, spanning from late October through early November. Redds are dug by females in water 8 to 24 inches deep, in substrate gravels 0.2 to 2 inches in diameter (Wydoski and Whitney 1979). Emergence generally occurs in the spring. Bull trout are opportunistic feeders, consuming fish in the water column and insects on the bottom (WDW 1991). Low stream temperatures and clean substrates are key features of bull trout habitat. This species is most commonly associated with pristine or only slightly disturbed basins (USFWS 1998).

1.8.2 Distribution

Bull trout are documented in Nookachamps Creek and the West Fork Nookachamps Creek, but not the EF Nookachamps Creek or its tributaries (SWIFD 2022). Bull trout are present in the Skagit River where they spawn in the fall and migrate into Puget Sound in the spring. It is likely juvenile bull trout use the lower Nookachamps for feeding on their migration to Puget Sound, however the lower Nookachamps has summer water temperatures above the preferred thermal tolerance for bull trout (USFWS 2004).

2.0 Relative Role of Habitat in Healthy Populations of Natural Spawning Salmon (excerpted from WSCC 2003)

This section provides an excerpt from Washington State Conservation Commission (2003) Habitat Limiting Factors Analysis which provides an excellent overview of the importance of habitat for salmon and the impacts of modifications on habitats.

The Relative Role Of Habitat In Healthy Populations Of Natural Spawning Salmon

During the last 10,000 years, Washington State anadromous salmonid populations have evolved in their specific habitats (Miller 1965). Water chemistry, flow, and the physical stream components unique to each stream have helped shaped the characteristics of every salmon population. These unique physical attributes have resulted in a wide variety of distinct salmon stocks for each salmon species throughout the State. Within a given species, stocks are population units that do not extensively interbreed because returning adults rely on a stream's unique chemical and physical characteristics to guide them to their natal grounds to spawn. This maintains the separation of stocks during reproduction, thus preserving the distinctiveness of each stock.

Throughout the salmon's life cycle, the dependence between the stream and a stock continues. Adults spawn in areas near their own origin because survival favors those that do. The timing of juveniles leaving the river and entering the estuary is tied to high natural river flows. It has been theorized that the faster speed during out-migration reduces predation on the young salmon and perhaps is coincident to favorable feeding conditions in the estuary (Wetherall 1971). These are a few examples that illustrate how a salmon stock and its environment are intertwined throughout the entire life cycle.

Salmon habitat includes the physical, chemical and biological components of the environment that support salmon. Within freshwater and estuarine environments, these components include water quality, water quantity or flows, stream and river physical features, riparian zones, upland terrestrial conditions, and ecosystem interactions as they pertain to habitat. However, these components closely intertwine. Low stream flows can alter water quality by increasing temperatures and decreasing the amount of available dissolved oxygen, while concentrating toxic materials. Water quality can impact stream conditions through heavy sediment loads, which result in a corresponding increase in channel instability and decrease in spawning success. The riparian zone interacts with the stream environment, providing nutrients and a food web base, woody debris for habitat and flow control (stream features), filtering runoff prior to surface water entry (water quality), and providing shade to aid in water temperature control.

Salmon habitat includes clean, cool, well-oxygenated water flowing at a normal (natural) rate for all stages of freshwater life. In addition, salmon survival depends upon specific habitat needs for egg incubation, juvenile rearing, migration of juveniles to saltwater, estuary rearing, ocean rearing, adult migration to spawning areas, and spawning. These specific needs can vary by species and even by stock.

When adults return to spawn, they not only need adequate flows and water quality, but also unimpeded passage to their natal grounds. They need deep pools with vegetative cover and instream structures such as root wads for resting and shelter from predators. Successful spawning and incubation depend on sufficient gravel of the right size for that particular population, in addition to the constant need of adequate flows and water quality, all in unison at the necessary location. Also, delayed upstream migration can be critical. After entering freshwater, most salmon have a limited time to migrate and spawn, in some cases, as little as 2-3 weeks. Delays can results in pre-spawning mortality, or spawning in a sub-optimum location.

After spawning, the eggs need stable gravel that is not choked with sediment. River channel stability is vital at this life history stage. Floods have their greatest impact to salmon populations during incubation, and flood impacts are worsened by human activities. In a natural river system, the upland areas are forested, and the trees and their roots store precipitation, which slows the rate of storm water into the stream. The natural, healthy river is sinuous and contains large pieces of wood contributed by an intact, mature riparian zone. Both slow the speed of water downstream. Natural systems have floodplains that are connected directly to the river at many points, allowing wetlands to store flood water and later discharge this storage back to the river during lower flows. In a healthy river, erosion or sediment input is great enough to provide new gravel for spawning and incubation, but does not overwhelm the system, raising the riverbed and increasing channel instability. A stable incubation environment is essential for salmon, but is a complex function of nearly all habitat components contained within that river ecosystem.

Once the young fry emerge from the gravel nests, certain species such as chum, pink, and some chinook salmon quickly migrate downstream to the estuary. Other species, such as coho, steelhead, bull trout, and chinook, will search for suitable rearing habitat within the side sloughs and channels, tributaries, and spring-fed "seep" areas, as well as the outer edges of the stream. These quiet-water side margin and off channel slough areas are vital for early juvenile habitat. The presence of woody debris and overhead cover aid in food and nutrient inputs as well as provide protection from predators. For most of these species, juveniles use this type of habitat in the spring. Most sockeye populations migrate from their gravel nests quickly to larger lake environments where they have unique habitat requirements. These include water quality sufficient to produce the necessary complex food web to support one to three years of salmon growth in that lake habitat prior to outmigration to the estuary.

As growth continues, the juvenile salmon (parr) move away from the quiet shallow areas to deeper, faster areas of the stream. These include coho, steelhead, bull trout, and certain chinook. For some of these species, this movement is coincident with the summer low flows. Low flows constrain salmon production for stocks that rear within the stream. In non-glacial streams, summer flows are maintained by precipitation, connectivity to wetland discharges, and groundwater inputs. Reductions in these inputs will reduce that amount of habitat; hence the number of salmon dependent on adequate summer flows.

In the fall, juvenile salmon that remain in freshwater begin to move out of the mainstems, and again, off-channel habitat becomes important. During the winter, coho, steelhead, bull trout, and remaining chinook parr require habitat to sustain their growth and protect them from predators and winter flows. Wetlands, stream habitat protected from the effects of high flows, and pools with overhead cover are important habitat components during this time.

Except for bull trout and resident steelhead, juvenile parr convert to smolts as they migrate downstream towards the estuary. Again, flows are critical, and food and shelter are necessary. The natural flow regime in each river is unique, and has shaped the population's characteristics through adaptation over the last 10,000 years. Because of the close inter-relationship between a salmon stock and its stream, survival of the stock depends heavily on natural flow patterns.

The estuary provides an ideal area for rapid growth, and some salmon species are heavily dependent on estuaries, particularly chinook, chum, and to a lesser extent, pink salmon. Estuaries contain new food sources to support the rapid growth of salmon smolts, but adequate natural habitat must exist to support the detritus-based food web, such as eelgrass beds, mudflats, and salt marshes. Also, the processes that contribute nutrients and woody debris to these environments must be maintained to provide cover from predators and to sustain the food web. Common disruptions to these habitats include dikes, bulkheads, dredging and filling activities, pollution, and alteration of downstream components such as lack of woody debris and sediment transport.

All salmonid species need adequate flow and water quality, spawning riffles and pools, a functional riparian zone, and upland conditions that favor stability, but some of these specific needs vary by species, such as preferred spawning areas and gravel. Although some overlap occurs, different salmon species within a river are often staggered in their use of a particular type of habitat. Some are staggered in time, and others are separated by distance.

Chum and pink salmon use the streams the least amount of time. Washington adult pink salmon typically begin to enter the rivers in August and spawn in September and October, although Dungeness summer pink salmon enter and spawn a month earlier (WDFW and WWTIT 1994). During these times, low flows and associated high temperatures and low dissolved oxygen can be problems. Other disrupted habitat components, such as less frequent and shallow pools from sediment inputs and lack of canopy from an altered riparian zone or widened river channel, can worsen these flow and water quality problems because there are fewer refuges for the adults to hold prior to spawning.

Pink salmon fry emerge from their gravel nests around March and migrate downstream to the estuary within a month. After a limited rearing time in the estuary, pink salmon migrate to the ocean for a little over a year, until the next spawning cycle. Most pink salmon stocks in Washington return to the rivers only in odd years. The exceptions are the Snohomish and Nooksack Basins, which support both even- and odd-year pink salmon stocks.

In Washington, adult chum salmon (3-5 years old) have three major run types. Summer chum adults enter the rivers in August and September, and spawn in September and October. Fall chum adults enter the rivers in late October through November, and spawn in November and December. Winter chum adults enter from December through January and spawn from January through February. Chum salmon fry emerge from the nests in March and April, and quickly outmigrate to the estuary for rearing. In the estuary, juvenile chum follow prey availability. In Hood Canal, juveniles that arrive in the estuary in February and March migrate rapidly offshore. This migration rate decreases in May and June as levels of zooplankton increase. Later as the food supply dwindles, chum move offshore and switch diets (Simenstad and Salo 1982). Both chum and pink salmon have similar habitat needs such as unimpeded access to spawning habitat, a stable incubation environment, favorable downstream migration conditions (adequate flows in the spring), and because they rely heavily on the estuary for growth, good estuary habitat is essential.

Chinook salmon have three major run types in Washington State. Spring chinook are generally in their natal rivers throughout the calendar year. Adults begin river entry as early as February in the Chehalis, but in Puget Sound, entry doesn't begin until April or May. Spring chinook spawn from July through September and typically spawn in the upper watershed areas where higher gradient habitat exists. Incubation continues throughout the autumn and winter, and generally requires more time for the eggs to develop into fry because of the colder temperatures in the headwater areas. Fry begin to leave the gravel nests in February through early March. After a short rearing period in the shallow side margins and sloughs, all Puget Sound and coastal spring chinook stocks have juveniles that begin to leave the rivers to the estuary throughout spring and into summer (August). Within a given Puget Sound stock, it is not uncommon for other chinook juveniles to remain in the river for another year before leaving as yearlings, so that a wide variety of outmigration strategies are used by these stocks. The juveniles of spring chinook salmon stocks in the Columbia Basin exhibit some distinct juvenile life history characteristics. Generally, these stocks remain in the basin for a full year. However, some stocks migrate downstream from their natal tributaries in the fall and early winter into larger rivers, including the Columbia River, where they are believed to over-winter prior to outmigration the next spring as yearling smolts.

Adult summer chinook begin river entry as early as June in the Columbia, but not until August in Puget Sound. They generally spawn in September and/or October. Fall chinook stocks range in spawn timing from late September through December. All Washington summer and fall chinook stocks have juveniles that incubate in the gravel until January through early March, and outmigration downstream to the estuaries occurs over a broad time period (January through August). A few of these stocks have a component of juveniles that remain in freshwater for a full year after emerging from the gravel nests.

While some emerging chinook salmon fry outmigrate quickly, most inhabit the shallow side margins and side sloughs for up to two months. Then, some gradually move into the faster water areas of the stream to rear, while others outmigrate to the estuary. Most summer and fall chinook outmigrate within their first year of life, but a few stocks (Snohomish summer chinook, Snohomish fall chinook, upper Columbia summer chinook) have juveniles that remain in the river for an additional year, similar to many spring chinook (Marshall et al. 1995). However, those in the upper Columbia, have scale patterns that suggest that they rear in a reservoir-like environment (mainstem Columbia upstream from a dam) rather than in their natal streams and it is unknown whether this is a result of dam influence or whether it is a natural pattern.

The onset of coho salmon spawning is tied to the first significant fall freshet. They typically enter freshwater from September to early December, but has been observed as early as late July and as late as mid-January (WDF et al. 1993). They often mill near the river mouths or in lower river pools until freshets occur. Spawning usually occurs between November and early February, but is sometimes as early as mid-October and can extend into March. Spawning typically occurs in tributaries and sedimentation in these tributaries can be a problem, suffocating eggs. As chinook salmon fry exit the shallow low-velocity rearing areas, coho fry enter the same areas for the same purpose. As they grow, juveniles move into faster water and disperse into tributaries and areas which adults cannot access (Neave 1949). Pool habitat is important not only for returning adults, but for all stages of juvenile development. Preferred pool habitat includes deep pools with riparian cover and woody debris.

All coho juveniles remain in the river for a full year after leaving the gravel nests, but during the summer after early rearing, low flows can lead to problems such as a physical reduction of available habitat, increased stranding, decreased dissolved oxygen, increased temperature, and increased predation. Juvenile coho are highly territorial and can occupy the same area for a long period of time (Hoar 1958). The abundance of coho can be limited by the number of suitable territories available (Larkin 1977). Streams with more structure (logs, undercut banks, etc.) support more coho (Scrivener and Andersen 1982), not only because they provide more territories (useable habitat), but they also provide more food and cover. There is a positive correlation between their primary diet of insect material in stomachs and the extent the stream was overgrown with vegetation (Chapman 1965). In addition, the leaf litter in the fall contributes to aquatic insect production (Meehan et al. 1977).

In the autumn as the temperatures decrease, juvenile coho move into deeper pools, hide under logs, tree roots, and undercut banks (Hartman 1965). The fall freshets redistribute them (Scarlett and Cederholm 1984), and over-wintering generally occurs in available side channels, spring-fed ponds, and other off-channel sites to avoid winter floods (Peterson 1980). The lack of side channels and small tributaries may limit coho survival (Cederholm and Scarlett 1981). As coho juveniles grow into yearlings, they become more predatory on other salmonids. Coho begin to leave the river a full year after emerging from their gravel nests with the peak outmigration occurring in early May. Coho use estuaries primarily for interim food while they adjust physiologically to saltwater.

Sockeye salmon have a wide variety of life history patterns, including landlocked populations of kokanee which never enter saltwater. Of the populations that migrate to sea, adult freshwater entry varies from spring for the Quinault stock, summer for Ozette, to summer for Columbia River stocks, and summer and fall for Puget Sound stocks. Spawning ranges from September through February, depending on the stock.

After fry emerge from the gravel, most migrate to a lake for rearing, although some types of fry migrate to the sea. Lake rearing ranges from 1-3 years. In the spring after lake rearing is completed, juveniles enter the ocean where more growth occurs prior to adult return for spawning.

Sockeye spawning habitat varies widely. Some populations spawn in rivers (Cedar River) while other populations spawn along the beaches of their natal lake (Ozette), typically in areas of upwelling groundwater. Sockeye also spawn in side channels and spring-fed ponds. The spawning beaches along lakes provide a unique habitat that is often altered by human activities, such as pier and dock construction, dredging, and weed control.

Steelhead have the most complex life history patterns of any Pacific salmonid species (Shapovalov and Taft 1954). In Washington, there are two major run types, winter and summer steelhead. Winter steelhead adults begin river entry in a mature reproductive state in December and generally spawn from February through May. Summer steelhead adults enter the river from about May through October with spawning from about February through April. They enter the river in an immature state and require several months to mature (Burgner et al 1992). Summer steelhead usually spawn farther upstream than winter stocks (Withler 1966) and dominate inland areas such as the Columbia Basin. However, the coastal streams support more winter steelhead populations.

Juvenile steelhead can either migrate to sea or remain in freshwater as rainbow or redband trout. In Washington, those that are anadromous usually spend 1-3 years in freshwater, with the greatest proportion spending two years (Busby et al. 1996). Because of this, steelhead rely heavily on the freshwater habitat and are present in streams all year long.

Bull trout/Dolly Varden stocks are also very dependent on the freshwater environment, where they reproduce only in clean, cold, relatively pristine streams. Within a given stock, some adults remain in freshwater their entire lives, while others migrate to the estuary where they stay during the spring and summer. They then return upstream to spawn in late summer. Those that remain in freshwater either stay near their spawning areas as residents, or migrate upstream throughout the winter, spring, and early summer, residing in pools. They return to spawning areas in late summer. In some stocks juveniles migrate downstream in spring, overwinter in the lower river, then enter the estuary and Puget Sound the following late winter to early spring (WDFW 1998). Because these life history types have restrictive habitat requirements, especially as it relates to temperature, bull trout are generally recognized as a sensitive species by natural resource management agencies. Reductions in their abundance or distribution are inferred to represent strong evidence of habitat degradation.

In addition to the above-described relationships between various salmonid species and their habitats, there are also interactions between the species that have evolved over the last 10,000 years such that the survival of one species might be enhanced or impacted by the presence of another. Pink and chum salmon fry are frequently food items for coho smolts, Dolly Varden char, and steelhead (Hunter 1959). Chum fry have decreased feeding and growth rates when pink salmon juveniles are abundant (Ivankov and Andreyev 1971), probably the result of occupying the same habitat at the same time (competition). These are just a few examples.

Most streams in Washington are home to several salmonid species, which together, rely upon freshwater and estuary habitat the entire calendar year. As the habitat and salmon review indicated, there are complex interactions among different habitat components, between salmon and their habitat, and between different species of salmon. For just as habitat dictates salmon types and production, salmon contribute to habitat and to other species.

Introduction to Habitat Impacts

The quantity and quality of aquatic habitat present in any stream, river, lake or estuary is a reflection of the existing physical habitat characteristics (e.g. depth, structure, gradient) as well as the water quality (e.g. temperature and suspended sediment load). There are a number of processes that create and maintain these features of aquatic habitat. In general, the key processes regulating the condition of aquatic habitats are the delivery and routing of water (and its associated constituents such as nutrients), sediment, and wood. These processes operate over the terrestrial and aquatic landscape. For example, climatic conditions operating over very large scales can drive many habitat-forming processes while the position of a fish in the stream channel can depend upon delivery of wood from the forest adjacent to the stream. In addition, ecological processes operate at various spatial and temporal scales and have components that are lateral (e.g., floodplain and riparian), longitudinal (e.g., landslides in upstream areas) and vertical (hyporheic processes).

The effect of each process on habitat characteristics is a function of variations in local geomorphology, climatic gradients, spatial and temporal scales of natural disturbance, and terrestrial and aquatic vegetation. For example, wood is a more critical component of stream habitat than in lakes, where it is primarily an element of littoral habitats. In stream systems, the routing of water is primarily via the stream channel and subsurface routes whereas in lakes, water is routed by circulation patterns resulting from inflow, outflow and climatic conditions.

Human activities degrade and eliminate aquatic habitats by altering the key natural processes described above. This can occur by disrupting the lateral, longitudinal, and vertical connections of system components as well as altering spatial and temporal variability of the components. In addition, humans have further altered habitats by creating new processes such as the actions of exotic species. The following sections identify and describe the major alterations of aquatic habitat that have occurred and why they have occurred. These alterations are discussed as limiting factors. Provided first though, is a general description of the current and historic status of habitat and salmon populations.

Appendix C.
Field Survey

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Attachments

1.0 Reach Delineation

To supplement information on the geomorphic and fish habitat conditions in the East Fork Nookachamps Creek, field data were collected at representative locations within the major tributaries of the basin. Each sub-watershed within the East Fork Nookachamps Creek watershed was delineated into "reaches" for field investigation and analysis. The reaches do not extend throughout the entire creek system, rather the reaches encompass the portion of each creek that is accessible to anadromous salmonids. Each reach is identified to provide representative data for the broader tributary and sub-basin; the reaches are a section of a stream where the geomorphic character (e.g., slope), habitat conditions, and salmonid distribution are similar based on a review of available data. The reaches were delineated through desktop analysis of stream slope, major infrastructure, historical fisheries surveys (e.g., WDFW 2016 steelhead spawner survey), riparian cover, and salmonid distributions in the project area. Reach lengths varied based on the factors above. In each reach, field data were collected from a representative area approximately 200 feet long where the creek could be accessed.

A total of 28 study reaches were delineated. Of those 28, 22 were accessible for field survey data collection. **Table C-1** provides a summary of the reaches. **Figure C-1** shows their locations.

TABLE C-1
DELINEATED REACHES FOR THE FIELD DATA COLLECTION AND ANALYSIS

Stream	Reach	River Miles	Accessed	Description
Nookachamps Creek	N1	0.0 – 1.6	Y	Relic Skagit River Channel
	N2	1.6 – 2.8	Y	Relic channel to mouth of EF
East Fork Nookachamps Creek	EF1	0.0 – 1.8	Y	Mouth to just downstream of Highway 9 Bridge
	EF2	1.8 – 2.4	Y	Highway 9 bridge and confluence with Turner Creek
	EF3	2.4 – 3.5	Y	Leveed section
	EF4	3.5 – 5.0	N	Leveed section upstream to Walker Creek
	EF5	5.0+	Y	Above confluence w/ Walker Creek
Mud Lake Creek	Mud1	0.0 – 1.8+	Y	Outlet of Mud Lake
Turner Creek	T1	0.0 – 1.0	Y	Dredged reach
	T2	1.1 - 1.9	Y	Beaver Lake Rd to Elk Dr.
	T3	1.9 – 2.5	Y	Elk Dr. to BPA lines
	T4	2.5+	N	Above the BPA lines
Little Day Creek	LD1	0.0 - 1.2	Y	Around Beaver Lake
	LD2	1.2+	Y	Above Beaver Lake
Mundt Creek	M1	0.0 – 0.9	Y	Mouth to passable falls
	M2	0.9+	Y	Upstream of falls
Cold Spring Creek	CS1	0.0 – 0.5	N	Below BPA lines
	CS2	0.5+	N	Above BPA lines
Unnamed Trib. 1	UNK1-1	0.0 – 1.0	N	Below private dam
	UNK1-2	1.0+	Y	Above private dam
Klahowya Creek	K1	0.0 – 0.8	Y	Below BPA lines
	K2	0.8 – 1.8	Y	Above BPA lines to scout camp
	K3	1.8+	N	Above scout camp
Lake Challenge Creek	C1	0.0 – 2.0	N	Below Lake Challenge
Walker Creek	W1	0.0 – 0.5	Y	Centered around Taylor Rd
	W2	0.5 – 2.0	N	Forested section
	W3	2.0-4.0	N	Upstream from W2 to BPA lines
	W4	4.0+	Y	Above BPA lines

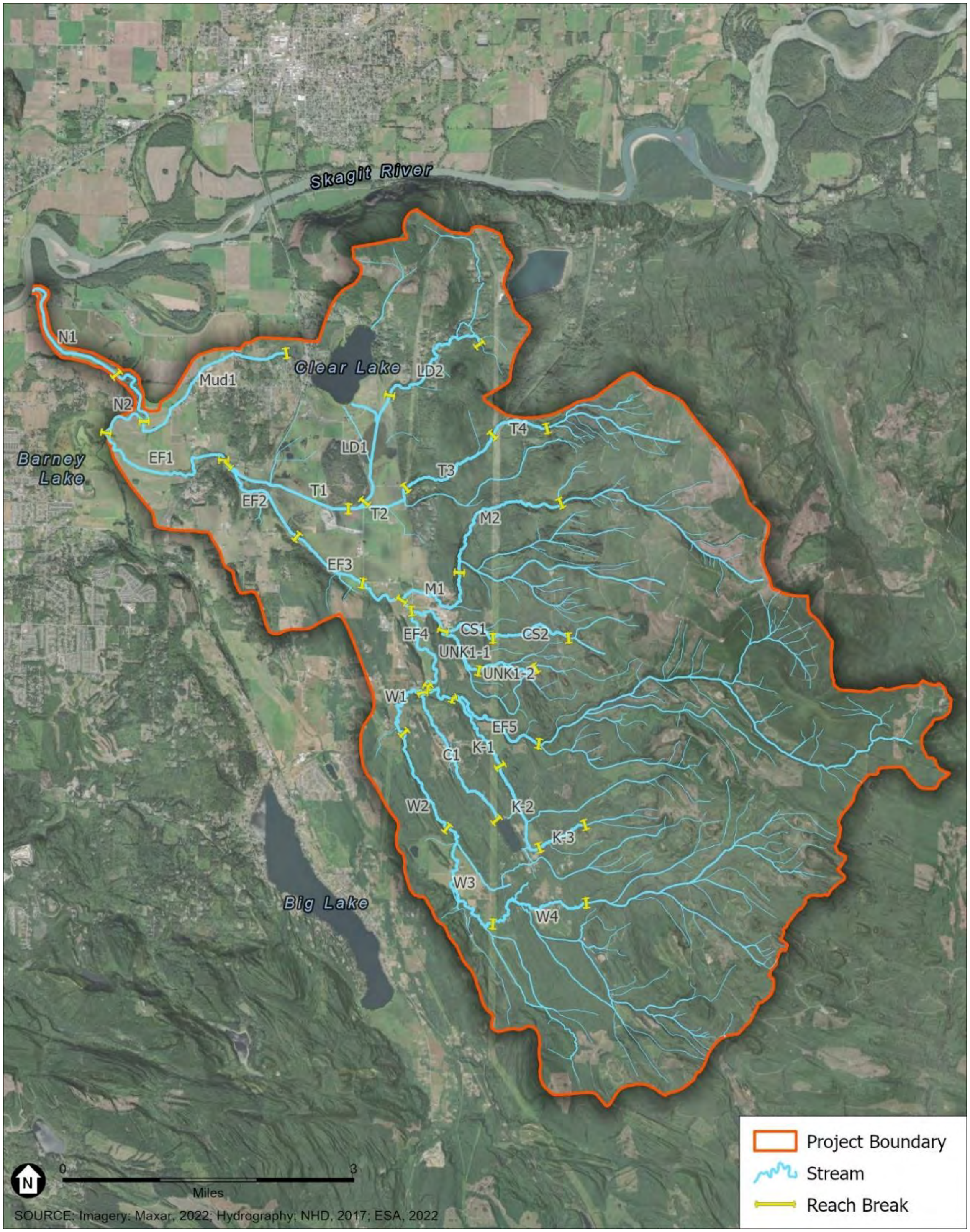


Figure C-1
Study Reaches with Project Boundary

2.0 Data Collection Methods

Field data collection included collecting information to characterize the geomorphic and fish habitat conditions within a 200-foot-long section of each reach. The survey area was intended to be representative of conditions throughout the reach, but was also selected based on access to the creek at road crossings or willing landowner access. The field crew used ARC GIS Collector © maps to navigate to access areas within each reach identified during the desktop analysis. The field crew determined whether each reach could be accessed factoring in accessibility due to dense riparian cover, whether a bank was too steep to traverse safely to the streambed, and whether there were any private property restrictions. The field crew did not have permission to access private property and entered each site from established road crossings wherever possible. Exact field data collection locations are shown in **Figure C-2.**

Once access to a reach had been located, the field crew recorded the start of the habitat on Collector and stretched a transect tape 200 feet upstream or downstream. Water temperature and dissolved oxygen readings were taken once per reach since these parameters were unlikely to change significantly within 200 feet of each other.

A habitat survey was done for each of the “habitat units” found within the 200 feet transect whether the habitat unit was completely contained within the transect or contained several shorter habitats. Each habitat within the transect was defined as a habitat unit and the start/stop location was recorded in Collector. A new datasheet in Fulcrum © was filled out completely for each of the habitat units. Representative site photographs of each habitat were taken and are found in Appendix B.

2.1 Geomorphic Assessment Methods

The field crew used a real-time kinematic (RTK) global positioning system (GPS) rover unit to survey multiple cross sections at each reach. The RTK unit collects highly accurate vertical and horizontal positioning data which are then corrected using a known Washington State Department of Transportation (WSDOT) benchmark. A typical cross section includes elevation and coordinate measurements for top-of-bank, toe-of-bank, channel, and thalweg. When possible, the field crew also recorded elevations at crossings like culverts and bridges and other notable stream features, such as gravel bars or large wood. See **Figure C-3** for all crossings in the project area. The RTK unit relies on connections with GPS satellites and loses accuracy in high density canopy. Because RTK use is limited by heavy canopy cover, RTK surveys were not performed for heavily forested reaches. In these reaches, visual observations and light detection and ranging (LiDAR) data were used together to determine channel characteristics.

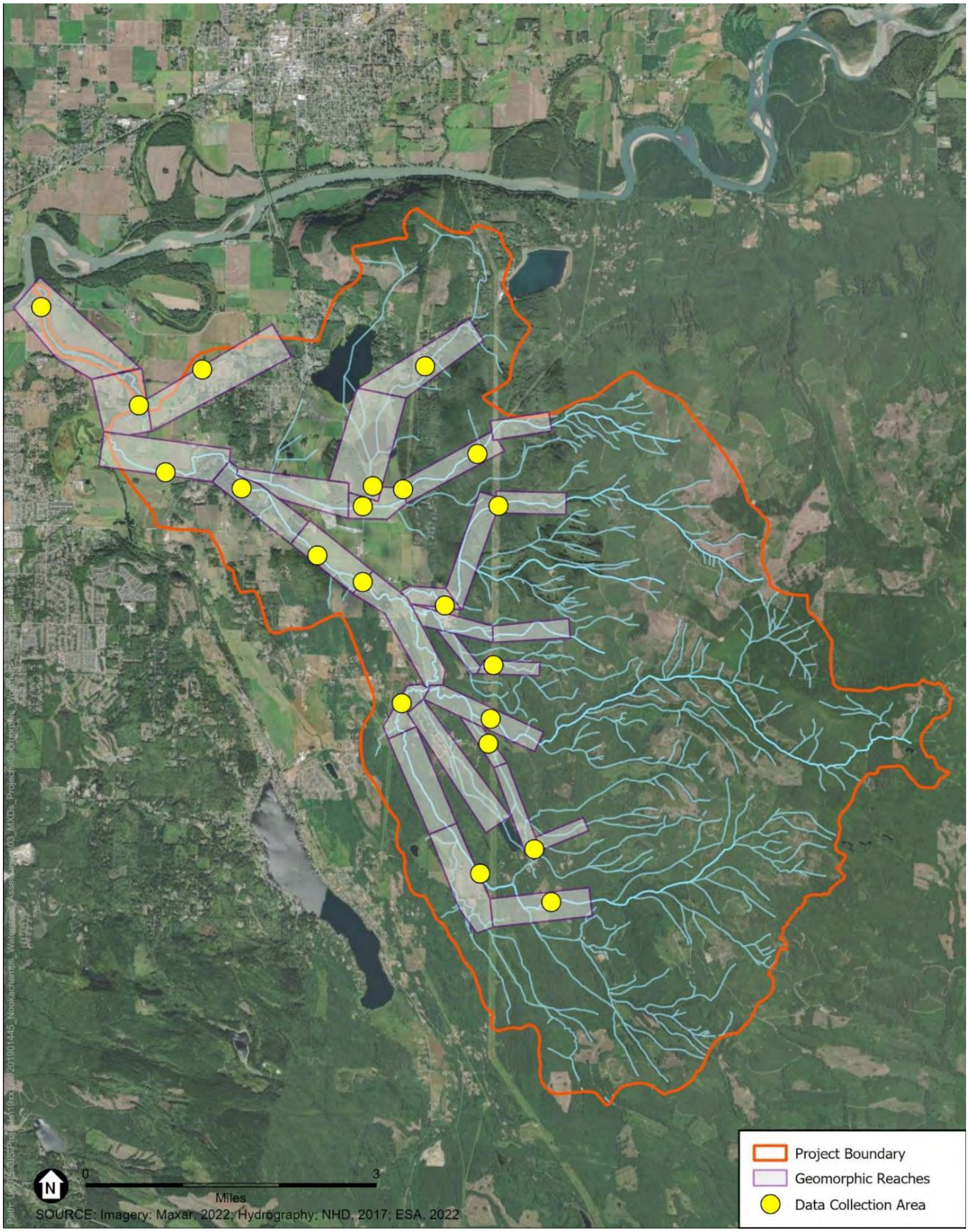


Figure C-2
Data Collection Locations

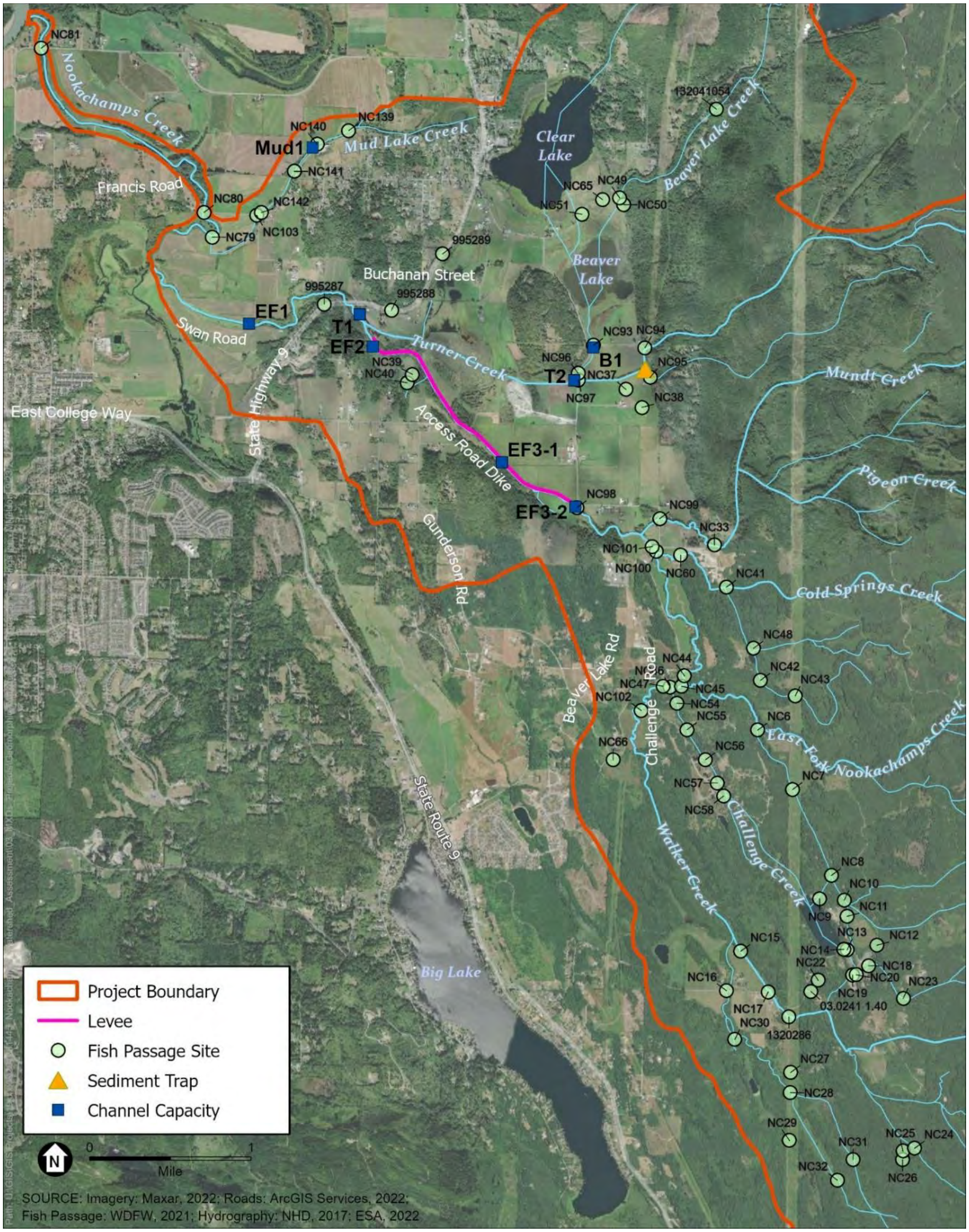


Figure C-3
WDFW Water Crossing Sites within the Project Boundary

The field crew performed Wolman pebble counts to characterize substrate size distributions at most study reaches. Within each study reach, pebble counts were conducted in an area that best represented the reach, near measured cross sections. Pebble counts were performed according to the guidance provided in the 1994 USDA Stream Channel Reference Sites: An Illustrated Guide to Field Technique. For each reference reach, the observer starts at a randomly selected point near bankfull width and selects a random particle. A gravelometer is used to measure the intermediate axis of the particle and tally it into the correct size class. In this study, smaller class intervals based on 1/2 phi values were used (2, 4, 6, 8, 11, 16, 22, 32 millimeters etc.) The observer then takes one step and selects another random particle. When they reached the opposite bank, they continued upstream or downstream in a zig-zag pattern. This process was repeated for a minimum of 100 particles. The field crew did not perform pebble counts in reaches where the channel was too deep, as in the mainstem Nookachamps creek, or when the streambed consisted entirely of fines that were too small to measure.

2.2 Fish Habitat Assessment Methods

The survey protocol for conducting the field habitat assessment followed a modified version of WDFW's Reduced Sample Full Survey methodology from Chapter 10 of the Fish Passage Inventory, Assessment, and Prioritization Manual (WDFW 2019), and the Timber Fish and Wildlife Monitoring Program Manual (TFW 1999). The purpose of this assessment was to focus on the portions of the project area that are Tier 1 or 2 priority reaches for Chinook salmon and steelhead and reaches with documented salmon and steelhead distributions in SWIFD or historical fisheries surveys.

Water temperature (°F) and dissolved oxygen (DO) were taken at each reach using a YSI© DO PRO, as these were unlikely to show much variation within less than 200 feet of each other. All remaining data were collected from each individual habitat unit. "Habitat units" are the changes within in-stream hydraulic conditions including depth and velocity. The TWF (1999) protocol relies on two general terms, "riffle" and "pool", which apply to a broad range of wetted channel conditions that could be encountered in the field. A greater level of detail was used for the purpose of this habitat assessment to more accurately show the habitats found in the East Fork Nookachamps Creek. Each habitat unit was classified into the following categories:

- Riffle – a shallow and low gradient area with surface turbulence associated with increased velocity of flow over gravel or cobble.
- Pool – a depression in the streambed is caused by fluvial processes.
- Run – a swiftly flowing reaches with little surface agitation and no major flow obstructions, typically flooded riffles in high flows.
- Glide – a wide, uniform channel bottom, low to moderate velocities, lacking pronounced turbulence.
- Pocketwater – an area of swift-flowing stream containing numerous boulders or other large obstructions that create eddies or scour holes (pockets) behind the obstructions.

Dominant and subdominant substrates were recorded for each habitat unit. Substrates were classified as either silt/clay (fines), sand, gravel, small cobble, large cobble, boulders, or bedrock. Size cutoffs for each substrate are listed below:

- Bedrock: Greater than 160 inches
- Boulder: 10 to 160 inches
- Large cobble: 6 to10 inches
- Small cobble: 3 to 6 inches
- Gravel: 0.2 to 3.0 inches
- Sand: 0.06 millimeters to 0.2 in
- Silt/clay: Less than 0.06 millimeters

Woody debris was classified as small (diameter less than 20 inches), large (diameter greater than 20 inches), and rooted trees if the wood originated within the bankfull channel. The dominant tree and/or ground vegetation providing bank/canopy cover was identified. The total percentage of aquatic vegetation within the wetted channel was estimated in percentage for the habitat unit. The total percentage of algae covering the habitat unit was estimated. Embeddedness is the degree in which cobble and gravel are buried in fine sediments and sand. A level of embeddedness of 0-25 percent is considered good quality spawning habitat for salmon and steelhead (Flosi 2004). As embeddedness increases to 50 percent and above it becomes difficult for salmonids to construct a redd.

Embeddedness was recorded for spawning substrates found in each habitat unit and also at pool tailouts and riffles as these are key spawning habitat locations. Embeddedness was recorded in 25 percent increments.

The field crew used a 200-feet tape measure to take wetted width, the width of the wetted stream at the time of the survey, bankfull width (BFW) (i.e., the stream width at bankfull discharge elevation) measurements at approximately three locations in each study reach. Mean BFW for each habitat unit was calculated after the field effort. Slope measurements were taken from RTK-surveyed thalweg points or using a clinometer to estimate streambed slope. Maximum depth (feet) was recorded at each habitat unit using a stadia rod. Depths greater than 5.0 feet were estimated unless the deepest portion was along the bank and accessible to surveyors. For each pool surveyed the depth at the top of that thalweg was recorded as "Pool Crest Depth," in addition to maximum depth. For any culverts encountered during the survey the diameter (inches), length (feet), and material of each culvert were recorded. Spawning habitat quality modifiers (HQM) were recorded at each habitat unit to assess the habitat suitability for rearing juveniles and spawning adults. The spawning HQM was determined by a visual estimate of the percentage of embedded fines within potential spawning gravel patches within each habitat unit. The estimate is a combination of subjective evaluations of gravel surface composition, silt plume characteristics as a boot heel is dug into a gravel patch, and the composition of several handfuls of the underlying substrate. Spawning gravel patches with less than 16% fine particles were given a score of 1.0. Spawning gravel patches show moderate to widespread signs of instability (scour/filling), and/or > 16% to 21% fine particles. Spawning gravel patches show widespread to major signs of instability (scour/filling), and/or 21% to 26% fine particles. A 0 was assigned for patches with greater than 26% fine particles (WDFW 2019).

Rearing HQM is an evaluation of physical characteristics that influence the ability of juvenile salmonids to survive and grow in a freshwater stream which include water quality, adequate depth and flow, cover in the form of undercut banks, woody debris, or overhanging vegetation (WDFW 2019). For each habitat unit surveyed the score began at 1. If there were no limiting factors for juvenile rearing identified the habitat would be assigned a 1. If there were limiting factors identified but the habit still showed beneficial components for juvenile rearing the score would be assigned 0.66. If there were several limiting factors identified and the majority of the habitat unit showed little rearing habitat the score was assigned a 0.33. If the habitat unit had no juvenile rearing it was assigned a 0 (WDFW 2019).

2.2.1 Field Effort Summary

The field crew conducted field surveys in the East Fork Nookachamps Creek watershed from July 25th through July 29th, 2022. Creek conditions during this time were typical of low flow summer conditions as little to no rain had fallen in the preceding weeks. Staff surveyed 22 of the 28 reaches identified in the desktop review.

The following reaches were not surveyed: Cold Spring Reach 1 (CS1), Cold Spring Reach 2 (CS2), Klahowya Creek Reach 3 (K3), Walker Reach 2 (W2), Walker Reach 3 (W3), and Lake Challenge Reach 1 (C1). Private property restrictions prevented the crew from sampling the reaches listed above except for Lake Challenge Creek Reach 1. Data were not collected in Lake Challenge Creek Reach 1 because it was not wetted at the time of the field survey.

2.3 Water Crossings and Channel Conveyance Capacity

The water crossings in each reach were identified using information in the Washington Department of Fish and Wildlife (WDFW) Fish Passage and Diversion Screening Inventory (WDFW 2023). For a subset of crossings that appeared to potentially restrict flow, the conveyance capacity of the culvert was evaluated using HY-8 modeling software to determine how much flow the culvert can convey before overtopping.

Surveyed cross section data and pebble counts from the field surveys were used to evaluate the channel capacity of several of the lower reaches. The analysis requires factors including channel geometry, channel slope, channel material, Manning's "n" roughness value, and bankfull width to estimate the bankfull flow. Flows greater than the bankfull flow will overtop the channel and spill into the surrounding areas. Channel capacity was only calculated for reaches in the lower watershed that are prone to flooding and overflowing their banks.

3.0 Results

Following is a summary of results creek. Observations are reported for the entire creek and on a reach-by-reach basis.

3.1 Nookachamps Creek

Both reaches of Nookachamps Creek were visited during the field assessment, but the field crew did not conduct a full fish habitat or geomorphic assessment due to the deep water present in both reaches. The field assessment methods were tailored to waterbodies that are wadeable, where the surveyors can walk from one end to the other. In both reaches of Nookachamps Creek, water depths exceeded wading depth within a few feet of the bank. Instead, general observations were made at bridge crossings in each reach. The field crew accessed reach N1 from the Francis Road bridge and reach N2 from the Swan Road bridge.

In both reaches of Nookachamps Creek, flow is conveyed in a single, deep channel. The creek is surrounded by agricultural fields and has been artificially straightened and simplified. Field observations are summarized in **Table C-2**. The reaches are comprised of long glides with fine sediment and very little instream wood for habitat structure. The riparian corridors in both reaches are variable as some areas have relatively wide buffers of maturing trees, but others have narrower vegetated corridors with a mix of shrubs and trees. Long stretches of N1 appear to have been recently planted with wide riparian buffers which will benefit creek habitats greatly as the vegetation grows taller. Nookachamps Creek does not provide suitable habitat for salmon spawning, primarily due to the lack of spawning substrate. Nookachamps Creek provides fair to moderate summer rearing habitat. The two reaches are important for salmon migrating into and out of the upstream portions of the watershed. In addition, Nookachamps Creek likely provides rearing and refuge habitat for juvenile salmon originating in other parts of the Skagit River system.

TABLE C-2
FIELD DATA SUMMARY FOR NOOKACHAMPS CREEK REACHES

Parameter		Reach	
		N1	N2
River Miles		0.0-1.6	1.6-2.8
Average Bankfull Width (feet)		n/a	n/a
Slope	Field Measure	0.00%	0.00%
	LiDAR (full reach)	0.01%	0.02%
Habitat Types		Glide	Glide
Substrate	D50 (mm)	fines	fines
	Dominant, Subdominant	Silt/Clay, Sand	Silt/Clay, Sand
	Total Embeddedness	n/a	n/a
Woody Debris	LWD and Rootwad Count	1	4
	SWD Count	0	0
Habitat Quality	Spawning HQM	0	0
	Rearing HQM	0.33	0.66
Water Quality	Water Temperature (°C)	17.1	17.1
	Dissolved Oxygen (mg/l)	8.9	8.9
Number of Juvenile Salmonids Observed		0	0

3.1.1 Bridge and Culvert Crossings

Within the project area, the lower reach of Nookachamps Creek crosses under two roads. At RM 0.3, the Francis Road bridge crosses the creek just above its confluence with the Skagit River. Swan Road bridge crosses the creek at RM 2.0, approximately 1.7 miles upstream of the Francis Road bridge. While these bridges may slightly constrict the channel, they are higher than the surrounding fields and do not compound or significantly alter flows during flood events. See **Table C-3** for a summary of both crossings on Nookachamps Creek.

TABLE C-3
CROSSINGS ON NOOKACHAMPS CREEK

Number	Crossing Type	Road	River Mile	WDFW Site ID
1	Concrete Bridge	Francis Road	0.3	NC81
2	Concrete Bridge	Swan Road	2.0	NC80

3.1.2 Channel Capacity

Although the two bridge crossings over Nookachamps Creek have foundations and piers that encroach on the channel, they do not significantly alter hydraulics or restrict the channel capacity. No significant debris was observed collecting on either of the bridges' piers that would restrict flow. Both bridges are higher than the surrounding banks and flow will spill over the banks before overtopping the bridges. The lower reach of Nookachamps Creek is likely aggrading and was dredged in 1947 after it filled its channel (The Mount Vernon Argus, 1947). Because of its depth, it is difficult to tell the current rate of aggradation. While this reach likely has the channel capacity to convey flood flows downstream, its proximity to the Skagit River and extremely low slope subject it to backwatering. This combination of backwatering from Skagit River floodwaters and flows from the upstream tributaries create flooding that regularly inundates the surrounding fields. The field crew was unable to survey channel cross sections due to the creek's depth and did not model the channel capacity.

3.2 Mud Lake Creek

During the survey most of Mud Lake Creek was dry in the lower sections near Swan Road. The creek is bounded by Mud Lake Road to the south and east and agricultural fields on the north and west. Field observations are summarized in **Table C-4**. The creek was stagnant with silt/clay substrate. No large woody debris (LWD) or small woody debris (SWD) was observed in the creek. The riparian corridor is generally lacking of woody vegetation and the lower reaches are dominated by invasive reed canary grass. Midway up the creek, there is one section with a wide planted buffer of trees. The upper reach nearing the lake is lined by a single row of mature trees between the road and the ditched creek. Water quality in Mud Lake Creek would be lethal to any salmonids in the summer months with a measured water temperature of 18.7°C and dissolved oxygen of 1.1 milligrams per liter (mg/l). There have been no published fisheries surveys of Mud Lake Creek although the creek is considered gradient accessible for salmon, steelhead, and coastal cutthroat trout (SWIFD 2022). Mud Lake Creek is not likely to support salmonids other than a few strays due to its poor water quality.

TABLE C-4
FIELD DATA SUMMARY FOR MUD LAKE CREEK REACHES

Parameter		Reach
		Mud1
River Miles		0.0-1.8
Average Bankfull Width (feet)		10
Slope	Field Measure	0.00%
	LiDAR (full reach)	0.07%
Habitat Types		Stagnant
Substrate	D50 (mm)	fines
	Dominant, Subdominant	Silt/Clay
	Total Embeddedness	n/a
Woody Debris	LWD and Rootwad Count	0
	SWD Count	0
Habitat Quality	Spawning HQM	0
	Rearing HQM	0.33
Water Quality	Water Temperature (C)	18.7
	Dissolved Oxygen (mg/l)	1.1
Number of Juvenile Salmonids Observed		0

3.2.1 Bridge and Culvert Crossings

There are several small culvert crossings on Mud Lake Creek. The first crossing of Mud Lake Creek occurs at RM 0.3, where the creek crosses under Swan Road. Swan Road overtops during flood events. The rest of the upstream crossings all provide private access to adjacent agricultural fields. During the field surveys, the failing, partially collapsed crossing at RM 1.0 was observed. See **Table C-5** for a summary of all crossings on Mud Lake Creek.

TABLE C-5
CROSSINGS ON MUD LAKE CREEK

Number	Crossing Type	Road	River Mile	WDFW Site ID
1	Squash Structural Plate Steel Culvert	Swan Road	0.3	NC103
2	Round Corrugated Steel Culvert	Field Access Road	0.4	NC142
3	Round Corrugated Steel Culvert	Field Access Road	0.7	NC141
4	Box Cast-in-place Concrete Culvert	Field Access Road	1.0	NC140
5	Elliptical Smooth Steel Culvert	Field Access Road	1.3	NC139

The capacity of the largest culvert crossing, Culvert 1 at Swan Lake, was evaluated using HY-8 modeling software to determine how much flow the culvert can convey before overtopping, see Appendix D. The culvert has adequate capacity to convey flows up to 580 cfs, far greater than projected 2-year flow of 12 cfs. This indicates that overtopping at Swan Lake Road is likely due to backwatering from the Skagit River.

3.2.2 Channel Capacity

Surveyed cross section data and pebble counts from the field surveys were used to evaluate the channel capacity of several of the lower reaches. The analysis requires factors including channel geometry, channel slope, channel material, Manning's "n" roughness value, and bankfull width to estimate the bankfull flow. Flows greater than the bankfull flow will overtop the channel and spill into the surrounding areas. Channel capacity was only calculated for reaches in the lower watershed that are prone to flooding and overflowing their banks, like Mud Creek Lake. **Table C-6** shows the calculated channel capacity for the study reach compared to the estimated 2-year peak flow, pulled from Stream Stats, for the same location. The 2-year peak flow (50% annual exceedance probability event) is typically considered a bankfull event; therefore, channels without the capacity to pass the 2-year peak flow within its banks may be considered undersized for its hydrology.

Mud Lake Creek's complete lack of sinuosity and artificial channel path, including the 90-degree bend directly before its confluence with Nookachamps Creek., suggest it was constructed to drain Mud Lake and the surrounding fields. The creek has small flood flows due to its small drainage area and adequate channel capacity to pass the flows. Flooding is more likely cause by backwatering from the Skagit River, which travels up Nookachamps Creek and into Mud Lake Creek or spills over from Debays Slough to the north. The low slope of the creek and failing and or unmaintained private crossings along Beaver Lake road likely prevent floodwaters from draining once they recede.

TABLE C-6
ESTIMATED CHANNEL CAPACITY VERSUS 2-YEAR PEAK FLOOD FOR SELECT REACHES

Creek	Reach	Minimum Bankfull Flow Cross-section1 (cfs)	Minimum Bankfull Flow Cross-section 2 (cfs)	2-Year Flow (cfs), *StreamStats*
Mud Lake Creek	Mud1	48.7	NA	10.5

3.3 East Fork Nookachamps Creek

Field observations are summarized in **Table C-7**. Four of the five surveyed areas included at least one pool. Unidentified juvenile salmonids were identified in each reach. Habitat quality for spawning and rearing salmonids get progressively better moving upstream. The second EF3 survey area and EF5 both provide optimal spawning and rearing habitat. Water temperatures in East Fork Nookachamps Creek were among the highest in the sub-basin, measuring at or near 20°C throughout much of its extent.

EF1 flows through several agriculture parcels in the Skagit Valley. The channel is uniform and the only canopy cover in the survey area was invasive reed canarygrass. The EF1 field survey area included two different habitat units, a glide and a pool. The primary substrates in the reach are silt/clay and no spawning gravel is present. Undercut banks provided cover for juvenile salmonids, which were present during the survey. Water quality in EF1 was poor with a measured water temperature of 21.1°C and dissolved oxygen of 6.04 mg/L. The primary limiting factors for this reach were poor water quality, a lack of spawning gravel, and no canopy cover other than reed canarygrass on both banks.

TABLE C-7
FIELD DATA SUMMARY FOR EAST FORK NOOKACHAMPS CREEK REACHES

Parameter		Reach				
		EF1	EF2	EF3	EF3	EF5
River Miles		0.0-1.8	1.8-2.4	2.4-3.5	2.4-3.5	5.0+
Average Bankfull Width (feet)		23.8	38.6	32.1	33.3	30.5
Slope	Field Measure	0.29%	0.37%	0.22%		
	LiDAR (full reach)	0.10%	0.16%	0.13%		1.62%
Habitat Types		Glide, Pool	Glide, Pool	Glide, Riffle	Glide, Pool	Pool, Pocketwater
Substrate	D50 (mm)	6.8	9.1	23.0		35.9
	Dominant, Subdominant	Silt/Clay, Gravel	Sand, Gravel	Gravel, Sm. Cobble	Sand, Gravel	Lg. Cobble, Boulder
	Total Embeddedness	76-100%	26-50%	51-75%	51-75%	0-25%
Woody Debris	LWD and Rootwad Count	0	2	2	4	0
	SWD Count	6	9	6	0	1
Habitat Quality	Spawning HQM	0	0.66	0.66	1	1
	Rearing HQM	0.66	0.66	0.66	1	1
Water Quality	Water Temperature (°C)	21.1	19.8	16.9	21	19.3
	Dissolved Oxygen (mg/l)	6.04	8.08	9.05	10.52	9.63
Number of Juvenile Salmonids Observed		1-49	1-49	1-49	>100	50-99

EF2 is located upstream of the Highway 9 bridge crossing. The creek channel is bordered by expansive wetlands or wetted fields along much of its extent. A levee along its right bank when looking downstream lessens flooding of adjacent areas and limits fish access to floodplain habitats. The EF2 field survey area included a glide and a pool. The pool was a log induced scour pool, with a backwater present that appeared to be a remnant of the old channel, which likely changed course during high flows. The pool contained a high degree of complexity, with several pieces of large and small woody debris, depth of over 5 feet, an undercut bank, and a pool tailout with spawning gravel. The glide was primarily sand/gravel and lacked larger substrates used by salmon for spawning. Additionally, there was no woody debris, and the depth overall was shallow. Primary limiting factors for the pool were the presence of algae and silt in the pool tailout during the midsummer sampling. Unidentified juvenile salmonids were present in both habitat units during the survey.

EF3 flows through several agricultural parcels. The levee in EF2 continues in EF3 along the right bank. Two surveys were conducted in EF3 at approximately RM 4.2 and RM 4.7 which included four habitat units, one riffle, one pool, and two glides. The quality of spawning and rearing habitat was better at the upstream end of the reach compared to the downstream end. The primary limiting factors for EF3 are lack of woody debris, a bubble curtain, and the presence of silt on spawning substrate.

EF4 was not surveyed. In EF5, the survey area included a pool and pocketwater habitats. The substrate was large cobble and boulders. This is much larger substrate than documented in downstream reaches. EF5 is in undeveloped forest land and both banks contained extensive hardwood riparian canopy cover.

3.3.1 Bridge and Culvert Crossings

There are several bridge crossings on the lower reaches of East Fork Nookachamps Creek that are not likely to contribute to flooding. There are no culvert crossings in the lower reaches of the creek.

East Fork Nookachamps Creek crosses under the Highway 9 bridge at RM 1.8. A new single-span bridge, adjacent to the existing Highway 9 bridge, is currently under construction. Upstream, East Fork Nookachamps Creek crosses under a private driveway bridge, off of Beaver Lake Road and a third private timber bridge before crossing under Beaver Lake Road at RM 4.2. The last crossing is a concrete bridge carrying a private driveway. As all the crossings are bridges, rather than culverts, it is unlikely that they are impounding water during high flow events or contributing to backwatering. See **Table C-8** for a summary of all crossings on East Fork Nookachamps Creek.

TABLE C-8
CROSSINGS ON EAST FORK NOOKACHAMPS CREEK

Number	Crossing Type	Road	River Mile	WDFW Site ID
1	Concrete Bridge	Highway 9	1.8	NC92
2	Timber Bridge	Private Driveway	3.5	NC98
3	Timber Bridge	Private Driveway	4.1	NC101
4	Cast in-place Concrete Bridge	Beaver Lake Road	4.2	NC100
5	Concrete Bridge	Star View Drive	5.05	NC44

3.3.2 Channel Capacity

Field staff surveyed several cross sections on the East Fork Nookachamps Creek and used the data to evaluate channel capacity at the reaches of the creek prone to flooding. At the most downstream reach of East Fork Nookachamps Creek, the channel capacity is between 1,400 and 2,300 cfs, compared to the 2-year flow of 1,400 cfs. This indicates that the channel will likely overtop during the 2-year flow. Although the active channel is relatively small in this reach, it is situated within a larger channel that can accommodate flood flows before spilling into the surrounding agricultural fields. Both banks are of nearly equal height; however, the right bank is slightly lower and would over top first, sending flood flows north. This reach is likely more susceptible to backwatering from Nookachamps Creek and the Skagit River.

Upstream, just above the confluence with Turner Creek, the East Fork Nookachamps Creek has a much smaller channel capacity, approximately 50 cfs, compared to the 2-year flow of 1,260 cfs (**Table C-9**). This reach showed signs of aggradation, with an inactive relic channel on river right appearing to have filled in with gravels and cobbles. The creek is now flowing river left into a wetland area that lacked defined banks. At a flow greater than 50 cfs, water would begin to spill into the adjacent wooded wetland area between the creek and a hillslope to the west and into the relic channel to the east. This section of East Fork Nookachamps Creek is confined by a levee running along river right, with an elevation of 41 feet.

Channel capacity for the third reach of the East Fork Nookachamps Creek was estimated at two cross sections: the first near Beaver Lake Road and the second approximately 3,000 feet downstream in the middle of the reach. Channel capacity was estimated at 1,200 and 800 cfs compared to a 2-year flow of 1,260 cfs. Because of the levee along the right bank of the river, at the downstream cross section, flows greater than 800 cfs will spill over the left bank into a wooded wetland area. At the upstream cross section, flows greater than 1,200 cfs will spill over the left bank into an agricultural field to the south.

TABLE C-9
ESTIMATED CHANNEL CAPACITY VERSUS 2-YEAR PEAK FLOOD FOR SELECT REACHES

Creek	Reach	Minimum Bankfull Flow Cross-section1 (cfs)	Minimum Bankfull Flow Cross-section 2 (cfs)	2-Year Flow (cfs), *StreamStats*
East Fork Nookachamps Creek	EFN1	1,390	2,284	1,420
East Fork Nookachamps Creek	EFN2	48.7	49.9	1,260
East Fork Nookachamps Creek	EFN3	1,159	810	1,260

Overall, East Fork Nookachamps Creek is an aggradational system, especially at Reach EF2 and EF4. At the start of Reach EF2, at the Highway 9 bridge, the creek goes through a “pinch point” with high-elevations hills confining the channel within several hundred feet to the southwest and northeast. As shown in **Figure 9**, the majority of the project area’s watershed has to drain through this point. 1937 aerials appear to show a multi-channel network at this location, which was converted to a single, straightened channel by 1969. In the 1969 aerials, East Fork Nookachamps Creek occupies now what is now the lowest 600 feet of Turner Creek. Today, the channel has migrated 150 feet to the west. Additionally, the confluence of Turner Creek and East Fork Nookachamps Creek has shifted 2,000 feet downstream between 1937 and present day, likely in human efforts to increase drainage as the old channel filled with sediment. During their site visit, field staff noted large deposits of pebble and gravel in the vicinity of the confluence and observed that, upstream of the confluence, the East Fork Nookachamps had filled its main channel and was creating a new channel through a wetland area. These changes all indicate that the creek is actively depositing sediment in this reach, forcing the channel to frequently change course.

Reach EF3 is relatively straight and confined by the levee on its right bank. Further upstream in Reach EF4, at Ecology Gage 03100 on Beaver Lake Rd, stage has increased by 1.2 feet in the last 20 years. This means that at the same flow, WSEs have increased by 1.2 feet. This increase in WSE is associated with an increase in the channel bed elevation and can be used to generalize that approximately 1.2 feet of sediment is deposited every 20 years. According to anecdotal reports, the section of creek near the timber driveway bridge at the end of EF 4, was dredged annually.

3.4 Turner Creek

Field observations are summarized in **Table C-10**. Turner Creek provides poor salmon spawning and rearing habitat downstream of the sediment trap. The channel in T1 and T2 provides limited habitat structure and poor water quality. Upstream of the sediment trap, the gradient increases as does habitat complexity. The upper reaches of the creek provide higher quality habitat for salmonids and much improved water quality conditions.

TABLE C-10
FIELD DATA SUMMARY FOR TURNER CREEK REACHES

Parameter		Reach			
		T1	T2	T3	T4
River Miles		0.0-1.0	1.0-1.4	1.4-2.5	2.5+
Average Bankfull Width (feet)		39.0	20.1	11.1	9.5
Slope	Field Measure	0.30%	0.26%	1.64%	
	LiDAR (full reach)	0.06%	0.51%		
Habitat Types		Glide	Glide, Riffle, Pool	Riffle, Pool	Pool, Pocketwater
Substrate	D50 (mm)	8.2	6.0	10.4	29.3
	Dominant, Subdominant	Gravel, Silt/Clay	Sand, Gravel	Gravel, Sm. Cobble	Sm. Cobble, Lg. Cobble
	Total Embeddedness	51-75%	76-100%	26-50%	0-25%
Woody Debris	LWD and Rootwad Count	0	0	5	13
	SWD Count	0	0	21	11
Habitat Quality	Spawning HQM	0.33	0	1	1
	Rearing HQM	0.33	0.33	1	1
Water Quality	Water Temperature (°C)	23.0	17.5	16.9	15.7
	Dissolved Oxygen (mg/l)	4.38	8.72	8.90	9.69
Number of Juvenile Salmonids Observed		0	0	50-99	0

T1 did not possess any habitat breaks or channel complexity in the modified channel. Water quality was poor with a water temperature of 23.0°C and dissolved oxygen of 4.38 mg/l. The primary substrates were gravel and fines, and both banks were covered in reed canarygrass. There was also a high amount of silt in the reach and no spawning gravel visible. The primary limiting factors for T1 are dangerously poor water quality during summer, no overhead canopy cover, and a lack of complex habitat.

The T2 survey area included a glide, a riffle, a pool, and RTK measurements at the sediment trap upstream. The T2 survey area is located immediately downstream of Beaver Lake Road and is the boundary of the channel modification from 2020. Water quality in T2 improved when compared to T1 with a water temperature of 17.5°C and a dissolved oxygen of 8.72 mg/l, but farther downstream and closer to T1, the water quality conditions are expected to be much closer to the high water temperatures and low dissolved oxygen recorded in T1. The T2 survey area included a pool, a riffle, and a glide. The main channel pool in T2 was created by the culvert on Beaver Lake Road. The total length of the pool was 42 feet and the maximum depth was 2.2 feet at the time of the survey. The culvert, the water depth in the pool, and surrounding vegetation provide some cover for salmonids. During summer conditions when flows are low, this pool is likely the only suitable habitat for juvenile salmon in the reach. In T2, the available substrate for all habitats was sand and gravel. The banks of T2 are lined with reed canarygrass and there is no overhead canopy cover. Several steelhead redds were observed in T3 during the 2016 surveys (WDFW 2016). The primary limiting factors for T2 are poor water quality, lack of overhead canopy cover for thermal refugia, and very limited woody debris for habitat structure.

In T3, salmon habitat conditions improved markedly. There were no limiting factors in T3. Five habitats were sampled in T3, three riffles, and two pools. Each habitat's primary substrate composition was gravel and small cobble, with the exception of one of the pools which was sand and small cobble. A redd survey flag was seen in the creek in T3 from a previous year and juvenile salmonids were seen using each of the habitats. A migration barrier may present in T3 from a cottonwood (*Populus trichocarpa*) that fell across the channel a few months before the survey, according to a local landowner.

The primary habitat located in T4 was pocketwater, which could be a result of the low water, with a maximum depth of 0.4 feet in the surveyed reach. The substrate in the pocketwater was small cobble and large cobble. One small pool with a length of 9 feet and 1.4 feet in depth was surveyed. The substrate in the pool included gravel and bedrock, while the pool tailout was composed of small cobble. The embeddedness of the entire survey area was less than 25%.

T4 had a large amount of woody debris within the channel, including one log jam. The total amount of woody debris observed in the 200feet survey reach was 10 pieces of LWD, including 1 log jam with 8 of those pieces, 3 root wads within the channel, and 11 pieces of small woody debris. The primary cover was hardwood. There were no limiting factors in T4, although depth in summer would be insufficient to support fish larger than juveniles.

As discussed in the section above, Reach T1, especially near the confluence with East Fork Nookachamps Creek, has changed positions since the first aerial imagery taken in 1937. This reach has been heavily modified by repeated dredging and experiences heavy aggradation. There are only three culvert crossings on Turner Creek. Of those, the lowermost one on Beaver Lake Road (WDFW ID NC97) is the only one likely to cause backwatering. The other two are further upstream in steeper gradient reaches. ESA evaluated channel capacity of Turner Creek in Reach T1, near the confluence with East Fork Nookachamps Creek and in Reach T2, just downstream of Beaver Lake Road. Both reaches are unable to convey the estimated 2-year flow.

3.4.1 Bridge and Culvert Crossings

The first crossing on Turner Creek is Beaver Lake Road at RM 1.0. During the field surveys, the low-slope culvert was observed to be mostly submerged and could potentially contribute to backwatering during flood events. At the two upstream culverts, Turner Creek is higher gradient and transitions to a riffle-pool planform with less potential for backwatering. See **Table C-11** for a summary of all crossings on Turner Creek. The capacity of two lower culverts were evaluated using HY-8 modeling software to determine how much flow the culvert can convey before overtopping, see Appendix D. Beaver Lake Road, over Culvert 1 will overtop during a 102 cfs flow, which is less than the 2-year flow of 146 cfs. Elk Road, at Culvert 2 will not overtop until a 200-year flood flow.

TABLE C-11
CROSSINGS ON TURNER CREEK

Number	Crossing Type	Road	River Mile	WDFW Site ID
1	Round Corrugated Steel Culvert	Beaver Lake Road	1.0	NC97
2	Round Structural Plate Steel Culvert	Elk Road	1.4	NC94
3	Round Corrugated Steel Culvert	Janicki Road	2.3	NA

3.4.2 Channel Capacity

Field staff surveyed several cross sections on Turner Creek and used the data to evaluate channel capacity at the reaches of the creek prone to flooding. Reach T1 is just above the confluence with East Fork Nookachamps Creek, while Reach T2 is just below Beaver Lake Road. Both areas of channel are undersized and will overtop during the 2-year flow (**Table C-12**).

TABLE C-12
ESTIMATED CHANNEL CAPACITY VERSUS 2-YEAR PEAK FLOOD FOR SELECT REACHES

Creek	Reach	Minimum Bankfull Flow Cross-section 1 (cfs)	Minimum Bankfull Flow Cross-section 2 (cfs)	2-Year Flow (cfs), *StreamStats*
Turner Creek	T1	144	NA	243
Turner Creek	T2	191	383	234

5.5 Little Day Creek

Field observations are summarized in **Table C-13**. Reach LD1 is a ditched channel surrounded by wetlands and wet agricultural fields. During the summer, the lakes and creek channels get very warm and low flows result in stagnation and low dissolved oxygen in the creek channel. During the field survey, the LD1 water temperature was 24.1°C and dissolved oxygen was 1.39 mg/l both of which exceed lethal tolerances for salmonids. Largemouth bass, a warmwater fish who is a major predator of juvenile salmon, were observed. The LD1 ditch is a simple channel with no wood or habitat complexity. The bank is stabilized with large cobble and the substrate in the channel was primarily fine sediment. The banks were lined with reed canary grass and over 75% of the water's surface was covered by aquatic vegetation. In the winter wet season and during higher flow events, water covers the surrounding fields. For any fish in the area, the shallow water across the valley creates a stranding risk when flows recede. The limiting factors in LD1 include water quality, water flow, invasive species, and lack of suitable salmon habitat.

TABLE C-13
FIELD DATA SUMMARY FOR LITTLE DAY CREEK REACHES

Parameter		Reach	
		LD1	LD1
River Miles		0.0-1.2	1.2+
Average Bankfull Width (feet)			12.8
Slope	Field Measure	0.02%	
	LiDAR (full reach)	0.08%	4.51%
Habitat Types		Glide	Pocketwater
Substrate	D50 (mm)	fines	14.1
	Dominant, Subdominant	Lg. Cobble	Sm. Cobble, Lg. Cobble
	Total Embeddedness	0-25%	51-75%
Woody Debris	LWD and Rootwad Count	0	2
	SWD Count	0	1
Habitat Quality	Spawning HQM	0	1
	Rearing HQM	0	1
Water Quality	Water Temperature (°C)	24.1	16.4
	Dissolved Oxygen (mg/l)	1.39	9.49
Number of Juvenile Salmonids Observed		0	1-49

Reach LD2 begins at RM 1.2, as Little Day Creek transitions from the valley floor to higher gradient hills. At this reach, Little Day Creek is a small creek with low flows in the summer. LD2 was classified as pocketwater habitat. The primary substrates were small cobble and large cobble, but these substrates were highly embedded (50-75%). Wood in the creek provided some instream cover, and canopy cover was dense hardwood. Juvenile salmonids were seen during the survey. Water quality was considerably better in LD2 with water temperature measured as 16.4°C and dissolved oxygen as 9.49 mg/l. There were no limiting factors for this habitat.

1.1.1 Bridge and Culvert Crossings

Little Day Creek is the primary outlet of Beaver and Clear lakes. Within the lakes' floodplain, the creek is very low-gradient and functions more as a ditch with little observable flow. It crosses through three culverts in Reach LD1 and one bridge in Reach LD2, see **Table C-14** for a summary of all crossings on Little Day Creek. The Fonk Road crossing is known to overtop during floods, and last flooded in February of 2020 according to local newspapers.

TABLE C-14
CROSSINGS ON LITTLE DAY CREEK

Number	Crossing Type	Road	River Mile	WDFW Site ID
1	Squash Structural Plate Steel Culvert	Beaver Lake Road	0.1	NC96
2	Round Corrugated Steel Culvert	Fonk Road	0.3	NC93
3	Squash Corrugated Steel Culvert	Fox Road	0.2 (from Beaver Lake)	NC49
4	Iron beam bridge with concrete deck	Wayward Way	0.8 (from Beaver Lake)	NA

The capacity of two lower culverts were evaluated using HY-8 modeling software to determine how much flow the culvert can convey before overtopping, see Appendix D.

3.4.3 Channel Capacity

Field staff surveyed several cross sections on Little Day Creek and used the data to evaluate channel capacity at the reaches of the creek prone to flooding. At the surveyed cross sections, just downstream of Fonk Road, the channel is unable to convey the 2-year flow without overtopping (**Table C-15**).

TABLE C-15
ESTIMATED CHANNEL CAPACITY VERSUS 2-YEAR PEAK FLOOD FOR SELECT REACHES

Creek	Reach	Minimum Bankfull Flow Cross-section1 (cfs)	Minimum Bankfull Flow Cross-section 2 (cfs)	2-Year Flow (cfs), *StreamStats*
Little Day Creek	LD1	78	95	109

3.5 Mundt Creek

Field observations are summarized in **Table C-16**. Mundt Creek is an important salmon creek due to the quality of its habitat and its strong production of salmon over the years. The M1 survey area was comprised of three habitat units: a riffle, a pool, and pocketwater. All three contained small cobble and large cobble as their primary substrate All three habitats in M1 contained a mix of spawning gravel, thermal cover, large and small woody debris, and a bubble curtain that contribute to the overall habitat complexity. The pool was 50.0 feet long, had a maximum depth of 1.2 feet and the pool tailout substrate was small cobble. No limiting factors were identified in M1, although algae were present on approximately 30% of the substrate. During the survey, the field crew noted the presence of an old redd survey flagging in the reach and a high number of juvenile salmonids in each habitat unit surveyed. M1 is a primary spawning reach in the East Fork Nookachamps Creek watershed and provides spawning habitat for Chinook salmon, coho salmon, chum salmon, pink salmon, and steelhead.

M2 exhibits characteristics of a high-gradient stream with its primary substrates consisting of large cobble and boulders. The two habitat units observed in the reach were a pool and pocketwater. The reach provided optimal habitat for rearing, but lower quality spawning habitat due to the large substrate. There was no woody debris in M2. Despite containing cold water in summer months with adequate flow to support salmonids year-round very few juveniles were observed in this reach. M2 is approximately 1.0 mile upstream of a gradient barrier noted by WDFW that limits spawning habitat (WDFW 2016). Spawning surveys have not been conducted in M2 due to the change in gradient and the opinion that no salmon or steelhead would spawn in this reach (WDFW 2016).

TABLE C-16
FIELD DATA SUMMARY FOR MUNDT CREEK REACHES

Parameter		Reach	
		M1	M2
River Miles		0.0-0.6	0.6-2.0
Average Bankfull Width (feet)		19.3	16.7
Slope	Field Measure		8.69%
	LiDAR (full reach)	1.63%	3.75%
Habitat Types		Riffle, Pool, Pocketwater	Pool, Pocketwater
Substrate	D50 (mm)	25.7	22.0
	Dominant, Subdominant	SC, LC	LC, Gr
	Total Embeddedness	51-75%	0-25%
Woody Debris	LWD and Rootwad Count	4	0
	SWD Count	0	0
Habitat Quality	Spawning HQM	1	0.33
	Rearing HQM	1	1
Water Quality	Water Temperature (°C)	17.1	16.7
	Dissolved Oxygen (mg/l)	9.8	8.9
Number of Juvenile Salmonids Observed		1-49	1-49

3.5.1 Bridge and Culvert Crossings

There are three road crossings on Mundt Creek. The creek flows through two culverts under Beaver Lake Road, 0.1 miles upstream of its confluence with East Fork Nookachamps Creek. Upstream, there are two I-beam bridges as stream begins to transition to a higher gradient. See **Table C-17** for a summary of all crossings on Mundt Creek. These crossings are positioned higher in the watershed and are unlikely to backwater. Their hydraulic capacity was not evaluated.

TABLE C-17
CROSSINGS ON MUNDT CREEK

Number	Crossing Type	Road	River Mile	WDFW Site ID
1	Two Squash Structural Plate Steel Culverts	Beaver Lake Road	0.1	NC99
2	I-beam bridge with concrete deck	Private Driveway	0.6	NC33
3	I-beam bridge with concrete deck	BPA Access Road / Janicki Road	1.9	NA

3.6 Klahowya Creek

Field observations are summarized in **Table C-18**. K3 was not surveyed because there was no water in the channel at the time of the survey.

TABLE C-18
FIELD DATA SUMMARY FOR UNNAMED TRIBUTARY (03.0248) REACHES

Parameter		Reach		
		K1	K2	K3
River Miles		0.0-0.8	0.8-1.8	1.8+
Average Bankfull Width (feet)		10.4	7.5	
Slope	Field Measure			
	LiDAR (full reach)			
Habitat Types		Pocketwater	Riffle	
Substrate	D50 (mm)			
	Dominant, Subdominant	Gravel, Boulder	Gravel, Sm. Cobble	
	Total Embeddedness	51-75%	26-50%	
Woody Debris	LWD and Rootwad Count	7	0	
	SWD Count	2	0	
Habitat Quality	Spawning HQM	1	0.66	
	Rearing HQM	1	1	
Water Quality	Water Temperature (°C)	18.1	19	
	Dissolved Oxygen (mg/l)	9.7	9.8	
Number of Juvenile Salmonids Observed		1-49	1-49	

K1 was surveyed near the transmission line right-of-way in the densely forested region of the project area. Flows were low and the entire survey area was pocketwater. The dominant/subdominant substrate was gravel and boulder and the substrate had a high embeddedness over 75%. This reach is surrounded by hardwood and there were several downed pieces of woody debris in the stream, including 7 pieces of LWD and 2 pieces of SWD. Juvenile salmonids were observed during the survey. Unk2-1 provides good salmonid spawning and rearing habitat.

K2 is located at the Boy Scout Camp and was restored for fish passage in 1998 (SFEG 2007). K2 had minimal flow with a maximum depth of only 0.3 feet during the survey. The survey was limited to a 140 feet section due to dense blackberries. The habitat one riffle. No woody debris was present, but the reach did contain overhead canopy cover from cottonwood trees. Despite the shallow depths, juvenile salmonids were observed in the reach during the survey. Limiting factors in the reach were shallow water depth and lack of woody debris

3.6.1 Bridge and Culvert Crossings

There are several bridge and culvert crossings on Klahowya Creek, see **Table C-19** below. Because the creek is relatively small and outside areas that are reported to frequently flood, the hydraulic capacity of the crossings was not evaluated.

TABLE C-19
CROSSINGS ON KLAHOWYA CREEK

Number	Crossing Type	Road	River Mile	WDFW Site ID
1	Round Corrugated Steel Culvert	Private Road	0.15	NC6
2	Squash Corrugated Steel Culvert	BPA Access Road	0.6	NC7
3	Wooden Bridge	Swinomish Lane	01.2	NC8
4	Round Corrugated Steel Culvert	Klahowya Rd	1.4	NC10

3.7 Cold Spring Creek and Unnamed Tributary 1 (3.0237)

The field crew was unable to access Cold Spring Creek to assess fish habitat and geomorphic conditions. A 30-foot-long section of Unk1-1 was surveyed beyond which dense blackberries prevented further surveying. Field observations are summarized in **Table C-20**. Unk 1-1 included a pool providing good spawning and rearing habitat for salmonids. The water temperature in the creek (15.7ºC) tied for the lowest measured in the project area.

TABLE C-20
FIELD DATA SUMMARY FOR UNNAMED TRIBUTARY (03.0237) REACHES

Parameter		Reach	
		Unk1-1	Unk1-2
River Miles		0.0-1.0	1.0-1.8
Average Bankfull Width (feet)			
Slope	Field Measure		
	LiDAR (full reach)		
Habitat Types		Pool	

Parameter		Reach	
		Unk1-1	Unk1-2
Substrate	D50 (mm)		
	Dominant, Subdominant	Gravel, Boulder	
	Total Embeddedness	51-75%	
Woody Debris	LWD and Rootwad Count	0	
	SWD Count	0	
Habitat Quality	Spawning HQM	1	
	Rearing HQM	1	
Water Quality	Water Temperature (°C)	15.7	
	Dissolved Oxygen (mg/l)	9.7	
Number of Juvenile Salmonids Observed		0	

3.7.1 Bridge and Culvert Crossings

There are several private crossings on both Cold Spring Creek and Unnamed tributary 1 (**Tables C-21** and **C-22**, respectively). As these crossings are in high-gradient areas, not prone to flooding, their hydraulic capacity was not evaluated.

TABLE C-21
CROSSINGS ON COLD SPRING CREEK

Number	Crossing Type	Road	River Mile	WDFW Site ID
1	Two Round Corrugated Steel Culverts	Private Driveway	0.1	NC60
2	Round Corrugated Steel Culvert	Abandoned Forest Road	0.5	NC41
3	Culvert	BPA Access Road / Janicki Road	1.1	NA

TABLE C-22
CROSSINGS ON UNNAMED TRIBUTARY 1

Number	Crossing Type	Road	River Mile	WDFW Site ID
1	Dam	NA	0.4	NC131
2	Culvert	BPA Access Road / Janicki Rd	0.7	NA

3.8 Walker Creek

Field observations are summarized in **Table C-23**. The W1 survey area was comprised of three habitat units: a glide, a riffle, and a pool. The primary substrate sizes in the reach were small cobble and silt/clay. The reach had higher wood counts than any other reach surveyed. W1 provides high quality salmonid spawning and rearing habitat. The measured water temperature was quite high (20.1°C). During the survey, the field crew noted the presence of an old redd survey flagging in the reach and a high number of juvenile salmonids in each habitat unit surveyed. M1 is a primary rearing reach in the East Fork Nookachamps Creek watershed providing habitat for Chinook salmon, coho salmon, chum salmon, pink salmon, and steelhead.

W2 and W3 are located entirely on private property and were not able to be accessed. The field crew collected data in East Fork Walker Creek to provide information on this part of the creek. The East Fork Walker Creek survey area was from the culvert on Walker Valley Road and continuing onto developed farmland.

W4 contains complex pool riffle habitats. The substrate was primarily large cobble and boulders. Much of the reach provides good spawning and rearing conditions, although the availability of suitably sized substrate for spawning was limited in part of the reach. The riparian corridor contains mature conifer trees.

The East Fork Walker Creek survey reach contains additional good salmon spawning and rearing habitat, although water temperatures exceeded 20 C. Juvenile salmonids were observed during the survey.

TABLE C-23
FIELD DATA SUMMARY FOR WALKER CREEK REACHES

Parameter		Reach				
		W1	W2	W3	W4	EFW1
River Miles		0.0-0.5	0.5-2.0	2.0-2.5	2.5+	
Average Bankfull Width (feet)		31.5			28.0	7.2
Slope	Field Measure	1.15%				0.61%
	LiDAR (full reach)	0.49%			5.32%	1.24%
Habitat Types		Glide, Riffle, Pool			Riffle, Pool	Glide
Substrate	D50 (mm)	17.5			20.7	
	Dominant, Subdominant	Sm. Cobble, Silt/Clay			Gravel, Sm. Cobble	Gravel, Sm. Cobble
	Total Embeddedness	51-75%			26-50%	26-50%
Woody Debris	LWD and Rootwad Count	11			0	0
	SWD Count	21			0	0
Habitat Quality	Spawning HQM	0.66			1	0.66
	Rearing HQM	1			0.66	0.66
Water Quality	Water Temperature (°C)	20.1			19.0	20.3
	Dissolved Oxygen (mg/l)	8.85			9.8	8.94
Number of Juvenile Salmonids Observed		50-99			1-49	1-49

3.8.1 Bridge and Culvert Crossings

Upstream of its confluence with East Fork Nookachamps Creek, Walker Creek crosses under three private bridges. The field crew did not evaluate these crossings during the field surveys. As all the crossings are farther upstream in the watershed, outside of East Fork Nookachamps Creek Valley, their hydraulic capacity was not evaluated. See **Table C-24** for a summary of all crossings on Walker Creek.

TABLE C-24
CROSSINGS ON WALKER CREEK

Number	Crossing Type	Road	River Mile	WDFW Site ID
1	Steel I-beam Bridge with Wood Decking	Private Road	0.05	NC45
2	Steel I-beam Bridge with Wood Decking	Private Road	0.15	NC46
3	Wooden Footbridge	Footpath	0.2	NC47
4	Concrete Bridge	Taylor Road	0.4	NC102
5	Round Structural Plate Steel Culvert	Peter Burns Road		NC17

3.9 Summary of Pebble Count Data

Pebble counts showed an increase in fine sediments in the several of the downstream reaches including EF1 and EF2. Overall, pebble size increased with distance upstream (**Figure C-4)**. Pebble Count Distribution). Fine sediment impacts salmon and steelhead spawning by filling the spaces between spawning gravels, reducing oxygen availability to the eggs, and can cause infilling of primary habitats.

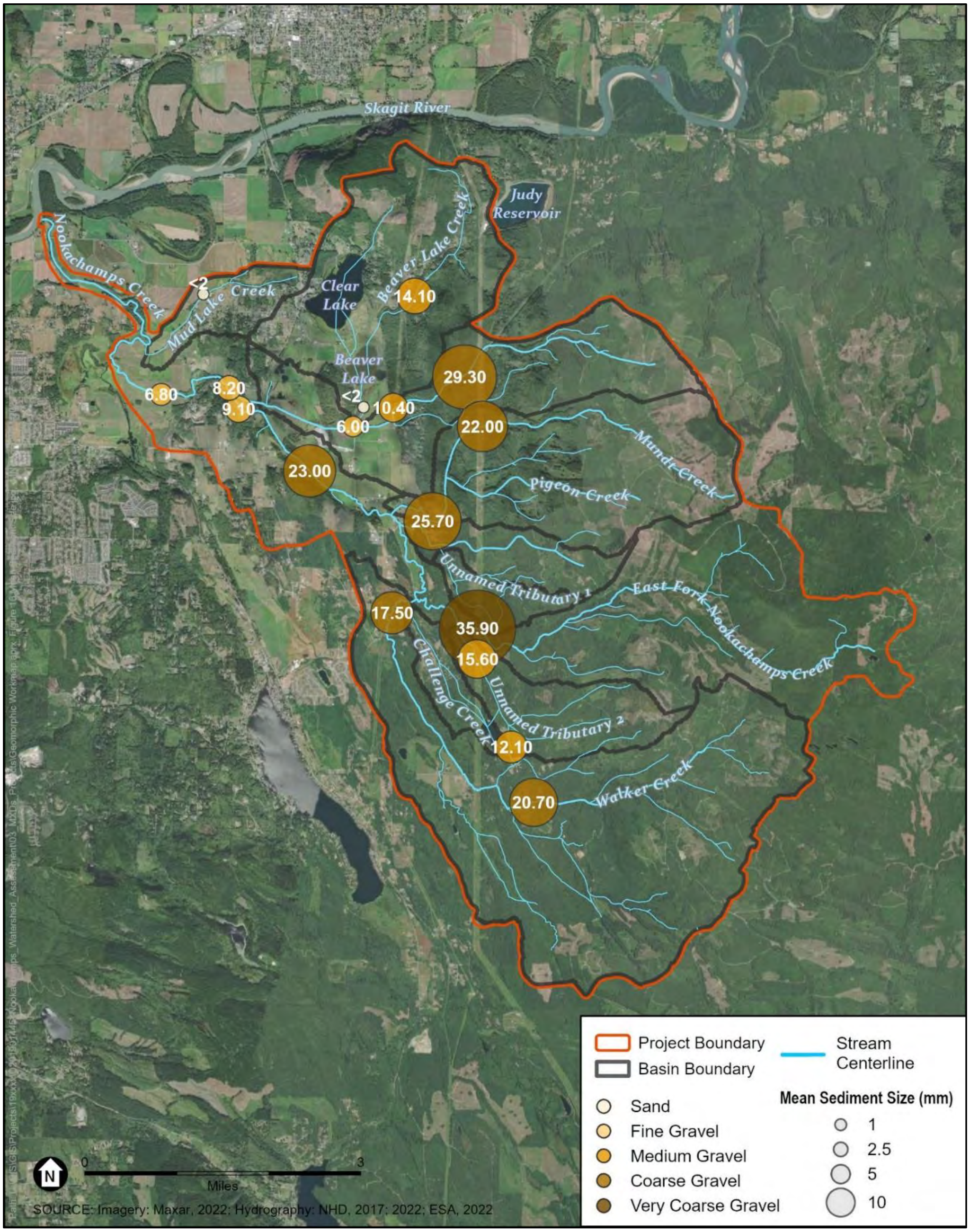


Figure C-4
Mean Sediment Size at Study Reaches

Attachment C-1.

Representative Site Photos

EF1. Looking downstream.

EF2. Looking upstream from bottom of the pool habitat unit.


EF3. Looking upstream.


EF4. Looking downstream.

EF5. Looking downstream.


M1. Looking upstream.


M2. Looking upstream.


T1. Looking upstream.


T2. Looking downstream.


T3. Looking upstream.


T4. Looking upstream.

W1. Looking downstream.

W4. Looking at pool from top of culvert


EFW1. Looking downstream.


LD1. Looking downstream.


LD2. Looking upstream.


Unk1-1. Looking downstream from culvert.

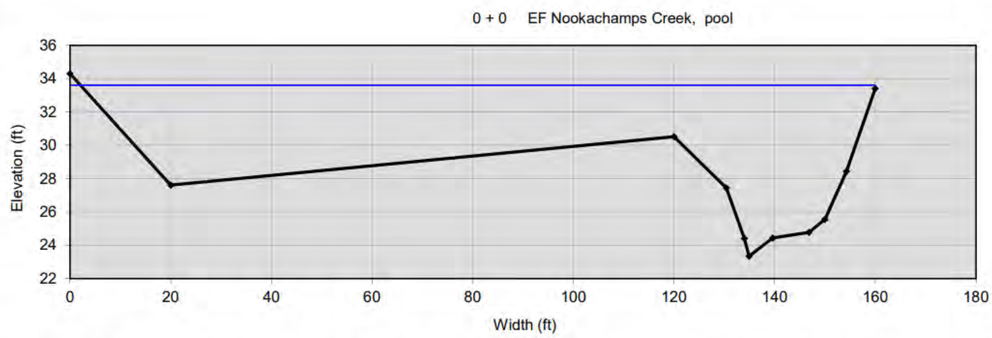
K1. Looking upstream

K2. Looking upstream.

Attachment C-2.
Channel Capacity Analysis

East Fork Nookachamps Reach 1 Cross Sections

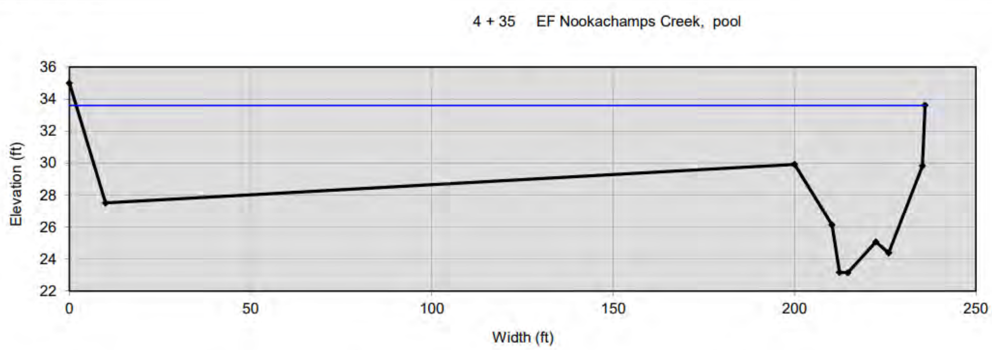
Cross Section 1



Bankfull Dimensions		Flood Dimensions		Materials	
773.8	x-section area (ft.sq.)	500.0	W flood prone area (ft)	4.7	D50 Bed (mm)
157.9	width (ft)	3.2	entrenchment ratio	8.7	D84 Bed (mm)
4.9	mean depth (ft)	10.1	low bank height (ft)	7	threshold grain size (mm):
10.3	max depth (ft)	1.0	low bank height ratio		
163.9	wetted parimeter (ft)				
4.7	hyd radi (ft)				
32.2	width-depth ratio				

Bankfull Flow		Flow Resistance		Forces & Power	
1.8	velocity (ft/s)	0.050	Manning's roughness	0.046	channel slope (%)
1390.3	discharge rate (cfs)	0.17	D'Arcy-Weisbach fric.	0.14	shear stress (lb/sq.ft.)
0.15	Froude number	16.2	resistance factor u/u*	0.26	shear velocity (ft/s)
		171.7	relative roughness	0.25	unit strm power (lb/ft/s)

Cross Section 2



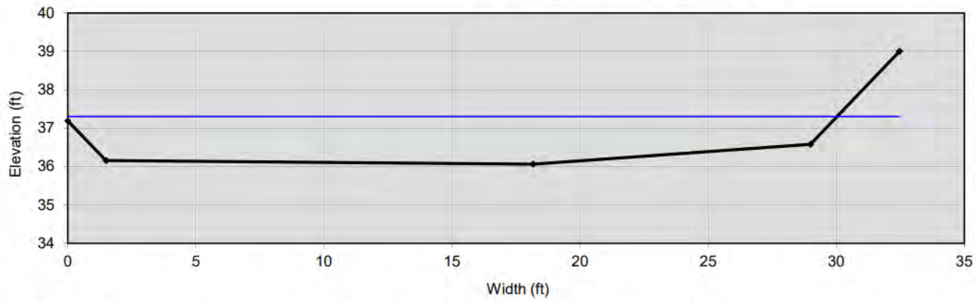
Bankfull Dimensions		Flood Dimensions		Materials	
1220.6	x-section area (ft.sq.)	500.0	W flood prone area (ft)	4.7	D50 Bed (mm)
234.1	width (ft)	2.1	entrenchment ratio	8.7	D84 Bed (mm)
5.2	mean depth (ft)	10.5	low bank height (ft)	7	threshold grain size (mm):
10.5	max depth (ft)	1.0	low bank height ratio		
243.3	wetted parimeter (ft)				
5.0	hyd radi (ft)				
44.9	width-depth ratio				

Bankfull Flow		Flow Resistance		Forces & Power	
1.9	velocity (ft/s)	0.050	Manning's roughness	0.046	channel slope (%)
2283.8	discharge rate (cfs)	0.17	D'Arcy-Weisbach fric.	0.14	shear stress (lb/sq.ft.)
0.15	Froude number	16.4	resistance factor u/u*	0.27	shear velocity (ft/s)
		182.6	relative roughness	0.28	unit strm power (lb/ft/s)

East Fork Nookachamps Reach 2 Cross Sections

Cross Section 1

0 + 0 EF Nookachamps Creek Reach 2, riffle

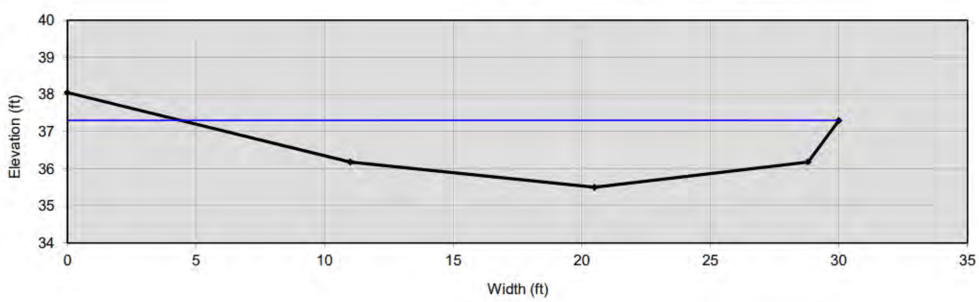


Bankfull Dimensions		Flood Dimensions		Materials	
31.9	x-section area (ft.sq.)	200.0	W flood prone area (ft)	9.1	D50 Bed (mm)
30.0	width (ft)	6.7	entrenchment ratio	16	D84 Bed (mm)
1.1	mean depth (ft)	1.1	low bank height (ft)	8	threshold grain size (mm):
1.2	max depth (ft)	0.9	low bank height ratio		
30.6	wetted parimeter (ft)				
1.0	hyd radi (ft)				
28.3	width-depth ratio				

Bankfull Flow		Flow Resistance		Forces & Power	
1.5	velocity (ft/s)	0.050	Manning's roughness	0.25	channel slope (%)
48.7	discharge rate (cfs)	0.29	D'Arcy-Weisbach fric.	0.16	shear stress (lb/sq.ft.)
0.26	Froude number	10.5	resistance factor u/u*	0.29	shear velocity (ft/s)
		20.2	relative roughness	0.25	unit strm power (lb/ft/s)

Cross Section 2

2 + 25 EF Nookachamps Creek Reach 2, riffle

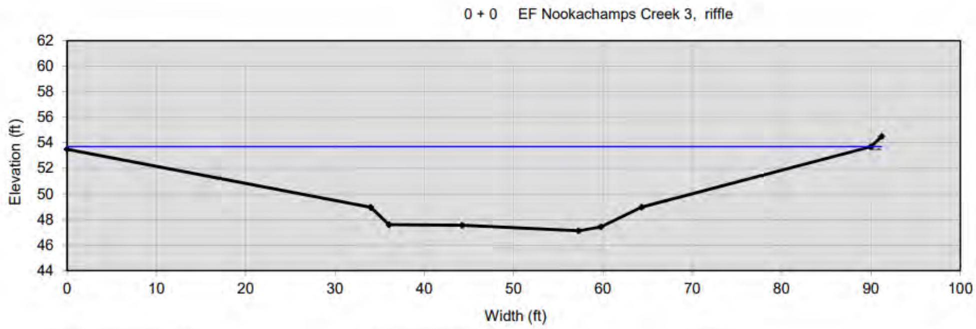


Bankfull Dimensions		Flood Dimensions		Materials	
30.3	x-section area (ft.sq.)	200.0	W flood prone area (ft)	9.1	D50 Bed (mm)
25.6	width (ft)	7.8	entrenchment ratio	16	D84 Bed (mm)
1.2	mean depth (ft)	1.8	low bank height (ft)	9	threshold grain size (mm):
1.8	max depth (ft)	1.0	low bank height ratio		
26.2	wetted parimeter (ft)				
1.2	hyd radi (ft)				
21.6	width-depth ratio				

Bankfull Flow		Flow Resistance		Forces & Power	
1.6	velocity (ft/s)	0.050	Manning's roughness	0.25	channel slope (%)
49.9	discharge rate (cfs)	0.28	D'Arcy-Weisbach fric.	0.18	shear stress (lb/sq.ft.)
0.27	Froude number	11.0	resistance factor u/u*	0.31	shear velocity (ft/s)
		22.6	relative roughness	0.3	unit strm power (lb/ft/s)

East Fork Nookachamps Reach 3 Cross Sections

Cross Section 1



Bankfull Dimensions	
330.5	x-section area (ft.sq.)
90.0	width (ft)
3.7	mean depth (ft)
6.6	max depth (ft)
91.4	wetted parimeter (ft)
3.6	hyd radi (ft)
24.5	width-depth ratio

Flood Dimensions	
200.0	W flood prone area (ft)
2.2	entrenchment ratio
6.4	low bank height (ft)
1.0	low bank height ratio

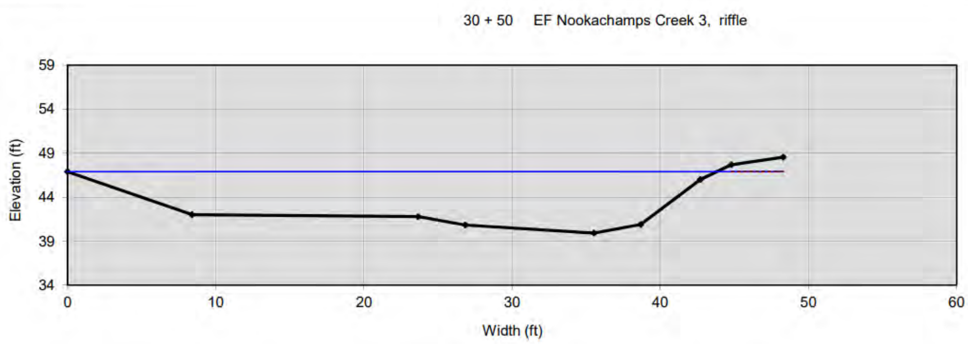
Materials	
22	D50 Bed (mm)
35	D84 Bed (mm)
28	threshold grain size (mm):

Bankfull Flow	
3.5	velocity (ft/s)
1159.1	discharge rate (cfs)
0.33	Froude number

Flow Resistance	
0.050	Manning's roughness
0.19	D'Arcy-Weisbach fric.
12.0	resistance factor u/u*
32.0	relative roughness

Forces & Power	
0.25	channel slope (%)
0.56	shear stress (lb/sq.ft.)
0.54	shear velocity (ft/s)
2	unit strm power (lb/ft/s)

Cross Section 2



Bankfull Dimensions	
206.6	x-section area (ft.sq.)
43.8	width (ft)
4.7	mean depth (ft)
7.0	max depth (ft)
48.3	wetted parimeter (ft)
4.3	hyd radi (ft)
9.3	width-depth ratio

Flood Dimensions	
200.0	W flood prone area (ft)
4.6	entrenchment ratio
7.0	low bank height (ft)
1.0	low bank height ratio

Materials	
22	D50 Bed (mm)
35	D84 Bed (mm)
33	threshold grain size (mm):

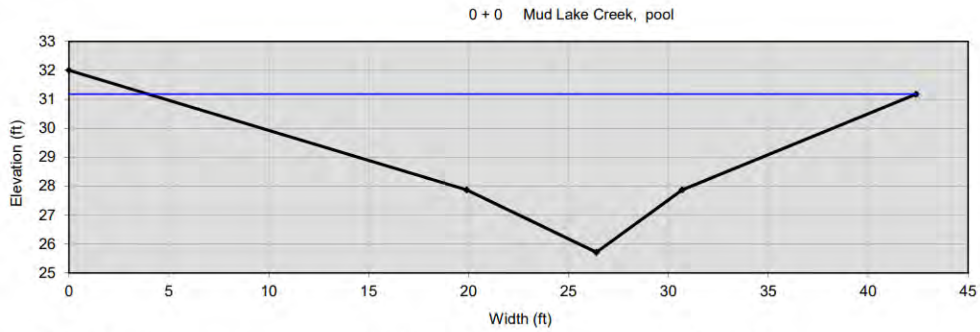
Bankfull Flow	
3.9	velocity (ft/s)
810.3	discharge rate (cfs)
0.33	Froude number

Flow Resistance	
0.050	Manning's roughness
0.18	D'Arcy-Weisbach fric.
12.3	resistance factor u/u*
41.1	relative roughness

Forces & Power	
0.25	channel slope (%)
0.67	shear stress (lb/sq.ft.)
0.59	shear velocity (ft/s)
2.9	unit strm power (lb/ft/s)

Mud Lake Creek Reach 1 Cross Section

Cross Section 1



Bankfull Dimensions	
93.2	x-section area (ft.sq.)
38.4	width (ft)
2.4	mean depth (ft)
5.5	max depth (ft)
40.1	wetted parimeter (ft)
2.3	hyd radi (ft)
15.9	width-depth ratio

Flood Dimensions	
300.0	W flood prone area (ft)
7.8	entrenchment ratio
5.5	low bank height (ft)
1.0	low bank height ratio

Materials	
0.92	D50 Bed (mm)
7.6	D84 Bed (mm)
1	threshold grain size (mm):

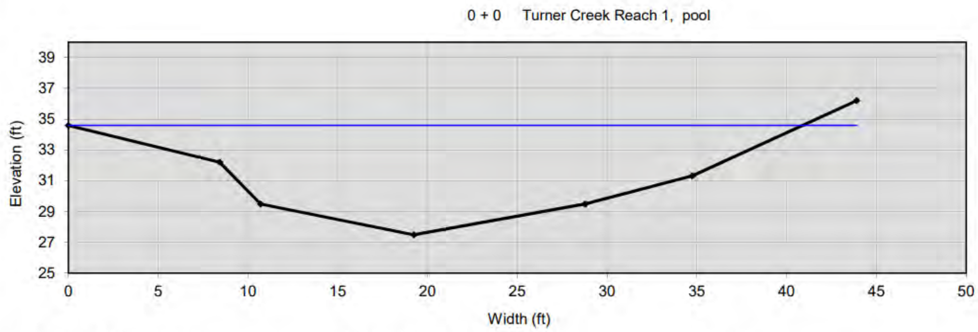
Bankfull Flow	
0.5	velocity (ft/s)
48.7	discharge rate (cfs)
0.06	Froude number

Flow Resistance	
0.050	Manning's roughness
0.22	D'Arcy-Weisbach fric.
14.9	resistance factor u/u*
97.2	relative roughness

Forces & Power	
0.01	channel slope (%)
0.01	shear stress (lb/sq.ft.)
0.09	shear velocity (ft/s)
0.0079	unit strm power (lb/ft/s)

Turner Creek Reach 1 Cross Sections

Cross Section 1



Bankfull Dimensions

164.2	x-section area (ft.sq.)
40.9	width (ft)
4.0	mean depth (ft)
7.1	max depth (ft)
44.0	wetted parimeter (ft)
3.7	hyd radi (ft)
10.2	width-depth ratio

Flood Dimensions

200.0	W flood prone area (ft)
4.9	entrenchment ratio
7.1	low bank height (ft)
1.0	low bank height ratio

Materials

8.2	D50 Bed (mm)
17	D84 Bed (mm)
2	threshold grain size (mm):

Bankfull Flow

0.9	velocity (ft/s)
144.0	discharge rate (cfs)
0.08	Froude number

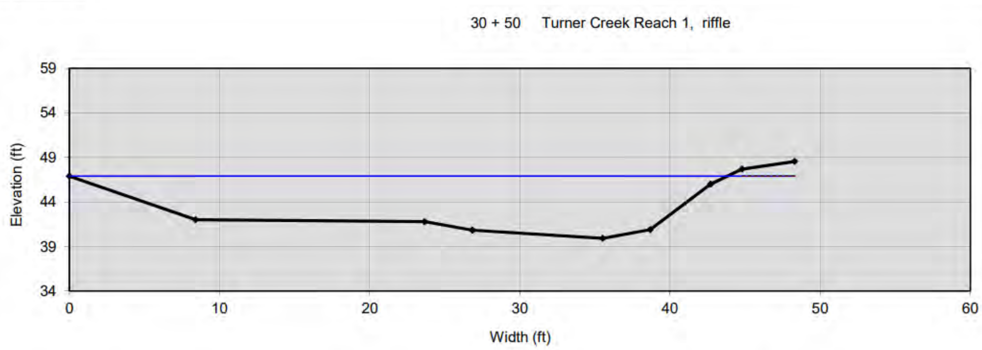
Flow Resistance

0.050	Manning's roughness
0.19	D'Arcy-Weisbach fric.
13.9	resistance factor u/u*
72.0	relative roughness

Forces & Power

0.015	channel slope (%)
0.03	shear stress (lb/sq.ft.)
0.13	shear velocity (ft/s)
0.033	unit strm power (lb/ft/s)

Cross Section 2



Bankfull Dimensions

206.6	x-section area (ft.sq.)
43.8	width (ft)
4.7	mean depth (ft)
7.0	max depth (ft)
48.3	wetted parimeter (ft)
4.3	hyd radi (ft)
9.3	width-depth ratio

Flood Dimensions

200.0	W flood prone area (ft)
4.6	entrenchment ratio
7.0	low bank height (ft)
1.0	low bank height ratio

Materials

8.2	D50 Bed (mm)
17	D84 Bed (mm)
33	threshold grain size (mm):

Bankfull Flow

3.9	velocity (ft/s)
810.3	discharge rate (cfs)
0.33	Froude number

Flow Resistance

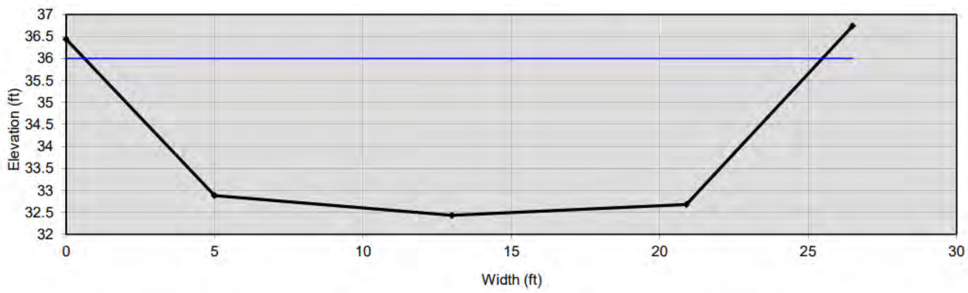
0.050	Manning's roughness
0.18	D'Arcy-Weisbach fric.
14.1	resistance factor u/u*
84.5	relative roughness

Forces & Power

0.25	channel slope (%)
0.67	shear stress (lb/sq.ft.)
0.59	shear velocity (ft/s)
2.9	unit strm power (lb/ft/s)

Cross Section 2

0 + 80 Turner Creek, pool



Bankfull Dimensions

68.4	x-section area (ft.sq.)
24.9	width (ft)
2.8	mean depth (ft)
3.6	max depth (ft)
27.0	wetted parimeter (ft)
2.5	hyd radi (ft)
9.0	width-depth ratio

Flood Dimensions

1500.0	W flood prone area (ft)
60.3	entrenchment ratio
4.0	low bank height (ft)
1.1	low bank height ratio

Materials

0.92	D50 Bed (mm)
7.6	D84 Bed (mm)
20	threshold grain size (mm):

Bankfull Flow

2.8	velocity (ft/s)
193.3	discharge rate (cfs)
0.31	Froude number

Flow Resistance

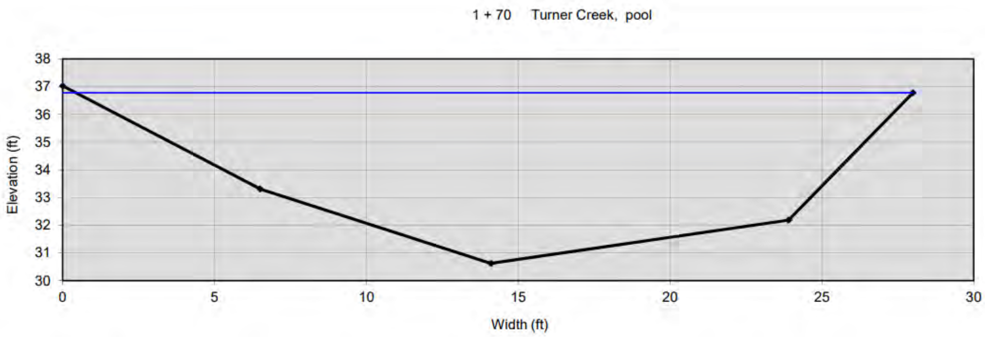
0.050	Manning's roughness
0.21	D'Arcy-Weisbach fric.
14.7	resistance factor u/u*
110.4	relative roughness

Forces & Power

0.26	channel slope (%)
0.41	shear stress (lb/sq.ft.)
0.46	shear velocity (ft/s)
1.26	unit strm power (lb/ft/s)

Turner Creek Reach 2 Cross Sections

Cross Section 3



Bankfull Dimensions	
109.3	x-section area (ft.sq.)
27.6	width (ft)
4.0	mean depth (ft)
6.2	max depth (ft)
31.1	wetted parimeter (ft)
3.5	hyd radi (ft)
7.0	width-depth ratio

Flood Dimensions	
600.0	W flood prone area (ft)
21.8	entrenchment ratio
6.2	low bank height (ft)
1.0	low bank height ratio

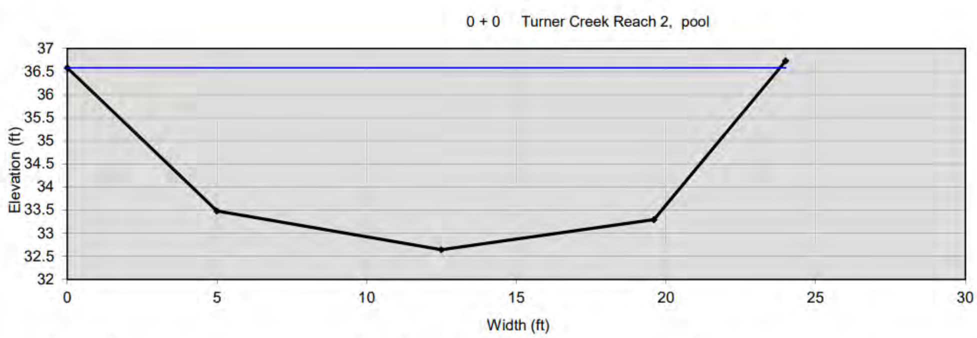
Materials	
0.92	D50 Bed (mm)
7.6	D84 Bed (mm)
28	threshold grain size (mm):

Bankfull Flow	
3.5	velocity (ft/s)
383.1	discharge rate (cfs)
0.33	Froude number

Flow Resistance	
0.050	Manning's roughness
0.19	D'Arcy-Weisbach fric.
15.7	resistance factor u/u*
159.0	relative roughness

Forces & Power	
0.26	channel slope (%)
0.57	shear stress (lb/sq.ft.)
0.54	shear velocity (ft/s)
2.3	unit strm power (lb/ft/s)

Cross Section 1



Bankfull Dimensions	
66.7	x-section area (ft.sq.)
23.8	width (ft)
2.8	mean depth (ft)
3.9	max depth (ft)
25.9	wetted parimeter (ft)
2.6	hyd radi (ft)
8.5	width-depth ratio

Flood Dimensions	
600.0	W flood prone area (ft)
25.2	entrenchment ratio
3.9	low bank height (ft)
1.0	low bank height ratio

Materials	
0.92	D50 Bed (mm)
7.6	D84 Bed (mm)
21	threshold grain size (mm):

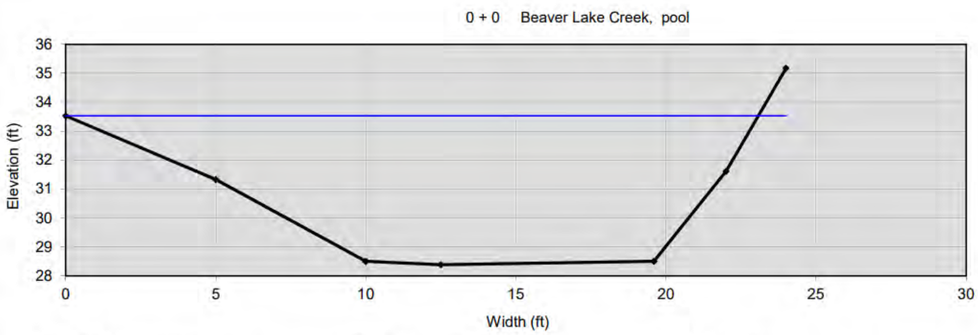
Bankfull Flow	
2.9	velocity (ft/s)
190.5	discharge rate (cfs)
0.31	Froude number

Flow Resistance	
0.050	Manning's roughness
0.21	D'Arcy-Weisbach fric.
14.8	resistance factor u/u*
112.4	relative roughness

Forces & Power	
0.26	channel slope (%)
0.42	shear stress (lb/sq.ft.)
0.46	shear velocity (ft/s)
1.3	unit strm power (lb/ft/s)

Little Day Creek Reach 1 Cross Sections

Cross Section 1



Bankfull Dimensions	
81.8	x-section area (ft.sq.)
23.1	width (ft)
3.5	mean depth (ft)
5.2	max depth (ft)
26.9	wetted parimeter (ft)
3.0	hyd radi (ft)
6.5	width-depth ratio

Flood Dimensions	
300.0	W flood prone area (ft)
13.0	entrenchment ratio
5.2	low bank height (ft)
1.0	low bank height ratio

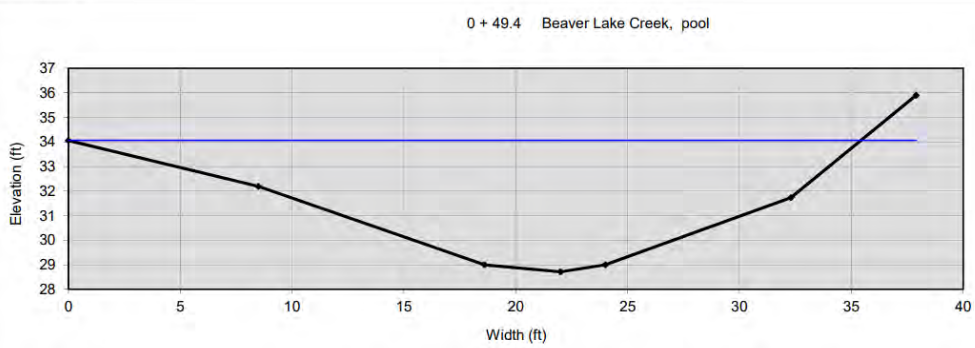
Materials	
0.92	D50 Bed (mm)
7.6	D84 Bed (mm)
2	threshold grain size (mm):

Bankfull Flow	
0.9	velocity (ft/s)
77.5	discharge rate (cfs)
0.10	Froude number

Flow Resistance	
0.050	Manning's roughness
0.20	D'Arcy-Weisbach fric.
15.3	resistance factor u/u*
142.2	relative roughness

Forces & Power	
0.023	channel slope (%)
0.04	shear stress (lb/sq.ft.)
0.15	shear velocity (ft/s)
0.048	unit strm power (lb/ft/s)

Cross Section 2



Bankfull Dimensions	
105.4	x-section area (ft.sq.)
35.4	width (ft)
3.0	mean depth (ft)
5.4	max depth (ft)
37.4	wetted parimeter (ft)
2.8	hyd radi (ft)
11.9	width-depth ratio

Flood Dimensions	
300.0	W flood prone area (ft)
8.5	entrenchment ratio
5.4	low bank height (ft)
1.0	low bank height ratio

Materials	
0.92	D50 Bed (mm)
7.6	D84 Bed (mm)
2	threshold grain size (mm):

Bankfull Flow	
0.9	velocity (ft/s)
95.0	discharge rate (cfs)
0.09	Froude number

Flow Resistance	
0.050	Manning's roughness
0.21	D'Arcy-Weisbach fric.
15.2	resistance factor u/u*
119.3	relative roughness

Forces & Power	
0.023	channel slope (%)
0.04	shear stress (lb/sq.ft.)
0.14	shear velocity (ft/s)
0.038	unit strm power (lb/ft/s)

Attachment C-3.

Hydraulic Assessment of Selected Culverts

TABLE 1
TURNER CREEK & BEAVER LAKE ROAD CROSSING

Headwater Elevation (FT NAVD88)	Discharge Name	Total Discharge (CFS)	Culvert 1 Discharge (CFS)	Roadway Discharge (CFS)
39.58	2 year	146.00	88.93	0.00
40.25	5 year	226.00	91.77	0.00
40.57	10 year	279.00	91.28	0.00
40.92	25 year	347.00	90.44	0.00
41.14	50 year	396.00	89.79	0.00
41.35	100 year	450.00	89.05	0.00
41.54	200 year	502.00	88.13	0.00
41.78	500 year	574.00	87.15	0.00
70.30	Overtopping	72.94	72.94	0.00

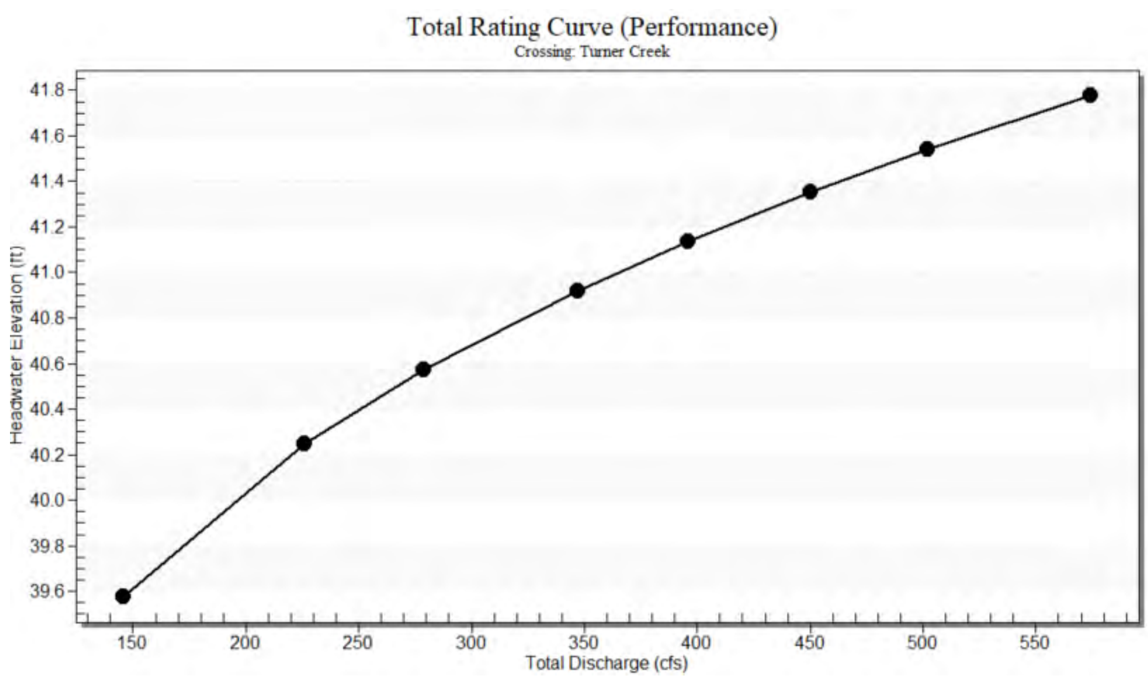


TABLE 2
TURNER CREEK & ELK ROAD CROSSING

Headwater Elevation (FT NAVD88)	Discharge Name	Total Discharge (CFS)	Culvert 1 Discharge (CFS)	Roadway Discharge (CFS)
64.97	2 year	146.00	69.70	76.31
66.34	5 year	226.00	87.05	138.93
67.16	10 year	279.00	96.38	182.60
68.14	25 year	347.00	107.10	239.90
68.81	50 year	396.00	114.11	281.85
69.53	100 year	450.00	121.35	328.64
70.21	200 year	502.00	127.96	373.92
70.61	500 year	574.00	129.06	399.41
70.30	Overtopping	508.97	128.87	380.10

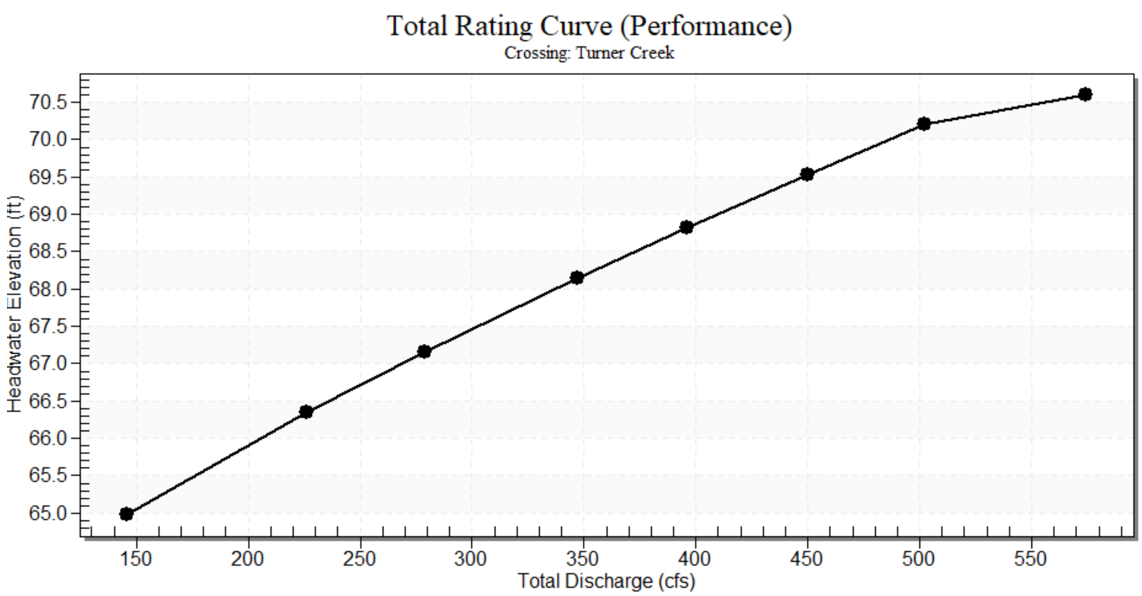


TABLE 3
LITTLE DAY CREEK & FONK RD CROSSING

Headwater Elevation (FT NAVD88)	Discharge Name	Total Discharge (CFS)	Culvert 1 Discharge (CFS)	Roadway Discharge (CFS)
35.26	2 year	109.00	109.00	0.00
36.97	5 year	172.00	172.00	0.00
38.59	10 year	215.00	215.00	0.00
39.80	25 year	270.00	241.48	28.26
39.97	50 year	312.00	244.95	66.88
40.11	100 year	357.00	247.88	108.86
40.24	200 year	401.00	250.35	150.21
40.40	500 year	463.00	253.42	209.38
39.57	Overtopping	236.78	236.78	0.00

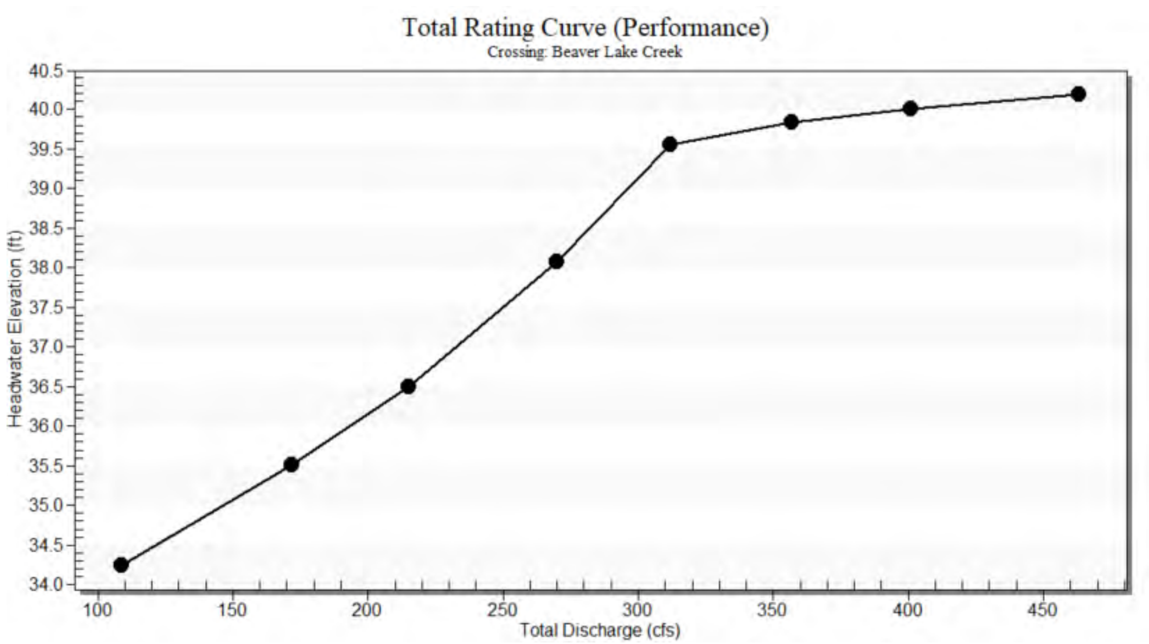


TABLE 4
LITTLE DAY CREEK & BEAVER LAKE ROAD CROSSING

Headwater Elevation (FT NAVD88)	Discharge Name	Total Discharge (CFS)	Culvert 1 Discharge (CFS)	Roadway Discharge (CFS)
36.10	2 year	111.00	111.00	0.00
37.42	5 year	175.00	175.00	0.00
38.33	10 year	218.00	218.00	0.00
39.85	25 year	275.00	275.00	0.00
40.49	50 year	317.00	292.76	24.15
40.66	100 year	363.00	296.98	65.90
40.80	200 year	408.00	300.44	107.39
40.98	500 year	471.00	302.43	168.16
40.30	Overtopping	287.39	287.39	0.00

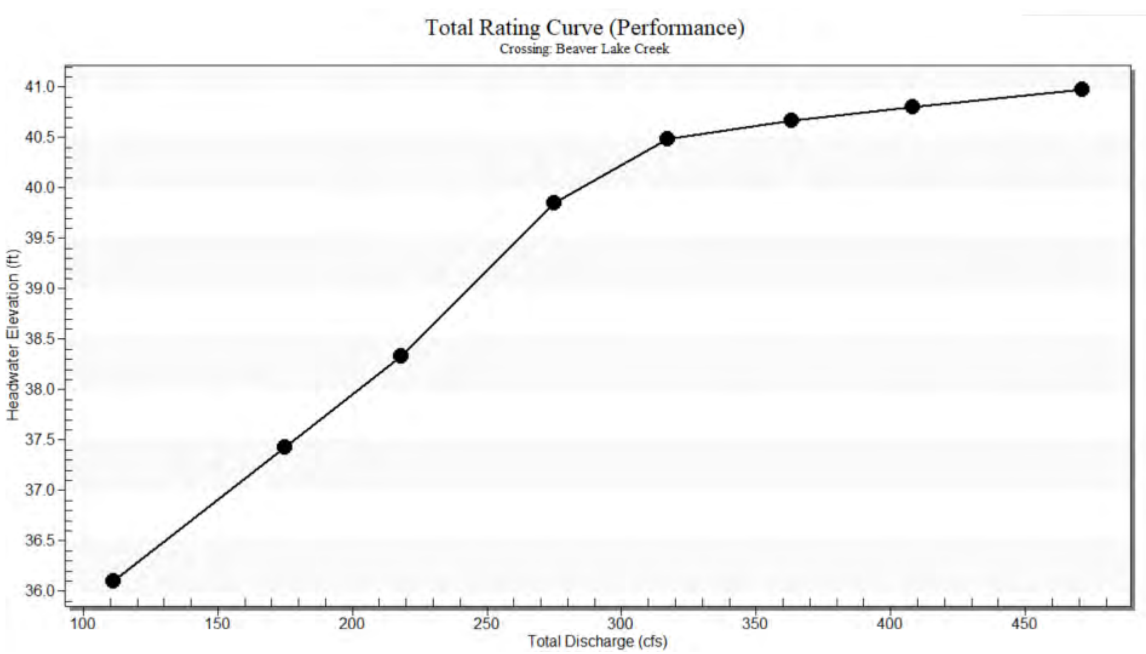
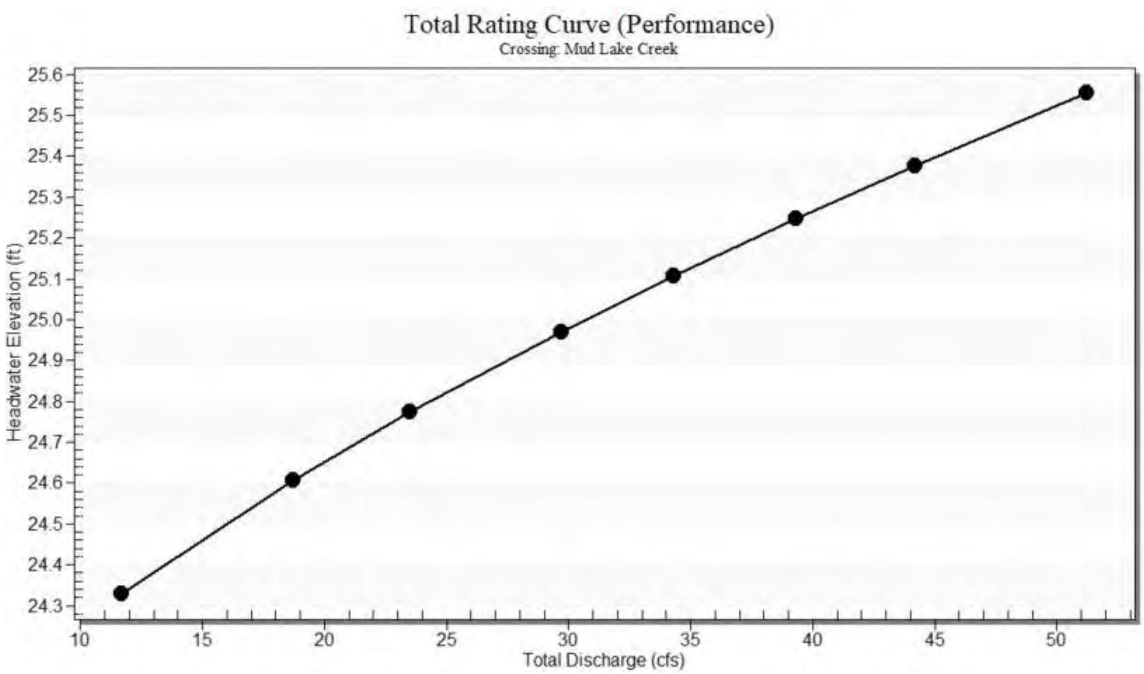


TABLE 5
MUD LAKE CREEK & SWAN ROAD CROSSING

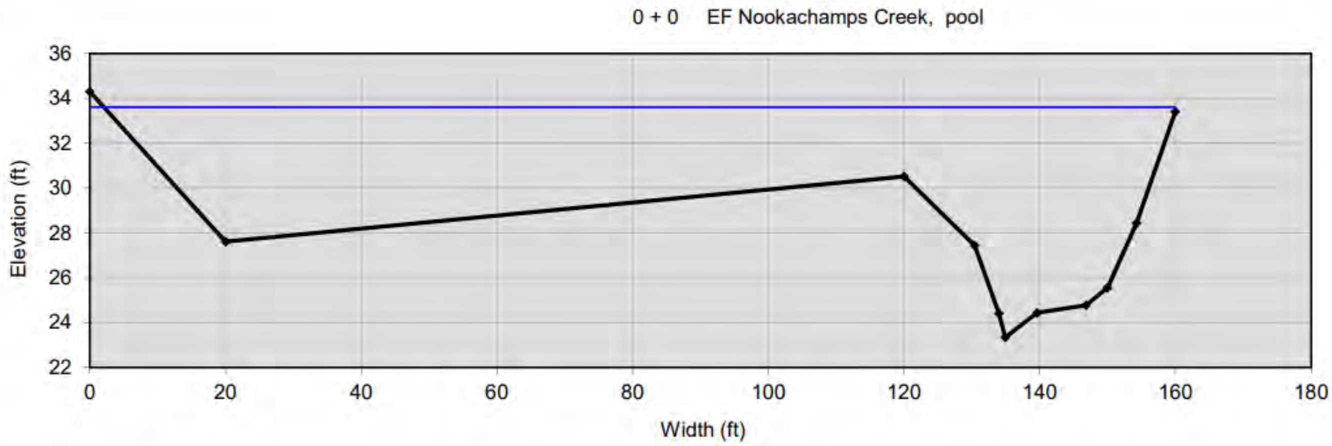
Headwater Elevation (FT NAVD88)	Discharge Name	Total Discharge (CFS)	Culvert 1 Discharge (CFS)	Roadway Discharge (CFS)
24.33	2 year	11.70	11.70	0.00
24.61	5 year	18.70	18.70	0.00
24.77	10 year	23.50	23.50	0.00
24.97	25 year	29.70	29.70	0.00
25.11	50 year	34.30	34.30	0.00
25.25	100 year	39.30	39.30	0.00
25.38	200 year	44.20	44.20	0.00
25.56	500 year	51.20	51.20	0.00
34.60	Overtopping	584.65	584.65	0.00



Appendix D. Channel Conveyance Capacity Analysis

East Fork Nookachamps Reach 1 Cross Sections

Cross Section 1



Bankfull Dimensions

773.8	x-section area (ft.sq.)
157.9	width (ft)
4.9	mean depth (ft)
10.3	max depth (ft)
163.9	wetted parimeter (ft)
4.7	hyd radi (ft)
32.2	width-depth ratio

Flood Dimensions

500.0	W flood prone area (ft)
3.2	entrenchment ratio
10.1	low bank height (ft)
1.0	low bank height ratio

Materials

4.7	D50 Bed (mm)
8.7	D84 Bed (mm)
7	threshold grain size (mm):

Bankfull Flow

1.8	velocity (ft/s)
1390.3	discharge rate (cfs)
0.15	Froude number

Flow Resistance

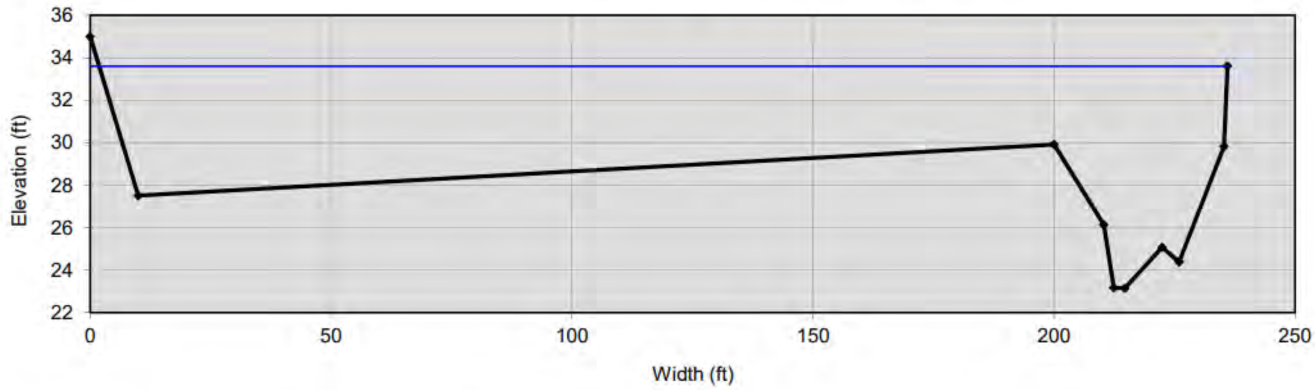
0.050	Manning's roughness
0.17	D'Arcy-Weisbach fric.
16.2	resistance factor u/u*
171.7	relative roughness

Forces & Power

0.046	channel slope (%)
0.14	shear stress (lb/sq.ft.)
0.26	shear velocity (ft/s)
0.25	unit strm power (lb/ft/s)

Cross Section 2

4 + 35 EF Nookachamps Creek, pool



Bankfull Dimensions	
1220.6	x-section area (ft.sq.)
234.1	width (ft)
5.2	mean depth (ft)
10.5	max depth (ft)
243.3	wetted parimeter (ft)
5.0	hyd radi (ft)
44.9	width-depth ratio

Flood Dimensions	
500.0	W flood prone area (ft)
2.1	entrenchment ratio
10.5	low bank height (ft)
1.0	low bank height ratio

Materials	
4.7	D50 Bed (mm)
8.7	D84 Bed (mm)
7	threshold grain size (mm):

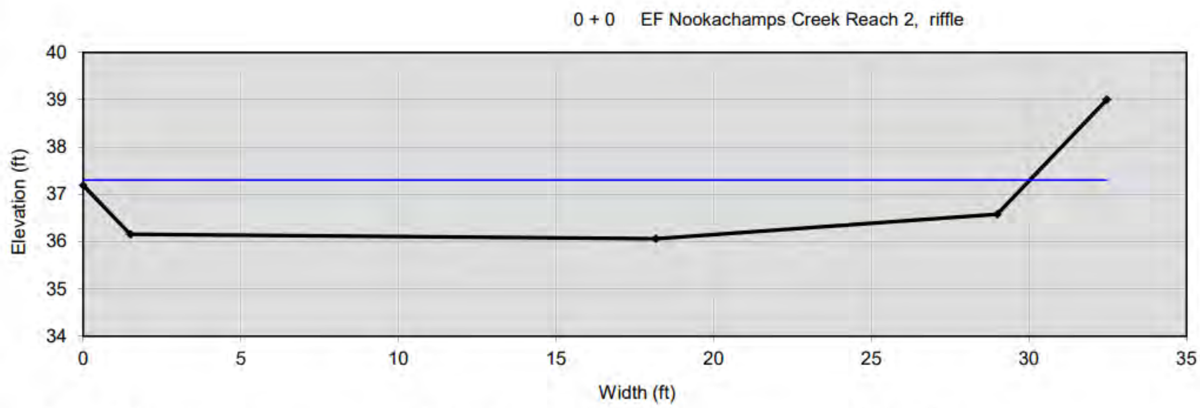
Bankfull Flow	
1.9	velocity (ft/s)
2283.8	discharge rate (cfs)
0.15	Froude number

Flow Resistance	
0.050	Manning's roughness
0.17	D'Arcy-Weisbach fric.
16.4	resistance factor u/u*
182.6	relative roughness

Forces & Power	
0.046	channel slope (%)
0.14	shear stress (lb/sq.ft.)
0.27	shear velocity (ft/s)
0.28	unit strm power (lb/ft/s)

East Fork Nookachamps Reach 2 Cross Sections

Cross Section 1



Bankfull Dimensions	
31.9	x-section area (ft.sq.)
30.0	width (ft)
1.1	mean depth (ft)
1.2	max depth (ft)
30.6	wetted parimeter (ft)
1.0	hyd radi (ft)
28.3	width-depth ratio

Flood Dimensions	
200.0	W flood prone area (ft)
6.7	entrenchment ratio
1.1	low bank height (ft)
0.9	low bank height ratio

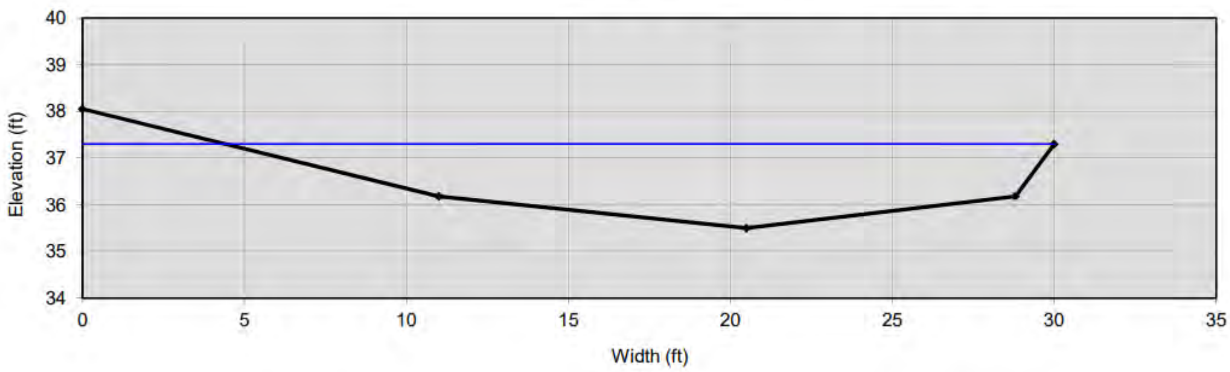
Materials	
9.1	D50 Bed (mm)
16	D84 Bed (mm)
8	threshold grain size (mm):

Bankfull Flow	
1.5	velocity (ft/s)
48.7	discharge rate (cfs)
0.26	Froude number

Flow Resistance	
0.050	Manning's roughness
0.29	D'Arcy-Weisbach fric.
10.5	resistance factor u/u*
20.2	relative roughness

Forces & Power	
0.25	channel slope (%)
0.16	shear stress (lb/sq.ft.)
0.29	shear velocity (ft/s)
0.25	unit strm power (lb/ft/s)

Cross Section 2



Bankfull Dimensions	
30.3	x-section area (ft.sq.)
25.6	width (ft)
1.2	mean depth (ft)
1.8	max depth (ft)
26.2	wetted parimeter (ft)
1.2	hyd radi (ft)
21.6	width-depth ratio

Flood Dimensions	
200.0	W flood prone area (ft)
7.8	entrenchment ratio
1.8	low bank height (ft)
1.0	low bank height ratio

Materials	
9.1	D50 Bed (mm)
16	D84 Bed (mm)
9	threshold grain size (mm):

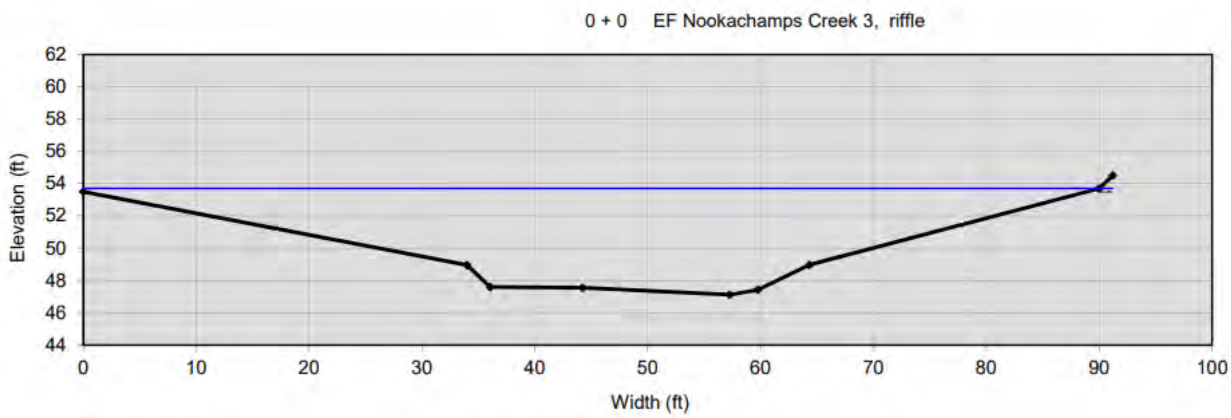
Bankfull Flow	
1.6	velocity (ft/s)
49.9	discharge rate (cfs)
0.27	Froude number

Flow Resistance	
0.050	Manning's roughness
0.28	D'Arcy-Weisbach fric.
11.0	resistance factor u/u*
22.6	relative roughness

Forces & Power	
0.25	channel slope (%)
0.18	shear stress (lb/sq.ft.)
0.31	shear velocity (ft/s)
0.3	unit strm power (lb/ft/s)

East Fork Nookachamps Reach 3 Cross Sections

Cross Section 1



Bankfull Dimensions

330.5	x-section area (ft.sq.)
90.0	width (ft)
3.7	mean depth (ft)
6.6	max depth (ft)
91.4	wetted parimeter (ft)
3.6	hyd radi (ft)
24.5	width-depth ratio

Flood Dimensions

200.0	W flood prone area (ft)
2.2	entrenchment ratio
6.4	low bank height (ft)
1.0	low bank height ratio

Materials

22	D50 Bed (mm)
35	D84 Bed (mm)
28	threshold grain size (mm):

Bankfull Flow

3.5	velocity (ft/s)
1159.1	discharge rate (cfs)
0.33	Froude number

Flow Resistance

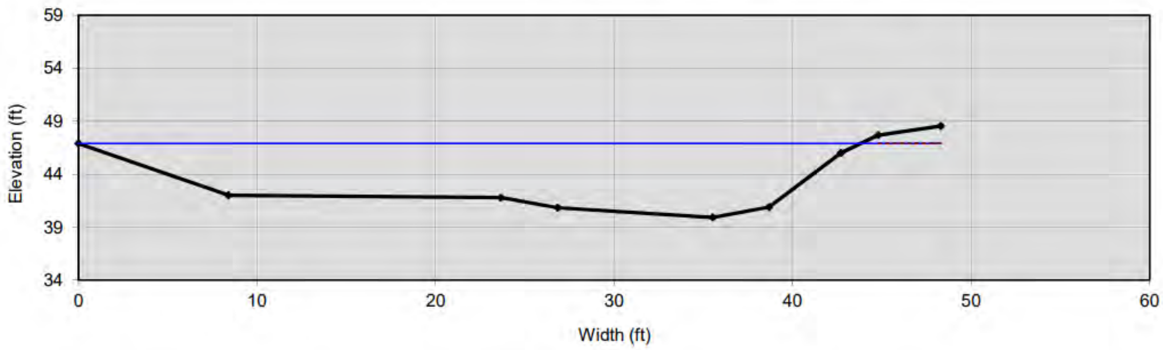
0.050	Manning's roughness
0.19	D'Arcy-Weisbach fric.
12.0	resistance factor u/u*
32.0	relative roughness

Forces & Power

0.25	channel slope (%)
0.56	shear stress (lb/sq.ft.)
0.54	shear velocity (ft/s)
2	unit strm power (lb/ft/s)

Cross Section 2

30 + 50 EF Nookachamps Creek 3, riffle



Bankfull Dimensions	
206.6	x-section area (ft.sq.)
43.8	width (ft)
4.7	mean depth (ft)
7.0	max depth (ft)
48.3	wetted parimeter (ft)
4.3	hyd radi (ft)
9.3	width-depth ratio

Flood Dimensions	
200.0	W flood prone area (ft)
4.6	entrenchment ratio
7.0	low bank height (ft)
1.0	low bank height ratio

Materials	
22	D50 Bed (mm)
35	D84 Bed (mm)
33	threshold grain size (mm):

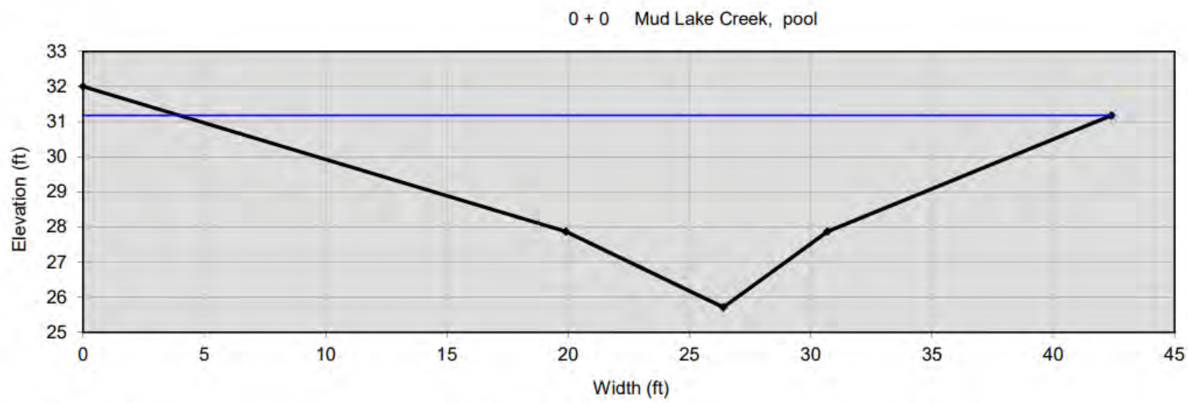
Bankfull Flow	
3.9	velocity (ft/s)
810.3	discharge rate (cfs)
0.33	Froude number

Flow Resistance	
0.050	Manning's roughness
0.18	D'Arcy-Weisbach fric.
12.3	resistance factor u/u*
41.1	relative roughness

Forces & Power	
0.25	channel slope (%)
0.67	shear stress (lb/sq.ft.)
0.59	shear velocity (ft/s)
2.9	unit strm power (lb/ft/s)

Mud Lake Creek Reach 1 Cross Section

Cross Section 1



Bankfull Dimensions	
93.2	x-section area (ft.sq.)
38.4	width (ft)
2.4	mean depth (ft)
5.5	max depth (ft)
40.1	wetted parimeter (ft)
2.3	hyd radi (ft)
15.9	width-depth ratio

Flood Dimensions	
300.0	W flood prone area (ft)
7.8	entrenchment ratio
5.5	low bank height (ft)
1.0	low bank height ratio

Materials	
0.92	D50 Bed (mm)
7.6	D84 Bed (mm)
1	threshold grain size (mm):

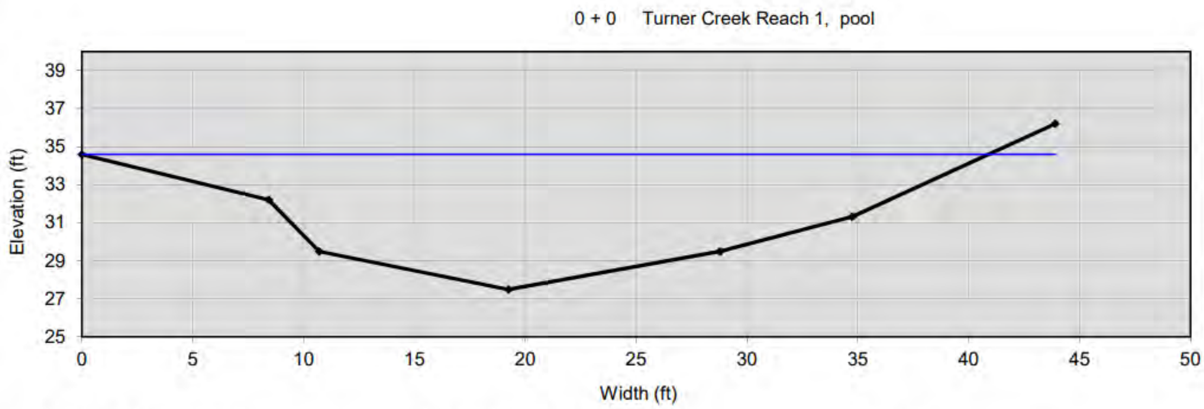
Bankfull Flow	
0.5	velocity (ft/s)
48.7	discharge rate (cfs)
0.06	Froude number

Flow Resistance	
0.050	Manning's roughness
0.22	D'Arcy-Weisbach fric.
14.9	resistance factor u/u*
97.2	relative roughness

Forces & Power	
0.01	channel slope (%)
0.01	shear stress (lb/sq.ft.)
0.09	shear velocity (ft/s)
0.0079	unit strm power (lb/ft/s)

Turner Creek Reach 1 Cross Sections

Cross Section 1



Bankfull Dimensions	
164.2	x-section area (ft.sq.)
40.9	width (ft)
4.0	mean depth (ft)
7.1	max depth (ft)
44.0	wetted parimeter (ft)
3.7	hyd radi (ft)
10.2	width-depth ratio

Flood Dimensions	
200.0	W flood prone area (ft)
4.9	entrenchment ratio
7.1	low bank height (ft)
1.0	low bank height ratio

Materials	
8.2	D50 Bed (mm)
17	D84 Bed (mm)
2	threshold grain size (mm):

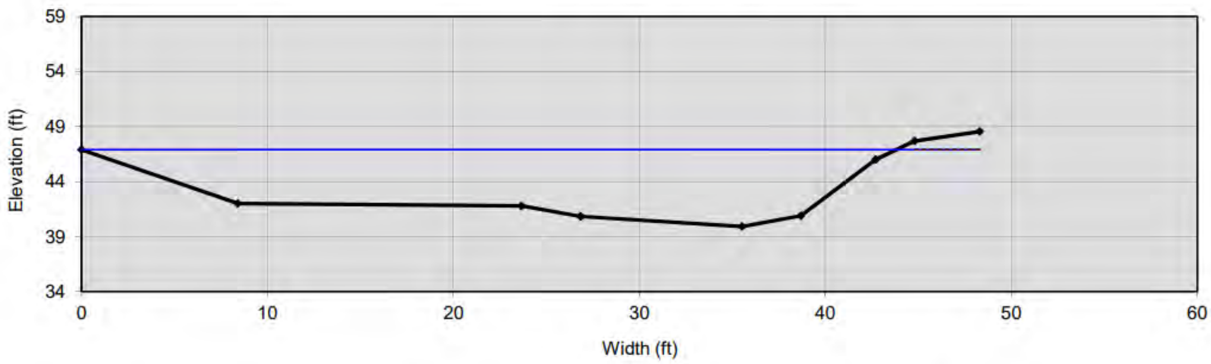
Bankfull Flow	
0.9	velocity (ft/s)
144.0	discharge rate (cfs)
0.08	Froude number

Flow Resistance	
0.050	Manning's roughness
0.19	D'Arcy-Weisbach fric.
13.9	resistance factor u/u*
72.0	relative roughness

Forces & Power	
0.015	channel slope (%)
0.03	shear stress (lb/sq.ft.)
0.13	shear velocity (ft/s)
0.033	unit strm power (lb/ft/s)

Cross Section 2

30 + 50 Turner Creek Reach 1, riffle



Bankfull Dimensions

206.6	x-section area (ft.sq.)
43.8	width (ft)
4.7	mean depth (ft)
7.0	max depth (ft)
48.3	wetted parimeter (ft)
4.3	hyd radi (ft)
9.3	width-depth ratio

Flood Dimensions

200.0	W flood prone area (ft)
4.6	entrenchment ratio
7.0	low bank height (ft)
1.0	low bank height ratio

Materials

8.2	D50 Bed (mm)
17	D84 Bed (mm)
33	threshold grain size (mm):

Bankfull Flow

3.9	velocity (ft/s)
810.3	discharge rate (cfs)
0.33	Froude number

Flow Resistance

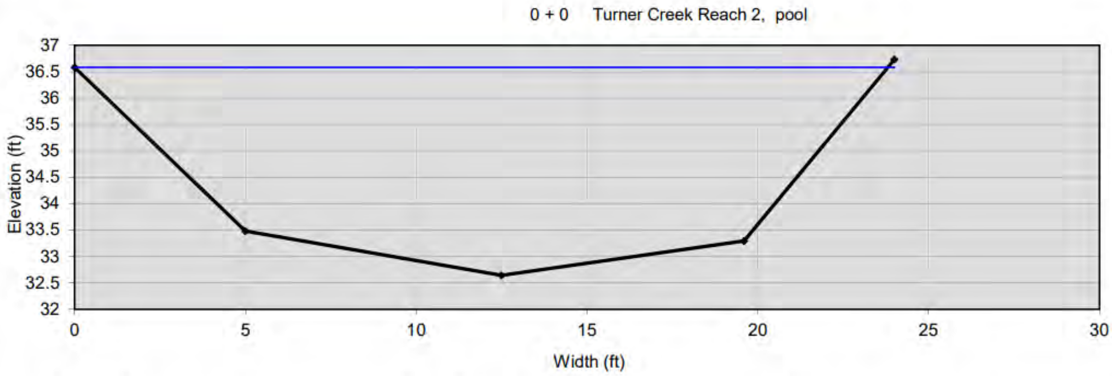
0.050	Manning's roughness
0.18	D'Arcy-Weisbach fric.
14.1	resistance factor u/u*
84.5	relative roughness

Forces & Power

0.25	channel slope (%)
0.67	shear stress (lb/sq.ft.)
0.59	shear velocity (ft/s)
2.9	unit strm power (lb/ft/s)

Turner Creek Reach 2 Cross Sections

Cross Section 1



Bankfull Dimensions

66.7	x-section area (ft.sq.)
23.8	width (ft)
2.8	mean depth (ft)
3.9	max depth (ft)
25.9	wetted parimeter (ft)
2.6	hyd radi (ft)
8.5	width-depth ratio

Flood Dimensions

600.0	W flood prone area (ft)
25.2	entrenchment ratio
3.9	low bank height (ft)
1.0	low bank height ratio

Materials

0.92	D50 Bed (mm)
7.6	D84 Bed (mm)
21	threshold grain size (mm):

Bankfull Flow

2.9	velocity (ft/s)
190.5	discharge rate (cfs)
0.31	Froude number

Flow Resistance

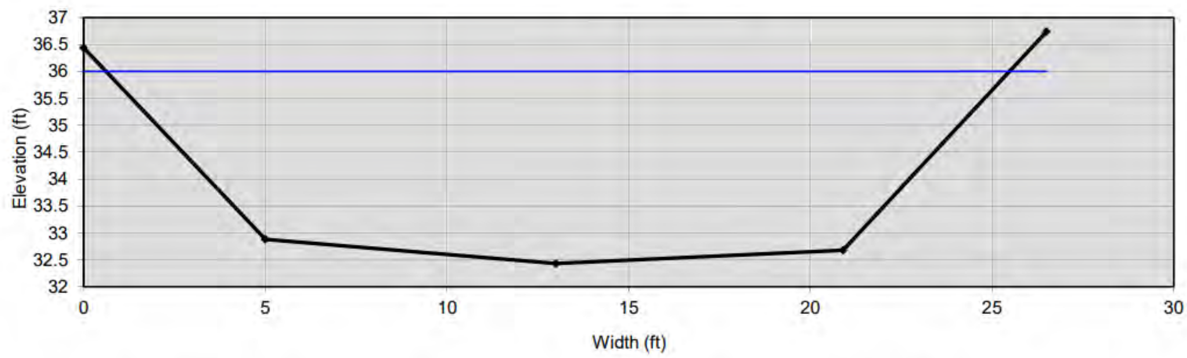
0.050	Manning's roughness
0.21	D'Arcy-Weisbach fric.
14.8	resistance factor u/u*
112.4	relative roughness

Forces & Power

0.26	channel slope (%)
0.42	shear stress (lb/sq.ft.)
0.46	shear velocity (ft/s)
1.3	unit strm power (lb/ft/s)

Cross Section 2

0 + 80 Turner Creek, pool



Bankfull Dimensions

68.4	x-section area (ft.sq.)
24.9	width (ft)
2.8	mean depth (ft)
3.6	max depth (ft)
27.0	wetted parimeter (ft)
2.5	hyd radi (ft)
9.0	width-depth ratio

Flood Dimensions

1500.0	W flood prone area (ft)
60.3	entrenchment ratio
4.0	low bank height (ft)
1.1	low bank height ratio

Materials

0.92	D50 Bed (mm)
7.6	D84 Bed (mm)
20	threshold grain size (mm):

Bankfull Flow

2.8	velocity (ft/s)
193.3	discharge rate (cfs)
0.31	Froude number

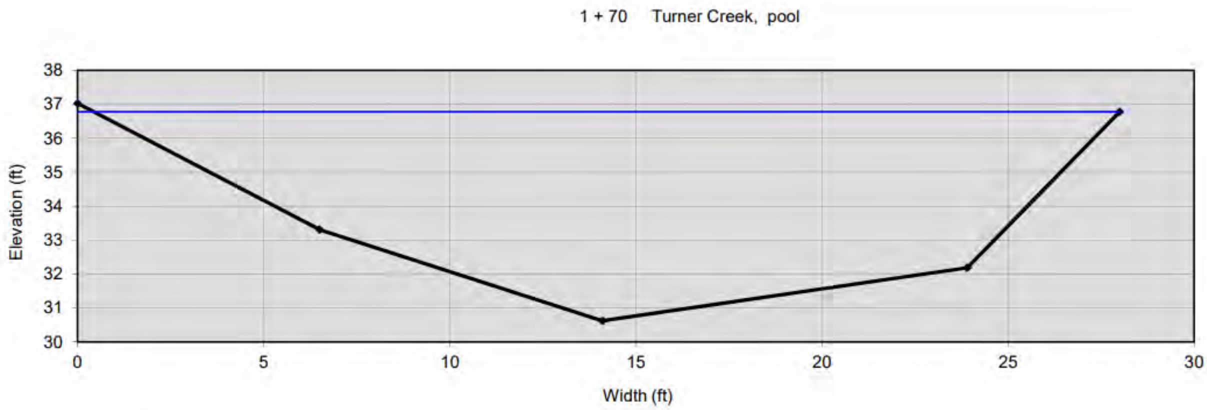
Flow Resistance

0.050	Manning's roughness
0.21	D'Arcy-Weisbach fric.
14.7	resistance factor u/u*
110.4	relative roughness

Forces & Power

0.26	channel slope (%)
0.41	shear stress (lb/sq.ft.)
0.46	shear velocity (ft/s)
1.26	unit strm power (lb/ft/s)

Cross Section 3



Bankfull Dimensions	
109.3	x-section area (ft.sq.)
27.6	width (ft)
4.0	mean depth (ft)
6.2	max depth (ft)
31.1	wetted parimeter (ft)
3.5	hyd radi (ft)
7.0	width-depth ratio

Flood Dimensions	
600.0	W flood prone area (ft)
21.8	entrenchment ratio
6.2	low bank height (ft)
1.0	low bank height ratio

Materials	
0.92	D50 Bed (mm)
7.6	D84 Bed (mm)
28	threshold grain size (mm):

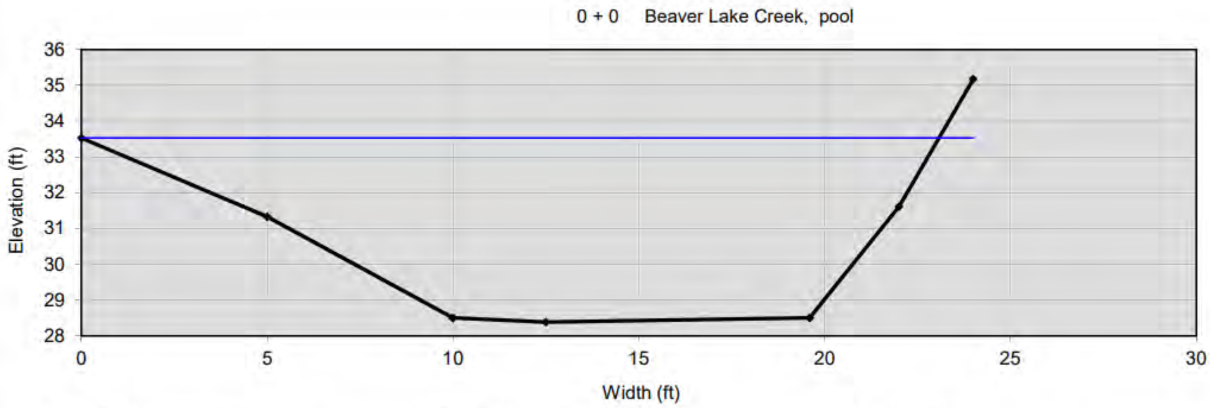
Bankfull Flow	
3.5	velocity (ft/s)
383.1	discharge rate (cfs)
0.33	Froude number

Flow Resistance	
0.050	Manning's roughness
0.19	D'Arcy-Weisbach fric.
15.7	resistance factor u/u*
159.0	relative roughness

Forces & Power	
0.26	channel slope (%)
0.57	shear stress (lb/sq.ft.)
0.54	shear velocity (ft/s)
2.3	unit strm power (lb/ft/s)

Beaver Lake Creek Reach 1 Cross Sections

Cross Section 1



Bankfull Dimensions	
81.8	x-section area (ft.sq.)
23.1	width (ft)
3.5	mean depth (ft)
5.2	max depth (ft)
26.9	wetted parimeter (ft)
3.0	hyd radi (ft)
6.5	width-depth ratio

Flood Dimensions	
300.0	W flood prone area (ft)
13.0	entrenchment ratio
5.2	low bank height (ft)
1.0	low bank height ratio

Materials	
0.92	D50 Bed (mm)
7.6	D84 Bed (mm)
2	threshold grain size (mm):

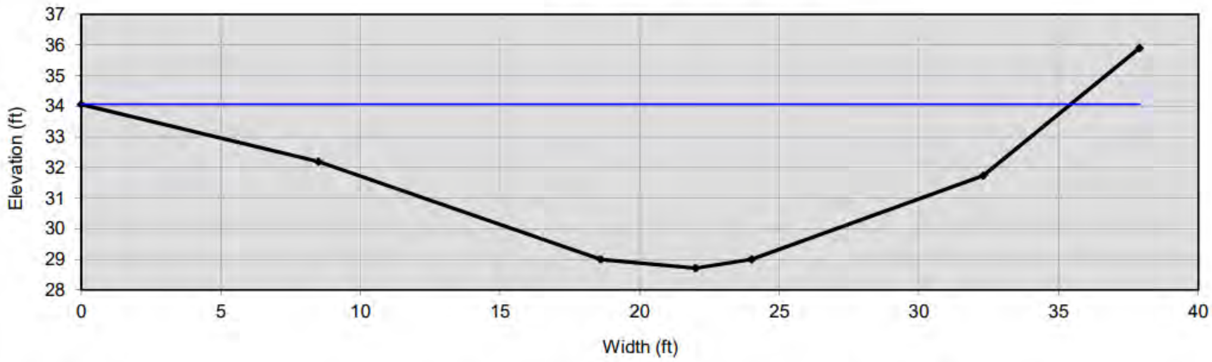
Bankfull Flow	
0.9	velocity (ft/s)
77.5	discharge rate (cfs)
0.10	Froude number

Flow Resistance	
0.050	Manning's roughness
0.20	D'Arcy-Weisbach fric.
15.3	resistance factor u/u*
142.2	relative roughness

Forces & Power	
0.023	channel slope (%)
0.04	shear stress (lb/sq.ft.)
0.15	shear velocity (ft/s)
0.048	unit strm power (lb/ft/s)

Cross Section 2

0 + 49.4 Beaver Lake Creek, pool



Bankfull Dimensions	
105.4	x-section area (ft.sq.)
35.4	width (ft)
3.0	mean depth (ft)
5.4	max depth (ft)
37.4	wetted parimeter (ft)
2.8	hyd radi (ft)
11.9	width-depth ratio

Flood Dimensions	
300.0	W flood prone area (ft)
8.5	entrenchment ratio
5.4	low bank height (ft)
1.0	low bank height ratio

Materials	
0.92	D50 Bed (mm)
7.6	D84 Bed (mm)
2	threshold grain size (mm):

Bankfull Flow	
0.9	velocity (ft/s)
95.0	discharge rate (cfs)
0.09	Froude number

Flow Resistance	
0.050	Manning's roughness
0.21	D'Arcy-Weisbach fric.
15.2	resistance factor u/u*
119.3	relative roughness

Forces & Power	
0.023	channel slope (%)
0.04	shear stress (lb/sq.ft.)
0.14	shear velocity (ft/s)
0.038	unit strm power (lb/ft/s)

Appendix E. Fish Habitat Field Assessment Methods and Data Tables

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Appendix E. Fish Habitat Field Assessment Methods and Data Tables

1.0 Fish Habitat Assessment Methods

The survey protocol for conducting the field habitat assessment followed a modified version of WDFW's Reduced Sample Full Survey methodology from Chapter 10 of the Fish Passage Inventory, Assessment, and Prioritization Manual (WDFW 2019), and the Timber Fish and Wildlife Monitoring Program Manual (TFW 1999). The purpose of this assessment was to focus on the portions of the project area that are Tier 2 priority reaches for Chinook salmon and steelhead and reaches with documented salmon and steelhead distributions in SWIFD or historical fisheries surveys (see **Figure 12**).

Water temperature (°F) and dissolved oxygen (DO) were taken at each reach using a YSI© DO PRO, as these were unlikely to show much variation within less than 200 feet of each other. All remaining data were collected from each individual habitat unit. "Habitat units" are the changes within in-stream hydraulic conditions including depth and velocity. The TWF (1999) protocol relies on two general terms, "riffle" and "pool", which apply to a broad range of wetted channel conditions that could be encountered in the field. A greater level of detail was used for the purpose of this habitat assessment to more accurately show the habitats found in the East Fork Nookachamps Creek. Each habitat unit was classified into the following categories:

- Riffle – a shallow and low gradient area with surface turbulence associated with increased velocity of flow over gravel or cobble.
- Pool – a depression in the streambed is caused by fluvial processes.
- Run – a swiftly flowing reaches with little surface agitation and no major flow obstructions, typically flooded riffles in high flows.
- Glide – a wide, uniform channel bottom, low to moderate velocities, lacking pronounced turbulence.
- Pocketwater – an area of swift-flowing stream containing numerous boulders or other large obstructions that create eddies or scour holes (pockets) behind the obstructions.

Dominant and subdominant substrates were recorded for each habitat unit. Substrates were classified as either silt/clay (fines), sand, gravel, small cobble, large cobble, boulders, or bedrock. Size cutoffs for each substrate are listed below:

- Bedrock: Greater than 160 inches
- Boulder: 10 to 160 inches
- Large cobble: 6 to10 inches
- Small cobble: 3 to 6 inches
- Gravel: 0.2 to 3.0 inches
- Sand: 0.06 millimeters to 0.2 in
- Silt/clay: Less than 0.06 millimeters

Woody debris was classified as small (diameter less than 20 inches), large (diameter greater than 20 inches), and rootwads. The dominant tree and/or ground vegetation providing bank/canopy cover was identified. The total percentage of aquatic vegetation within the wetted channel was estimated in percentage for the habitat unit.

Embeddedness is the degree in which cobble and gravel are buried in fine sediments and sand. A level of embeddedness of 0-25 percent is considered good quality spawning habitat for salmon and steelhead (Flosi 2004). As embeddedness increases to 50 percent and above it becomes difficult for salmonids to construct a redd. Embeddedness was recorded for spawning substrates found in each habitat unit as well as at pool tailouts and riffles as these are key spawning habitat locations. Embeddedness was recorded in 25 percent increments.

The field crew used a 200-feet tape measure to take wetted width, the width of the wetted stream at the time of the survey, bankfull width (BFW) (i.e., the stream width at bankfull discharge elevation) measurements at approximately three locations in each study reach. Mean BFW for each habitat unit was calculated after the field effort. Slope measurements were taken from RTK-surveyed thalweg points or using a clinometer to estimate streambed slope. Maximum depth (feet) was recorded at each habitat unit using a stadia rod. Depths greater than 5.0 feet were estimated unless the deepest portion was along the bank and accessible to surveyors. For each pool surveyed the depth at the top of that thalweg was recorded as "Pool Crest Depth," in addition to maximum depth. For any culverts encountered during the survey the diameter (inches), length (feet), and material of each culvert were recorded. Spawning habitat quality modifiers (HQM) were recorded at each habitat unit to assess the habitat suitability for rearing juveniles and spawning adults. The spawning HQM was determined by a visual estimate of the percentage of embedded fines within potential spawning gravel patches within each habitat unit. The estimate is a combination of subjective evaluations of gravel surface composition, silt plume characteristics as a boot heel is dug into a gravel patch, and the composition of several handfuls of the underlying substrate. Spawning gravel patches with less than 16% fine particles were given a score of 1.0. Spawning gravel patches show moderate to widespread signs of instability (scour/filling), and/or > 16% to 21% fine particles. Spawning gravel patches show widespread to major signs of instability (scour/filling), and/or 21% to 26% fine particles. A 0 was assigned for patches with greater than 26% fine particles (WDFW 2019).

Rearing HQM is an evaluation of physical characteristics that influence the ability of juvenile salmonids to survive and grow in a freshwater stream which include water quality, adequate depth and flow, cover in the form of undercut banks, woody debris, or overhanging vegetation (WDFW 2019). For each habitat unit surveyed the score began at 1. If there were no limiting factors for juvenile rearing identified the habitat would be assigned a 1. If there were limiting factors identified but the habit still showed beneficial components for juvenile rearing the score would be assigned 0.66. If there were several limiting factors identified and the majority of the habitat unit showed little rearing habitat the score was assigned a 0.33. If the habitat unit had no juvenile rearing it was assigned a 0 (WDFW 2019).

Field Effort Summary

The field crew conducted field surveys in the EF Nookachamps Creek watershed from July 25th through July 29th, 2022. Creek conditions during this time were typical of low flow summer conditions as little to no rain had fallen in the preceding weeks. Staff surveyed 22 of the 29 reaches identified in the desktop review.

The following reaches were not surveyed: Mundt Reach 3 (M3), Cold Springs Reach 1 (CS1), Cold Springs Reach 2 (CS2), Unnamed tributary 2 Reach 3 (Unk2-3), Walker Reach 2 (W2), Walker Reach 3 (W3), and Lake Challenge Reach 1 (C1). Private property restrictions prevented the crew from sampling the reaches listed above except for Lake Challenge Creek Reach 1 and Mundt Reach 3. Lake Challenge Creek Reach 1 was not wetted at the time of the field survey, so data were not collected. The accessible portion of Mundt Reach 3 was immediately upstream of Mundt Reach 2. The field crew determined that conditions in Mundt Reach 2 were adequately representative of conditions in Mundt Reach 3.

2.0 Fish Habitat Assessment Data Tables

Tables E-1 through E-4 summarize the fish habitat data collected in the field. Interpretation of these data are incorporated into the main report of the Watershed Assessment and Management Plan.

TABLE E-1. FISH HABITAT FIELD ASSESSMENT DATA

Stream	Reach Code	Sub-Reach ID	Latitude	Longitude	Reach length (ft)	Habitat Type	Dominant/ Subdominant Substrate	Total Substrate Embeddedness	Spawning Gravel Embeddedness	Pool Tailout Embeddedness
Nookachamps Creek	N1	1	48.46801	-122.29435	200	Glide	Silt/Clay, Sand	--	--	--
Nookachamps Creek	N2	1	48.45394	-122.27172	200	Glide	Silt/Clay, Sand	--	--	--
Mud Creek	M1	1	48.45979	-122.25714	200	Stagnant Glide	Silt/Clay	--	--	--
East Fork Nookachamps	EF1	1	48.44389	-122.26588	141	Glide	Silt/Clay, Gravel	76-100%	76-100%	--
East Fork Nookachamps	EF1	2	48.44387	-122.26516	59	Main Channel Pool	Silt/Clay, Sand	76-100%	76-100%	76-100%
East Fork Nookachamps	EF2	1	48.44205	-122.24883	51	Main Channel Pool	Sand, Gravel	51-75%	26-50%	51-75%
East Fork Nookachamps	EF2	2	48.44194	-122.24865	148	Glide	Sand, Gravel	26-50%	0-25%	--
East Fork Nookachamps	EF3	1	48.42806	-122.22065	53	Riffle	Gravel, Sm. Cobble	26-50%	0-25%	--
East Fork Nookachamps	EF3	2	48.42798	-122.22094	147	Glide	Gravel, Sm. Cobble	51-75%	26-50%	--
East Fork Nookachamps	EF3	3	48.43139	-122.23089	109	Glide	Silt/Clay, Gravel	51-75%	51-75%	--
East Fork Nookachamps	EF3	4	48.43216	-122.23120	100	Main Channel Pool	Sand, Sm. Cobble	51-75%	0-25%	--
East Fork Nookachamps	EF5	1	48.40802	-122.19211	28	"	Main Channel Pool"	Lg. Cobble, Bedrock	26-50%	26-50%
East Fork Nookachamps	EF5	2	48.40793	-122.19190	162	Pocketwater	Lg. Cobble, Boulder	0-25%	0-25%	--
Turner Creek	T1	1	--	--	200	Glide	Gravel, 1.Silt/Clay	51-75%	--	--
Turner Creek	T2	1	--	--	101	Glide	Sand, Gravel	76-100	--	--
Turner Creek	T2	2	--	--	57	Riffle	Sand, Gravel	76-100	--	--
Turner Creek	T2	3	--	--	42	Main Channel Pool	Sand, Gravel	76-100	--	76-100%
Turner Creek	T3	1	48.44146	-122.21198	36	Riffle	Gravel, Sm. Cobble	26-50%	26-50%	--
Turner Creek	T3	2	48.44114	-122.21207	18	Main Channel Pool	Sand, Sm. Cobble	26-50%	26-50%	26-50%
Turner Creek	T3	3	48.44167	-122.21206	53	Riffle	Gravel, Sm. Cobble	0-25%	0-25%	--
Turner Creek	T3	4	48.44176	-122.21204	35	Main Channel Pool	Gravel, Sm. Cobble	51-75%	26-50%	0-25%
Turner Creek	T3	5	48.44196	-122.21207	49	Riffle	Gravel, Sm. Cobble	26-50%	26-50%	--
Turner Creek	T4	1	48.44750	-122.19574	78	Pocketwater	Sm. Cobble, Lg. Cobble	0-25%	0-25%	--
Turner Creek	T4	2	48.44752	-122.19554	9	Main Channel Pool	Gravel, Bedrock	0-25%	0-25%	0-25%
Turner Creek	T4	3	48.44773	-122.19538	96	Pocketwater	Sm. Cobble, Lg. Cobble	0-25%	0-25%	--
Lower Day Creek	B1	1	48.44242	-122.21896	34	Glide	Lg. Cobble	0-25%	0-25%	--
Lower Day Creek	B2	1	48.46022	-122.20739	200	Pocketwater	Sm. Cobble, Lg. Cobble	51-75%	51-75%	--
Mundt Creek	M1	1	48.42471	-122.20256	35	Riffle	Sm. Cobble, Lg. Cobble	51-75%	26-50%	--
Mundt Creek	M1	2	48.42472	-122.20233	50	Main Channel Pool	Sm. Cobble, Lg. Cobble	51-75%	26-50%	26-50%
Mundt Creek	M1	3	48.42470	-122.20187	118	Pocketwater	Sm. Cobble, Lg. Cobble	--	--	--
Mundt Creek	M2	1	48.43969	-122.19067	96	Pocketwater	Lg. Cobble, Boulder	51-75%	0-25%	--
Mundt Creek	M2	2	48.43979	-122.19051	12	Main Channel Pool	Gravel, Boulder	0-25%	0-25%	0-25%
Mundt Creek	M2	3	48.43992	-122.19032	53	Pocketwater	Lg. Cobble, Boulder	26-50%	0-25%	--
Mundt Creek	M2	4	48.43999	-122.19025	39	Main Channel Pool	Lg. Cobble, Boulder	26-50%	26-50%	26-50%
Unknown Tributary 1	Unk1-1	1	48.41597	-122.19132	30	Main Channel Pool	Gravel, Boulder	51-75%	26-50%	26-50%
Klahowya Creek	K1	1	48.40419	-122.19193	200	Pocketwater	Gravel, Boulder	51-75%	26-50%	--

Stream	Reach Code	Sub-Reach ID	Latitude	Longitude	Reach length (ft)	Habitat Type	Dominant/ Subdominant Substrate	Total Substrate Embeddedness	Spawning Gravel Embeddedness	Pool Tailout Embeddedness
Klahowya Creek	K2	1	48.38860	-122.18132	140	Riffle	Gravel, Sm. Cobble	26-50%	0-25%	--
Walker Creek	W1	1	48.41042	-122.21096	85	Riffle	Sm. Cobble, Lg. Cobble	26-50%	26-50%	--
Walker Creek	W1	2	48.41012	-122.21133	30	Main Channel Pool	Gravel, Sm. Cobble	51-75%	51-75%	51-75%
Walker Creek	W1	3	48.41007	-122.21145	85	Glide	Silt/Clay, Gravel	51-75%	51-75%	--
Walker Creek	W4	1	48.38080	-122.17719	30	Main Channel Pool	Sm. Cobble, Lg. Cobble	--	--	--
Walker Creek	W4	2	48.38076	-122.17696	67	Riffle	Gravel, Lg. Cobble	51-75%	76-100%	--
Walker Creek	W4	3	48.38081	-122.17682	27	Main Channel Pool	Lg. Cobble, Boulder	26-50%	--	51-75%
Walker Creek	W4	4	48.38084	-122.17663	25	Riffle	Lg. Cobble, Boulder	0-25%	0-25%	--
East Fork Walker Creek	--	1	48.38479	-122.19334	150	Glide	Gravel, Sm. Cobble	26-50%	0-25%	--

TABLE E-2. FISH HABITAT FIELD ASSESSMENT DATA

Stream	Reach Code	Sub-Reach ID	Maximum Depth (ft)	Pool Crest Depth (ft)	Wetted Width 1 (ft)	Wetted Width 2 (ft)	Wetted Width 3 (ft)	Bankfull Width 1 (ft)	Bankfull Width 2 (ft)	Bankfull Width 3 (ft)
Nookachamps Creek	N1	1	--	--	--	--	--	--	--	--
Nookachamps Creek	N2	1	--	--	--	--	--	--	--	--
Mud Creek	M1	1	1.9		13.2	14.0	16.0	--	--	--
East Fork Nookachamps	EF1	1	6.0		17.5	15.0	13.7	18.5	20.6	32.4
East Fork Nookachamps	EF1	2	4.0	0.8	17.5	15.0	13.7	18.5	20.6	32.4
East Fork Nookachamps	EF2	1	4.5	1.2	53.3	21.8	21.7	62.3	28.3	37.3
East Fork Nookachamps	EF2	2	0.9		21.1	28.3	23.8	36.2	33.5	33.7
East Fork Nookachamps	EF3	1	0.4		29.9	29.2	22.5	37.0	31.9	27.6
East Fork Nookachamps	EF3	2	2.1		21.8	26.5	19.2	28.0	32.6	35.2
East Fork Nookachamps	EF3	3	4.0		27.8	26.6	28.4	34.3	34.4	53.0
East Fork Nookachamps	EF3	4	5.0	0.7	22.2	20.2	16.9	33.0	33.5	35.1
East Fork Nookachamps	EF5	1	2.7	0.6	12.1	21.4	15.0	12.5	24.2	22.8
East Fork Nookachamps	EF5	2	1.2		31.7	21.1	24.1	38.8	50.7	33.9
Turner Creek	T1	1	5.0		15.9	25.3	29.9	25.1	44.7	47.3
Turner Creek	T2	1	1.1		15.6	17.5	19.3	17.6	20.4	22.2
Turner Creek	T2	2	0.4		3.2	3.4	4.1	17.6	20.4	22.2
Turner Creek	T2	3	2.4	0.7	12.9	15.0	12.8	17.6	20.4	22.2
Turner Creek	T3	1	0.2		4.0	3.8	3.6	11.6	6.2	11.7
Turner Creek	T3	2	0.8	0.3	5.0	4.7	4.6	8.5	7.7	8.1
Turner Creek	T3	3	0.3		4.8	4.6	4.2	11.2	13.6	11.1
Turner Creek	T3	4	1.0	0.2	8.2	4.4	8.8	13.0	11.6	14.2
Turner Creek	T3	5	0.6		3.5	4.4	4.5	13.1	12.3	12.1
Turner Creek	T4	1	1.0	--	4.4	5.2	3.5	11.2	15.1	7.9

Stream	Reach Code	Sub-Reach ID	Maximum Depth (ft)	Pool Crest Depth (ft)	Wetted Width 1 (ft)	Wetted Width 2 (ft)	Wetted Width 3 (ft)	Bankfull Width 1 (ft)	Bankfull Width 2 (ft)	Bankfull Width 3 (ft)
Turner Creek	T4	2	1.4	0.3	5.5	4.1	4.0	5.8	4.5	6.7
Turner Creek	T4	3	0.4	--	7.6	5.6	6.5	11.9	12.6	9.6
Lower Day Creek	B1	1	6.0	--	32.0	32.0	32.0	--	--	--
Lower Day Creek	B2	1	0.5	--	11.4	8.9	6.6	12.0	12.2	14.3
Mundt Creek	M1	1	0.4	--	12.9	17.3	16.1	24.0	25.3	20.9
Mundt Creek	M1	2	1.2	0.4	10.8	14.5	14.2	16.2	15.5	24.1
Mundt Creek	M1	3	1.0	--	8.0	10.4	10.3	18.5	13.5	15.5
Mundt Creek	M2	1	0.8	--	13.1	10.6	11.9	21.1	22.5	20.1
Mundt Creek	M2	2	1.0	0.4	13.9	11.3	11.6	16.2	15.5	17.6
Mundt Creek	M2	3	0.8	--	7.1	7.1	4.3	15.1	18.3	21.5
Mundt Creek	M2	4	1.3	0.4	8.6	8.7	7.2	9.0	10.5	13.2
Unknown Tributary 1	Unk1-1	1	1.4	0.3	6.4	8.2	8.5	N/A	N/A	N/A
Klahowya Creek	K1	1	1.1	--	4.6	6.8	3.9	10.7	9.0	11.6
Klahowya Creek	K2	1	0.0	--	4.6	4.8	5.8	6.3	7.4	8.7
Walker Creek	W1	1	0.6	0.0	19.0	17.0	21.2	30.3	26.9	29.2
Walker Creek	W1	2	3.5	0.6	29.2	27.5	14.3	29.2	30.0	30.3
Walker Creek	W1	3	3.1	--	17.5	33.6	16.4	42.5	38.0	27.0
Walker Creek	W4	1	4.0	--	--	--	--	--	--	--
Walker Creek	W4	2	0.3	--	7.5	11.9	8.4	23.2	30.4	30.4
Walker Creek	W4	3	2.3	0.8	17.0	17.6	5.1	--	--	--
Walker Creek	W4	4	0.8	--	6.2	9.0	10.0	--	--	--
East Fork Walker Creek	--	1	0.6	--	4.5	4.8	5.0	6.6	7.0	8.0

TABLE E-3. FISH HABITAT FIELD ASSESSMENT DATA

Stream	Reach Code	Sub-Reach ID	Water Temp (F)	Dissolved Oxygen (mg/l)	LWD Count	Rootwad Count	SWD Count	Dominant Vegetation	Cover Type
Nookachamps Creek	N1	1	62.8	8.90	1	0	0	Willow	large tree, grass/small vegetation
Nookachamps Creek	N2	1	62.8	8.90	3	1	0	Dogwood	large tree, grass/small vegetation
Mud Creek	M1	1	65.7	1.10	0	0	0	Reed canary grass	bubble curtain
East Fork Nookachamps	EF1	1	70.0	6.04	0	0	1	Reed canary grass	undercut bank, grass/small vegetation
East Fork Nookachamps	EF1	2	70.0	6.01	0	0	5	Reed canary grass	undercut bank, grass/small vegetation
East Fork Nookachamps	EF2	1	67.6	8.08	1	1	5	Willow	large tree, undercut bank
East Fork Nookachamps	EF2	2	67.6	8.08	0	0	4	Reed canary grass/willow	large tree, undercut bank, grass/small vegetation
East Fork Nookachamps	EF3	1	62.4	9.05	0	0	1	Shrub (blackberry)	bubble curtain, grass/small vegetation
East Fork Nookachamps	EF3	2	62.4	9.05	0	2	5	Pacific ninebark	large tree, undercut bank, grass/small vegetation
East Fork Nookachamps	EF3	3	69.8	10.50	0	3	0	Cottonwood	large tree, undercut bank, grass/small vegetation

Stream	Reach Code	Sub-Reach ID	Water Temp (F)	Dissolved Oxygen (mg/l)	LWD Count	Rootwad Count	SWD Count	Dominant Vegetation	Cover Type
East Fork Nookachamps	EF3	4	69.8	10.52	1	0	0	Cottonwood	large tree, undercut bank, grass/small vegetation
East Fork Nookachamps	EF5	1	66.7	9.63	0	0	0	Hardwood	large tree, undercut bank, bubble curtain
East Fork Nookachamps	EF5	2	66.7	9.62	0	0	1	Hardwood	large tree, undercut bank, bubble curtain
Turner Creek	T1	1	73.4	4.38	0	0	0	Conifer	grass/small vegetation
Turner Creek	T2	1	63.5	8.72	0	0	0	planted decorative maple	grass/small vegetation
Turner Creek	T2	2	63.5	8.72	0	0	0	planted decorative maple	grass/small vegetation
Turner Creek	T2	3	63.5	8.72	0	0	0	planted decorative maple	grass/small vegetation
Turner Creek	T3	1	62.4	8.90	1	0	3	Cottonwood	large tree, bubble curtain, grass/small vegetation
Turner Creek	T3	2	62.4	8.90	1	0	3	Hardwood	large tree, undercut bank, bubble curtain
Turner Creek	T3	3	62.4	8.90	0	0	10	Cottonwood	large tree, bubble curtain
Turner Creek	T3	4	62.4	8.90	0	0	1	Cottonwood	large tree, undercut bank, bubble curtain
Turner Creek	T3	5	62.4	8.90	2	1	15	Cottonwood	large tree, undercut bank, bubble curtain, grass/small vegetation
Turner Creek	T4	1	60.3	9.69	10	2	5	Hardwood	large tree, undercut bank, bubble curtain
Turner Creek	T4	2	60.3	9.69	0	1	3	Hardwood	large tree, undercut bank, bubble curtain, grass/small vegetation
Turner Creek	T4	3	60.3	9.69	0	0	3	Hardwood	large tree, bubble curtain
Lower Day Creek	B1	1	75.4	1.39	0	0	0	Reed canary grass	grass/small vegetation
Lower Day Creek	B2	1	61.5	9.49	2	0	1	Hardwood	large tree, bubble curtain, grass/small vegetation
Mundt Creek	M1	1	62.8	9.80	0	0	0	Cottonwood	large tree, bubble curtain
Mundt Creek	M1	2	62.8	9.80	0	3	0	Cottonwood	large tree, undercut bank, bubble curtain, grass/small vegetation
Mundt Creek	M1	3	62.8	9.80	0	1	0	Cottonwood	large tree, undercut bank, bubble curtain, grass/small vegetation
Mundt Creek	M2	1	62.1	8.90	0	0	0	Shrub (blackberry)	undercut bank, bubble curtain
Mundt Creek	M2	2	62.1	8.90	0	0	0	Willow	large tree, bubble curtain
Mundt Creek	M2	3	62.1	8.90	0	0	0	Hardwood	large tree, undercut bank, bubble curtain
Mundt Creek	M2	4	62.1	8.90	0	0	0	Hardwood	large tree, undercut bank, bubble curtain
Unknown Tributary 1	Unk1-1	1	60.3	9.70	0	0	0	Shrub (blackberry)	undercut bank, bubble curtain, grass/small vegetation
Klahowya Creek	K1	1	64.6	9.70	7	0	2	Hardwood	large tree, undercut bank, bubble curtain, grass/small vegetation
Klahowya Creek	K2	1	66.2	9.80	0	0	0	Cottonwood/fern	large tree, grass/small vegetation
Walker Creek	W1	1	68.2	8.85	3	0	10	Riparian	large tree, grass/small vegetation
Walker Creek	W1	2	68.2	8.85	8	0	10	Riparian (willow)	large tree, undercut bank
Walker Creek	W1	3	68.2	8.85	0	0	1	Shrub(blackberry)	bubble curtain, grass/small vegetation
Walker Creek	W4	1	66.4	9.20	--	--	--	--	--
Walker Creek	W4	2	66.4	9.20	0	0	0	Cedar	large tree, bubble curtain
Walker Creek	W4	3	66.4	9.20	0	0	0	Cedar	large tree, undercut bank, bubble curtain, grass/small vegetation
Walker Creek	W4	4	66.4	9.20	0	0	1	Conifer	large tree, bubble curtain, grass/small vegetation
East Fork Walker Creek	--	1	68.5	8.94	0	0	0	Shrub(grass)	undercut bank, grass/small vegetation

TABLE E-4. FISH HABITAT FIELD ASSESSMENT DATA

Stream	Reach Code	Sub-Reach ID	Rearing HQM Report	Spawning HQM Report	Limiting Factors Documented	Limiting Factors Notes	Juvenile Salmon Presence	Juvenile Salmon Count
Nookachamps Creek	N1	1	0.33	0	yes	Slow moving water, no spawning substrate, high turbidity	No	0
Nookachamps Creek	N2	1	0.66	0	yes	Low flow, no spawning gravel, high turbidity	No	0
Mud Creek	M1	1	0.33	0	yes	Lethal DO, no rocky substrate, no flow, bullfrogs present	No	0
East Fork Nookachamps	EF1	1	0.66	0	yes	No spawning substrate	Yes, unidentified species	1-49
East Fork Nookachamps	EF1	2	0.66	0	yes	No spawning substrate	Yes, unidentified species	1-49
East Fork Nookachamps	EF2	1	0.66	0.33	yes	Silt present, limited spawning gravel	Yes, unidentified species	1-49
East Fork Nookachamps	EF2	2	0.66	0.66	yes	No cover, algae present in slower moving areas	Yes, unidentified species	1-49
East Fork Nookachamps	EF3	1	0.66	0.66	yes	Limited cover in stream or along margin	No	0
East Fork Nookachamps	EF3	2	0.66	0.66	yes	Presence of fine particles on spawning substrate	Yes, unidentified species	1-49
East Fork Nookachamps	EF3	3	0.66	0.66	yes	Silt present on spawning substrate	Yes, unidentified species	>100
East Fork Nookachamps	EF3	4	1	1	no		Yes, unidentified species	>100
East Fork Nookachamps	EF5	1	1	1	no		Yes, unidentified species	50-99
East Fork Nookachamps	EF5	2	1	1	no		Yes, unidentified species	1-49
Turner Creek	T1	1	0.33	0.33	yes	High water temp, low DO, no shade, high silt	No	0
Turner Creek	T2	1	0.33	0	yes	no shade, no spawning substrate, low flow	No	0
Turner Creek	T2	2	0.33	0	yes	no shade, no spawning substrate, low flow	No	0
Turner Creek	T2	3	0.33	0	yes	no shade, no spawning substrate, low flow	No	0
Turner Creek	T3	1	1	1	no		Yes, unidentified species	1-49
Turner Creek	T3	2	1	1	no		Yes, unidentified species	50-99
Turner Creek	T3	3	1	1	no		Yes, unidentified species	1-49
Turner Creek	T3	4	1	1	no		Yes, unidentified species	50-99
Turner Creek	T3	5	1	1	no		Yes, unidentified species	1-49
Turner Creek	T4	1	1	1	no		No	0
Turner Creek	T4	2	1	1	no		No	0
Turner Creek	T4	3	1	1	no		No	0
Lower Day Creek	B1	1	0	0	yes	DO is lethal, High-water temp	No	0
Lower Day Creek	B2	1	1	1	no		Yes, unidentified species	1-49
Mundt Creek	M1	1	1	1	no		Yes, unidentified species	1-49
Mundt Creek	M1	2	1	1	no		Yes, unidentified species	1-49
Mundt Creek	M1	3	1	1	no		Yes, unidentified species	1-49
Mundt Creek	M2	1	1	0.33	yes	Limited spawning substrate	Yes, unidentified species	1-49
Mundt Creek	M2	2	1	0.66	yes	Limited spawning substrate	Yes, unidentified species	1-49
Mundt Creek	M2	3	1	0.33	yes	Limited spawning substrate	No	0
Mundt Creek	M2	4	1	0.66	yes	Limited spawning substrate	Yes, unidentified species	1-49
Unknown Tributary 1	Unk1-1	1	1	1	no		No	0
Klahowya Creek	K1	1	1	1	no		Yes, unidentified species	1-49

Stream	Reach Code	Sub-Reach ID	Rearing HQM Report	Spawning HQM Report	Limiting Factors Documented	Limiting Factors Notes	Juvenile Salmon Presence	Juvenile Salmon Count
Klahowya Creek	K2	1	1	0.66	yes	Depth	Yes, unidentified species	1-49
Walker Creek	W1	1	1	1	no		Yes, unidentified species	1-49
Walker Creek	W1	2	1	0.66	no		Yes, unidentified species	50-99
Walker Creek	W1	3	0.66	0.33	yes	Algae, limited canopy, fine sediment	Yes, unidentified species	1-49
Walker Creek	W4	1	--	--	--		--	--
Walker Creek	W4	2	0.66	1	yes	Cover	No	0
Walker Creek	W4	3	1	1	no		No	0
Walker Creek	W4	4	0.66	0	yes	No spawning substrate	No	0
East Fork Walker Creek	--	1	0.66	0.66	yes	Depth	Yes, unidentified species	1-49

Appendix F.
Hydraulic Assessment of Select Culverts

TABLE 1
TURNER CREEK & BEAVER LAKE ROAD CROSSING

Headwater Elevation (FT NAVD88)	Discharge Name	Total Discharge (CFS)	Culvert 1 Discharge (CFS)	Roadway Discharge (CFS)
39.58	2 year	146.00	88.93	0.00
40.25	5 year	226.00	91.77	0.00
40.57	10 year	279.00	91.28	0.00
40.92	25 year	347.00	90.44	0.00
41.14	50 year	396.00	89.79	0.00
41.35	100 year	450.00	89.05	0.00
41.54	200 year	502.00	88.13	0.00
41.78	500 year	574.00	87.15	0.00
70.30	Overtopping	72.94	72.94	0.00

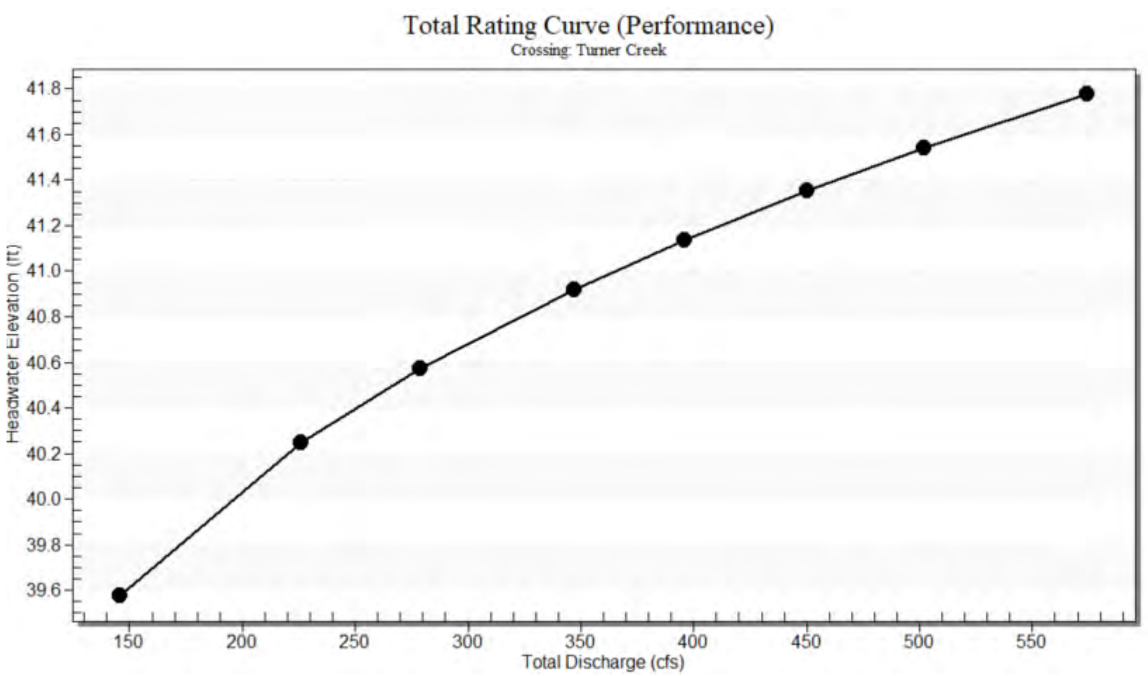


TABLE 2
TURNER CREEK & ELK ROAD CROSSING

Headwater Elevation (FT NAVD88)	Discharge Name	Total Discharge (CFS)	Culvert 1 Discharge (CFS)	Roadway Discharge (CFS)
64.97	2 year	146.00	69.70	76.31
66.34	5 year	226.00	87.05	138.93
67.16	10 year	279.00	96.38	182.60
68.14	25 year	347.00	107.10	239.90
68.81	50 year	396.00	114.11	281.85
69.53	100 year	450.00	121.35	328.64
70.21	200 year	502.00	127.96	373.92
70.61	500 year	574.00	129.06	399.41
70.30	Overtopping	508.97	128.87	380.10

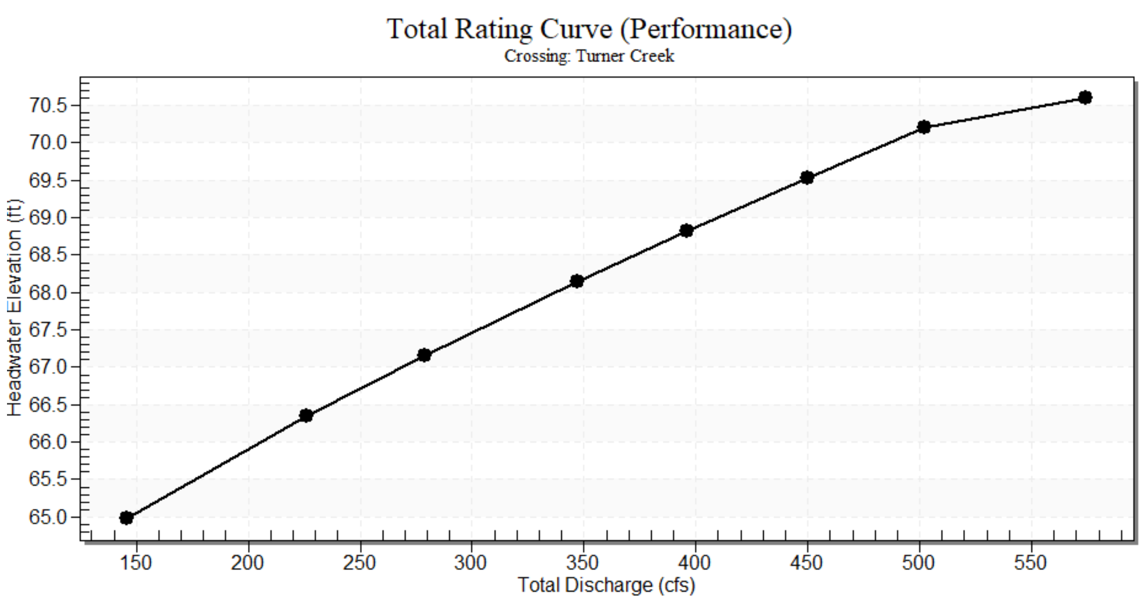


TABLE 3
BEAVER LAKE CREEK & FONK RD CROSSING

Headwater Elevation (FT NAVD88)	Discharge Name	Total Discharge (CFS)	Culvert 1 Discharge (CFS)	Roadway Discharge (CFS)
35.26	2 year	109.00	109.00	0.00
36.97	5 year	172.00	172.00	0.00
38.59	10 year	215.00	215.00	0.00
39.80	25 year	270.00	241.48	28.26
39.97	50 year	312.00	244.95	66.88
40.11	100 year	357.00	247.88	108.86
40.24	200 year	401.00	250.35	150.21
40.40	500 year	463.00	253.42	209.38
39.57	Overtopping	236.78	236.78	0.00

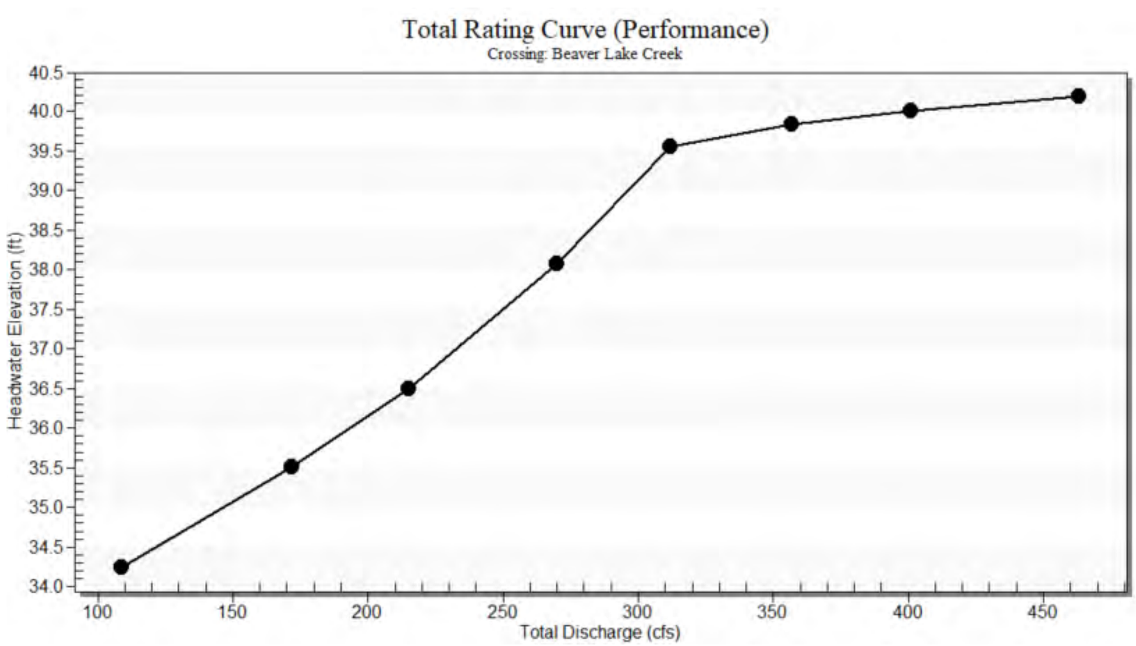


TABLE 4
BEAVER LAKE CREEK & BEAVER LAKE ROAD CROSSING

Headwater Elevation (FT NAVD88)	Discharge Name	Total Discharge (CFS)	Culvert 1 Discharge (CFS)	Roadway Discharge (CFS)
36.10	2 year	111.00	111.00	0.00
37.42	5 year	175.00	175.00	0.00
38.33	10 year	218.00	218.00	0.00
39.85	25 year	275.00	275.00	0.00
40.49	50 year	317.00	292.76	24.15
40.66	100 year	363.00	296.98	65.90
40.80	200 year	408.00	300.44	107.39
40.98	500 year	471.00	302.43	168.16
40.30	Overtopping	287.39	287.39	0.00

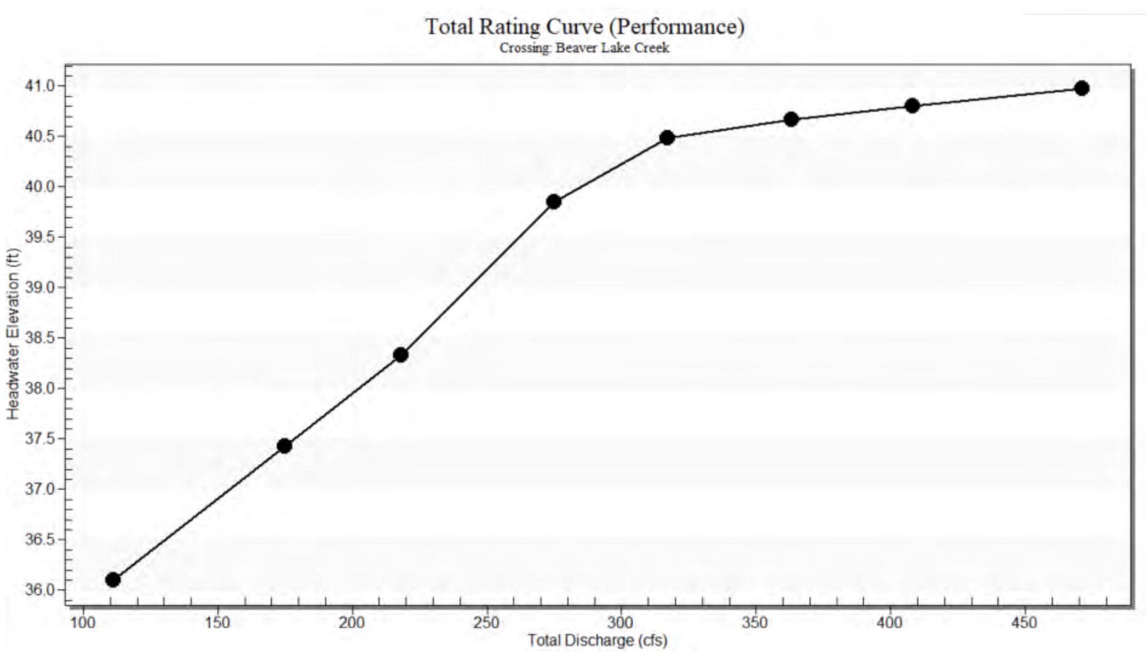
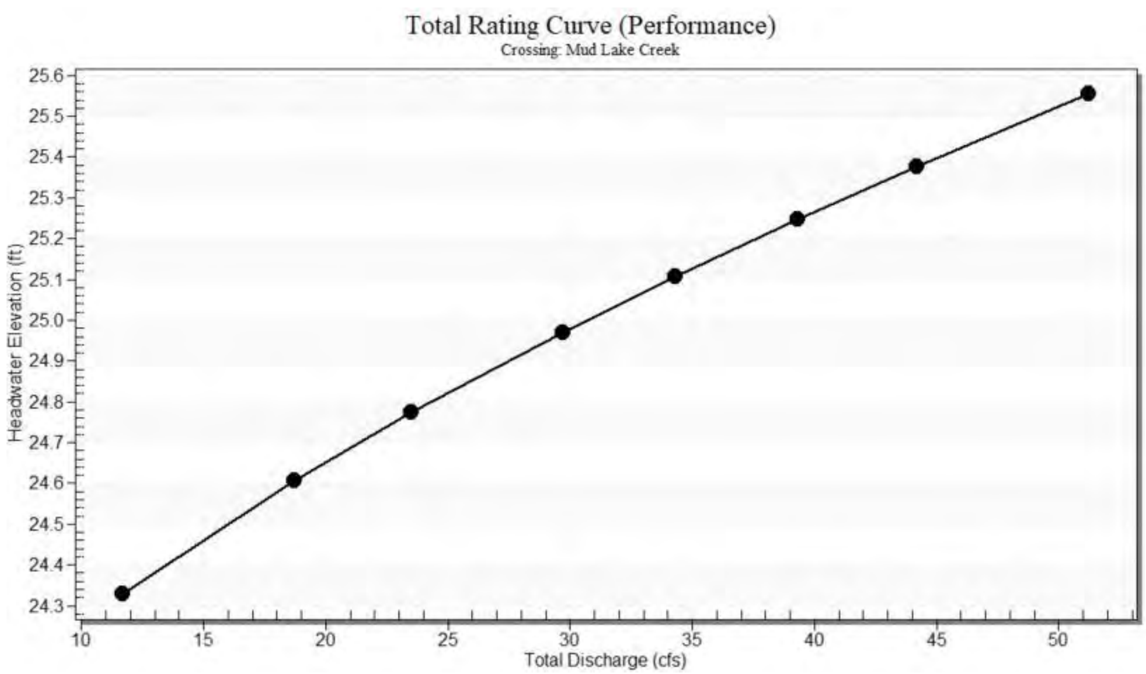


TABLE 5
MUD LAKE CREEK & SWAN ROAD CROSSING

Headwater Elevation (FT NAVD88)	Discharge Name	Total Discharge (CFS)	Culvert 1 Discharge (CFS)	Roadway Discharge (CFS)
24.33	2 year	11.70	11.70	0.00
24.61	5 year	18.70	18.70	0.00
24.77	10 year	23.50	23.50	0.00
24.97	25 year	29.70	29.70	0.00
25.11	50 year	34.30	34.30	0.00
25.25	100 year	39.30	39.30	0.00
25.38	200 year	44.20	44.20	0.00
25.56	500 year	51.20	51.20	0.00
34.60	Overtopping	584.65	584.65	0.00



Appendix G.
Hydraulic Modeling of East Fork Nookachamps Creek at Highway 9 Bridge Crossing

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Appendix G. Hydraulic Modeling of East Fork Nookachamps Creek at Highway 9 Bridge Crossing

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1.0 Introduction

The Upper Skagit Indian Tribe and Skagit County are partnering to develop a Watershed Assessment and Watershed Management Plan to address salmonid habitat degradation and flooding concerns in the East Fork Nookachamps Creek (EF Nookachamps Creek) watershed (**Figure 1**). EF Nookachamps Creek is the lowermost creek system of significance in the Skagit River watershed. The EF Nookachamps Creek watershed is home to a vibrant community largely centered around agriculture and with long, multigenerational histories in the area. In recent years, landowners have also been experiencing increased and longer duration flooding. In support of the Watershed Assessment and Watershed Management Plan, ESA developed a hydraulic model to assess the potential performance of some flood reduction alternatives. This memorandum describes the development of the hydraulic model, the scenarios evaluated with the model, modeling results, and recommended steps for future study.

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Figure 1
Project Area

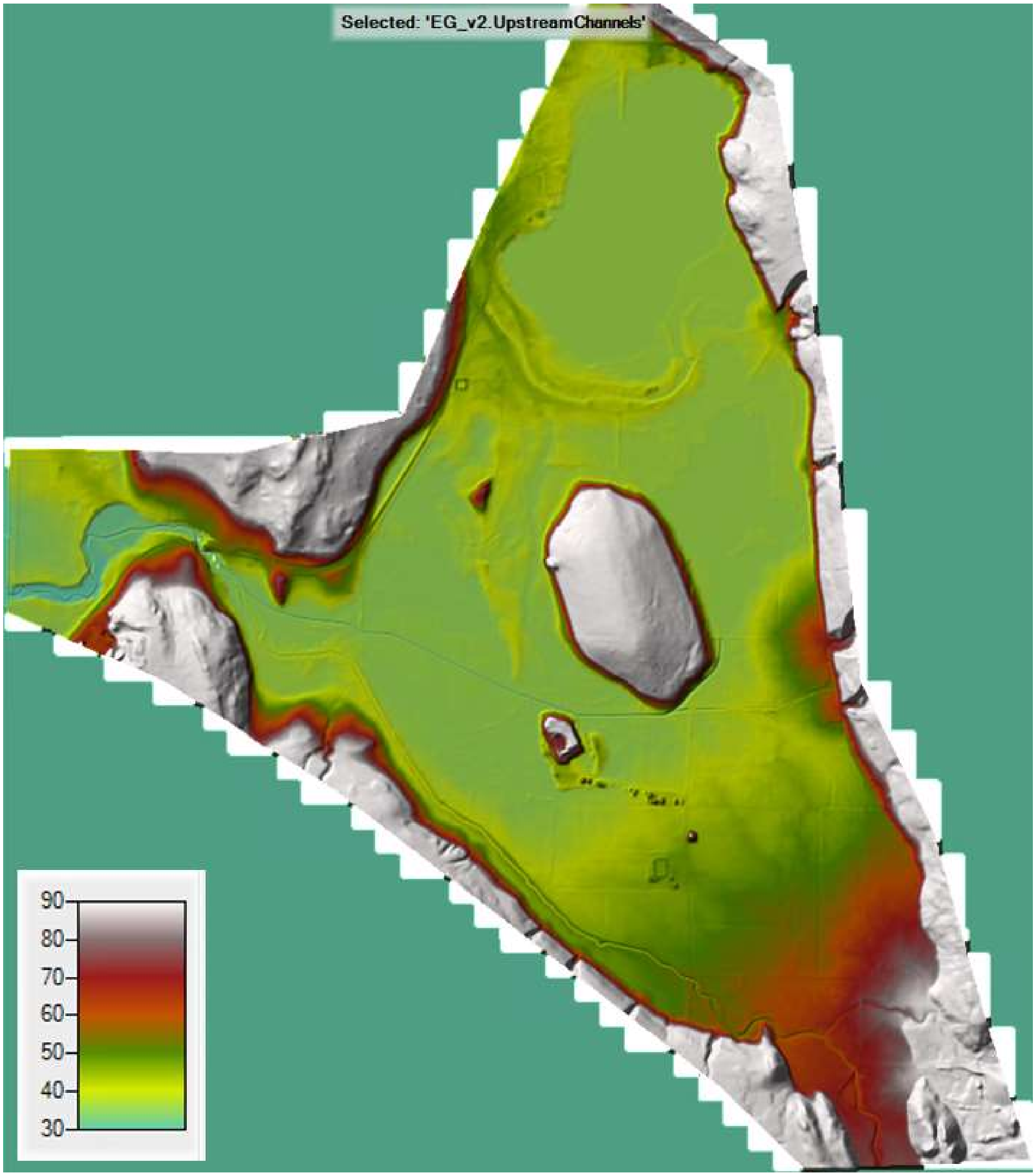
2.0 Hydraulic Model

Hydraulic modeling for this study was performed using the US Army Corps of Engineers Hydraulic Engineering Center's River Analysis System (HEC-RAS), a free software developed by the U.S. Army Corps of Engineers (USACE, 2023). HEC-RAS uses inputs of topography, streamflow, roughness, and structures to provide an estimate of flow depth and velocity for channels and floodplains. A two-dimensional (2D) hydraulic model was developed for this study to encompass flooding dynamics within the EF Nookachamps Creek valley.

2.1 Model Terrain

The existing conditions model terrain was developed by burning creek channels into a LIDAR elevation surface. The North Puget 2017 LIDAR was used as the base surface and other features were edited into the terrain using HEC-RAS terrain modification tools (Quantum Spatial, 2017). The LIDAR did not capture the bathymetry of the stream channels below the water surface. As part of the Watershed Assessment, ESA performed cross section surveys of EF Nookachamps and Turner creeks, with more detailed survey in the area immediately upstream of the Highway 9 crossing. Using the survey data, channel bathymetric surfaces were interpolated for EF Nookachamps and Turner Creek and burned into the LIDAR surface (**Figure 2**). **Figure 2** shows that the stream channels entering the valley transition from steep slopes to a largely flat channel bottom. This pattern is particularly noticeable along Turner Creek, which has a very low slope from Beaver Lake Road downstream to its confluence with EF Nookachamps creek. The Highway 9 crossing is located at a natural (geologically controlled) valley constriction where the channel becomes highly laterally constrained. The valley widens downstream of the Highway 9 crossing but remains much narrower than the wide valley upstream of Highway 9.

Three alternative scenarios were modeled to assess drainage improvement alternatives within the valley. The Highway 9 bridge crossing of EF Nookachamps creek causes a prominent narrowing of the stream and floodplain, beyond the geologic controls mentioned above. To test the effects of widening the highway crossing on flood dynamics, the highway embankment was removed from the model terrain to follow what appears to be the natural valley wall extents (**Figure 3**). Another potential source of backwatering in the valley upstream of Highway 9 was identified as the "Finger Dikes" which are located at the downstream extent of the model terrain. Similarly, the finger dikes were removed from the model terrain to the surrounding channel and floodplain elevations to assess if their removal would lower flood elevations (**Figure 4**). A final alternative supplemented the widening of the Highway 9 crossing to widen the most constrained portions of the valley upstream and downstream of Highway 9 (**Figure 5**). This model scenario is intended as a "bookend" to assess the possible maximum reduction in flood levels due to widening the constrained portion of the valley. The extents of grading for this option are conceptual and were chosen to maximize conveyance while not creating overly steep slopes or impacting landowner structures.



SOURCE: ESA (2023)

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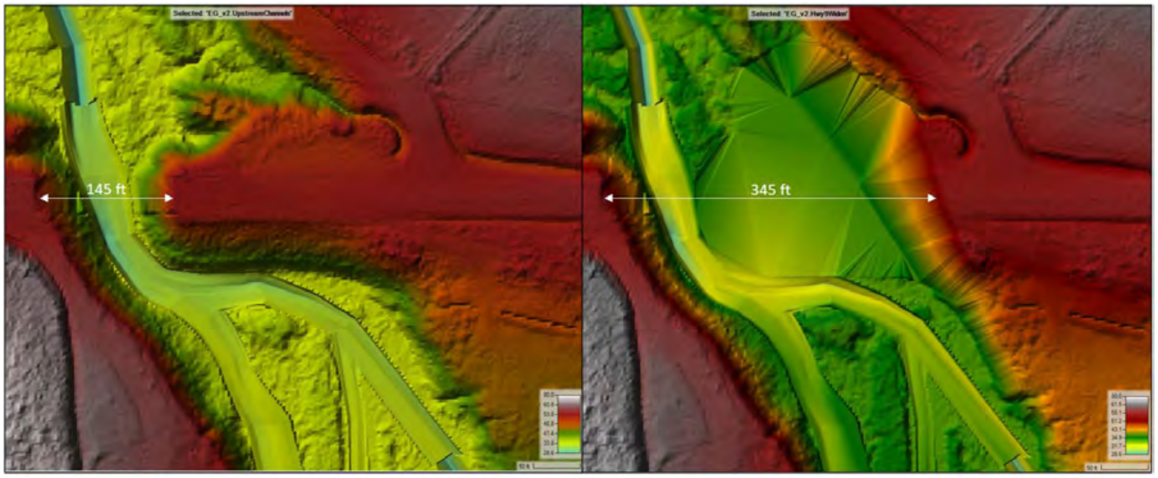
Figure 2
Model Terrain



SOURCE: ESA (2023)

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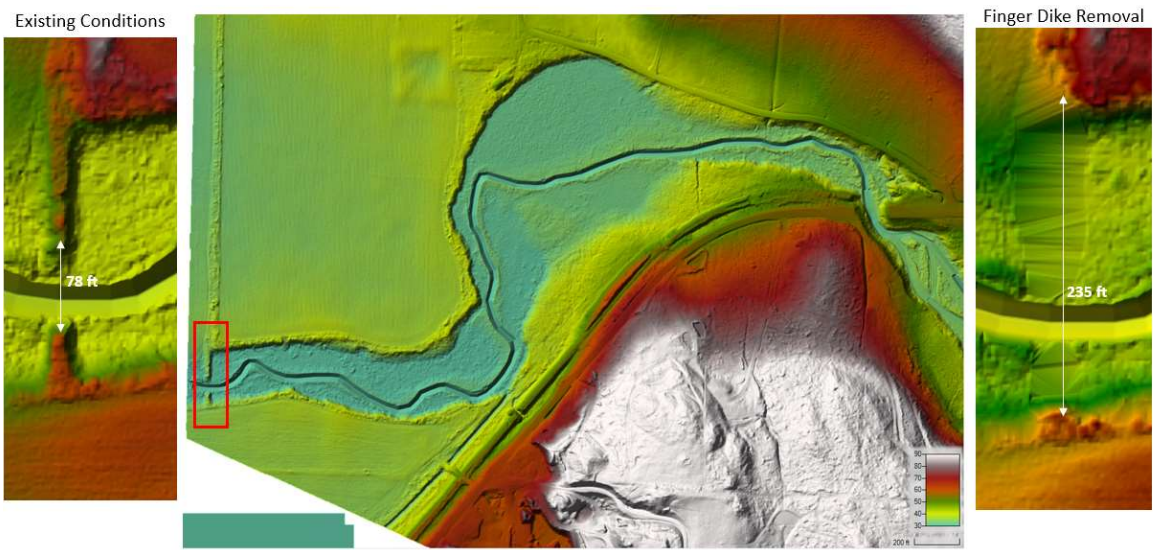
NOTES: Existing conditions (left), Highway 9 widening (right)

Figure 3
Highway 9 Widening Scenario



SOURCE: ESA (2023)

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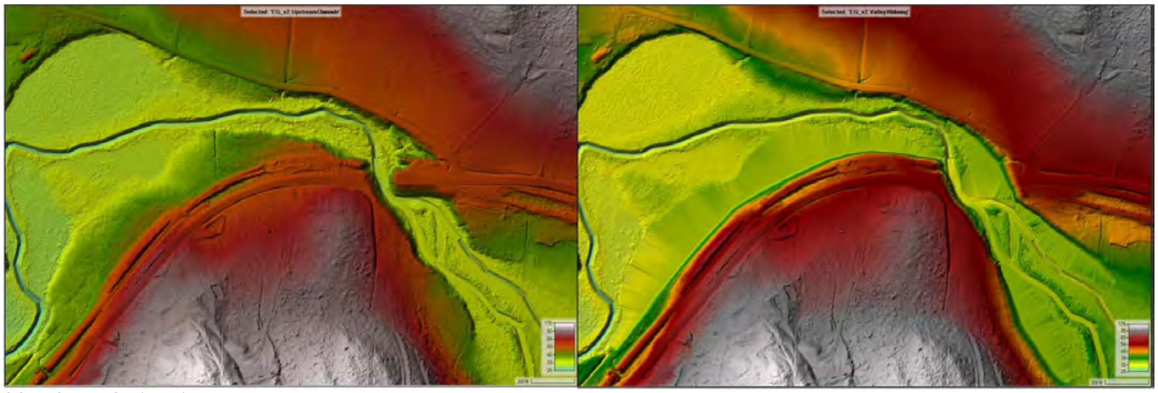
Figure 4
“Finger Dike” Removal Scenario



SOURCE: ESA (2023)

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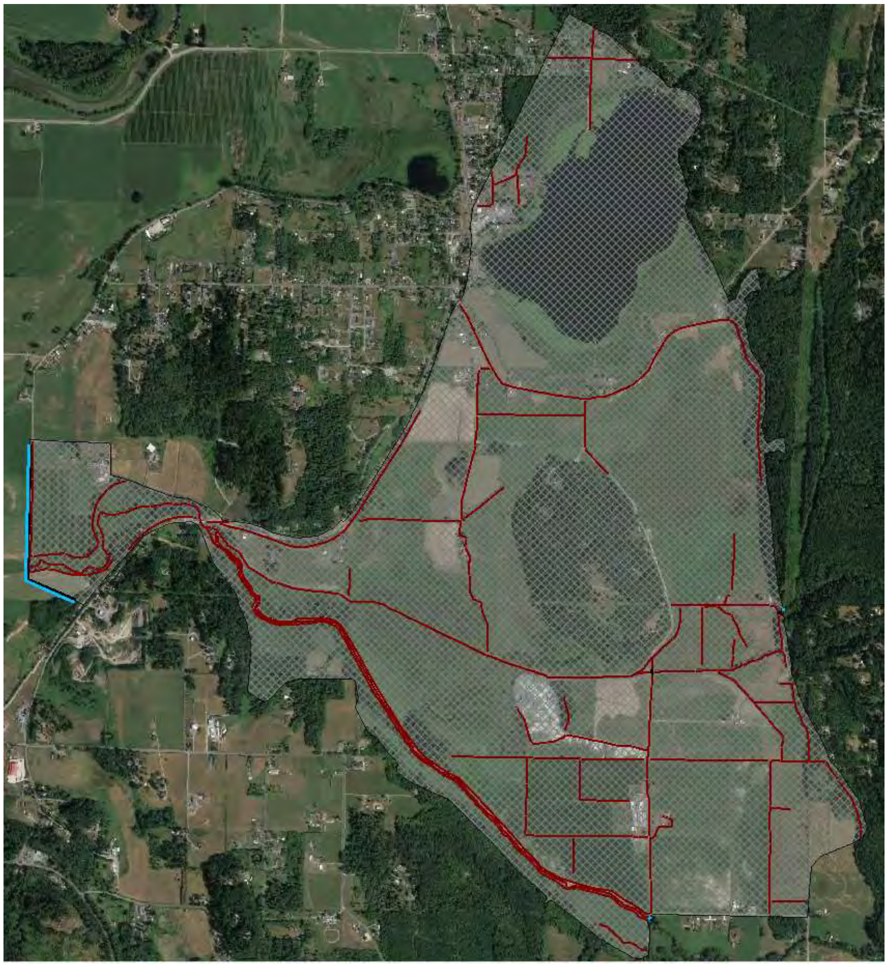
NOTES: Existing conditions (left), Valley widening (right)

Figure 5
Valley Widening Scenario

2.2 Model Mesh

The model extents for this study were set to capture the low-lying valley area upstream of Highway 9 and potential backwater effects due to the constrictions at the highway and downstream (**Figure 6**). The model extends upstream on EF Nookachamps to a residential road bridge on the corner of Beaver Lake Road and on Turner Creek to just upstream of Elk Road. The model extends to the north beyond Clear Lake and to the west to Highway 9. The downstream extent of the model is just downstream of the “Finger Dikes”.

The 2D model mesh discretizes the model domain into cells where water surface and discharge are calculated for each time step (**Figure 6**). Mesh size was set uniformly at 50-foot spacing in the floodplain. Breaklines were used in channels to orient cells to the flow direction, improving model stability, and to enhance model resolution in critical areas. Breaklines were also used to ensure that the mesh was accurately capturing features such as roadways and levees.



SOURCE: ESA (2023)

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NOTES: Boundary conditions are indicated by blue lines. Brown line indicate breaklines.

Figure 6
Model Mesh

2.3 Boundary Conditions

2.3.1 Inflow Hydrology

Inflow to the model was defined at the upstream boundaries for EF Nookachamps and Turner Creek. Streamflow data was available for the study area from Washington State Department of Ecology (Ecology) and Skagit Public Utilities District (SPUD) gages (**Figure 7**). Inflow for EF Nookachamps creek was developed by combining the Ecology gage data for EF Nookachamps Creek (03G100) and the SPUD gage for Mundt Creek (4EA0109A) (**Figure 8**). Turner Creek inflow data was obtained from the SPUD gage (EA003EC) (**Figure 8**). **Table 1** shows the peak flow for each of the hydrology sources by year. The EF Nookachamps Ecology gage data in **Table 1** does not exceed 1,600 cfs. This appears to be a false "ceiling" in the flow data, perhaps a function of the maximum stage available for the rating curve, and may underestimate the real flood peaks for those years.

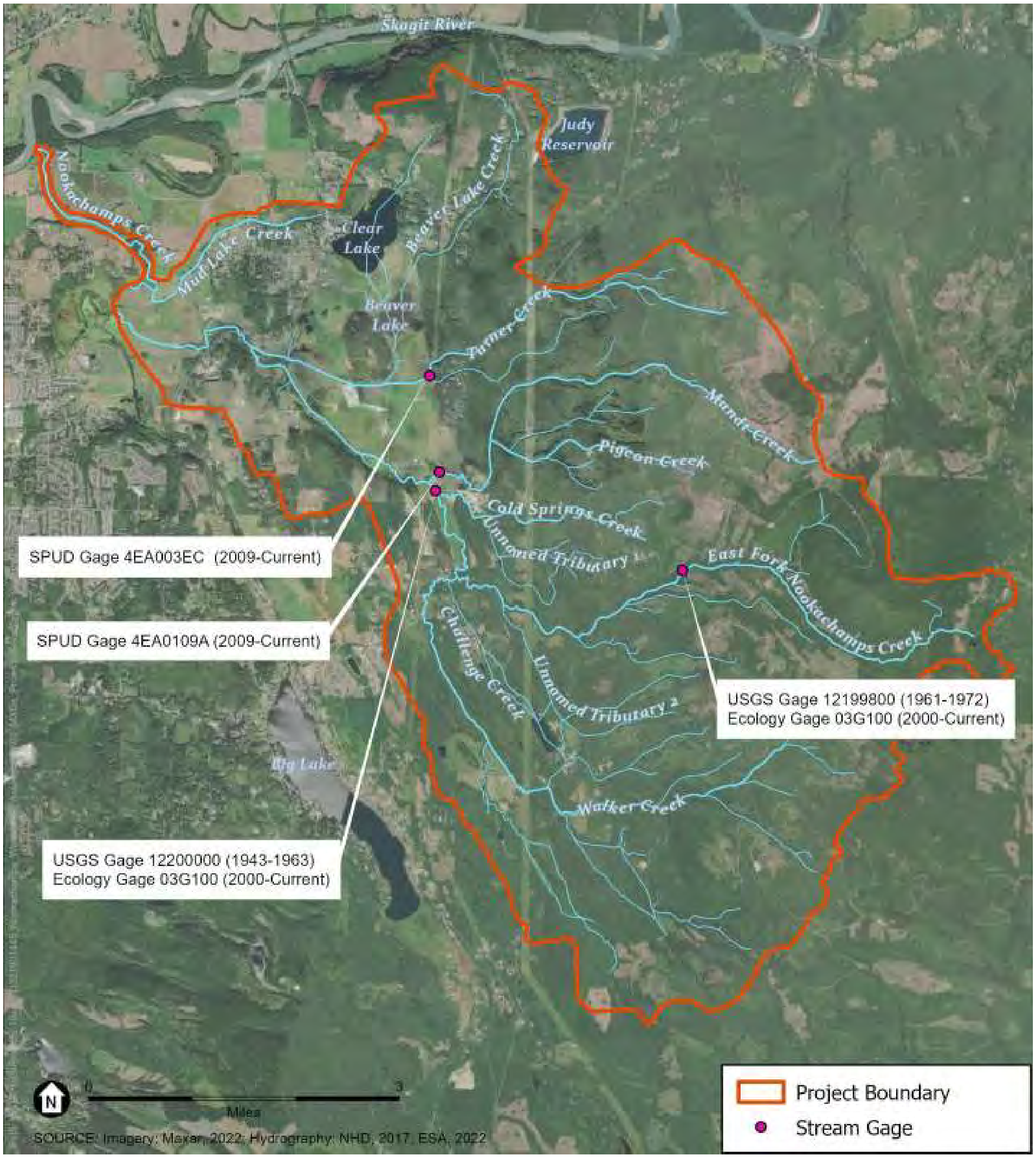

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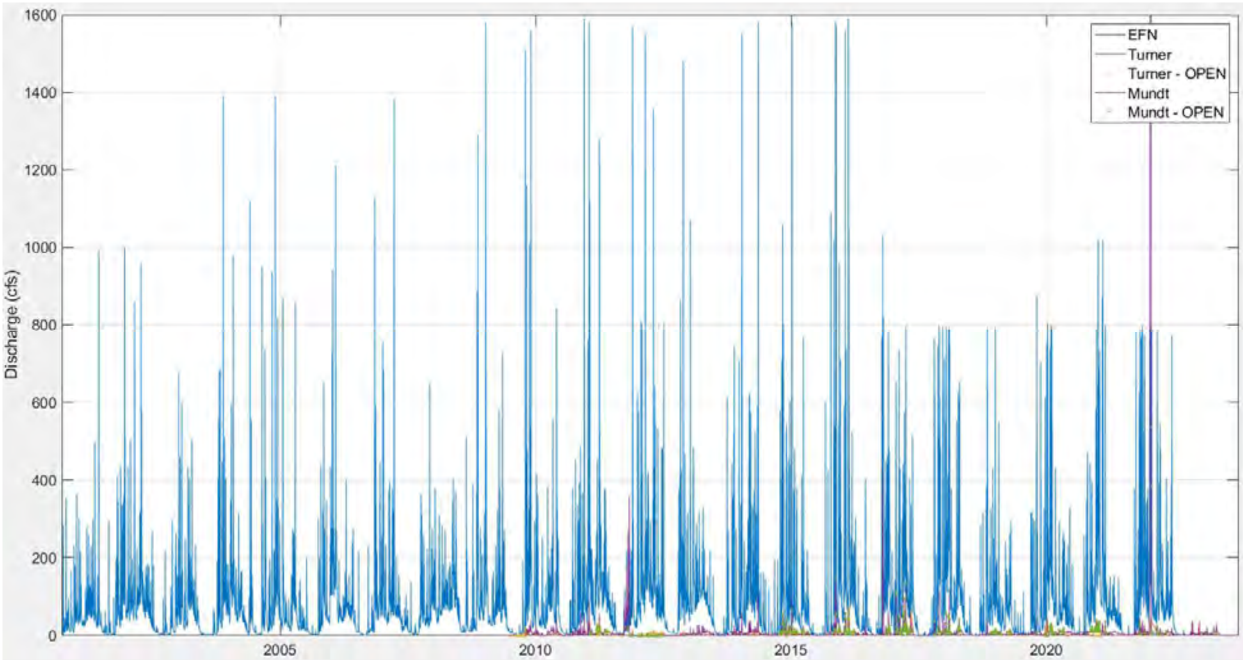
Figure 7
Hydrology Data Sources



SOURCE: Washington Ecology (2023), Skagit PUD (2023)

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.

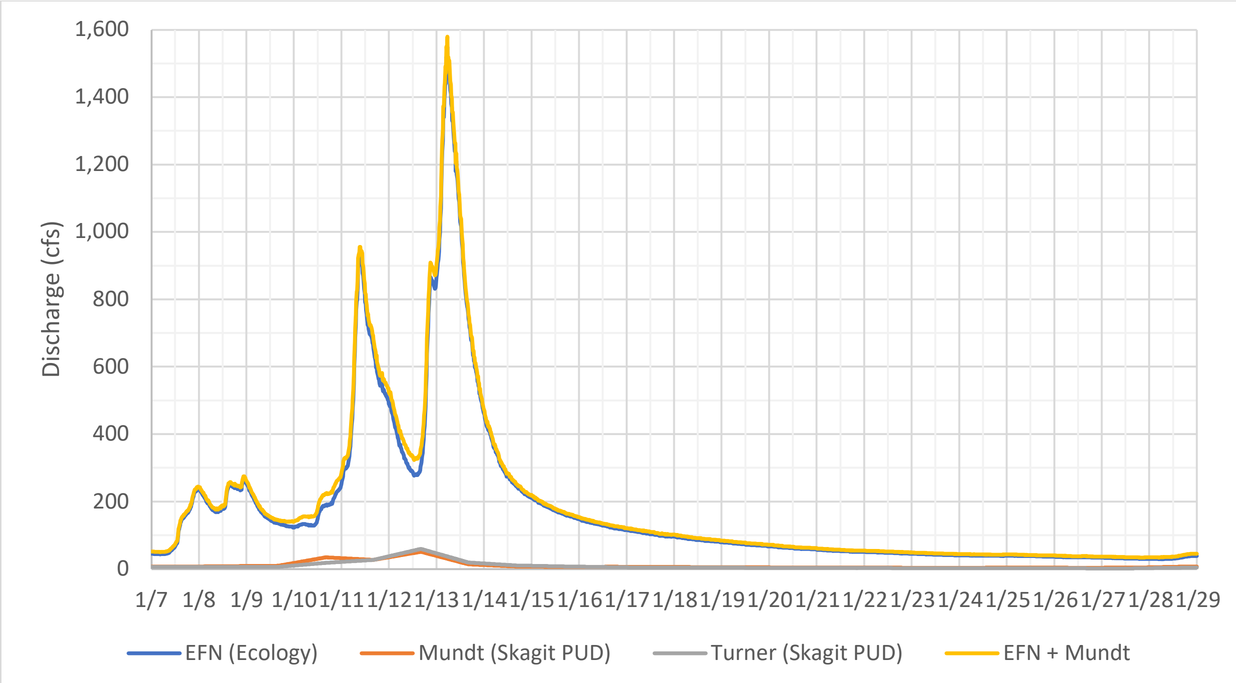
Figure 8
Hydrology Data

TABLE 1
PEAK FLOW VALUES BY YEAR

Year	EF Nookachamps Creek (WA Ecology 03G100) (cfs)	Mundt Creek (SPUD 4EA0109A) (cfs)	Turner Creek (SPUD EA003EC) (cfs)
2000	284	--	--
2001	994	--	--
2002	1,000	--	--
2003	674	--	--
2004	1,390	--	--
2005	1,390	--	--
2006	1,210	--	--
2007	1,380	--	--
2008	649	--	--
2009	1,580	--	0
2010	1,560	45	41
2011	1,590	93	69
2012	1,570	358	28
2013	1,480	28	16
2014	1,580	100	69
2015	1,580	102	60
2016	1,590	144	89
2017	1,030	418	63
2018	800	118	44
2019	794	43	18
2020	875	43	44
2021	1,020	39	28
2022	799	3,574	44

SOURCE: WA Ecology (2023), Skagit PUD (2023)
NOTES: Values in red potentially erroneous

After reviewing the flow data in **Figure 8**, a representative flood event was selected from 1/7/2014-1/29/2014 (**Figure 9**). This flood event is characterized by a single, smaller peak followed by the main flood peak and a long recessional limb. This event was selected because the flow represents a typical large flood event where the data for EF Nookachamps did not appear to be arbitrarily constrained by the 1,600 cfs ceiling. The return interval for the gage data is not known, given the small period of record and the potential issues with the peak flow data. **Table 2** shows the StreamStats estimates for EF Nookachamps and Turner Creeks at the model boundary locations. The StreamStats data suggests that the EF Nookachamps flood of 1,580 cfs is somewhere between a 2-year (1,260 cfs) and 5-year event (1,910 cfs). The Turner Creek streamflow estimate is much higher in StreamStats, however StreamStats does not take into consideration flow diversion from Turner Creek. The Turner Creek peak flow represents approximately 4% of the estimated flow into the valley.



SOURCE: Washington Ecology (2023), Skagit PUD (2023)

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Figure 9
Inflow Hydrograph for Representative Flood Event- 1/7/14- 1/29/14

TABLE 2
STREAMSTATS PREDICTED RETURN INTERVAL DISCHARGES

Return Interval	EF Nookachamps at Beaver Lake Rd (cfs)	Turner Creek at Fonk Rd (cfs)
2-Year	1,260	234
5-Year	1,910	363
10-Year	2,350	452
20-Year	2,910	566
50-Year	3,310	650
100-Year	3,760	742

SOURCE: StreamStats (2023)

2.3.2 2.3.2 Downstream Water Level

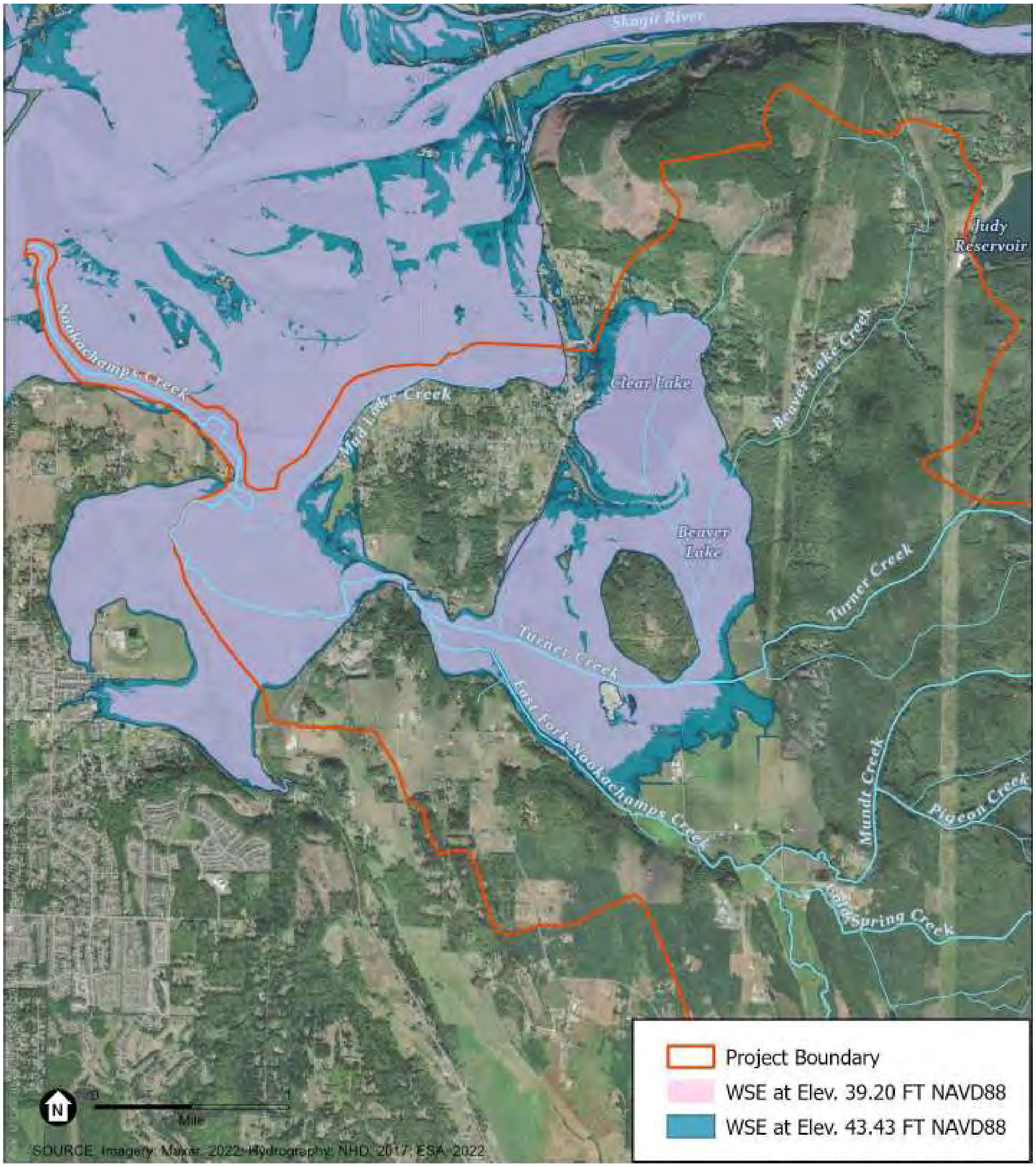
Flooding within the valley can be caused by either streamflow driven flooding from EF Nookachamps and its tributaries, backwatering from the Skagit River, or as some combination of the two. Because the EF Nookachamps basin is much smaller than the Skagit River basin, it cannot be assumed that peak flows are coincident (peaking at the same time) between the systems. It is possible for EF Nookachamps to experience flooding without elevated water levels downstream in the Skagit River and vice versa.

Due to the relatively low slope within the lower reaches of the EF Nookachamps basin, backwatering from the Skagit River may cause major flooding in the valley upstream of Highway 9. Natural Systems Design is currently developing a hydraulic model for the Skagit River and provided water surface elevations for various flow levels at the confluence of the Nookachamps River with the Skagit River (**Table 3**). **Figure 10** shows the inundation that would be caused at the backwater level for the 2–5-year flood event and the major 2021 flood event. These flood extents are likely slightly underestimating the flood levels that would occur as they do not consider any tributary flows or hydraulic structures within the project area. At either of the backwater levels mapped in **Figure 10**, the inundation covers nearly the entire valley upstream of the Highway 9 crossing.

TABLE 3
MODELED BACKWATER LEVELS AT NOOKACHAMPS CONFLUENCE

Skagit Flow (cfs)	Flow Condition	Water Surface Elevation at Nookachamps Confluence (ft, NAVD88)
8,000	Typical Aug-Oct low	17.17
15,000	Winter swan habitat	21.97
22,000	25% exceedance for Nov-Jan	25.39
82,000	Typical flooding (2-5 year event)	39.20

SOURCE: NSD (2023)



NOTES: Predicted WSE for 2-5-year event and 2021 major flood event are 39.20 ft NAVD88 and 43.43 ft, respectively

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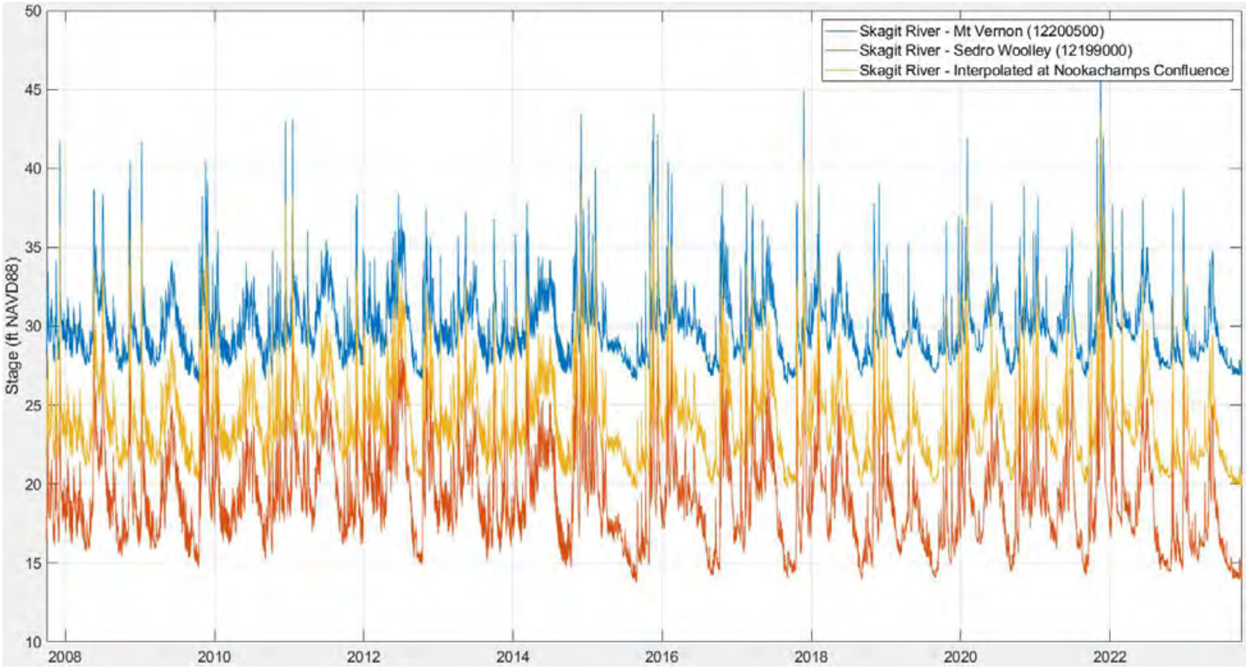
Figure 10
Approximate Backwater Flooding Extents from the Skagit River for 2-5-year flood event and major 2021 flood event

To better understand the relative frequency of backwater flooding from the Skagit in the model area, Skagit River stage was interpolated to the Nookachamps confluence using gage data. There are USGS gages upstream and downstream of the Nookachamps confluence at Sedro Wooley (12199000) and Mount Vernon (12200500). Stage data was downloaded for the period of record for both gages and adjusted to the NAVD88 datum from gage datum. The approximate water level time series for the Nookachamps confluence was calculated by linearly interpolating between the gages using the distance along the river line. Interpolation was conducted assuming a constant river slope (**Figure 11**). This is not an exact method but was intended to provide a relative metric for the frequency and magnitude of inundation within the model area. **Table 4** shows the peak interpolated water surface for each year. The approximate thalweg elevation of EF Nookachamps at the Highway 9 crossing is 31.7 ft NAVD88, which is exceeded by approximated Nookachamps backwatering level in every year, suggesting that some backwater flooding of the valley upstream of Highway 9 occurs each year.

TABLE 4
ESTIMATED ANNUAL MAXIMUM SKAGIT RIVER LEVELS AT NOOKACHAMPS CONFLUENCE

Year	Water Surface Elevation at Nookachamps Confluence (ft, NAVD88)
2008	36.3
2009	36.6
2010	35.7
2011	38.4
2012	34.0
2013	32.9
2014	33.3
2015	38.9
2016	38.4
2017	34.0
2018	40.5
2019	34.3
2020	37.2
2021	34.3
2022	43.8

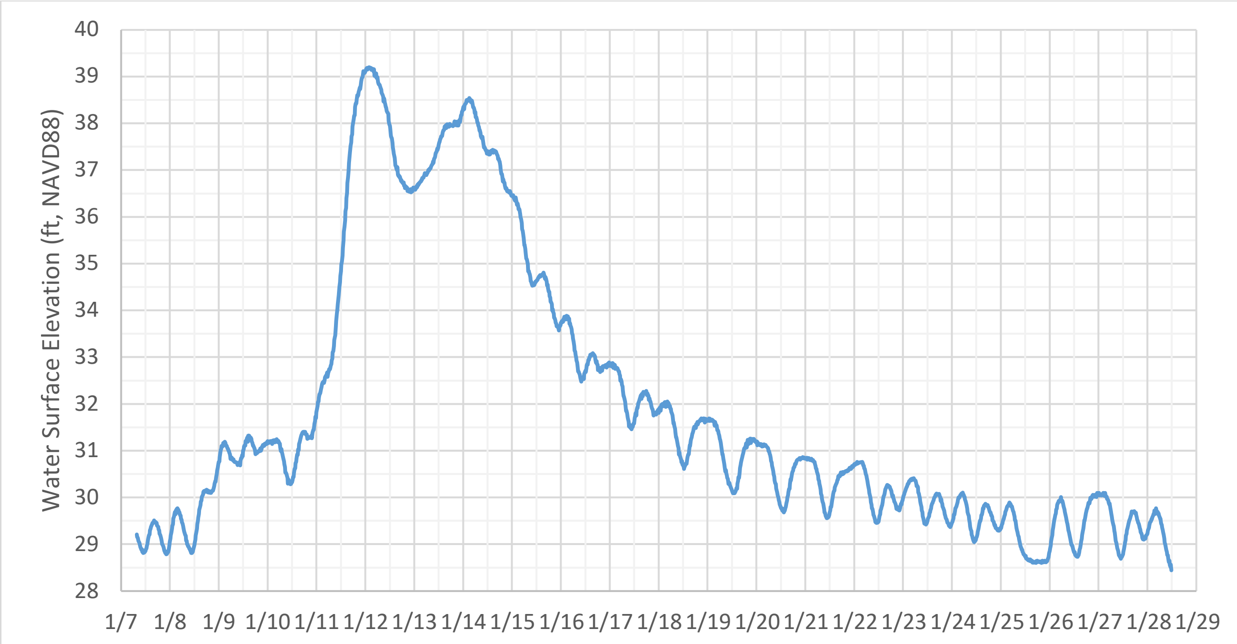
SOURCE: ESA (2023)



SOURCE: USGS (2023), ESA (2023) D201901447 - ESIT EF Nookachamps Watershed Assessment

Figure 11
Approximate Skagit River Level at Nookachamps Confluence

To assess the impact of flood mitigation alternatives under a range of conditions, simulations were performed both with and without Skagit backwater in the model area. Simulations were performed without the backwater downstream condition as this was assumed to be the scenario under which drainage improvements would show the largest effect. To simulate flooding in the model area from just EF Nookachamps and its tributaries, the model was run with a normal depth downstream boundary. The normal depth condition assumes that the water surface slope at the downstream boundary approximates the slope of the channel and uses that relationship to calculate a water surface. To simulate flooding under backwater conditions from the Skagit River the model was also run using scaled interpolated water level data at the confluence of Nookachamps and Skagit rivers during the January 2014 flood event. The peak interpolated water level at the Nookachamps confluence for the period of the January 2014 flood event was 31.0 ft NAVD88, which would not cause backwater flooding upstream of Highway 9. To better reflect Skagit backwater flooding, the interpolated Nookachamps water levels for the January 2014 period were scaled so that the peak water surface elevation reached the estimated 39.2 ft NAVD88 level for a 2–5-year Skagit maximum flood level from the NSD modeling (**Figure 12**).

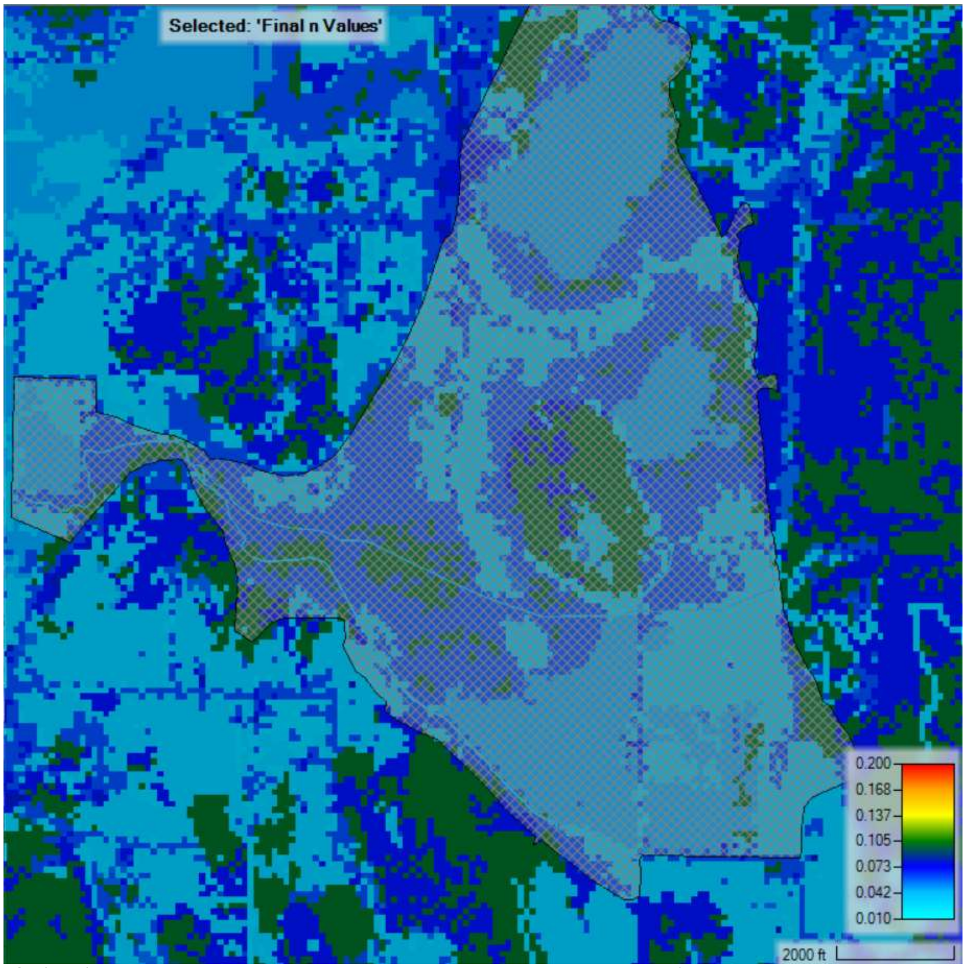


SOURCE: ESA (2023) D201901447 - ESIT EF Nookachamps Watershed Assessment

Figure 12
Backwater Boundary Condition Hydrograph

2.4 Model Roughness

Roughness is a model input that describes the resistance to flow. This parameter combines the influence of multiple factors such as bed roughness from sediment particle size, vegetation type and density, turbulence of flow, and other factors. Spatially varied roughness data was added to the model using gridded 2021 National Land Cover Database (NLCD) data (**Figure 13**). The NLCD grid data is at a 30-meter spatial resolution and as such does not capture the small channels. Stream channels were manually defined in the roughness palette used in the hydraulic model. Roughness values were entered into the model as Manning's *n* values, which were assigned for each land cover type or defined stream area. During calibration of a hydraulic model, roughness values are typically adjusted to achieve the best fit to observed data. Because observed data was not available within the model area for this study, calibration was not performed, and Manning's *n* values were estimated using engineering judgment.



SOURCE: ESA (2023) D201901447 - ESIT EF Nookachamps Watershed Assessment

.NOTES: Roughness values are for Manning's *n*

Figure 13
Model Roughness

2.5 Structures and Flood Infrastructure

Hydraulic structures such as culverts and the EF Nookachamps levee were added into the model to ensure proper flow dynamics within the modeled channels. Culverts were modeled on Turner Creek at Elk Road and Fonk Road. No culverts were modeled on EF Nookachamps as the upstream boundary condition was located downstream of private road bridge crossing. The EF Nookachamps levee was modeled using a breakline in the model mesh to ensure that the high point elevations of the levee were properly captured from the LIDAR data and that water did not prematurely "leak" into the floodplain. Other culverts and flood infrastructure were not entered in the hydraulic model as these structures were on channels where flow input was not specified. The Highway 9 bridge was not modeled as a hydraulic structure as the low chord of the bridge is high enough that it would not contact flood flows and the LIDAR data captures the encroachment of the roadway approaching the bridge.

3.0 Model Limitations

Hydraulic modeling performed for this study should be considered approximate and is intended for relative comparison of flood impacts between existing conditions and modeled alternatives. Calibration and validation of the hydraulic model has not been performed at this time and as such flood levels and modeled differences in flood levels should not be viewed as exact values.

4.0 Modeling Results

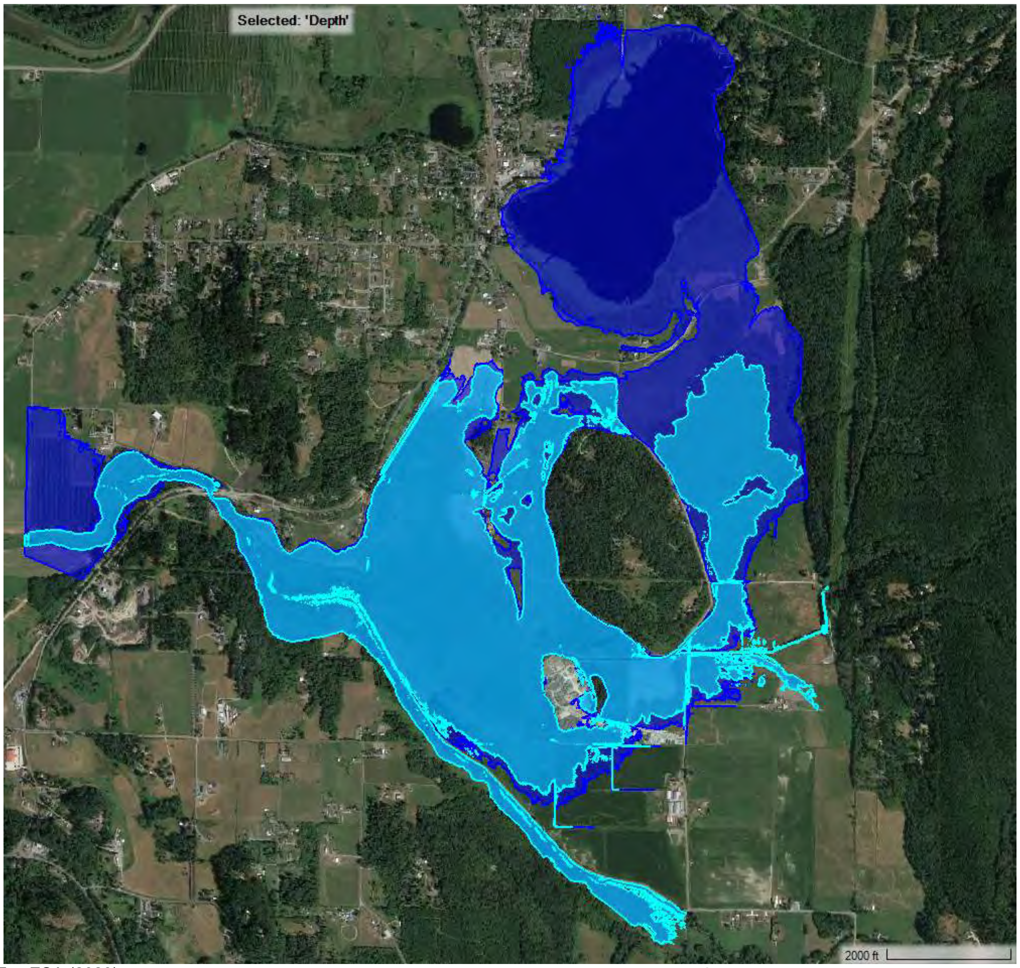
The January 2014 flood event was simulated in the hydraulic model with and without backwatering flooding for existing conditions and the three described proposed conditions scenarios. Flood impacts were assessed for flood extent, magnitude of flood depth reduction, and duration of inundation. The model results here present the relative effect of simulated alternatives and results should not be considered exact.

The existing conditions model predicts that the January 2014 flood event would inundate much of the valley upstream of Highway 9 with and without Skagit backwater flooding (**Figure 14**). Predicted flood extents under existing conditions without backwatering are upstream of the gravel pit and Fonk Road on Turner Creek and Beaver Lake to the north. Flooding within EF Nookachamps is not predicted to overtop the levee except downstream near the confluence with Turner Creek. The predicted flood extents with backwater from the Skagit mostly extend farther north along the flatter part of the valley into Clear Lake.

The magnitude of flood reduction potential was assessed at the peak of the flood event for project alternatives with and without backwatering (**Figure 15** and **Figure 16**). Flood reduction was greatest under the without backwatering scenario (**Figure 15**). For the without backwatering scenario, flood reduction potential was greatest for the valley widening and Highway 9 widening scenarios, representing a reduction of approximately 0.4 and 0.2 feet, respectively. Removal of the Finger Dikes did result in a local flood reduction upstream of the Finger Dikes that decreases moving upstream and showed no difference from existing conditions approximately 3,000 feet upstream of the Finger Dikes, not resulting in any flood reduction the valley upstream of Highway 9. (**Figure 15**).

The pattern of flood reduction was reversed under the scenario with Skagit River backwater flooding where the alternatives showed an adverse flood impact (**Figure 16**). Under this scenario, the largest increase in flood levels was observed under the valley widening and Highway 9 widening alternatives with approximately 0.15 and 0.1 feet of rise, respectively. Removal of the Finger Dikes also caused a minor rise of approximately 0.05 feet at peak water surface elevation. The pattern of flow was more complex under the Skagit backwater flooding scenario as flow switched from flowing into the valley upstream of Highway 9 to downstream and back into the valley several times over the simulation as Skagit River water levels rose and fell. The greater flow capacity due to channel and valley widening under the project alternatives allowed more flow into the valley during the higher Skagit water levels and increased the flood level compared to existing conditions.

Modeled alternatives allowed for a slight increase in the speed of drainage due to the increased flow capacity (**Figure 17** and **Figure 18**). Multiple points were sampled from the model to provide a representation of expected duration of inundation on landowner fields. **Figure 18** shows that the duration of inundation is slightly shorter under the modeled alternatives on the order of hours. This is also true under the backwatering scenario even though the peak flood levels were higher under the modeled alternatives.



SOURCE: ESA (2023)

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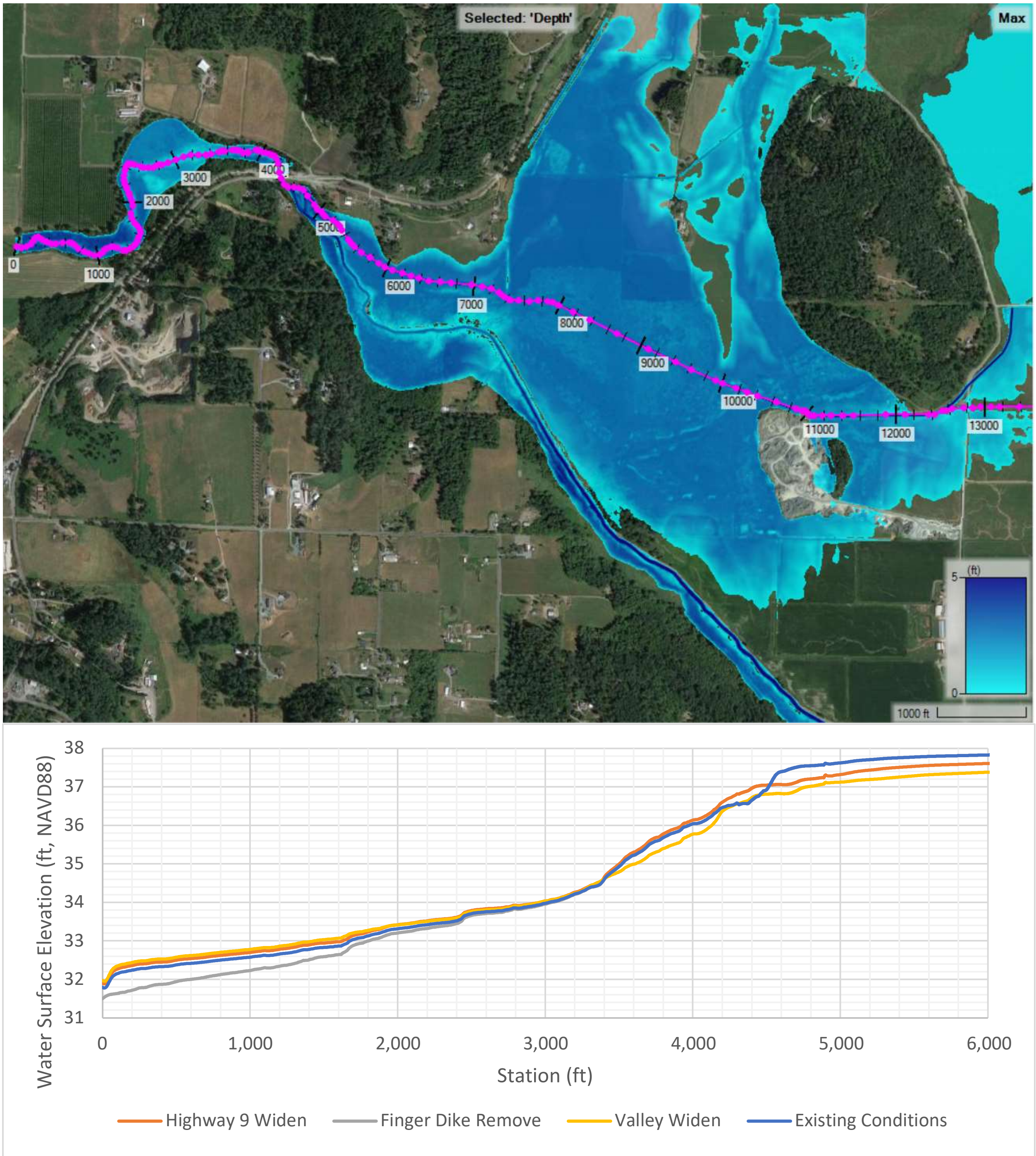
.NOTES: Light blue represent normal depth downstream boundary condition and dark blue represents the scaled Skagit tailwater condition

Figure 14
Existing Conditions Flood Extents



SOURCE: ESA (2023)

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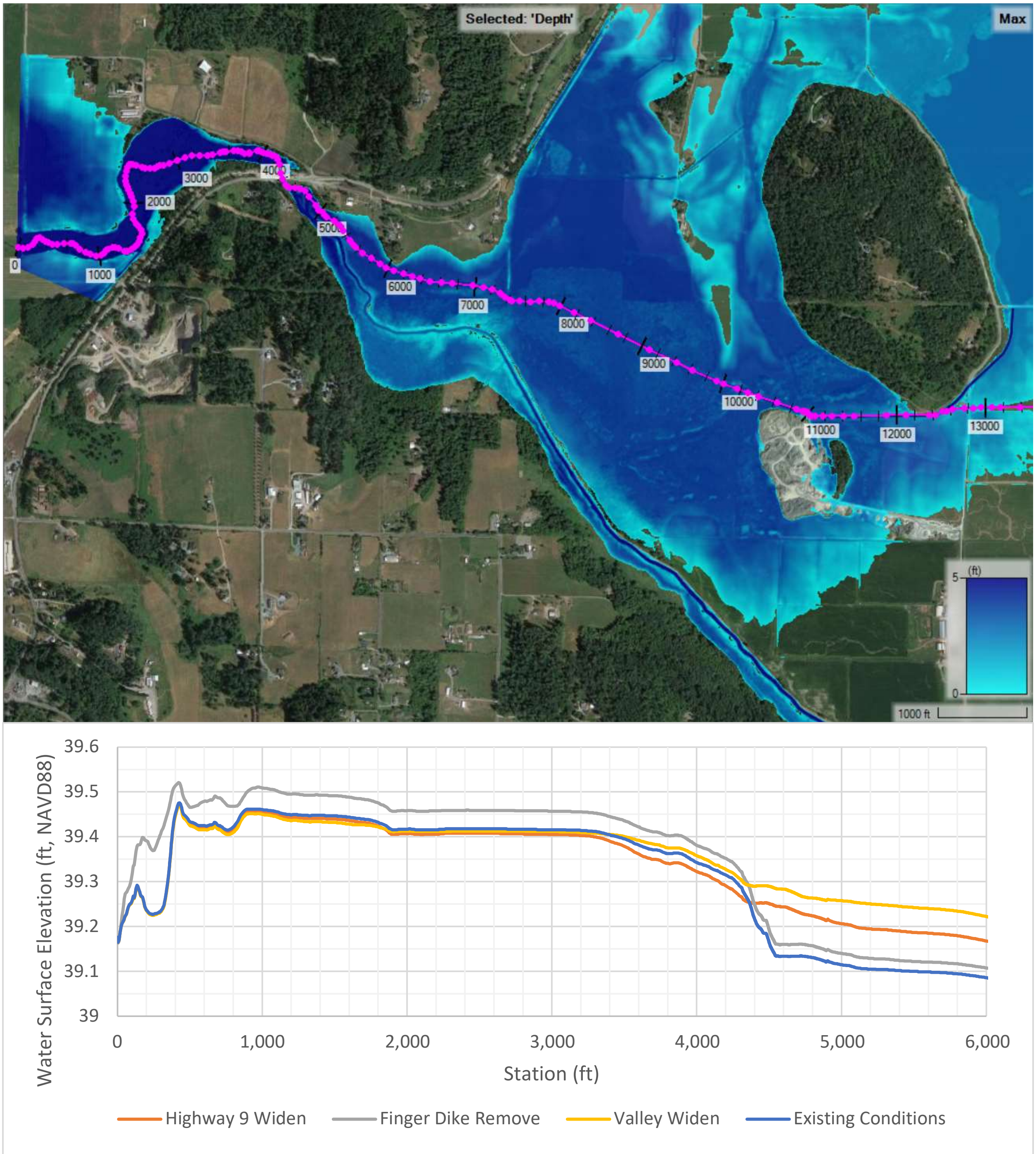
Figure 15
Water Surface Profile – Without Backwatering



SOURCE: ESA (2023)

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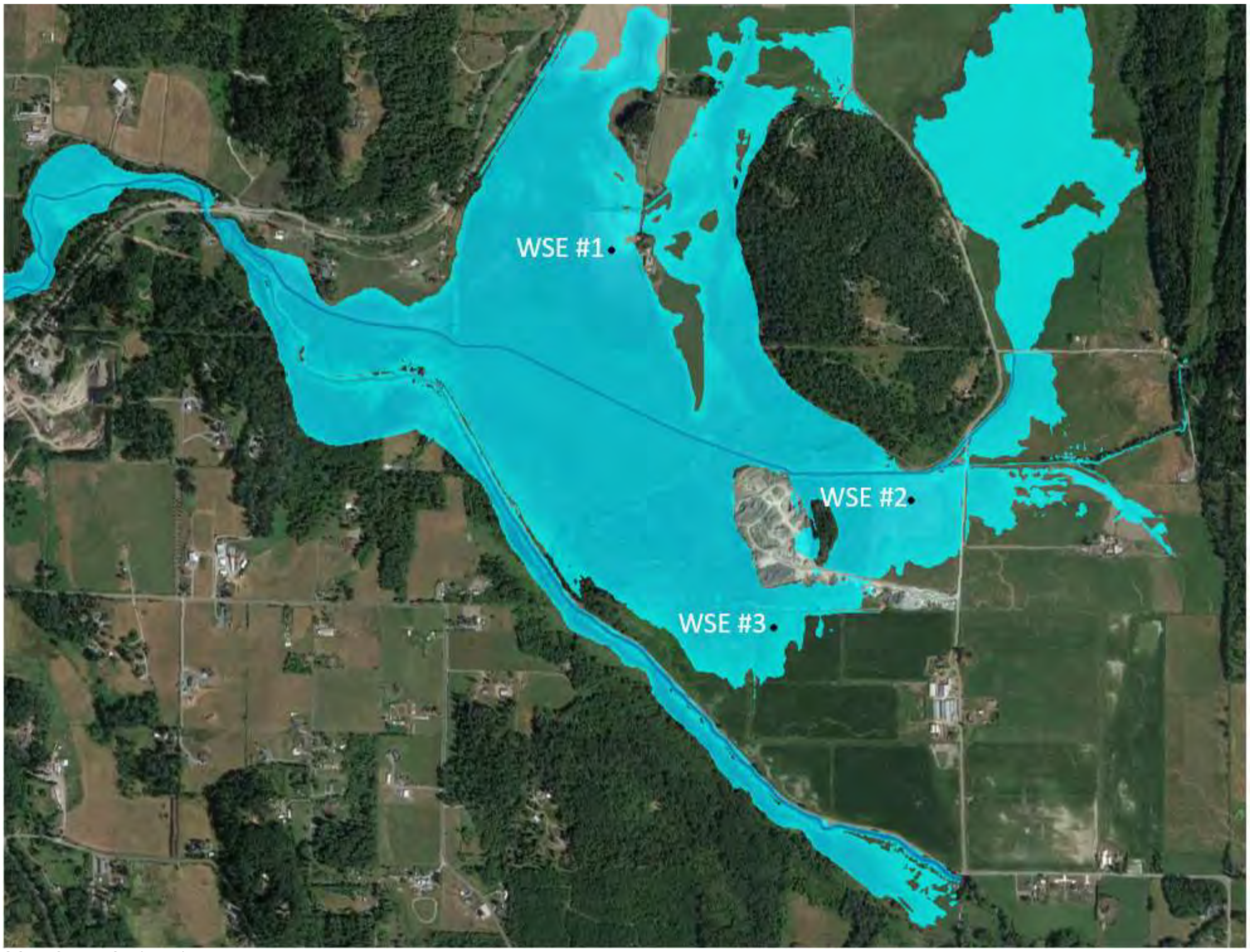
Figure 16

Water Surface Profile – With Skagit Backwatering



SOURCE: ESA (2023)

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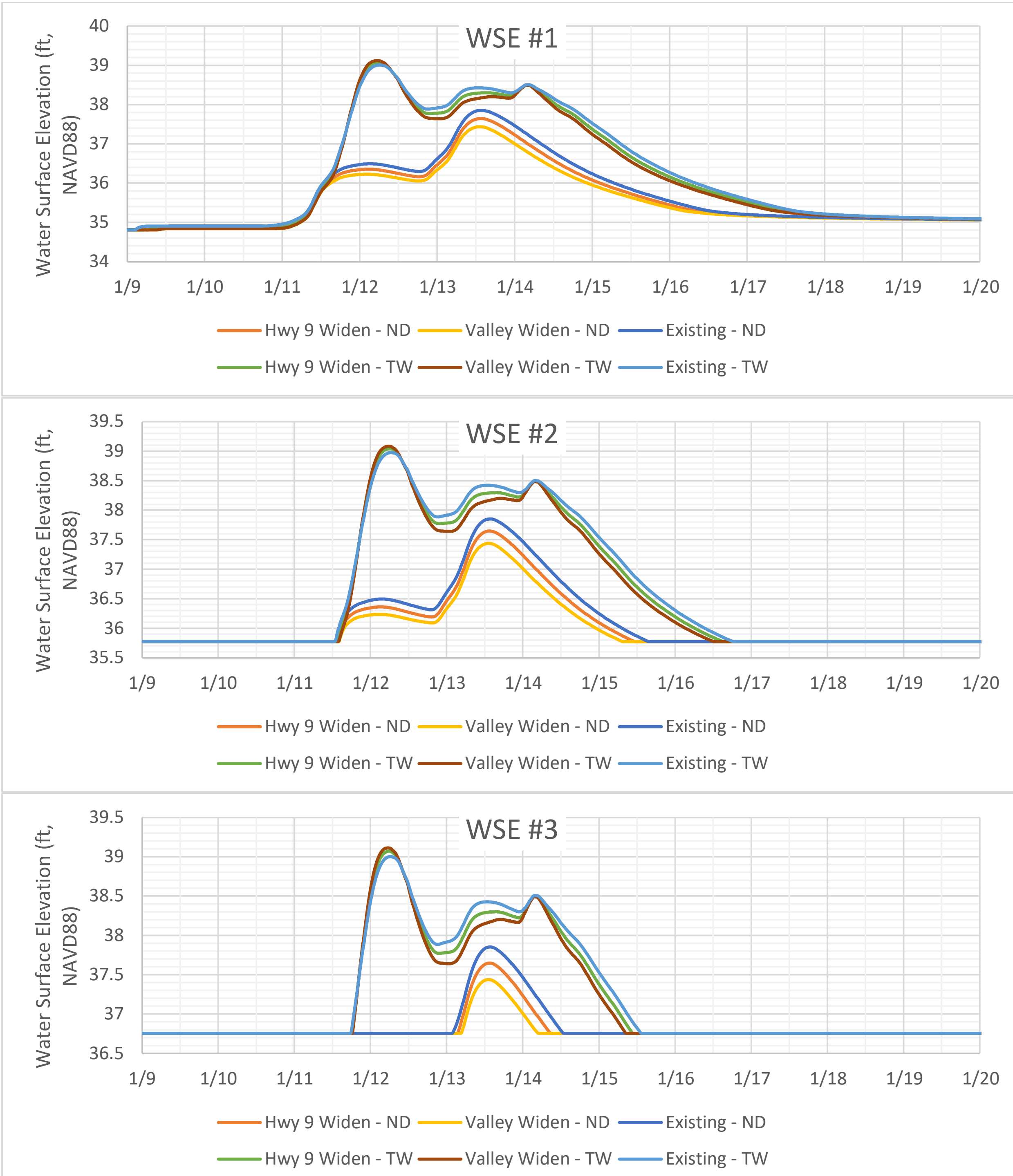
Figure 17
Water Surface Sample Locations



SOURCE: ESA (2023)

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.NOTES: ND = normal depth condition, TW = Skagit tailwater condition

Figure 18
Water Surface Sample – Time Series

5.0 Future Study

This study assessed and documented the relative flood reduction potential for the model area for several alternatives under a typical flood event. The current hydraulic model is uncalibrated. Care was taken to ensure reasonable input values were used and modeling results did not appear to be erroneous. Further refinement of the model would reduce uncertainty in modeling results. In discussion with the USIT and the County staff, it was noted that the model appears to be greatly underpredicting the duration of inundation or standing water on the receding limb of the flood. Landowners in the valley have noted that flood water can remain on their fields for weeks or even up to a month. Calibrating the model to better represent the duration of inundation would help better assess the impacts of flood reduction alternatives on shortening the duration of flooding. Calibration of the model would require observed water levels within the valley upstream of Highway 9 during a flood event. The slow draining of flood waters during the receding limb of flood events is likely due to some combination of local drainage issues, shallow groundwater, and elevated water levels on the Skagit River. Better understanding of the interplay between these factors would improve model fit.

If major flood reduction cannot reasonably be achieved by large scale drainage improvements, like the widening of the Highway 9 crossing, small-scale improvements such as raising targeted sections of roadway or increasing culvert flow capacity may lead to meaningful improvements for landowners with regards to access/egress or local flood depths. Additional modeling could be performed to assess the flood impact of small-scale changes to structures, berms and levees, and roadways.

Lastly, this study simulated the flooding dynamics under a typical flooding event. Due to lack of measured high flow data, larger flood events (i.e. 100-year flood event) were not simulated at this time. Future hydrologic analysis could be performed to refine larger peak flow values and further modeling could be performed for higher return interval floods to assess if flood reduction is lesser or greater for larger flood events.

6.0 Conclusion

Assessment of several flood improvement alternatives was performed using a HEC-RAS 2D hydraulic model. Flood impacts were compared against existing conditions for widening the Highway 9 crossing, removing the “Finger Dike” structures downstream of the Highway 9 crossing, and as a bookend scenario, large-scale widening of the most confined portions of the valley upstream and downstream of the Highway 9 crossing. Flood impacts were assessed by simulating a January 2014 flood event with and without backwatering from the Skagit River for each of the modeled scenarios. Removal of the finger dikes showed no flood relief benefit to the landowners in the valley upstream of Highway 9. Widening the Highway 9 crossing and the valley widening both showed a flood benefit for Nookachamps and tributary related flooding, but caused an adverse flood impact when backwater flooding from the Skagit River was modeled. Drainage of flood flows was faster under the Highway 9 widening and valley widening scenarios for both the with and without Skagit backwater conditions, but only on the order of several hours. Future refinement of the model could be performed to address issues with model fit to flood recession within the project area. It is unclear at this time whether widening of the Highway crossing or valley would provide a net flood benefit for the area upstream of Highway 9 due to the complex interplay between EF Nookachamps and tributary flooding and Skagit backwater caused flooding.

7.0 References

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Quantum Spatial, (2017). Western Washington 3DEP LiDAR Technical Data Report: Contract No. G16PC00016, Task Order No. G16PD00383. Prepared for U.S. Geological Survey. September 29, 2017.

U.S. Army Corps of Engineers (USACE), (2023). HEC-RAS User’s Manual. https://www.hec.usace.army.mil/confluence/rasdocs/rasum/latest. Accessed on December 21, 2023.