WRIA 1 Salmonid Recovery Plan

April 30, 2005

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1. INTRODUCTION

1.1. Problem Statement

At the same time, the "humpy" salmon were running… These salmon completely filled the stream; literally, there were millions of them. On the riffles they were so thick, that when we were wading the river at such places, they would dart between our legs, and sometimes nearly trip us up… The salmon at work on the riffles in such vast numbers, rooting like so many hogs among the boulders and gravel, made a noise which could be heard for one-fourth of a mile.

- E. Morse, describing 1881 journey down South Fork Nooksack River valley (Morse 1883)

The decline of salmonids throughout Washington and the Pacific Northwest over the past century is well established (Nehlsen et al. 1991; WDFW 2002a). Since 1991, numerous evolutionarily significant units (ESUs) of Pacific salmonids have been listed as endangered or threatened under the Endangered Species Act (ESA), including 9 of 17 chinook ESUs, 3 of 6 coho ESUs, 2 of 4 chum ESUs, 2 of 7 sockeye ESUs , and 10 of 15 steelhead ESUs (NMFS 2003). Decline in salmonid abundances have been attributed to widespread loss and degradation of habitat, due to hydropower, residential and urban development, agriculture, and forestry (Spence et al. 1996; Bishop and Morgan 1996; Nehlsen et al. 1991). Fishing and hatchery production have also contributed to declines (Nehlsen et al. 1991).

In the Nooksack basin, it is clear that abundances of several salmonid stocks have diminished substantially from historical levels. Estimated historic abundances of early-timed chinook in the Nooksack basin were 26,000 and 13,000[1], respectively, for North Fork/Middle Fork Nooksack (NF/MF) and South Fork Nooksack (SF) chinook stocks (Mobrand Biometrics, unpublished data). Recent escapements of wild fish for the two early populations averaged 170[2] (NF/MF) and 210 (SF) from 1997 through 2004

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[1] Estimated from Ecosystem Diagnosis and Treatment (EDT) model developed by Mobrand Biometrics, Inc, based on simulated historic conditions in Nooksack River freshwater and estuarine environments. The model also estimated historic conditions in the lower Nooksack River watershed had the potential to support 23,000 late-timed chinook. These estimates may be conservatively low, since the EDT model does not currently account for changes in channel length from historic conditions.
[2] Estimated escapement of natural origin spawners, i.e. naturally spawning adults that were not hatchery produced. The North Fork/Middle Fork Nooksack chinook stock is also supported by hatchery supplementation from WDFW Kendall hatchery.

(Fisheries Comanagers, unpublished data). Status of both stocks was deemed "critical" in the first Washington Salmon and Steelhead Stock Inventory (SASSI, WDF et al. 1993), ratings that persist in the updated Salmonid Stock Inventory (SASI; WDFW 2002a). In a status review of Pacific salmonids throughout the Pacific Northwest (Nehlsen et al. 1991), Nooksack native coho were considered to be potentially extinct; the run is managed for and dominated by hatchery production (Weitkamp et al. 1995), although there is strong evidence of wild-spawning coho that are genetically distinct from hatchery coho in the upper North Fork Nooksack River (upstream of river mile 48; Small 2003). Further, only 3 of 25 salmonid stocks (Table 1.1) identified in Water Resource Inventory Area (WRIA) 1 by Washington State Salmonid Stock Inventories are currently considered healthy: North Fork Nooksack fall chum, Samish/Independents fall chum, and North Fork/Middle Fork Nooksack pink salmon (WDFW 1998; Blakely et al. 2000; WDFW 2002a).

Status of local bull trout and chinook populations is also reflected in recent ESA listings that affect WRIA 1. The Puget Sound chinook salmon ESU, of which WRIA 1 constitutes 1 of the 5 delineated geographic regions (Figure 1.1), has been listed as threatened under the ESA. This listing encompasses "all naturally-spawned populations of chinook salmon from rivers and streams flowing into Puget Sound,… including rivers and streams flowing into…North Sound and the Strait of Georgia in Washington…"(64 FR 14308, Mar. 24, 1999); thus, chinook in the Nooksack River and Independent Coastal drainages in WRIA 1 are included, but chinook in the Sumas and Chilliwack systems are not. WRIA 1 constitutes 1 of the 5 geographic regions delineated in the ESU (Figure 1.1). Both South Fork Nooksack chinook and North Fork/Middle Fork Nooksack chinook stocks are considered essential for recovery of the ESU (64 FR 14308, Mar. 24, 1999). The extent to which Mainstem Nooksack late-timed chinook will contribute to ESU recovery is currently being evaluated. Bull trout in WRIA 1 constitute a component of the Coastal-Puget Sound Distinct Population Segment (DPS), also listed as threatened (64 FR 58910, Nov. 1, 1999). WRIA 1 bull trout comprise two of the eight core areas that have been defined within the Puget Sound Recovery Unit: Nooksack and Chilliwack (Figure 1.2). Further, Puget Sound/Strait of Georgia coho salmon, including Nooksack coho, is a species of concern, and NOAA Fisheries has accepted a petition for Puget Sound steelhead, and will be conducting a biologic review.

The declines in local salmonid stocks, especially chinook salmon, have had profound economic, cultural and social impacts on the greater WRIA 1

Table 1.1. Salmonid Stocks in Water Resource Inventory Area (WRIA) 1, as identified in Washington Salmonid Stock Inventories.

Sources: WDFW 1998; Blakely et al. 2000; WDFW 2002a[1].

Basin	Name	Stock Status	Stock Origin	Production Type
Nooksack	South Fork Nooksack Chinook[2]	Critical	Native	Wild
	North Fork/Middle Fork Nooksack Chinook[2]	Critical	Native	Composite
	Samish/Mainstem Nooksack Chinook[3, 4]	Unknown	Non-Native[5]	Composite
	Lower Nooksack Bull Trout/Dolly Varden[6]	Unknown	Native	Wild
	Upper Middle Fork Nooksack Bull Trout/Dolly Varden[6]	Unknown	Native	Wild
	Canyon Creek Bull Trout/Dolly Varden[6]	Unknown	Native	Wild
	Nooksack Coho	Unknown	Mixed	Composite
	Mainstem/South Fork Nooksack Fall Chum	Unknown	Native	Wild
	North Fork Nooksack Fall Chum	Healthy	Native	Wild
	South Fork Nooksack Pink[7]	Unknown	Native	Wild
	North Fork/Middle Fork Nooksack Pink[7]	Healthy	Native	Wild
	South Fork Nooksack Summer Steelhead	Unknown	Native	Wild
	Mainstem/North Fork Nooksack Winter Steelhead	Unknown	Native	Wild
	Middle Fork Nooksack Winter Steelhead	Unknown	Native	Wild
	South Fork Nooksack Winter Steelhead	Unknown	Native	Wild
	Nooksack Coastal Cutthroat	Unknown	Mixed	Composite

[1] These inventories exclude the following salmonids, also known to occur in WRIA 1: Even-year pink salmon (Nooksack Basin), riverine sockeye (Nooksack Basin), odd-year pink salmon (Whatcom Creek, introduced from Middle Fork), chinook salmon (Dakota Creek), bull trout (known in Squalicum and Whatcom Creeks, presumed in other Coastal streams), steelhead (Sumas, Chilliwack systems), and sockeye (Sumas, Chilliwack systems). See *Technical Background* (Appendix C) for detail.

[2] Early-timed chinook stock.

[3] Late-timed chinook stock.

[4] Samish River system is outside of WRIA 1, and thus beyond the geographic scope of this recovery plan.

[5] Nooksack Tribal elders have indicated there were historically native, late-timed chinook in the Nooksack River watershed. Genetic analyses conducted to date of a limited number of samples have found no compelling evidence for the existence of an additional chinook stock in the Nooksack River.

[6] Bull trout populations in WRIA 1 are being delineated as part of the recovery plan for the Puget Sound Bull Trout Recovery Unit.

[7] Odd-year spawn timing. Although even-year pink salmon have been observed spawning in the South Fork Nooksack system, SASI (WDFW 2002a) only identifies the considerably more numerous South Fork odd-year pink salmon stock which, given the rigid 2-year life cycle of pink salmon, is reproductively isolated and thus distinct from even-year pink salmon stocks.

Table 1.1. (continued).

Basin	Name	Stock Status	Stock Origin	Production Type
Coastal	North Puget Sound Tributaries Coho	Unknown	Mixed	Wild
	Samish/Independents Fall Chum[1]	Healthy	Mixed	Composite
	Dakota Creek Winter Steelhead[2]	Unknown	Native	Wild
	North Puget Sound Tributaries Coastal Cutthroat	Unknown	Native	Wild
	Whatcom Creek Coastal Cutthroat	Unknown	Native	Wild
Fraser	Sumas/Chilliwack Coho	Unknown	Native	Wild
	Chilliwack/Silesia Creek Bull Trout/Dolly Varden[3]	Unknown	Native	Wild
	Sumas/Chilliwack Fall Chum	Unknown	Native	Wild
	Sumas Coastal Cutthroat	Unknown	Native	Wild

[1] Samish River system is outside of WRIA 1, and thus beyond the geographic scope of this recovery plan.
[2] In addition to Dakota Creek, steelhead are known or presumed to occur in numerous other independent coastal tributaries.
[3] Bull trout populations in WRIA 1 are being delineated as part of the recovery plan for the Puget Sound Bull Trout Recovery Unit..

Figure 1.1. Geographic regions identified within Puget Sound chinook ESU for evaluation of ESU-wide recovery scenarios
(Source: Puget Sound Shared Strategy, www.sharedsalmonstrategy.org).

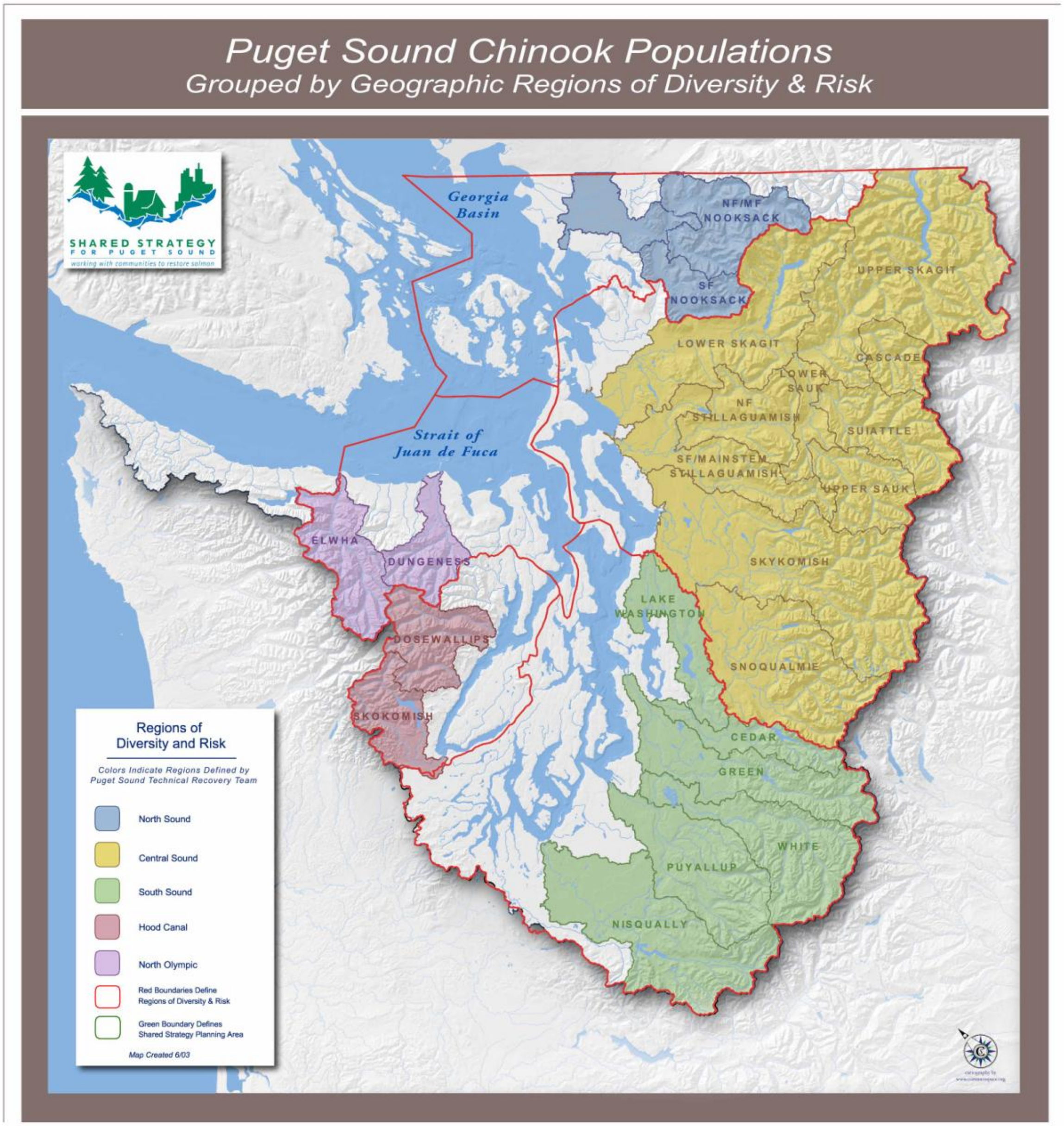


Figure 1.2. Core areas of Puget Sound Recovery Unit of Coastal/Puget Sound Bull Trout Distinct Population Segment. (Source: Puget Sound Shared Strategy).

community. Direct impacts include reduced jobs and income for commercial fisherman, severe curtailment of ceremonial and subsistence catch, and loss of tourism associated with recreational fishing. In addition, ESA listings impose constraints on the activities of local and tribal governments, businesses, the agricultural community, and citizens, who must seek to avoid or minimize take of listed species. Nonetheless, salmon remain an integral part of the natural and social landscape of Whatcom County and the Nooksack River watershed. Recent watershed recovery planning and restoration efforts by federal, state, local and tribal governments, non-profit organizations, businesses, and private citizens demonstrate a commitment to salmon recovery in WRIA 1.

1.2. Regulatory Context

The purposes of the Endangered Species Act (ESA) of 1973 are "to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved" and "to provide a program for the conservation of such endangered species and threatened species". The ESA provides guidance regarding: (1) the promulgation of protective rules (e.g. 4(d) rules), the listing determination process, designation of critical habitat, and recovery plans (Section 4); (2) conference and consultation processes that focus on activities with a federal nexus, i.e. involving and/or funded by federal agencies (Section 7); (3) activities determined to result in take (Section 9); (4) issuance of incidental take permits and habitat conservation plans (Section 10); and (5) citizen lawsuits (Section 11; LLTK 2003).

Jurisdiction to implement the act is shared by NOAA Fisheries (formerly National Marine Fisheries Service or NMFS) for marine and anadromous fish species and the U.S. Fish and Wildlife Service (USFWS) for terrestrial plants and animals and fish that spend all or a majority of their life history in freshwater. For WRIA 1 listed species, NOAA Fisheries implements ESA for chinook and USFWS implements ESA for bull trout. Both agencies are obligated under the ESA to protect against the risk of species extinction (LLTK 2003). Under the ESA, the "take" of endangered species is unlawful; take means to "harass, harm, pursue, hunt, shoot, wound, kill, trip, capture, or collect, or to attempt to engage in any such conduct." Harm has been further defined by NOAA Fisheries and USFWS as any act that actually kills or injures a listed species, including extensive habitat modification and degradation. Additional salient details of the ESA and its implementation are summarized in the *Endangered Species Act Handbook: for Local Governments in Washington* (LLTK 2003).

Critical habitat for Puget Sound chinook had been designated as all freshwater and estuarine areas accessible to the ESU, including "all waterways, substrate, and adjacent riparian zones below longstanding, naturally impassable barriers", but excluding tribal lands (65 FR 7764, Feb. 16, 2000), but that designation was withdrawn by NOAA

Fisheries in response to litigation challenging the process for designation (Court approved NMFS consent decree on 4/30/02; NOAA Fisheries 2003). Critical habitat has not been designated for Puget Sound bull trout but is under development. Although Critical Habitat is designated for neither species in WRIA 1, rules governing take have been in effect since listing for Coastal/Puget Sound bull trout (64 FR 58910, Nov. 1, 1999) and since July 10, 2000, for Puget Sound chinook (65 FR 42422). While the recovery plan for Puget Sound Chinook is being coordinated through the voluntary Shared Strategy for Puget Sound (Shared Strategy) process (see below), NOAA Fisheries bears ultimate responsibility to evaluate whether recommended actions and management strategies will lead to recovery and ultimate delisting. Driven by a court-mandated timeline for designating critical habitat, USFWS has convened a Recovery Unit Team composed of technical staff from a number of agencies and stakeholders to draft the Puget Sound chapter of the Bull Trout Recovery Plan. Integration and coordination with recovery planning by local watersheds and the Shared Strategy is anticipated.

The Shared Strategy for Puget Sound is a voluntary collaborative effort that seeks to protect and restore salmon runs across Puget Sound by engaging local citizens, tribes, technical experts, and policy makers in recovery planning. The Shared Strategy mission enjoys widespread support and involvement across the Puget Sound region. The organization consists of a Board of Directors, Development Committee, and Work Group, in addition to the broad-based and inclusive membership of the Shared Strategy Council. Numerous federal and state agencies, tribes, and local governments provide policy guidance through membership on the Board and Development Committee, including NOAA Fisheries, USFWS, the Governor's Office, Washington Department of Fish and Wildlife (WDFW), Washington Department of Ecology (WDOE), the Salmon Recovery Funding Board (SRFB), Northwest Indian Fisheries Commission (NWIFC), Western Washington tribes (including Lummi Nation and Nooksack Tribe), county and city governments (including Whatcom County), and forestry, agricultural, and environmental interest groups. The goal of the Shared Strategy is to "build a practical, cost-effective recovery plan endorsed by the people living and working in the watersheds of Puget Sound" (Shared Strategy 2003).

1.3. Purpose

The purpose of the *WRIA 1 Salmonid Recovery Plan* is to identify the actions necessary to recover WRIA 1 salmonid populations, especially listed species, and to outline the framework for implementation of recommended actions that have been agreed to by local, state, tribal, and federal governments and stakeholders in WRIA 1.

The WRIA 1 Salmonid Recovery Plan, and appendices, has been developed locally, but will be incorporated as a chapter into the Shared Strategy's "Plan for Recovery of Puget

Sound Salmon" (Shared Strategy 2001). As stated above, NOAA Fisheries will evaluate the Puget Sound Plan for likelihood that it will lead to recovery and delisting of the Puget Sound Chinook ESU and, if deemed acceptable, will adopt it as the formal Puget Sound Chinook Recovery Plan. USFWS, on track to completing their own recovery plan for Puget Sound Bull Trout, is hopeful that local watershed salmon recovery plans will provide the means for implementation of their recommended actions for recovery.

1.4. Scope

The geographic scope of the WRIA 1 Salmonid Recovery Plan (Figure 1.3) incorporates all upland, freshwater, estuarine and nearshore habitats in WRIA 1, including watersheds of the Nooksack and Lummi Rivers, independent coastal drainages (Dakota Creek, California Creek, Terrell Creek, Squalicum Creek, Whatcom Creek, Padden Creek, Chuckanut Creek, Oyster Creek, Colony Creek, and Whitehall Creek watersheds), and Fraser River tributaries south of the Canadian border (Sumas and Chilliwack Rivers). The Plan covers all WRIA 1 salmonid species (Table 1.1), with primary emphasis placed on ESA-listed species, and will include recommendations for all habitat, harvest, hatchery, hydropower and recreation actions that affect those salmonid populations. Such actions include both those over which local, state, tribal and federal governments in WRIA 1 have jurisdictional authority, as well as voluntary and incentive-based actions by private citizens, businesses, and stakeholders that will be key to successful recovery plan implementation.

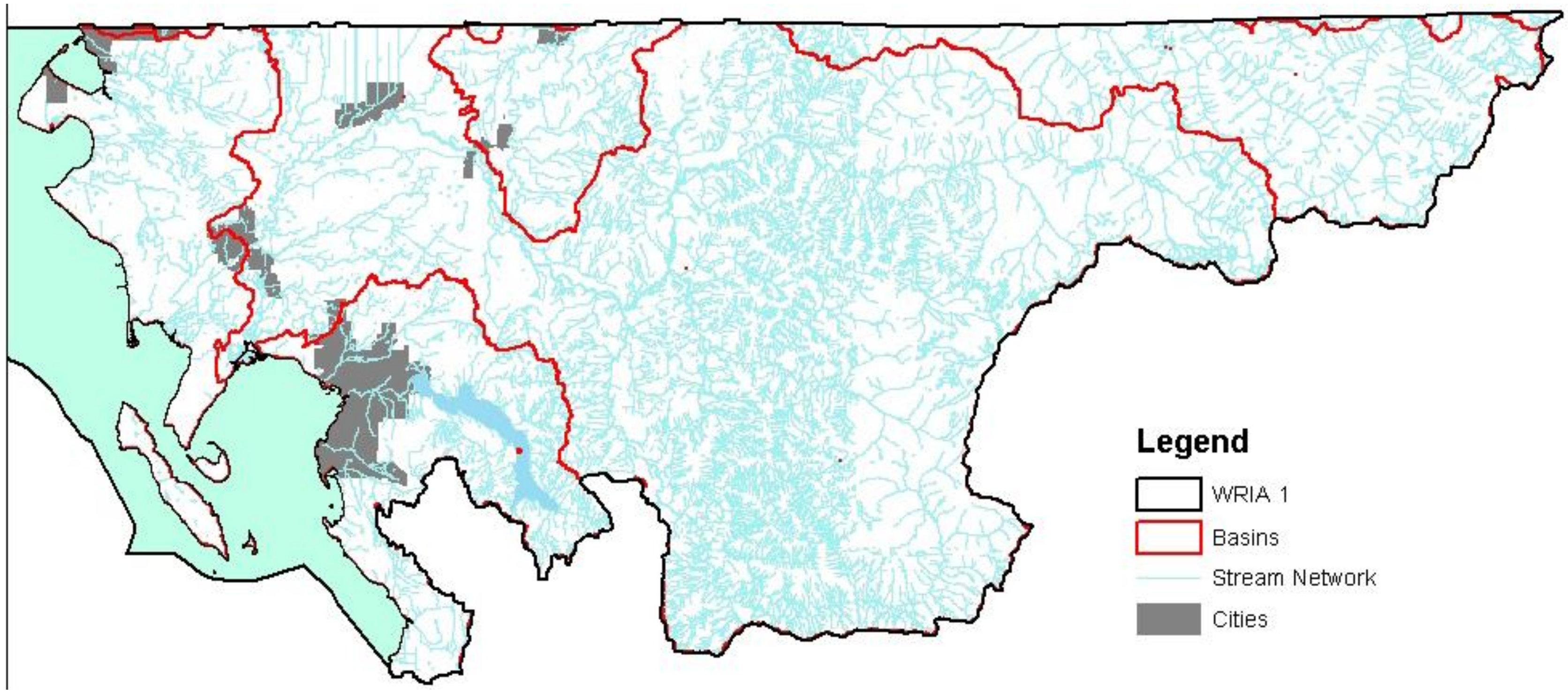
While the Plan addresses recovery broadly, the focus for restoration actions is first on restoring habitat forming processes in the geographic areas of highest importance to the early chinook populations, consistent with the intent of the WRIA 1 Inter-local Agreement (ILA) that was signed in 2004. The ILA was signed by WRIA 1 local governments and fisheries co-managers, and it established the WRIA 1 Salmon Recovery Board. Recovery actions in these geographic areas will also help recovery bull trout, as both species spawn entirely in the Nooksack forks and their tributaries, and both also use the mainstem and nearshore areas. Other species will also benefit from focused efforts in these areas. Appendix B describes the near–term (10-year) actions that have been agreed to in WRIA 1. While chinook and bull trout are discussed in this Plan, much of the more detailed information is contained in Appendix C (Technical Background), where other anadromous salmonids, and their needs, are more briefly described. Appendix D. is our species periodicity table. Appendix E is the WRIA 1 Habitat Restoration Strategy. While actions for other geographic areas including Fraser tributaries, Independent tributaries, and lower mainstem Nooksack tributaries are less specific, habitat improvements are anticipated through effective use of land-use regulations combined with incentive-based and voluntary restoration actions. Due to the importance of recovering the two early-chinook populations, and anticipated funding limitations, the highest priority is focusing on restoring habitats used by North/Middle Fork and South Fork chinook.

1.5. Plan Organization

This Plan is organized into the following sections:

- *Goals.* Biological and general goals for salmon recovery in WRIA 1.
- *Background.* General watershed description and review and synthesis of the state of knowledge on chinook and bull trout populations.
- *Limiting Factors.* Descriptions of limiting factors associated with habitat, harvest, hatcheries, hydropower.
- *Strategies and Actions.* Recommendations for habitat-, harvest-, hatchery- and hydropower-related actions necessary to achieve recovery goals are presented in *Necessary Actions*. In identification of necessary actions, the Plan will build on and integrate past and ongoing salmon and watershed.
- *Implementation.* Includes monitoring and evaluation of salmon recovery efforts, a description of the decision-making structure, education and outreach components and preliminary funding estimates.

Figure 1.3. Water Resource Inventory Area (WRIA) 1.



2. GOALS

2.1. Watershed Vision

Quality of life is a major asset for Whatcom County, and protecting and restoring fish, their habitats, and the watershed processes that support them are essential to the long-term physical, cultural, and economic health of the community. Salmonids are indicators of the overall health of the natural environment, which attracts visitors and residents to the county. They are a cornerstone in the food web of terrestrial and aquatic ecosystems.

Additionally, restoring salmon runs to harvestable levels is vital to the culture and economy of the region. Western Washington Treaty Tribes, including the Nooksack Tribe and Lummi Nation, retain fishing rights to these fish as specifically described by the 1974 court case *U.S. v. Washington.* Protection of this treaty-guaranteed right is essential to preserving the cultural and economic center of tribal communities. Non-tribal harvest among commercial and recreational users is also an important element.

The local vision for salmon recovery in WRIA 1 is to recover self-sustaining salmonid runs to harvestable levels through the restoration of healthy rivers and natural stream processes, careful use of hatcheries, and responsible harvest, and with the active participation and support of local landowners, businesses, and the larger community. Achieving this vision will require: (1) a range of voluntary actions that will accommodate community needs and interests; (2) regulatory actions to ensure no net loss of properly functioning conditions in salmonid habitats; and (3) on-going public involvement and education, both to help policymakers understand community needs and balance competing interests, and to build public support for actions necessary to successfully recover salmon.

2.2. Near-Term Priorities

A more proximate goal, and one that underlies much of the federal and state funding allocated to salmon recovery in recent years, is the recovery and delisting of endangered and threatened species and the subsequent relief to local governments, businesses and citizens from the regulatory constraints of ESA. This goal necessitates prioritization of listed species in recovery planning efforts. Employing a process-oriented approach to restoration that is based on sound scientific understanding of the biological and physical processes limiting salmonid production, however, will ensure benefit to and facilitate recovery of multiple species, even while benefits to priority species are maximized. Such a watershed-based approach will also reduce the likelihood for future salmonid listings, as well as facilitate conservation of the natural habitats and ecosystems valued by humans, wildlife, and other biota.

The approach to salmon recovery in the near-term (10-year time frame) is to:

- Focus and prioritize salmon recovery efforts to maximize benefit to the two independent chinook populations identified by the Technical Recovery Team (PSTRT 2001):
    - North Fork/Middle Fork Nooksack early chinook.
    - South Fork Nooksack early chinook.
- Address late-timed chinook through adaptive management, focusing in the near-term on identifying hatchery- versus naturally-produced population components.
- Facilitate recovery of WRIA 1 bull trout by:
    - Implementing actions with mutual benefit to both early chinook and bull trout .
    - Removing fish passage barriers in presumed bull trout spawning and rearing habitats in the upper Nooksack River watershed.
- Address other salmonid populations by:
    - Protecting and restoring salmonid habitats and habitat-forming processes throughout WRIA 1 through regulatory and incentive-based programs.
    - Encouraging and supporting voluntary actions that benefit other WRIA 1 salmonid populations without diverting attention from early chinook recovery.

2.3. Treaty Rights

In 1974, *U.S. vs. Washington* (the "Boldt decision") reaffirmed the rights of the Point Elliot treaty tribes, which includes the Lummi Nation and Nooksack Indian Tribe, to their treaty-reserved fishing rights and established the tribes as co-managers of the resource entitled to 50% of the harvestable number of salmon and trout returning to Washington waters. Fishing is vital to the tribes for cultural, economic, and subsistence purposes, and both the Lummi Nation and Nooksack Indian Tribe will continue to exercise their legally established fishing rights as salmon recovery proceeds in WRIA 1.

To this end, the tribes' goals with respect to fisheries harvest are as follows:

- Near-term (1 to 10 years)
    - Manage harvest to provide for exercise of treaty-reserved fishing rights while not impeding recovery of early chinook populations.
    - Protect current harvest levels for late-timed chinook, sockeye, pink, coho, steelhead and chum salmon.
- Intermediate time frame (11 to 25 years)

    - Expand harvest of early chinook to include more meaningful ceremonial and subsistence use and of other stocks.
- Long-term (25 to 100 years)
    - Expand fisheries further to sustainably harvest recovered, self-sustaining salmonid populations.

2.4. Biological Goals

The success of this Recovery Plan will be measured by the recovery of listed salmonid species, as well as the quantity and quality of the habitats upon which they depend. Biological goals in the form of species-specific targets are presented in the sections below for chinook and bull trout.

Table 2.1. Recovery Goals for WRIA 1 Chinook Populations by Viable Salmonid Population (VSP) parameter. See text for description of how goals were derived.

Population	Spawner Abundance			Outmigrant Smolt Abundance		Diversity	Spatial Structure
	Low Productivity		High Productivity	Low Productivity	High Productivity		
	Planning Range for Abundance	Planning Targets for Abundance (productivity in parentheses)					
South Fork Nooksack Early Chinook	9,900[1] – 13,000[2] (1.0)	9,900 (1.0) [1]	2,300 (3.3) [1]	410,000[1]	280,000[1]	*To be established through adaptive management.*	
North Fork/Middle Fork Early Nooksack Chinook	14,000[1] – 22,000[2] (1.0)	14,000 (1.0) [1]	3,400 (3.1) [1]	610,000[1]	410,000[1]		

[1] Derived from EDT model, PFC+ scenario.
[2] Derived from EDT model, Historical Conditions scenario.
[3] As depicted for the population in WRIA 1 Salmonid Distribution maps. Given interannual variation in environmental conditions and population abundances, a reach is considered occupied if a life stage is observed within the reach any time within a 10-year time frame.

2.4.1. Chinook

2.4.1.1. Recovery Goals

NOAA Fisheries has appointed a Puget Sound Technical Recovery Team (TRT) to assist in development and evaluation of the Puget Sound Chinook Recovery Plan. The TRT has developed planning ranges and preliminary guidance for the recovery and delisting of the Puget Sound Chinook ESU (PSTRT 2002). WRIA 1 constitutes one of five geographic regions in Puget Sound for the evaluation of ESU-wide recovery scenarios (Figure 1.1; PSTRT 2002). The TRT recommends "at least 2 to 4 viable chinook salmon populations in each of the 5 geographic regions" with "one or more viable populations from each major genetic and life history group historically present within that geographic region." A salmonid population is considered viable if it "has a negligible risk of extinction due to threats from demographic variation, local environmental variation, and genetic diversity changes over a 100-year time frame" (McElhany et al. 2000); an acceptable risk of extinction is 5% or less (PSTRT 2002). Population viability will be evaluated in terms of the following Viable Salmonid Population (VSP) parameters: (1) abundance, the number of individuals in the population at a given life stage or time; (2) productivity/growth rate: the actual or expected ratio of abundance in the next generation to current abundance; (3) population spatial structure: how the abundance at any life stage is distributed among available or potentially available habitats; and (4) diversity: the variety of life histories, sizes, and other characteristics expressed by individuals within a population. (McElhany et al. 2000; PSTRT 2002).

Table 2.1 presents the planning ranges and targets for abundance and productivity for local chinook populations (Shared Strategy 2002), which were developed jointly by the TRT, WDFW, Lummi Nation, and Nooksack Tribe. Planning ranges were developed using several technical models and provide a broad estimate of the abundance needed for a population to be viable over time (Shared Strategy 2002). Planning targets reflect the acceptable trade-off between abundance and productivity, i.e. lower abundances are acceptable if a population is more productive. A more detailed explanation of how targets and ranges were derived is provided in *Planning Ranges and Preliminary Guidelines for the Delisting and Recovery of the Puget Sound Chinook Salmon Evolutionarily Significant Unit* (PSTRT 2002). Locally developed diversity and spatial structure goals are also presented.

Abundance and productivity targets were estimated using the Ecosystem Diagnosis and Treatment (EDT) model, which models chinook population performance based on different habitat conditions scenarios (see Section 4 *Limiting Factors* for a description of EDT). Targets and ranges presented for abundance, productivity, and diversity in Table 2.1 are derived as described below:

Planning Range for Abundance:

Minimum: Number of spawners at a point in spawner-recruit curve where one spawner produces only one adult fish in the subsequent generation (i.e. productivity of 1.0). Curve is modeled based on properly functioning conditions in the freshwater environment and historical conditions in the estuarine environment.

Maximum: As above, except curve is based on historical conditions in the freshwater and estuarine environments.

Planning Targets for Abundance:
Since EDT explicitly models survival by life stage, number of outmigrant smolts can also be modeled under different habitat conditions scenarios. For both spawner and smolt abundance, curves are based on properly functioning conditions in the freshwater environment and historical conditions in the estuarine environment.
Low Productivity: For spawners, same as Minimum of Planning Range. For smolts, the number of smolts expected to survive to outmigration based on that number of spawners. Both spawner and smolt number are based on properly functioning conditions in the freshwater environment and historical conditions in the estuarine environment.
High Productivity: For spawners, number of spawners at a point in spawner-recruit curve where the population provides the highest sustainable yield for every spawner. For smolts, the number of smolts expected to survive to outmigration based on that number of spawners. The productivity ratio associated with this point is the number of recruits (returning adults) per spawner (e.g. 3.6 for South Fork Nooksack Early Chinook, Table 2.1).

Diversity and Spatial Structure
The goals for chinook diversity and spatial structure will be developed at a later date as part of the adaptive management framework.

2.4.1.2. Interim Benchmarks
Even with implementation of actions recommended in this Plan, accomplishment of the chinook recovery goals listed above is expected to take at least 100 years. Establishment of interim targets is necessary to ensure that consistent and measurable progress is made towards chinook recovery. Additional objectives are provided below as interim benchmarks for recovery:

- June 2015: Full implementation of Early Actions list (see Appendix B).
- June 2030:
    - North/Middle Fork Nooksack early chinook
        - Abundance: 3,283
        - Productivity: 3.4
        - Diversity Index: 77%
    - South Fork Nooksack early chinook

- Abundance: 1,562
- Productivity: 2.9
- Diversity Index: 79%

The June 2030 interim benchmarks were developed using the Ecosystem Diagnosis and Treatment (EDT) model, which integrates the effects of multiple reach-level habitat attributes on chinook population performance. The benchmarks represent the population performance associated with an estimate of habitat potential after 25 years, assuming that the 10-year actions presented in Appendix B are implemented, in addition to similar actions that can be implemented over the longer time scale of 25 years (i.e., year 11 to year 25). The modeled scenario assumes no degradation of existing function. Further, the scenario does not incorporate the benefits of either actions to be implemented in the nearshore environment or additional actions to be implemented from year 11-25 in the lower Nooksack River tributaries and in the estuary. Accordingly, the benchmarks should be considered conservative in terms of possible restoration actions, and may be optimistic in terms of protection.

It is anticipated that these benchmarks will be refined and more time scales added as more information becomes available and further analysis and modeling are conducted.

2.4.2. Bull Trout

The Puget Sound Bull Trout Recovery Unit Team (PSRUT) has also provided recovery planning guidance for the Puget Sound bull trout recovery unit (PSRUT 2002). In evaluating recovery for delisting, the PSRUT will consider the following characteristics within each core area population: (1) abundance, the number of adult spawners; (2) distribution, measured by the number of local populations and their spatial structure; (3) trend, (productivity or the reproductive rate of the population as measured by population trend and variability); and (4) connectivity (the diversity of the population as measured by the persistence of the migratory life history forms and of the supporting functional habitat**)** within the core area.

Table 2.2 presents the bull trout recovery goals for WRIA 1. Goals are derived from the *Draft Recovery Plan for the Coastal-Puget Sound Distinct Population Segment of Bull Trout* (USFWS 2004). A timeframe of at least 3 to 5 bull trout generations (15 to 25 years), or longer, is expected to achieve recovery, depending on the extent of and timeline for implementation of bull trout recovery actions (USFWS 2004).

The proposed goals for the respective core areas are based on minimum effective population sizes for the respective local population groups that comprise the core areas (USFWS 2004). The Nooksack core area has 10 local populations tentatively identified, and Chilliwack has three, with a fourth potential local population in Depot Creek (if use is confirmed on the U.S. side of the border). The three Chilliwack local populations are upper Chilliwack River, Little Chilliwack River, and Silesia Creek. See Section 4.1.5.1 for a listing of the Nooksack local populations.

Local populations are groupings of bull trout that are thought to represent reproductively interactive units. The combination these locally reproductive populations make up core population areas, and occasional gene flow may occur between local populations. The recovered abundance targets for each core area were proposed with consideration for the minimum number of adult spawners needed to avoid deleterious effects of genetic drift, and the recovery team selected 1,000 spawners as the general minimum for a core population. Additionally, each local population was recommended to have a minimum population of 200 spawners. This number was chosen as data from the Skagit River indicate that only 50% of spawners are first time spawners (reducing effective population size), to avoid inbreeding depression.

Table 2.2. Recovery Goals for WRIA 1 Bull Trout Populations by core population and population parameter.

Core Area	Abundance	Distribution	Trend	Connectivity
Nooksack	2000	Maintain or expand the current distribution	Stable or increasing trends in abundance at or above the recovered abundance target level in each core area, based on 10- to 15-year time frame.	Restore connectivity by identifying and addressing specific existing and potential barriers to bull trout movement in each core area.
Chilliwack	600	Maintain or expand the current distribution		

3. BACKGROUND

3.1. Basin Description

3.1.1. Introduction

Water Resource Inventory Area (WRIA 1) encompasses 3638 km^2 (1400 mi^2) and includes the watersheds and associated estuaries of the Nooksack River, Lummi River, and independent coastal tributaries, as well as Fraser River tributaries south of the Canadian border in Whatcom County (Chilliwack River and Sumas River) and nearshore marine areas from the US/Canada border to Colony Creek (Figure 3.1). Most of WRIA 1 is located within Whatcom County, although portions of Samish Bay and South Fork Nooksack watersheds extend southwards into Skagit County. Cities in WRIA 1 include Bellingham, Ferndale, Lynden, Blaine, Sumas, Everson, and Nooksack. Federal ownership is concentrated in the upland areas to the east and includes Mt. Baker-Snoqualmie National Forest (mid- to upper North and Middle Fork Nooksack watersheds), North Cascades National Park (upper North Fork Nooksack and Chilliwack watersheds), and Mt. Baker National Recreation Area (upper Middle Fork Nooksack watershed). Forested uplands to the west of federal forested lands are under a mix of state and private ownership. WRIA 1 also contains the reservation and tribal trust lands of the Nooksack Indian Tribe and Lummi Nation reservations.

A total of 3814 miles of watercourse length (streams, rivers, lakes, ponds, wetlands) has been delineated in WRIA 1, of which just under 38% (1437 miles) are or have the potential to be salmonid-bearing (Figure 3.2; Appendix C Table C3). WRIA 1 salmonid distribution maps (NWIFC 2004) indicate that the area currently[3] provides habitat for every species of native Pacific salmonid. Presumed historic and/or potential habitat has also been mapped for most salmonids, based on species-specific stream gradient preferences, presence of natural fish passage barriers, and local knowledge of stream conditions. Such *presumed historic/potential* stream segments constitutes habitat that would reasonably be expected to have supported or be able in the future to support a given species. Salmonid habitat by species in WRIA 1 is presented in Table 3.1.

WRIA 1 can be divided into fourteen subbasins in three general regions (Table 3.2): (1) the Nooksack region, including the Nooksack and Lummi River watersheds; (2) Coastal region, which includes independent coastal tributary watersheds; and (3) Fraser region, including Fraser River tributaries south of the US/Canada border. Most of WRIA 1 area is in the Nooksack region (62%), with the remainder split between Coastal and Fraser regions.

[3] Includes current known and current presumed distribution, as mapped by local experts.

3.1.2. Nooksack River Watershed

3.1.2.1. General

The Nooksack River Watershed comprises the majority (62%) of the land area in WRIA 1 (US only). Three major forks form the Nooksack River: the North Fork, Middle Fork, and South Fork. The North Fork is the main fork of the Nooksack River. The Middle and South Fork confluences are at river mile (RM) 40.5 and 36.6, respectively. The North and Middle Forks originate from Mount Baker glaciers and snowfields and are typically turbid with moderate flows during summer due to glacial melt (Smith 2002). By contrast, the South Fork drains the slopes of the Twin Sisters and is usually lower and clear in the summer. There is a diversion dam on the Middle Fork at RM 7.2, which diverts surface water to Lake Whatcom to supplement the City of Bellingham's water supply. Downstream of the confluence of the North and South Forks, the river becomes the Nooksack River. The Lummi River is a largely disconnected distributary of the Nooksack River, although at the time of first Euro-American settlement, the Lummi River was the dominant distributary (Collins & Sheikh 2004b).

3.1.2.2. Major Tributaries

Major tributaries of the Nooksack River watershed by subbasin are: (1) North Fork: Racehorse Creek, Kendall Creek, Maple Creek, Boulder Creek, Canyon Creek, Glacier Creek, Wells Creek; (2) Middle Fork: Canyon Lake Creek, Porter Creek, Clearwater Creek, Warm Creek, Wallace Creek, Ridley Creek; (3) South Fork: Black Slough, Hutchinson Creek, Skookum Creek, Cavanaugh Creek, Howard Creek and Wanlick Creek; (4) Lower Mainstem: Silver Creek, Tenmile Creek (including Deer and Fourmile Creeks), Wiser Lake Creek, Bertrand Creek, Fishtrap Creek, Kamm Creek, Anderson Creek, and Smith Creek; (5) Lummi River: Schell Creek.

3.1.2.3. Political/Land Ownership

The cites of Lynden, Ferndale, and most (68%) of Everson and the Lummi Nation and Nooksack Indian Tribe reservations are located within the Nooksack River watershed (Figure 3.1). The Lummi Reservation encompasses much of the Lummi River watershed. The lower Nooksack River (at ~ river mile 6) flows through Ferndale city limits, as do parts of Tenmile, Deer, and Silver Creeks. Lynden is located further upstream on the northern shore of the Nooksack River (at ~river mile 17.5) and encompasses parts of the lower Fishtrap Creek watershed. The Nooksack River flows through Everson further upstream (~ at river mile 23.8). Less than 0.1% of the Nooksack River watershed lies within Bellingham city limits (Figure 3.1). Parts of the lower North, Middle, and South Fork Nooksack watersheds are in DNR ownership. The mid to upper North and Middle Fork Nooksack and the upper South Fork watershed lie within the Mt. Baker-Snoqualmie National Forest, with parts of the uplands in designated wilderness areas. North Cascades National Park and Mt. Baker National Recreation Area encompass the upper North Fork and Middle Fork Nooksack River watersheds, respectively. Uplands to the west lie within Mt. Baker-Snoqualmie National Forest. A small fraction (5.9%; Appendix C, Table C4) of the Nooksack River watershed is in Canada, including the upper Fishtrap, Bertrand, and Kendall Creek watersheds. Skagit County encompasses parts of the South Fork Nooksack subbasin, comprising 7.5% of the total Nooksack River watershed area (Appendix C, Table C4).

3.1.2.4. Streams

A total of 2707 miles of watercourse length has been delineated in the Nooksack region, of which 2127 miles have been classified under the Salmon and Steelhead Habitat Inventory and Assessment Project according to gradient, confinement and habitat type (SSHIAP; Figure 3.3; Appendix C, Table C6). Over half (54%) of the SSHIAP length is classified as small tributaries greater than 20% in gradient in confined valleys, most of which (95%) occur in the Forks subbasins. Other than the Nooksack River and its Forks, the only other large tributaries are Bertrand, Fishtrap, and Tenmile Creeks in the Lower Nooksack subbasin and Canyon Creek in the North Fork subbasin. Most of the North Fork, lower Middle Fork, and South Fork mainstems are low gradient (less than 2% gradient); gradient of the upper Middle Fork ranges from 2 to 8%. The lower South Fork, mainstem Nooksack River, and Lummi Rivers are all less than 1% gradient, unconfined channels. Over 80% of primary channel length in Forks subbasins is greater than 4% gradient, while most of the primary channel length (68%) in the Lower Nooksack and Lummi River subbasins is less than 1% gradient. Since SSHIAP mapping is based primarily on USGS topographic maps, it is not a reliable source for comprehensive floodplain habitat inventories. However, anastomosing and braided reaches in large tributaries are evident, especially in the delta and lower North and Middle Forks and to a lesser extent in the lower South Fork and upper mainstem Nooksack.

About one-third (34%) of the total watercourse length (916 miles) is known or presumed to be currently salmonid bearing (Figure 3.2; Appendix C, Table C3). Salmonid habitat is distributed throughout streams of the Lower Nooksack and Lummi River subbasins and in the Forks and most large and low-gradient sections of smaller tributaries to the Forks (Figure 3.2). Of all the drainages in WRIA 1, the Nooksack River watershed produces the greatest abundance of salmonids and the greatest number of salmonid stocks (Smith 2002).

3.1.3. Independent Coastal Tributaries

3.1.3.1. General

Independent coastal tributary watersheds comprise 19% of the total land area in WRIA 1. Dakota and California Creeks are formed by springs and surface water run-off from the low hillslopes in northwest WRIA 1 (Phinney and Williams 1975, cited in Smith 2002), and drain largely rural lands before flowing through urbanized areas into Drayton Harbor. Wetlands are a significant feature of the Dakota Creek watershed, comprising an estimated 21% of the land cover if mudflats are included (Nelson et al. 1991, cited in Smith 2002). Terrell Creek is formed by Lake Terrell and the springs to Fingalson Creek (Phinney and Williams 1975, cited in Smith 2002) and drains a mix of rural and urban lands before flowing into Birch Bay. Squalicum, Whatcom, and Padden Creeks originate from lakes and flow through urbanized and industrial areas to drain into Bellingham Bay (Smith 2002). Whatcom Falls near RM 3 on Whatcom Creek prevents anadromous salmonid access to Lake Whatcom (DNR 1997a, cited in Smith 2002), the largest lake in Whatcom County. Oyster and Colony Creeks originate on Chuckanut Mountain and drain into Samish Bay.

3.1.3.2. Major Tributaries

Major tributaries of the Coastal Region by subbasin are: (1) Drayton Harbor: Dakota Creek, California Creek; (2) Birch Bay: Terrell Creek; (3) Bellingham Bay (includes Chuckanut Bay): Squalicum Creek, Whatcom Creek (including Lake Whatcom tributaries: Carpenter Creek, Olsen Creek, Smith Creek, Austin Creek), Padden Creek, and Chuckanut Creek; (4) Samish Bay: Oyster Creek, Colony Creek.

3.1.3.3. Political/Land Ownership

Blaine city limits encompasses the lower end of the Dakota Creek watershed and much of the Drayton Harbor shoreline, extending east into land draining to Canada (Other Fraser subbasin; Figure 3.1). Bellingham extends east and north from the eastern shore of Bellingham Bay and northeastern shore of Chuckanut Bay, encompassing the lower Squalicum, Whatcom, Padden and Chuckanut Creek watersheds. A very small portion (0.68%) of the Drayton Harbor subbasin lies within Canada. Skagit County encompasses parts of the Bellingham Bay (1%; Lake Whatcom watershed) and Samish Bay (85%) subbasins. The vast majority of land in the Coastal subbasin is privately owned, with some state (DNR) and tribal ownership (Lummi Reservation). Much of the Lake Whatcom watershed and Oyster Creek watersheds are in DNR ownership.

3.1.3.4. Streams

A total of 573 miles of watercourse length has been delineated in the Coastal region, of which 404 miles have been classified under the Salmon and Steelhead Habitat Inventory and Assessment Project (SSHIAP; Figure 3.3; Appendix C, Table C6). Virtually all the classified primary channel length in the region is classified as small tributaries. Most streams (71% of length) in Drayton Harbor, Birch Bay, and Georgia Strait subbasins are less than 1% in gradient. In contrast, most (61%) in the Bellingham Bay and Samish subbasins are at least 4% in gradient. Highest-gradient (>20%) streams occur throughout much of the Lake Whatcom watershed and on Chuckanut Mountain northern portion of Samish Bay subbasin.

Most (58%) of the total watercourse length (573 miles) in the Coastal region is or has the potential to be salmonid bearing (Figure 3.2; Appendix C, Table C3). Salmonid habitat is distributed throughout streams of the Drayton Harbor, Birch Bay, and Georgia Strait subbasins and in lower gradient reaches of the Samish Bay subbasin (Figure 3.2). In the Bellingham Bay subbasin, salmonid habitat occurs throughout Squalicum Creek and lower Whatcom Creek, and in lower gradient segments of Padden and Chuckanut

Creeks and tributaries to Lake Whatcom. Resident salmonid habitat is available in Lake Whatcom tributaries, including Anderson, Olson, Carpenter, Smith, Brannian, and Austin Creeks.

3.1.4. Fraser River Tributaries

3.1.4.1. General

Watersheds of Fraser River tributaries on U.S. lands comprise 18% of the land area in WRIA 1. The Sumas and Chilliwack Rivers originate in Washington State but ultimately drain into the Vedder River, a tributary to the Fraser River, in British Columbia. The Sumas River and its eastern tributaries drain the forested lands of Sumas Mountain, then flow through predominantly agricultural and rural lands that were historically wetlands and Sumas Lake, a large tidally influenced lake that filled much of the Sumas Valley (Smith 2002). In Canada, the Sumas River flows through the Sumas Prairie, a low-lying floodplain bordered by steep mountains on both sides. The Chilliwack River is a low gradient fourth order stream that drains mountainous, forested terrain in Washington State, much of which lies within North Cascades National Park or Mount Baker-Snoqualmie National Forest (Smith 2002). The Chilliwack River flows into Chilliwack Lake before draining into the Vedder River.

3.1.4.2. Major Tributaries

Major tributaries of the Fraser region by subbasin are: (1) Sumas: Sumas River (drains to the Vedder Canal), Saar Creek and Johnson Creek (Sumas River tributaries); (2) Chilliwack: Chilliwack River and its tributaries: Little Chilliwack River, Damfino Creek, Tomyhoi Creek (tributary to Damfino Creek), Frost Creek, Depot Creek and Silesia Creek.

3.1.4.3. Political/Land Ownership

The cities of Sumas and Nooksack and parts of Everson are located within the Sumas River watershed (Figure 3.1). Sumas encompasses the lower end of Johnson Creek and parts of the lower end of the Sumas River. Nooksack is located higher in the watershed of the Sumas River, which delineates the southeast boundary of the city. Everson is located adjacent to Nooksack to the southwest. Much of the Sumas subbasin (>80%) is in private ownership, with some lands in DNR ownership (Smith 2002).

The Chilliwack subbasin is in predominantly federal ownership (Smith 2002). Nearly the entire length (99%) of the Chilliwack River on the U.S. side, as well as the upper reaches of Silesia Creek, is protected within North Cascades National Park (Smith 2002). The lower Silesia Creek watershed is contained within the Mount Baker Wilderness section of the Mount Baker-Snoqualmie National Forest. Tomyhoi and Damfino Creeks flow through National Forest lands, while Frost Creek drains private forest lands (Smith 2002).

3.1.4.4. Streams

A total of 535 miles of watercourse length has been delineated in the Fraser Region south of the US/Canada border, with 361 miles in Chilliwack subbasin and 173 miles in Sumas subbasin. Stream segments have not been classified under SSHIAP. About 35% of that length is or has the potential to be salmonid bearing, with most mapped salmonid habitat occurring throughout the Sumas River basin (Figure 3.2; Appendix C, Table C3).

3.1.5. WRIA 1 Estuarine and Nearshore Areas[4]

WRIA 1 contains 155 miles of marine shoreline (DNR 2001), including the shorelines around Point Roberts and Lummi, Eliza, Portage, and Chuckanut Islands, and along Drayton Harbor, Birch Bay, Strait of Georgia, Lummi Bay, Portage Bay, Bellingham Bay, Chuckanut Bay, and Samish Bay.

Point Roberts is a peninsula that is separated from the remainder of WRIA 1, connected by land to Canada. Shoreline type is predominantly (84%) sand and/or gravel beaches and flats, with 15% man-made shoreline (DNR 2001).

Drayton Harbor is a shallow bay that nearly empties at low tide (Scott and McDowell 1994). Its exposure to offshore marine habitat is limited by Semiahmoo Spit and the pier and marina owned by the City of Blaine. Dakota Creek and California Creek estuaries Shoreline type is about one-third each of estuarine wetland and mud flat, with 10% man-made (DNR 2001). Drayton Harbor estuarine habitat includes the Dakota Creek and California Creek estuaries.

Birch Bay opens to the Strait of Georgia and is extremely shallow for up to one mile offshore, which results in warm water temperatures in the summer (Scott and McDowell 1994). Shoreline type is predominantly sand flat (62%), 8% man-made, with the remainder sand/gravel beaches and flats (DNR 2001). The Birch Bay shoreline also includes the Terrell Creek estuary.

The shoreline along the Strait of Georgia includes Cherry Point and is predominantly (88%) sand and/or gravel beaches and flats, with 5% man-made shoreline (DNR 2001).

Lummi Bay receives flow from the Lummi River, a former distributary of the Nooksack River watershed that is now largely disconnected except at the highest flows. The shoreline is largely (48%) man-made due to aquaculture; the remainder is estuarine wetland (19%), mud flat (11%), and sand/gravel beaches and flats (DNR 2001).

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[4] Excerpted from Salmon and Steelhead Habitat Limiting Factors in WRIA 1, the Nooksack basin. C.J. Smith, Washington Conservation Commission, Lacey, WA. July 2002.

Bellingham Bay has been the most heavily altered with substantial industrial and commercial shoreline development. Shoreline type is 37% man-made, 37% estuarine wetland, 10% mud flat, and the remainder sand/gravel beaches and flats (DNR 2001). Flowing into Bellingham Bay is the Nooksack River, the primary distributary channel of the Nooksack River watershed since the Lummi River was disconnected in the late 1800s. The Nooksack delta is relatively young and is increasing in size into Bellingham Bay (People for Puget Sound 1997). It has been less altered by human activities compared to other estuaries in Puget Sound. Smaller estuaries include those associated with Whatcom, Squalicum, and Padden Creeks.

Chuckanut Bay is a smaller bay with substantial proportion of shoreline in rock cliffs (28%), followed by man-made (22%; due to railroad) and rock with gravel and sand beach (20%). Chuckanut Creek flows into Chuckanut Bay.

The Samish Bay delta has been diked to support pastureland, and this land now supports migratory birds (Determan 1995, Whatcom County Council of Governments 2000, cited in Smith 2002). Shoreline type is predominantly (48%) mud flat, followed by rock with gravel or sand beach (18%), estuarine wetland (10%), rock cliffs (9%), with the remainder sand and/or gravel beaches and flats. Oyster and Colony Creek estuaries are included in Samish Bay.

3.2. Listed Salmonid Populations

The following section provides salient information on chinook salmon and bull trout in WRIA 1. Information on other WRIA 1 salmonid populations can be found in Appendix C.

3.2.1. Chinook Salmon

3.2.1.1. Distribution

Most of the current chinook salmon habitat in WRIA 1 is in the Nooksack River watershed (81%), followed by the independent coastal tributaries (12%) and Fraser River tributaries (7.0%; Figure 3.4; Appendix C, table C3). Figure 3.4 depicts the current known and current presumed, as well as the potential/historic distribution of chinook in WRIA 01, including small numbers of late-timed ("fall") chinook in the Dakota Creek and other independent drainages, and includes occasional observations in the Sumas River drainage. A small number of early-timed chinook have recently been observed spawning in the U.S. portion of the Chilliwack River (Brad Fanos, Canada Department of Fisheries and Oceans, pers. comm. 2003).

The Nooksack basin supports two independent populations of early-timed (spring/summer) chinook: North Fork early chinook (including the Middle Fork), and South Fork early chinook (PSTRT 2004), and a late-timed (fall) stock (WDFW 2002a).

3.2.1.2. Stock Characterization

3.2.1.2.1. Early-timed Chinook

The North Fork/Middle Fork (NF/MF) and South Fork (SF) early-timed chinook populations are both considered native. They are distinctive from chinook salmon in the rest of Puget Sound, and the genetic distance separating fish from the two populations is the second largest for the entire Puget Sound region (PSTRT 2004). WDFW determined that these two chinook populations comprise two of five genetic diversity units in Puget Sound Chinook (Marshall et al. 1995).

North/Middle Fork early chinook have composite production (a combination of hatchery and wild), and South Fork early chinook currently have only wild production, although it has been composite in the past, and a run re-building program is proposed for the future.

Early chinook spawn in the North Fork from the confluence of the South Fork at river mile (RM) 36.6 to Nooksack Falls at RM 65, and in the lower Middle Fork, downstream of the diversion dam, located at RM 7.2. Spawning also occurs in numerous larger tributaries including Deadhorse, Boyd, Thompson, Cornell, Canyon, Boulder, Maple, Kendall, MacDonald and Racehorse creeks, and in Canyon Lake Creek in the Middle Fork. Highest spawning densities are in the North Fork between Racehorse Creek (RM

45.2) and RM 63. In very recent years most spawners have been returns from Kendall Hatchery or acclimation ponds, and adult affinity to release locations are likely affecting dominant use areas.

The Middle Fork is a tributary to the North Fork, and anecdotal accounts from Nooksack tribal elders reported chinook in the upper Middle Fork in the 1930's and 1940's (STS Heislers Creek Hydro L.P. 1994). Small numbers of chinook have also occasionally been observed jumping at the diversion dam in recent years. The authors evaluated mainstem habitat upstream of the diversion dam and determined that suitable habitat extends to RM 16.2. Clearwater, Warm, Wallace, Sisters and Ridley Creek are also considered suitable habitat (Nooksack Tribe, unpublished data).

The South Fork early chinook population spawns from the confluence with the North Fork up to Sylvester's Falls at RM 25, and in many years spawning occurs upstream of the 11-12 foot falls to RM 30.4. Highest density of South Fork population early chinook spawning occurs between Acme (RM 8.5) and Larson's Bridge (RM 20.7). They also spawn in larger tributaries including Hutchinson, Skookum, Deer and Plumbago creeks. The majority of recent early chinook tributary spawning has been in Hutchinson Creek in recent years (Maudlin et al. 2002).

In the Chilliwack River, small numbers of late August to early September spawning chinook were observed in 2003 near Bear Creek (Brad Fanos, Canada Department of Fisheries and Oceans, pers. comm. 2003).

3.2.1.2.2. Late-timed Chinook

Anecdotal information indicates that late timed-chinook were indigenous to the Nooksack watershed, including information from Nooksack elders. Norgore and Anderson (1921) reported chinook fingerlings in Bertrand Creek and chinook were reported as present in Bertrand and Fishtrap creeks, and in Dakota Creek in biological surveys of 1929-1930 (WDFG 1932, p. 136). It is unknown whether the indigenous late-timed chinook in the Nooksack basin were a unique population or were a component of populations with a broader distribution of return timing than exists now (PSTRT 2004). Historic and present geographic use areas include areas apparently unused, at least for spawning, by either of the early timed populations. The TRT's preliminary conclusion is that the late returning life history was part of the historical diversity of chinook salmon within the basin, but could not determine whether it historically constituted an independent population. They have included it as an extinct population or aggregation, with the present fall stock considered introduced.

While historically indigenous, the original population or aggregation is considered extinct. Current Nooksack late-timed chinook are now considered non-native, and primarily Green River origin, due to the extensive history of non-native hatchery releases (Young and Shaklee 2002). Washington Department of Fish and Wildlife's

Kendall Creek Hatchery on North Fork Nooksack River and Samish River Hatchery on Friday Creek both began operations in 1899. Samish River late timed chinook hatchery production was derived from Green River origin fall chinook. While no chinook were spawned at Samish Hatchery in 1925 or 1926, 1,000,000 eggs were transferred in 1926 and 977,705 fry were planted (WDFG 1928, pp. 113, 185). No chinook eggs were taken at the Samish Hatchery prior to 1937, that eggs transplanted from Green River to the Samish River in 1937 resulted in 3,796 adults returning in 1941, with additional adults spawning downstream of the hatchery trap (WDF 1941). Chinook eggs were taken in 1937-1940, and the 1939 report states, "every effort will be made to continue the program of transplanting a chinook run to the Samish River" (WDF 1939). Late timed chinook were transplanted from this facility to Kendall Creek hatchery in 1954 (HSRG 2003). Out of basin fall chinook transfers from Samish Hatchery with releases to the Nooksack River occurred in 24 years between 1955 and 1993, and from Green River into the Nooksack River for 18 years between 1956 and 1989. While the Kendall Hatchery no longer releases late timed chinook, this stock continues to be released in the lower Nooksack River, Lummi Bay, and in the Samish River.

The Nooksack late timed chinook stock's current genetic baseline was derived from microsatellite DNA analysis of hatchery fish tissue samples collected from Kendall Creek Hatchery. Despite the management history, this stock showed significant genetic differences at several microsatellite DNA loci from the population currently reared at the Green River's Soos Creek Hatchery (Young and Shaklee 2002). Allozyme characterizations of the fall chinook populations at many hatcheries that have transplanted Green River fall chinook indicates that they are genetically similar cultivars of Green River fall Chinook (Young and Shaklee 2002, PSTRT 2004).

Late-timed chinook in the South Fork Nooksack River were considered a possible remnant native late-timed chinook population, as relatively consistent late spawning has been recorded in Hutchinson Creek since the early 1950's (Maudlin et al. 2002). However, microsatellite DNA analysis of a late-spawning aggregation collected from adults in the South Fork found that they were not statistically different from the Kendall Creek Hatchery late-timed chinook (Young and Shaklee 2002). Until recent years, most late-timed chinook hatchery releases in and near the Nooksack basin were not mass-marked through adipose fin clips or coded wire tags (CWT), so it is likely that some of the adults in the aggregation were hatchery strays. Substantial numbers of late chinook were released from Skookum Creek Hatchery on the South Fork Nooksack River from 1974-1987, and these almost certainly also originated from Green River, Samish River, or Kendall Creek broodstock (Young and Shaklee 2002).

Shaklee and Young (2002) also evaluated outmigrating juvenile chinook from the lower South Fork and mainstem rotary screw smolt traps for DNA stock of origin, and determined that about 84% of South Fork smolt trap's juvenile outmigrants in 2000 were assigned to the Kendall Creek Hatchery fall chinook stock, about 7% were NF/MF stock and about 9% were SF stock (Young and Shaklee 2002). No hatchery late-timed chinook are currently released into the South Fork, and this demonstrates that substantial fall chinook natural production is occurring.

Late-timed chinook in the Nooksack watershed are considered to have composite production (WDFW 2002a), although it is uncertain what proportion of recent spawners are hatchery release returns from the lower river, Lummi Bay, or the Samish River releases. Late carcass recoveries that include returns from recent mass marking show that current spawners are a fairly even mix of hatchery returns and wild fish.

Late-timed chinook currently spawn in the mainstem down to at least river mile 10.2 in the vicinity of Wiser Lake Creek (A. Pfundt, Lummi Natural Resources, pers. comm.), and in mainstem tributaries including Bertrand, Fishtrap, Tenmile, Anderson, and Smith Creeks. They also spawn in all three forks and in larger tributaries to them. In 2002 a helicopter survey on October 8 enumerated 302 redds in the mainstem from RM 15.3 to RM 36.6, 249 redds in the South Fork downstream of RM 22.8, 102 redds in the North Fork between mile 36.6 and Kendall Creek (RM 46), and 18 redds in the lower five miles of the Middle Fork. While the survey did not cover all spawning areas, and viewing conditions were not optimal, this flight gives some indication of relative distribution and abundance. Fisheries co-manager ground based surveys generally recorded higher numbers in 2002 than the overflight did. Very few late spawners were recorded in tributaries in 2002, as fall stream discharges were very low. During years when adequate discharge occurs, appreciable spawning has been recorded in larger tributaries including Bertrand, Fishtrap, Tenmile, Anderson and Smith creeks. While viewing conditions were poor in 2004, abundances appeared to be appreciably smaller in 2004.

While our current understanding is that Nooksack late-timed chinook are essentially a non-native stock, their continued presence, and demonstrated reproductive success, shows that the watershed continues to have the capacity to produce late timed chinook, and that the non-indigenous strain can successfully reproduce. Continued late stock chinook use of Dakota Creek also suggests it also has the capacity to produce a small number of adults. Less is known about chinook use in the Sumas River drainage, although small numbers of late chinook have occasionally been observed in it, for example in Saar and Kinney creeks (D. Huddle, WDFW, pers. comm. 2005). Few spawn surveys are conducted. It is unknown whether late chinook spawn in the Chilliwack River in the U.S., as surveys have not been conducted during their spawning period (Brad Fanos, Canada Department of Fisheries and Oceans, pers. comm. 2003). While our understanding of the Nooksack late chinook stock has increased in the recent years, there are still uncertainties regarding this stock.

3.2.1.3. Population Status

North and South Fork early chinook populations are both considered critical status due to very low adult abundance for the South Fork population, and very low natural origin (wild) abundance for the North Fork population. Table 3.3 shows recent escapement abundance for both populations.

South Fork early chinook escapement estimates are determined by combined survey coverage by Nooksack co-managers (Nooksack Tribe, Lummi Nation, and WDFW) enumerating redds in August and September, assuming 2.5 fish per redd, and subtracting the proportion of redds assumed to be from non-SF population hatchery strays. This proportion of redds is determined by evaluating the proportion of the carcasses recovered through October 7 that are hatchery origin.

NF/MF early chinook escapements are determined through expanding the total number of carcasses enumerated during spawn surveys from July through September, and expanding them by an averaged factor determined during the years when clear water viewing conditions enable the relationship to be established between total redds constructed and total carcasses recovered. While the Kendall Hatchery rebuilding program has resulted in increased abundances for the NF/MF population, natural origin abundances have increased much more modestly.

Productivity for both populations is currently very low. The South Fork replacement rate (adult return spawners per spawner 4 years earlier) averaged 1.13 for brood years 1997-2000. The North Fork replacement rate (adult wild return spawners produced per spawner in the parent brood) averaged 0.36 for brood years 1995-1998 (WDFW unpublished data). The lower return rate for this population may be attributable (or partially attributable) to having more adults spawning in the wild (including Kendall Hatchery contributions) than current habitat conditions have the capacity to support.

Spawn survey efforts are frequently limited for late-timed chinook by higher discharge, lower visibility conditions. Chinook redds that are constructed after October 1 are considered late timed chinook redds. While formal escapement estimates have not been attempted, recent survey efforts have led to a general understanding of their spawning areas in the Nooksack Watershed. In 2002, good viewing conditions occurred during the month of October, and redd enumerations from WDFW helicopter overflights and from stream surveys indicate an abundance a few thousand fish. Highest densities of spawning were in the mid-and upper mainstem Nooksack River, with appreciable spawning also occurring in all three forks. As it was a low discharge year, most spawning occurred in the mainstems. The geographic and temporal overlap of late chinook with early chinook is of concern, particularly for the South Fork as there is greater spawn timing overlap. In future years, more data will be available, including determining relative composition of wild and hatchery origin fall chinook spawners.

3.2.1.4. Life History Patterns

Nooksack chinook exhibit a combination of ocean-type (outmigrating as sub-yearling fry or fingerlings) and stream-type (outmigrating as yearlings) juveniles life history patterns. Until recently the majority of NF/MF population natural-origin (wild) outmigrants were thought to be sub-yearlings and most natural origin South Fork outmigrants were thought to be yearlings, based on analysis of scales collected from natural origin adults on the spawning grounds (Marshall et al. 1995). A recent NOAA Fisheries re-evaluation of this data, and including more recent data, with input and feedback from Nooksack co-managers, found quite different results (PSTRT 2003). The analysis of scales using the years when a minimum of 40 samples were available determined that the sub-yearling and yearling outmigration percentages for natural origin SF early chinook adults was 62% and 38% respectively. The sub-yearling and yearling outmigration percentages for natural origin NF/MF early chinook were 71% and 29% respectively.

This demonstrates that both early chinook populations have significant yearling and sub-yearling life history components. Juvenile outmigrants from the lower South Fork and lower mainstem smolt traps that were assigned to the late-chinook baseline also exhibited a combination of yearling and sub-yearling outmigration patterns (Young and Shaklee 2002). See Appendix D for the periodicities of respective Nooksack chinook life stages. The sub-yearling outmigrants observed at the lower mainstem trap range from very small, early outmigrants, to older, larger outmigrants that had longer freshwater residencies.

Both early chinook populations return over a range of ages, but predominately as 4 year olds. During the recent years when at least 40 natural origin individuals were aged from scale data by WDFW, age distributions for the two populations and the management unit are: North Fork: Age 2 (1%), Age 3 (16%), Age 4 (73%), Age 5 (10%); South Fork: Age 2 (0%), Age 3 (12%), Age 4 (72%), Age 5 (16%) (PSTRT 2003). While only recorded during years when less than 40 samples were analyzed, the North Fork population also had a very small percentage of six year old returns. Nooksack late chinook (likely hatchery origin) predominately returned as 4 year olds, followed, in decreasing order by three year olds, five year olds, and two year olds (Myers et al. 1998).

3.2.1.4.1. Upstream Migration

Historical catch records in Bellingham Bay and the Nooksack River indicate that adult wild chinook were present through most of the year. Historic catch data have recorded occasional chinook in the Nooksack River as early as January. Chinook peak river entry is May to June (Maudlin et al. 2002). For a 1981 radio-tagging study of chinook, fishing in the lower Nooksack River began in early April, and early chinook were caught the first week (Barclay 1981). Catch-per-unit-effort increased through mid-May, and the highest catch per day occurred the first week of June, after which fishing ended.

Adult upstream migration of early chinook occurs in four stages – river entry, upriver migration, holding, and spawning (Barclay 1980). Some spring chinook that were radio-tagged in the lower mainstem Nooksack River in 1980 and 1981 moved directly upriver after tagging, while others remained in the lower mainstem, even moving back out to saltwater. After the chinook were acclimated, though, they moved upriver at fairly uniform rates of 1.7 (1980) and 1.5 (1981) miles/day average (range 0.97 to 3.7 miles/day) for a total of 30 to 40 days transit time to the Forks confluence (Barclay 1980, Barclay 1981).

3.2.1.4.2. Holding

Early chinook hold for long periods during the summer in freshwater prior to spawning. The 1980 and 1981 radio tagging studies found that, once migrating chinook reached holding areas, migration dropped sharply (Barclay 1980, Barclay, 1981). Some fish held in the same pool for 2 to 4 weeks.

Schuett-Hames et al. (1988b) found that holding South Fork chinook had a clear preference for the deepest pools, and less than 2% of the chinook were holding in areas that did not have cover. Cover consisted of bedrock, boulders, undercut banks, large woody debris, rootwads, surface turbulence, or small woody debris. Holding chinook sought the deepest water available.

3.2.1.4.3. Spawning

NF/MF Fork early chinook spawn from late July through September, South Fork early chinook spawn from mid-August through September, with peak spawn timing about two weeks (Doughty 1987), or two to three weeks (Barclay 1980) later than North Fork early chinook. Late timed chinook spawn from early September through mid-November (WDFW 2002a). Peak spawning for late chinook is generally in October. South Fork early chinook and late timed chinook have some temporal and geographic overlap in spawning. An early investigation of potential chinook hatchery sites provides a description of historical spawning. During a 1902 or 1903 South Fork investigation on Sept. 18, a number of chinook were spawning in riffles of the river and creeks, a number were through and decaying, and still others had spawned earlier in the season and were dead and scattered along the river (WDFG 1904, p. 35). On Aug. 20 1921, a number of North Fork chinook were observed spawning in North Fork riffles near Kendall (Norgore and Anderson 1921). North Fork early chinook and the late stock have distribution overlap, but less temporal overlap.

3.2.1.4.4. Fry

Fry are present over the general time frame of early February through early May (Wunderlich et al. 1982), suggesting a prolonged emergence period. Chinook fry have been captured as early as 11/25 in the mainstem and 12/7 in the South Fork (Coe 2005).

After emergence from spawning grounds, most chinook fry disperse downstream to suitable freshwater or estuarine rearing areas, although some take up residence near spawning areas (Healey 1991). Fry typically migrate downstream at night, most likely to reduce vulnerability to predation, although substantial migration also occurs in association with high discharges that can displace fry (Godin 1982; various authors, cited in Healey 1991). Downstream displacement during spring floods can be considerable, unless fry can find refuge in floodplain habitats or low-gradient tributaries in lower reaches. Juvenile chinook were collected from May to June in seven of twenty-one non-natal tributaries sampled in the lower Fraser River basin, ranging from 0.4 to 6.5 km upstream (Murray and Rosenau 1989).

After emergence, chinook fry generally inhabit shallow stream margins, particularly in slow water where they can maintain position and in association with back eddies, undercut banks, or woody debris where they can escape predation (Lister and Genoe 1970). In recent beach seine surveys of the mainstem and South Fork, chinook fry were captured throughout during both winter and spring. Fry surveys conducted during the spring from 1994 to 1996 suggest a shift to off-channel habitats after emergence, especially in the South Fork (Castle and Huddle 1996b). From March to June 1994, spring chinook fry (34-45mm length) were found in more than half of the spring seeps feeding into the South Fork between RM 15.1 and 29.8; these sites were generally small in size, clear, and 5 to 11°F warmer than in the river (Castle and Huddle 1994). Additional areas with high concentrations included side channel complexes, abandoned channels, and terrace tributaries in the reach. Reduced fry abundances in similar surveys in 1995 and 1996 were attributed to reduced availability and connectivity of off-channel habitats since both years were relatively dry (Castle and Huddle 1995; Castle and Huddle 1996a). Chinook fry have also been collected in floodplain tributaries (Landing Strip Creek 3/13/2001, 5/15/2001; Hutchinson Creek 3/19/2001) and other off-channel habitats (Rothenbuhler Slough 4/3/2001; Roos Slough 4/24/2001; Naef 2002) in the Acme to Saxon reach.

3.2.1.4.5. Juvenile Rearing

Distribution of rearing chinook may vary between years depending on abundance of juvenile chinook and other species, hydrologic conditions and resource availability (various authors, cited in Healey 1991). Among mainstem habitats in the Nooksack River, subyearling chinook were captured by beach seine throughout much of the Mainstem Nooksack during winter (RM 0 – 30.9), spring (RM 3.1 – 36.6), and summer (RM 4.4 - 36.6), and throughout the upper mainstem during fall (Rm 27.4 – 36.5); distribution was limited in the lower mainstem during summer and fall (Coe 2005). In the South Fork, subyearling chinook were found throughout the sampled length (Rm 0 – 20.6) during spring and fall, with patchy distribution during winter and summer (Coe 2005). Densities were significantly higher in the South Fork than in the mainstem during summer and fall; densities were greatest in the upper South Fork, followed by lower South Fork, upper mainstem, and lower mainstem (Coe 2005).

Subyearling chinook were found in lower Smith Creek, Anderson Creek, and Fishtrap Creek during fall and in Smith Creek during winter. Snorkel surveys during summer indicate juvenile chinook presence in: (1) Mainstem tributaries: Anderson Creek, Fishtrap Creek; (2) North Fork tributaries: Bell Creek, Kenney Creek, Racehorse Creek, Coal Creek, Maple Creek, Cornell Creek, Gallop Creek, Cascade Creek; (3) Middle Fork tributaries: Canyon Lake Creek, Porter Creek; and (4) South Fork tributaries: Hutchinson Creek, Skookum Creek, Cavanaugh Creek, Deer Creek, Roaring Creek (Coe 2005). Juvenile chinook were also observed during snorkel surveys of Black Slough and Todd Creek near their confluences with the South Fork. From basinwide snorkel surveys, distribution of juvenile chinook in tributaries was most extensive (>1.5 km from mouth) in Skookum Creek, Racehorse Creek, Anderson Creek, Cornell Creek, Maple Creek, and Hutchinson Creek; distribution in the remainder of tributaries was less than 1 km from the mouth (Coe 2005). Stock origin of juvenile chinook present in tributaries, as in mainstem habitats, is unknown at this time. It is unclear how much use of non-natal tributaries occurs, but juvenile chinook use and growth in non-natal tributaries has been documented in the lower Fraser River watershed (Murray and Rosenau 1989).

Snorkel surveys of the South Fork indicate chinook densities were higher in the main channel than at the edges, in moderate and high velocities than low, and in wood than in other cover types (Coe 2005). Surveys of the South Fork Acme to Saxon Rd. bridge reach during summer (Dewberry 2003) found that most of the chinook (71%) were found in pools – which comprised only 43% of available habitat - with 24% and 5% of chinook in runs and riffles, respectively. Chinook were typically found near the heads of pools, with very few in the middle of pools. A substantial proportion of chinook were associated with edge habitat (37%); highest chinook densities in edge habitats were associated with wood (0.069 chinook/m2, almost 5 times higher than densities in riprap edge habitat and over 11 times higher than densities in cobble edge habitat). Juvenile chinook often occupy higher velocity areas midstream than juvenile coho, although there is a strong association with cover (Ecotrust, unpublished data). Snorkel surveys of a reach of the South Fork in 2001 indicate that 76% of the chinook were associated with wood cover, including 51% with complex cover (wood jams and aggregations) and 25% with simple cover (single logs and rootwads) (Ecotrust, unpublished data). Beach seine surveys indicate that catches tended to be higher in backwater eddy pools near the head end of gravel bars, especially in the mainstem Nooksack (Coe 2005).

Chinook that outmigrate as yearlings must survive the higher discharges and velocities and lower temperatures that occur during fall and winter (Morgan and Hinojosa 1996). Chinook often move out of tributary areas in late fall and into the river mainstem where they occupy deep pools or interstitial spaces in the substrate during winter (Healey 1991). Swales et al. (1986) found that chinook salmon abundance in two interior rivers in

British Columbia was generally low but highest in main channel pools containing log debris and very low in riprap areas, side channels, and off-channel ponds. In the Fraser River, Levings and Lauzier (1991; cited in Morgan and Hinojosa 1996) found that juvenile chinook in the Fraser River overwinter along the margins of the mainstem river and feed throughout the winter. Chinook also use interstitial space in the substrate during periods of cold temperature. In field and lab experiments, substantially more juvenile chinook remained in sites to which larger substrate (cobble and rubble) had been added; emigration from study sites was high in areas lacking in suitable substrate (Bjornn 1971; Hillman et al. 1987). Entry into the substrate was correlated with stream temperatures declining to 4 to 8°C. Chinook also appeared to select lower velocities in winter than in summer, avoiding velocities greater than 12 cm/s (Hillman et al. 1987).

3.2.1.4.6. Outmigration

Nooksack chinook salmon outmigrate as fry (migrating to estuaries soon after emergence), fingerlings (rearing for weeks to months, prior to outmigrating to estuaries in spring or summer), or as yearlings. The smolt outmigration period for individual stocks and subpopulations of chinook from the Nooksack is not well defined, although chinook outmigration generally occurs between January and mid-August. From 1994 through 1999, the Lummi Nation has operated a rotary screw trap in the lower Nooksack River at Hovander Park (RM 4.8) from around March 1 through mid-August (Conrad and MacKay 2000). Chinook smolts were identified over this entire period, and outmigration likely began before initiation of trap operations in any given year. On January 14, 2003 twelve chinook fry were enumerated at the mainstem smolt trap (M. MacKay, Lummi Natural Resources, pers. comm. 2003) which demonstrates that some juvenile chinook outmigrate very rapidly after emergence to estuarine areas.

Microsatellite DNA smolt trap assignments to the early populations and late stock were conducted on mainstem smolt trap outmigrants in 1999 and 2000, and the respective abundances of outmigrants were North Fork early population, late stock chinook, and South Fork early population (Young and Shaklee 2002). Kendall Hatchery releases of NF/MF early chinook do not have an external mark such as a fin clip, and it is unknown how much their inclusion biased the results mainstem outmigration stock assignments.

The Nooksack Tribe operates a smolt trap on the lower South Fork, and outmigrating chinook fry were recorded from mid-January through mid-July, which constitutes the entire period of operation (Nooksack Tribe, unpublished provisional data).

Downstream movement of chinook in other systems appears to occur predominantly at night, often in conjunction with periods of high river discharge (various authors, cited in Healey 1991). In the Nooksack River, while the relationship is not strictly linear, higher catches of chinook at the lower main-stem smolt trap generally occur with higher flow (Conrad and MacKay 2000). There is no strong evidence of difference in catch between day and night, although small sample size precludes definitive conclusion. Intraspecific (within-species) competition may also stimulate downstream migration (Healey 1991).

3.2.1.4.7. Estuarine and Nearshore Rearing[5]

There are four life history strategies that have been identified for Puget Sound chinook (Averill et al. 2004): fry migrants, delta fry, parr migrants, and yearling migrants. These strategies are delineated by age upon arrival and residence time in the estuary. Due to gaps in Nooksack estuarine residence data, it is difficult to determine which of the ocean-type strategies are common in the Nooksack estuary. The fourth strategy, exhibited by stream-type chinook juveniles (yearlings), is easier to identify, as they are considerably larger than their fry counterparts. Estuarine residence of these fish cannot be estimated with any degree of certainty, again, due to gaps in sampling data. As a result, Nooksack chinook juveniles in the estuary are referred to as either fry or yearling, based on size.

Estuarine life stage requirements for fry and yearling chinook differ in several ways. Chinook fry require smaller-sized prey items than those that can be assimilated by larger yearling chinook. In the estuary, fry rely on detritivores, shellfish larvae, and soft-bodied items like annelids. Yearlings may also feed on these items, but are capable of additionally preying on larger items such as appropriately sized fish, drift insects, and large larval stage invertebrates. High flows may force fry out of the delta earlier than necessary, and may limit their residence time in the estuary. Low flow refugia within the estuary, such as areas along channel margins, within log assemblages, or in the pools scoured out beneath them, may be more critical to fry than to yearling chinook, given the yearling's improved ability to navigate higher flows. Areas in the estuary that cater to the fry migrant's hydrologic needs include the margins of small side and distributary channels, and blind channels. Fry migrants have more potential predators than their larger yearling counterparts and have a greater need for protective cover from their predators. Undercut bank habitat and overhanging vegetation in scrub shrub and forested wetland landscapes provides protection. Fry-sized chinook have been observed to prefer lower salinity water during the estuarine rearing period; larger fish are better acclimated to tolerate sharp salinity gradients (Healey 1982). Brett (1952) estimates salinity requirements for rearing juvenile chinook salmon between 12-13 ppt. Chinook juveniles are also more tolerant of higher water temperatures than other Pacific salmon; optimum rearing temperatures are between 12-14°C (Brett 1952).

Although larger chinook juveniles are more efficient navigators of high discharge conditions, fry and yearlings both prefer surface waters in shallow flats and deepwater channels (Allen and Hassler 1986). The affinity of juvenile chinook for deep pools prevails in fresh as well as estuarine waters; Roper et al (1994) concluded that fry

[5] Adapted from Lummi Natural Resources (2005) report of Nooksack River estuarine conditions.

migrants were strongly associated with pools in estuarine habitats, and Glova and Duncan (1985) found that juvenile chinook prefer deep reaches of intertidal and estuarine habitats (McNeil 2001). Levy and Northcote (1981) researched the relationship between occurrence and abundance of chinook fry in various marsh habitats according to the physical characteristics of the habitat. Their results suggest that young chinook prefer tidal channels with low banks and many low tide refugia (wood, vegetation). Chinook tended to be associated with larger tidal channels that provided diverse micro-habitats (McNeil 2001).

Fish sampling efforts by Lummi Natural Resources delineated juvenile chinook in the estuary by fry (0-age) and yearling (1+ age) individuals. Fry migrants represent the majority of chinook juveniles migrating through the Nooksack estuary. They arrive as early as December and January, peak in May, and continue through June and July. Fry entering Nooksack estuary and nearshore habitats are a combination of wild and hatchery stocks. Hatchery releases occur in the beginning of May; these fish arrive in the estuary shortly thereafter; determination of origin is difficult. The temporal variation among the fry migrant population does not create significant differences in their estuarine requirements, but coincides with a distinct shift in resource availability and habitat variables. Water temperatures in delta channels disconnected from the river begin to increase in May, some nearing sub-lethal limits, and we observed a slight decrease in benthic invertebrate populations between March and June. Conversely, shelter opportunities improve as riparian vegetation produces leaves and flowers, drift insects populations increase, and kelp revegetates into thick beds used by juvenile salmon for cover.

Juveniles that enter the estuary after rearing for a year or more in freshwater habitats are described as yearling migrants. These fish typically enter the estuary at a length of 80 – 120+ mm fork lengths (Aitkin 1998), and spend a short time in the estuary before moving out to the nearshore. Yearling outmigrants are not common in the Nooksack system. From river and beach seine collections a total of 28 yearlings were caught in 2003, compared to 86 in 2004. These hauls were 0.3% of the total chinook catch in 2003, and 1.4% of the total in 2004. The ratio of hatchery yearling to river-origin yearling chinook present in the estuary is difficult to determine, considering the inconsistency in hatchery marking practices prior to analysis of these data. There seem to be two periods when yearling chinook arrive in the estuary, smaller numbers early in the season, and greater numbers in the mid-season. Most yearlings were caught during the middle of the outmigration season; however, in 2004, there appeared to be an initial period of yearling outmigration in January and early February. These catch results, when compared to fry migrant numbers, may underestimate their abundance in the estuary, in part due to the faster swimming speed of these larger fish and their ability to detect and avoid sampling gear, especially when the water is clear.

3.2.2. Bull Trout (and Dolly Varden)

3.2.2.1. Distribution

The native char distribution map (Figure 3.5) depicts current known and presumed distributions in WRIA 01, including the Nooksack and Chilliwack drainages, which support core spawning populations. The Nooksack and Chilliwack core spawning populations are being divided into local populations by U.S. Fish and Wildlife Service, and are anticipated to substantially refine and update information reflected in the stock descriptions in SASI (WDFW 1998). Most of the current native char habitat in WRIA 1 is in the Nooksack River watershed (69%), followed by the independent coastal tributaries (15%) and Fraser River tributaries (16%; Figure 3.5; Appendix C, Table C3).

3.2.2.2. Stock Characterization

Although these two species of "native char" were previously considered a single species, the bull trout and the Dolly Varden are now formally recognized as two separate species (Cavender 1978; Robins *et al*. 1980; Bond 1992). Genetic analyses can distinguish between the two species (Crane *et al*. 1994; Baxter *et al*. 1997; Leary and Allendorf 1997). Although morphometrics (measurements) and meristic variation (variation in characters that can be counted) can also be used successfully to distinguish the two species (Haas and McPhail 1991), there can be significant error associated with the application of this methodology by improperly trained users (Haas and McPhail 2001). Haas and McPhail (2001) determined that bull trout were much more likely to be misidentified as Dolly Varden (48 percent of the time), than Dolly Varden were to be misidentified as bull trout (2.5 percent of the time) when this methodology was applied.

In the Puget Sound Recovery Unit, Dolly Varden have been confirmed only in the Upper Skagit and Nooksack core areas (McPhail and Taylor 1995; Spruell and Maxwell 2002). Although hybridization resulting in fertile offspring has been documented between the two species in north-central British Columbia in the Peace River (MacKenzie watershed), they appear to be able to maintain distinct genomes (Baxter *et al*. 1997), indicating they can coexist together. It has been hypothesized that resulting hybrids are selected against because they are intermediate in their behavior, ecology, and morphology, and therefore cannot compete effectively against their parental forms (McPhail and Taylor 1995). McPhail and Taylor (1995) noted that in the Skagit River drainage upstream of Ross Lake, Dolly Varden are a small char (rarely exceeding 200 mm) that appeared to primarily eat aquatic insects, and predominated in tributary streams. In contrast, bull trout were much larger in size (not maturing until over after reaching 400 mm in length), appeared to be primarily piscivores (fish-eaters), and made size-related movements between the main river, tributary streams, and eventually the reservoir. A high percentage of the examined individuals were determined to be hybrids, although the species are maintaining themselves as distinct and separate entities, implying strong selection against hybrids (McPhail and Taylor 1995). Native char in other parts of Puget Sound including the lower Skagit drainage have been determined to be bull trout (Spruell and Maxwell 2002). In Western Washington, a number of genetics analyses of the large bodied native char that constitute migratory populations, including anadromous native char, have determined that they are bull trout. The Coastal-Puget Sound Distinct Population Segment of bull trout is the only recovery area in coterminous United States that includes anadromous life history forms (USFWS 2004).

All bull trout and Dolly Varden populations in the Nooksack and Chilliwack watersheds are native and wild. There are no records or reports of hatchery supplementation of native char in WRIA 01.

3.2.2.2.1. Nooksack Bull Trout and Dolly Varden

The Nooksack drainage contains populations of both bull trout and Dolly Varden; however, there is currently an incomplete understanding about the level of interaction between the two species and degree of overlap in their distribution. Limited genetic analysis and observational data suggest Dolly Varden in this core area primarily inhabit stream reaches above anadromous barriers. Native char collected from the Nooksack River within reaches currently or historically accessible to anadromous salmonids have been identified as bull trout, based on genetic analysis of a small number of samples collected from the upper South Fork Nooksack River (S. Young, WDFW, pers. comm. 2003, as cited in USFWS 2004), and on morphometric and meristic analysis by Dr. Gordon Haas of two individuals collected in the upper Middle Fork Nooksack River (STS Heislers Creek Hydro L.P. 1994). Nooksack River bull trout include the anadromous life history form (Lummi Nation, *in litt.* 2003, Barclay 1981), probably include the fluvial life history form, and may possibly include the resident life history form.

Morphometric and meristic analysis of native char from an isolated resident population located upstream of a barrier falls in Canyon Creek in the North Fork Nooksack River determined them to be Dolly Varden (D. Markel, Oregon State University, pers. comm. to Brady Green, U.S. Forest Service, 1985). Genetic analysis of tissue samples from this population confirmed them as Dolly Varden (Leary and Allendorf 1997). Additional tissue samples collected from native char in upper Canyon Creek (above barrier falls), one of its tributaries named Kidney Creek, and from a resident population in the South Fork headwater stream, Bell Creek, were also determined to be Dolly Varden (Spruell and Maxwell 2002). Additionally, genetic analysis of a small number of samples collected from a resident population in another tributary to the South Fork Nooksack River, known as "Pine Creek", were determined to be Dolly Varden (S. Young, WDFW, pers. comm. 2003). There is a single report from the mid 1980's of native char in the North Fork Nooksack River upstream from Nooksack Falls, above and below the confluence with White Salmon Creek, and within the lower part of this creek (B. Green, US Forest Service, pers. comm. 2003). If this population persists, they are considered likely to be Dolly Varden. Further investigation of headwater streams may result in identification of additional isolated resident Dolly Varden populations.

Nooksack bull trout spawning occurs in the North, Middle, and South Fork drainages, although, comprehensive spawn surveys have not been conducted within the Nooksack watershed. While limited survey data was very recently collected by Washington Department of Fish and Wildlife and U.S. Forest Service in a small number of streams, data are not yet sufficient to estimate spawner abundances. While tributaries with spawning and rearing are described, other unsurveyed adjacent and accessible tributaries are probably utilized.

In the North Fork Nooksack River, anadromous size adult bull trout have been recorded nearly to Nooksack Falls (D. Sahlfeld, WDFW, pers. comm. 2003). While visibility is generally poor, spawning has been observed in upper North Fork side-channels, and accessible reaches North Fork tributaries. Accessible tributaries with recorded bull trout redds, large adults observed during or prior to the spawning period, or juveniles include Wells Creek (Huddle 1995, FERC 1997), "Powerhouse Creek" (a small, low gradient tributary which enters the river just downstream from the Excelsior hydroelectric powerhouse) (D. Huddle, WDFW, pers. comm. 2003), Deadhorse and Cascade Creeks (Huddle 1995, WDFW and USFS, Nooksack Basin spawn survey records 2001-2002),"Ditch Creek" and a side channel immediately downstream of 'Ditch Creek" (D. Huddle, WDFW, pers. comm. 2002) "Chainup Creek"(D. Sahlfeld, WDFW, pers. comm. 2002), Deerhorn Creek (on USGS map, Lookout Creek in WRIA Catalog) (D. Huddle, WDFW, pers. comm. 2002), and Boyd Creek (Huddle 1995).

In the Glacier Creek watershed, migratory size bull trout have been recorded spawning in Thompson and Falls Creeks (WDFW and USFS, Nooksack Basin spawn survey records 2002), Coal Creek, and in a series of small left bank spring-fed tributaries downstream of Coal Creek (D. Huddle, WDFW, pers. comm. 2002), and in Little Creek (J. Schuett-Hames, Dept. of Ecology, pers. comm. 1999, as cited in USFWS 2004). Spawning probably occurs in Glacier Creek and several additional tributaries including an unnamed tributary (WRIA 01.0476) which enters Glacier Creek at RM 4.3, and Deep Creek (D. Huddle, WDFW, pers. comm. 2002), and small juveniles have been observed in lower Davis Creek suggesting spawning also occurs there (B. Green, US Forest Service, pers. comm. 2003).

There is an anecdotal report of bull trout spawning in a side-channel downstream of Glacier Creek (G. Dunphy, Lummi Natural Resources, pers. comm. 2002). Bull trout and redds have been recorded in Gallop Creek (Huddle in litt. 1995; D. Salhfeld, WDFW, pers. comm. 2003) and in a tributary to Gallop referred to as "Son of Gallop Creek"(D. Huddle, WDFW, pers. comm. 2002). Cornell Creek does not have recent records of bull trout, although native char were historically reported to use it (Norgore and Anderson 1921). Redds have also been recorded in Cornell Slough (Huddle, *in litt.*

1995), adults have been observed in Hedrick Creek (D. Huddle, WDFW, pers. comm. 2003), and adults and juveniles have been recorded in Canyon Creek (Zyskowski 1991, D. Huddle, WDFW, pers. comm. 2002) and Boulder Creek (Johnston 2000). While not surveyed, the accessible reaches of several north-facing tributaries including Wildcat, "McDonald," and "Aldrich" Creeks are presumed to support spawning and rearing (DNR 1995). A young of the year juvenile was caught in lower Wildcat Creek in 2004, and other juveniles were caught in the side channel downstream of the confluence (Nooksack Tribe, unpublished data). Adult bull trout have been observed in "McDonald Creek" (D. Huddle, WDFW, pers. comm. 2002). Adult bull trout have been observed in Maple Creek, Kenney Creek, and at the Kendall Creek Hatchery rack (D. Huddle, WDFW, pers. comm. 2003), although spawning has not been confirmed, and they may have been foraging. All accessible productive salmon streams are presumed to support foraging for subadult and adult bull.

Bull trout in the Middle Fork Nooksack River occur upstream and downstream of the City of Bellingham's unladdered diversion dam, which is located at RM 7.2. The Middle Fork's average gradient is 2.4 percent over its lower 28 kilometers (17.4 miles), with no natural barriers to adult migration to at least river mile 17.8 (STS Heislers Creek Hydro L.P. 1994). The lowest 10.9 kilometers (6.8 miles) transition upstream from a very low gradient braided channel to a more moderate gradient channel. At approximately river mile 6.8, the river exits from a 0.8-kilometer (0.5-mile) long bedrock gorge called Box Canyon. At its narrowest, the river is 9 feet wide in the gorge (Barclay 1989). In 1987, a landslide temporarily blocked fish passage, although it was restored in a subsequent flood. No permanent features block passage through the gorge (Barclay *in litt.* 1989). Norgore and Anderson (1921) also reported no falls greater than 3 feet high, and concluded there were no passage barriers. The diversion dam is located approximately 250 feet above the upstream entrance to the gorge. Constructed around 1960, this dam is 3.6 to 4.3 meter (12 to14 feet) high and diverts water from the Middle Fork Nooksack River to Lake Whatcom. The Middle Fork is accessible to river mile 17.5, approximately 0.4 kilometer (0.25 mile) upstream of Ridley Creek, with the reach between Wallace and Clearwater Creeks the lowest gradient portion above the diversion dam, averaging 2 to 3 percent (STS Heislers Creek Hydro L.P. 1994).

Salmon and trout, including what appeared to be a bull trout have been incidentally observed jumping at or over the diversion dam in 1986, 1992, 1993 (STS Heislers Creek Hydro L.P. 1994; Currence 2000), and in 2001 (del Corral 2001; E. Zapel, Northwest Hydraulics Consultants, pers. comm. 2001). A fisherman reported catching a 483-millimeter (19 inch) bull trout downstream of the Sven Larson Bridge (located upstream of the diversion dam at river mile 9.7) in the early 1990's (D. Huddle, WDFW, pers. comm. 2002). The size of this fish suggests it was anadromous. Upstream of the diversion dam, several creeks such as Sisters Creek and Clearwater Creek contain substantial low gradient habitat upstream from steeper cascades that are likely only passable to anadromous bull trout. Abundances and use are expected to change when full passage is restored at the City of Bellingham diversion dam.

In 1993, juvenile bull trout were caught in the upper Middle Fork Nooksack River and in side channels near river mile 13 (STS Heislers Creek Hydro L.P.1994). Two of these fish were submitted for morphometric and meristic analysis and were determined to be bull trout (STS Heislers Creek Hydro 1994; M. Barclay, Devine Tarbell and Associates, pers. comm. 2003). Two bull trout were also caught and released between river miles 10 and 11 in October 2000 (J. Lee, Whatcom County River and Flood, pers. comm. 2003).

Resident size native char were observed spawning in the mid-1970s in lower Green Creek (C. Kraemer, WDFW, pers. comm. 2002). Norgore and Anderson (1921) also reported advanced fry in a tributary between Green and Ridley Creeks, which they referred to as "Ward Creek," indicating nearby spawning. This creek was most likely Rankin Creek. Juvenile native char were also observed during electrofishing in the mid-1970s in lower Wallace Creek (C. Kraemer, WDFW, pers. comm. 2002). A low gradient right bank tributary that enters the Middle Fork near, and upstream, from Wallace Creek is also presumed to support bull trout spawning and rearing. A number of observations indicate spawning and rearing in lower Warm Creek (Norgore and Anderson 1921; J. Johnston, WDFW, pers. comm. 1999 as cited in USFWS 2004; C. Kraemer, WDFW, pers comm. 2002; FERC 2002). Norgore and Anderson (1921) also reported native char in Sisters Creek. Pautzke (1943) reported native char in Galbraith Creek**.** In 1986, resident-sized native char were reported spawning in Clearwater Creek at about river mile 2.5 (J. Johnston, WDFW, pers. comm.1999, as cited in USFWS 2004). Rocky Creek is low gradient and accessible with spawning and rearing presumed to be present in it. Ridley Creek is accessible (Nooksack Tribe unpublished data 2003), and affords substantial low gradient, high quality habitat (B. Green, U.S. Forest Service, pers. comm. 2003). Spawning and rearing are also presumed in Rankin Creek, an unnamed right bank tributary entering about a mile downstream of Warm Creek, another unnamed tributary entering the river 0.3 kilometer (0.2 mile) upstream of Seymour, and in a tributary that enters just upstream of the Sven Larson Bridge at mile 10.

Downstream from the diversion dam, anadromous size pre-spawning and post-spawning adults were observed in the 1970's at the outlet of Box Canyon (C. Kraemer, WDFW, pers. comm. 2002). A bull trout about 12 inches (sub-adult) was caught in October 2000 about 0.5 miles downstream of the outlet of the gorge (J. Lee, Whatcom County River and Flood, pers. comm. 2003). Spawning is presumed to occur in and downstream of the gorge. While not a total barrier to all anadromous fish, the diversion dam impedes bull trout migration to upstream habitats.
Juveniles were recently captured at approximately river mile 2.5 (Anchor Environmental, *in litt.* 2002). It is unknown whether these are progeny from local spawning or from the Upper Middle Fork. Norgore and Anderson (1921) and Pautzke

(1943) mentioned native char use in Canyon Lake Creek. Use is presumed in the Porter, Peat Bog Creek and an unnamed tributary (sometimes referred to as "Bear Creek") that enters just downstream of Peat Bog Creek, and in the right bank tributary that enters just upstream of Canyon Lake Creek.

The South Fork is the non-glacial fork, although it is fed by snowpack from Twin Sisters Mountain. It is predominately very low gradient, although is has confined reaches at Dyes Canyon (river mile 16 to17), Sylvester's Canyon (river mile 25), and near river mile 30.5. Although Sylvester's Falls (river mile 25) is approximately 3.4 meters (11 feet) tall, the presence of very large adults in the upper South Fork indicate that these falls, and the cascades at river mile 30.4 are passable to anadromous bull trout (in addition to summer run steelhead). Upstream from river mile 30.4 the river is again unconfined and low gradient, up to its headwaters above Elbow Creek.

Large adult bull trout have been observed up to about river mile 38 in the mainstem near the confluence with Elbow Creek (S. Zyskowski, National Park Service, pers. comm. 2003). Norgore and Anderson (1921) caught native char in the same general area, 2.5 miles downstream from Elbow Lake. The South Fork is accessible to at least the confluence of the major unnamed tributary that lies upstream of Elbow Creek (D. Huddle, WDFW, pers. comm. 2003). Spawning and rearing are presumed in these areas, and in the accessible portions of tributaries. Large adults, presumed to be anadromous, were observed spawning in the South Fork near Bell Creek in the 1970's (C. Kraemer, WDFW, pers. comm. 2002). In the 1990's tissue was collected from two fish (both approximately 200 mm) captured upstream of the 1260 road bridge (~ river mile 36) during night surveys (S. McGrath, WDFW, pers. comm. 2003). Genetic analysis determined that these were bull trout, while the samples from an isolated population of resident char in a nearby tributary called "Pine" Creek were determined to be Dolly Varden (S. Young, WDFW, pers. comm. 2003, as cited in USFWS 2004). Bell Creek has an impassible falls located at approximately river mile 0.25 (B. Green, U.S. Forest Service, pers. comm. 2003). Norgore and Anderson (1921) caught native char in Bell Creek, presumably downstream of these falls. Tissue samples from the resident native char population above the falls were determined to be Dolly Varden (Spruell and Maxwell 2002). Bull trout to 24 inches have also been observed during mainstem snorkel surveys at about river mile 36 (S. Zyskowski, National Park Service, pers. comm. 2003), and two adult bull trout were observed during recent spawner surveys conducted from mile 34.0 to 34.3 (WDFW and USFS, Nooksack Basin spawn survey records 2002).

Anadromous size bull trout were caught in Wanlick Creek, downstream of Monument Creek, during hook and line surveys (D. Huddle, WDFW, pers. comm. 2002). In 2002, an adult bull trout (~711 millimeters/28 inches) as well as multiple age classes of juveniles were observed during a snorkel survey of a small portion of the stream reach downstream of "Monument" Creek (Ecotrust, unpublished 2002 data). Bull trout to 16-

18 inches and young juveniles have been observed in Loomis Creek (S. Zyskowski, National Park Service, pers. comm. 2002 and 2003; D. Huddle, WDFW, pers comm. 2003). "Monument" Creek also supports spawning and rearing, as juvenile age classes were observed during 2002 snorkel surveys (Ecotrust, *in litt*. 2002).

A potential bull trout redd was observed in the first small right bank stream that enters the South Fork Nooksack River downstream from Wanlick Creek (D. Salhfeld, WDFW, pers. comm. 2002). Spawning bull trout have also been observed in the short accessible reach of the stream draining Bear Lake (D. Huddle, WDFW, pers. comm. 2002). Norgore and Anderson (1921) caught native char in lower Howard Creek. Adult bull trout were observed in the river between mile 25 and mile 30 in September 1990 and in September and October 1992, suggesting spawning occurs nearby. A newly emergent young-of the-year juvenile was caught in the river near river mile 20, off the mouth of Deer Creek around spring 2001 (G. Dunphy, Lummi Natural Resources, pers. comm. 2002). A dead adult bull trout was observed in lower Cavanaugh Creek in 2002 (Ecotrust, *in litt*. 2002). A juvenile was observed in lower Edfro Creek during electrofishing in the late 1970's (Curt Kraemer, WDFW, pers. comm. 2002). Bull trout have also been observed in lower Hutchinson Creek (G. Dunphy, Lummi Natural Resources, pers. comm. 2002; Coe 2003). Spawning and rearing is presumed in the other short accessible reaches of the other streams between Wanlick and Hutchinson Creeks. It is undetermined how far downstream in the South Fork bull trout spawn, but temperatures elevate progressively downstream, with spawning likely limited to cooler tributaries.

Hutchinson Creek is a large tributary with abundant, accessible, low gradient habitat to an 8-foot falls, which is located about mile 5.7 (DNR 1998). Pautzke (1943) reported that Hutchinson Creek supported a fair population of native char. Small juveniles have been captured in Hutchinson Creek downstream from a cascades located at mile 0.8 (Maudlin et al. 2002). A sub-adult was also recorded in this reach in the 1970's (C. Kraemer, WDFW, pers. comm. 2002). Recent snorkel surveys recorded juvenile bull trout upstream of river mile 5 (Ecotrust, *in litt*. 2002). These observations indicate migratory bull trout also spawn in upper Hutchinson Creek, as these juveniles are unlikely to ascend the cascades at river mile 0.8. There are several low gradient tributaries in this area draining Bowman Mountain, and spawning and rearing is presumed to occur in these systems.

The tributaries downstream from Hutchinson Creek are considered unlikely to support spawning and rearing as they have lower elevation settings more subject to thermal heating, are smaller, and have relatively short accessible reaches. Use in the lower South Fork, the mainstem Nooksack River and tributaries to both rivers consists of foraging by sub-adults and adults, upstream and downstream migration and overwintering. Observations of bull trout use of freshwater floodplain habitats have been recorded in the lower end of the Black Slough, which is a lower South Fork

Nooksack River tributary (Nooksack Tribe, unpublished 2002 data) and below a beaver dam area in an unnamed South Fork slough (Castle and Huddle 1994); and in a mainstem Nooksack River side-channel with combined flow from the river and Anderson Creek (Coe 2003), in the North Fork Nooksack River watershed, where spring fed waters enter a Glacier Creek overflow channel (Brady Green, USFS, pers. comm. 2003). Productive salmon streams provide important forage for bull trout. Marine nearshore habitats adjacent to WRIA 01, including forage fish spawning areas, are considered very important foraging areas for anadromous bull trout. Mainstem areas, including productive spawning areas such as the lower North Fork which supports disproportional chum spawning, are considered very important forage and overwintering areas (P. Castle, WDFW, pers. comm. 2003).

3.2.2.2.2. Chilliwack Bull Trout and Dolly Varden

Tissue samples collected from Chilliwack Lake have been identified the native char as bull trout based on genetic analysis, although Dolly Varden are also known to exist within the Fraser River system (Nelson and Caverhill 1999). The bull trout within the Chilliwack system are believed to express fluvial, adfluvial, and potentially resident and anadromous life histories (D. Jesson, British Columbia Ministry of Water, Land and Air Protection, pers. comm. 2002). An isolated resident population of native char has also been identified in Tomyhoi Creek, however, it has not been determined whether these are bull trout or Dolly Varden. This population is isolated above a complete anadromous barrier (Teskey 1986), so they are currently believed to be Dolly Varden based on their isolation above a natural barrier, which is a comparable situation to Dolly Varden populations found in the Upper Skagit and Nooksack Rivers. Tomyhoi Creek and one of its tributaries, Damfino Creek, initiate from the Mount Baker Wilderness in the United States and flow northwest into Canada. Similar to the Nooksack drainage, an extensive survey effort for bull trout has not yet occurred within the upper Chilliwack River system, making it difficult to estimate spawner abundance (R. Glesne, National Park Service, pers. comm. 2002). However, limited survey efforts have helped determine distribution (M.A. Whelen and Associates Ltd and TSSHRC 1996; Nelson and Caverhill 1999; Doyle et al. 2000).

In the upper Chilliwack River, rearing bull trout (juveniles) have been observed in the mainstem Chilliwack River from Chilliwack Lake upstream to approximately Easy Creek (R. Glesne, National Park Service, pers. comm. 2002). Limited spawning has also been documented in the mainstem of Chilliwack River above Chilliwack Lake (Doyle et al. 2000), and suitable spawning habitat in the mainstem is believed to span from approximately 3.2 kilometers (2 miles) above Chilliwack Lake upstream to an area just above Easy Creek (R. Glesne, National Park Service, pers. comm. 2002). Accessible habitat on the mainstem Chilliwack River ends approximately 3.2 kilometers (2 miles) upstream from Easy Creek, near the confluence with Copper Creek. In 1999, a bull trout was observed in Indian Creek during limited National Park Service surveys (Doyle et al. 2000). Although bull trout were not observed within Bear Creek and Brush

Creek during recent limited survey efforts, habitat in their lower reaches is clearly accessible and likely provides some spawning and rearing habitat. Bull trout were observed near the mouth of Bear Creek, within the lower reaches of Brush and Easy Creeks, and throughout Indian Creek in the mid 1970's (Glesne 1993). Although native char presence has been documented in Little Chilliwack River, spawning has not yet to been confirmed in this tributary (R. Glesne, National Park Service, pers. comm. 2002). The Little Chilliwack River is thought to be accessible to approximately river mile 6 and river mile 3.5 on its major tributary, the Little Fork; however, this has not been verified with field surveys (S. Zyskowski, National Park Service, pers. comm. 2003). Habitat is essentially pristine, and likely supports some level of spawning. Spawning and rearing distribution is incomplete for Silesia Creek. Juvenile and young-of-year bull trout have been observed in British Columbia reaches, while spawning and rearing is assumed to extending upstream to all accessible reaches in the United States. It is unknown what proportion of the Silesia Creek population spawns within Washington.

In British Columbia, bull trout spawning is also believed to occur in Depot and Paleface Creeks based on the juvenile life stages (young-of-year and age one +) that have been documented rearing in these streams (D. Jesson, British Columbia Ministry of Water, Land and Air Protection, pers. comm. 2002). The upper extent of bull trout spawning and rearing use in Depot Creek is currently uncertain since neither fish nor habitat surveys have been conducted in reaches within United States. Accessible habitat occurs upstream as far as the United States-Canada border (M.A. Whelen and Associates Ltd and TSSHRC 1996), while topographic maps indicate approximately 3.2 kilometers (2 miles) of additional accessible habitat upstream of this point. In addition to Depot and Paleface Creeks, several other tributaries to the mainstem Chilliwack River between Silesia Creek and the outlet of Chilliwack Lake are known to support bull trout, as young of the year and 1+ juvenile bull trout have been observed in them (Foley Creek, a tributary to Foley Creek named Airplane Creek, Borden Creek, Centre Creek, and Newakwatch Creek (M.A. Whelen and Associates Ltd and TSSHRC 1996).

Migratory bull trout in the Chilliwack system spend all or part of their subadult and adult lives either in the mainstem of the Chilliwack River, Chilliwack Lake, and Fraser River. If anadromous forms exist in this population, they would also use nearshore waters of the Strait of Georgia. All these areas provide foraging, migration, and overwintering habitat, however, Chilliwack Lake appears to be very important to the majority of local populations in this system. Both sockeye and kokanee use the lake to rear, and either the lake’s tributaries (kokanee) (Nelson and Caverhill 1999) or Upper Chilliwack River system (sockeye) to spawn (Doyle et al. 2000). They provide an important source of forage for bull trout in this part of the Chilliwack River basin. Migratory bull trout may potentially forage within the Sumas River and other tributaries that are accessible to migratory forms, but distribution and extent of use within these systems is not well known. Native char have been reported in the Sumas River tributary, Lonzo Creek, within British Columbia (Norecol, Dames & Moore, Inc.

1999). Although the Sumas River is a highly productive anadromous salmon system, it is unlikely that bull trout spawning or rearing occurs in the Sumas River or its tributaries given the relatively low elevation of this drainage.

3.2.2.3. Population Status

Estimates of adult abundances are not available for either the Nooksack or Chilliwack drainages. The WDFW listed all native char in these drainages as unknown stock status (WDFW 1998). In the late 1980s, two indexes were established in Puget Sound due to concerns about apparent declines (South Fork Sauk, upper North Fork Skykomish River) (Kraemer 1994). To date, no index areas have been established in WRIA 1, although some spawning reaches have been fairly consistently surveyed. All observations of spawning adults and redds in the Nooksack drainage during spawn surveys have recorded only modest numbers. The greatest single day count of adults that has been recorded is 22 adults and 9 redds recorded in Thompson Creek during spawn surveys in 2002 (WDFW and USFS, Nooksack Basin spawn survey records 2002).

While abundance estimates are not available in any of the three forks, relative abundances appear to increase moving upstream, and higher in elevation, in the accessible reaches. Native char were the most common species collected in a proposed hydropower bypass reach in Glacier Creek from approximately river mile 3.5 to 5.6 (FERC 1997). They were described as relatively common in the upper Middle Fork, apparently more abundant in upstream reaches (STS Heislers Creek Hydro L.P.1994). Daytime snorkel surveys in Wanlick and “Monument” Creeks in the upper South Fork recorded the greatest number of bull trout juveniles of any tributaries they snorkeled (Ecotrust, *in litt*. 2002). While comparisons between descriptions from 1921 (Norgore and Anderson) and 1943 (Pautzke) and contemporary observations need to be made cautiously, it seems likely that abundances, or even spawning distributions, are diminished in tributaries located further downstream in the respective forks relative to earlier accounts. Limited USFS snorkel surveying in upper Canyon Creek suggests that the resident Dolly Varden are appreciably more numerous than the migratory bull trout located downstream of the anadromous barrier.

Creel census data for Chilliwack Lake can provide a conservative minimum combined estimate for Depot and Paleface Creeks and the Little Chilliwack and Upper Chilliwack Rivers, assuming that the majority of bull trout captured in the lake spawn in one of these four systems. In 1998, a lake angler survey conducted by LGL Limited Environmental Research Associates estimated that 731 bull trout were captured during their May 23 to September 29 sampling period. It was noted, however, that a key spring fishery on bull trout that occurs in April and May was missed by the sample period, so overall annual catch may be significantly higher. Length-frequency distribution of bull trout sampled in the survey (n=166) show that 90 percent of those captured were greater than 350 millimeters (13.8 inches) in length (Nelson and Caverhill 1999). Assuming that bull trout equal to or greater than 350 millimeters (13.8 inches) are likely sexually mature, then approximately 658 mature adults were caught during the sample period. Based on this estimate, we believe the Depot Creek, Paleface Creek, Little Chilliwack River, and Upper Chilliwack River local populations support at least 1,000 adult spawners, and the Chilliwack (excluding British Columbia areas) likely supports a minimum of between 500 and 750 adult spawners when including Silesia Creek.

3.2.2.4. Life History Patterns

Appendix D reflects the periodicity of the various life stages of bull trout and Dolly Varden in WRIA 1. Bull trout exhibit both resident and migratory (fluvial, adfluvial, anadromous) life-history strategies, although in WRIA 1, only migratory life-history strategies have been confirmed, with resident native char, thus far, identified as Dolly Varden. Resident native char complete their entire life cycle in tributary (or nearby) streams. Migratory bull trout spawn in tributaries, or upper rivers, where juvenile fish rear one to four years before migrating to either a lake (adfluvial form), river (fluvial form) (Kraemer 1994), or to saltwater (anadromous form). Nooksack bull trout include the anadromous form, and most likely the fluvial form, and possibly the resident form. Scale reads from Skagit drainage bull trout show evidence of shifts in life history forms by individual fish based on growth patterns (e.g. anadromous shifting to fluvial, resident shifting to migratory) (Kraemer 2003). The bull trout within the Chilliwack system are believed to express fluvial, adfluvial, and potentially resident and anadromous life histories. Chilliwack Lake supports one of only two naturally occurring adfluvial populations in the Puget Sound area.

All life forms can be long lived and spawn a number of times. Fluvial and anadromous bull trout in the Skagit drainage mostly reach sexual maturity at age 4, with rare fish maturing at age 3 or 5 (Kraemer 2003). The bull trout spawned annually once they reached maturity, and 48% and 59% of fluvial and anadromous fish, respectively had spawned at least twice previous to being evaluated. Individual fish can reached an age of at least 10 years. Excepting isolated resident populations, spawning populations can include a mixture of life history forms, and even have small resident males spawn with large fluvial or anadromous females. Resident native char are small, reaching sexual maturity at a length of about 200-250mm, fluvial bull trout at about 350mm, and anadromous fish on average between 425 and 450mm (Kraemer 2003). Adfluvial bull trout also reach very large sizes with age. Among resident, fluvial, and anadromous fish, the anadromous ones show the fastest growth, and may grow more than 25 mm per month in the March through May period that they are typically foraging in estuaries or along nearshore areas (Kraemer 1994). During this period, they can be 30 or 40 km from river mouths.

3.2.2.4.1. Upstream Migration

After overwintering in lower mainstem areas (including large pools), anadromous bull trout enter salt water as early as late February to forage for several months. Kraemer (1994) reports that mature and maturing adults then begin their upstream migrations in late May, June, or early July, although they have also been reported to begin upstream migrations as early as April (Fraley and Shepard 1989). Radiotagging from the Skykomish drainage found that when migration to the upper watershed occurred, they typically moved 2-3 km per day, and in the lower river fish may travel even faster (Kraemer 1994). Migration can occur at any light, but most movement seemed to occur during low light periods just after dawn or before sunset during the low flow migration period of summer and fall. Water temperatures above 15 deg. C. (59 deg. C.) are generally thought to limit bull trout distribution (Fraley and Shepard 1989; Rieman and McIntire 1995). Adult, pre-spawning migrations eventually lead to upper watershed spawning areas.

Sub-adults that re-enter freshwater after a few months of marine rearing do so somewhat later than adults, and do not migrate to their natal streams to spawn, as they are not sexually mature. These fish typically spend spring and most of the summer in marine areas where they rapidly grow (25-40 mm per month), then in late summer and early fall they re-enter freshwater to forage in mainstems and their tributaries (Kraemer 1994). At this stage they are 250-350 mm, and after overwintering in the lower river system, they again outmigrate to salt water the following late winter or spring.

3.2.2.4.2. Holding

During the upstream migration phase, fish hold during periods when they are not moving. If stream temperatures are elevated, they may occupy local thermal refugia if it exists, such as cooler tributaries or thermally stratified pools. As spawning grounds are approached, fish then stage in holding areas. Prior to spawning, adult bull trout stage in holding areas near spawning grounds, and these holding areas are often deep pools, long runs with cover, undercut banks, or log jams (Kraemer 1994). They stay in the same general area, even the same pool, for several months. Sometimes adults are concentrated in a few holding areas, and many holding areas have groundwater upwelling. With dropping water temperatures adults migrate from these holding areas to the spawning areas.

Overwintering adults and sub-adults are generally found in relatively quiet waters of large pools and long slow runs of mainstems, typically in pools and runs in 1-2 meters of water. In November and December it is common to find some char with spawning salmon, especially chum. While growth generally does not occur during winter, foraging occurs, and survivors regain their body condition (Kraemer 1994). Bull trout are known to feed on dislodged eggs and other food sources while chum and pink salmon spawn. In the Skagit drainage, faster annual growth occurred, especially for fluvial fish, during years when odd-year pink salmon provided more abundant forage opportunities including eggs, fry, and carcasses (Kraemer 2003).

3.2.2.4.3. Spawning

Adult bull trout spawn in the upper portions of watersheds in late summer through fall, often at the extreme upper limits of anadromous waters (Kraemer 1994). Spawning commences as water temperatures drop to about 8 degrees C. (Kraemer 1994), and spawning areas are often associated with cold-water springs, groundwater infiltration, and the coldest streams in a watershed (Pratt 1992; Rieman and McIntire 1993; Rieman et. 1997; Baxter et al. 1997). Preferred spawning habitat consists of low gradient reaches with loose, clean gravel (Fraley and Shepard 1989). However, since they spawn in the upper watershed, they are frequently found in higher gradient streams with limited spawning gravels (Kraemer 1994). Generally, fish complete spawning in a day or two, and following spawning migratory bull trout (anadromous, fluvial, adfluvial) quickly leave spawning areas, moving downstream to mainstem areas.

3.2.2.4.4. Emergence

Optimal water temperatures for incubation are 2-4 deg. C. Because bull trout spawn in cold streams in late summer or fall as temperatures are dropping, they have very long incubation periods. In North Puget Sound, most native char emerge from the gravel during late April through May (Kraemer 1994).

3.2.2.4.5. Juvenile Rearing

Juvenile bull trout, particularly young of year, have very specific habitat requirements. In large rivers, the highest abundance of juveniles can be found near rocks, along the stream margin, or in side channels (Pratt 1985, 1992; Goetz 1994). Juveniles show preferential use of side channels based on their size and the distance from their point of emergence with fry using smaller side channels, age 1+ fish using slightly larger channels within natal streams, while age 2+ and age 3+ juveniles can be found at a significant distance from natal areas in moderate to large off-channel habitat areas in larger streams and major rivers. Early rearing for char in North Puget Sound occurs near their parental spawning areas, and fry are associated with large substrate (cobbles, boulders), or large woody debris including root wads (Kraemer 1994). These fish frequently hide during the day, especially if other species of salmonids are present. After two or three years in these headwater early rearing areas, migratory bull trout (fluvial, adfluvial, anadromous) move downstream, possibly to seek improved forage opportunities. At this stage they are referred to as sub-adults, and those that migrate down and take up residence in rivers are fluvial, in lakes (including Chilliwack Lake) are adfluvial, and that outmigrate to sea are anadromous. Fluvial sub-adults can be found anywhere within accessible portions of a watershed, and are typically associated with the deepest pools. In North Puget Sound, many sub-adults become anadromous (Kraemer 1994). Once reaching adulthood (age 4) migratory forms return to headwater streams and rivers (including side channels) to spawn. All life-history stages of bull trout are associated with complex cover, including large woody debris, undercut banks, boulders, and pools (Fraley and Shepard 1989; Goetz 1989; Hoelscher and Bjornn 1989;

Sedell and Everest 1991; Pratt 1992; Thomas 1992; Rich 1996; Sexauer and James 1997; Watson and Hillman 1997).

Anadromous and fluvial life history forms typically have widely distributed foraging, migration, and overwintering habitat. In freshwater, important forage include loose salmon eggs, salmon fry and smolts, sculpins, whitefish and other small fish (Kraemer 1994). Foraging juvenile and subadult bull trout can migrate throughout a watershed looking for these feeding opportunities. Freshwater foraging habitat may be found anywhere in the watershed downstream of spawning areas and accessible to anadromous salmonids. Bull trout also use non-natal watersheds (e.g. Sumas, Samish, or Whatcom Creek drainages) to forage, migrate, and potentially overwinter. Both freshwater floodplain habitats and tidally influenced areas are believed to play an important role in maintaining fluvial and anadromous populations of bull trout.

Migratory (fluvial, adfluvial, and anadromous) bull trout use of off-channel habitats in floodplain areas (freshwater and tidally influenced) has been studied little in larger mainstem rivers. Prior to 2002, reports of bull trout use of floodplain habitats in western Washington were generally unavailable. Recent review of grey literature and personal contacts show there is increasing information available demonstrating subadult and adult bull trout use of lower elevation floodplain habitats. Bull trout use of freshwater floodplain habitats have been recorded in the lower end of the Black Slough, in the lower South Fork Nooksack drainage (Nooksack Tribe, unpublished 2002 data) and below a beaver dam area in an unnamed South Fork slough (Castle and Huddle 1994) and in a mainstem Nooksack River side-channel with combined flow from the river and Anderson Creek (Coe 2003), and in the North Fork Nooksack River watershed, where spring fed waters enter a Glacier Creek overflow channel (Brady Green, U.S. Forest Service, pers. comm. 2003).

3.2.2.4.6. Outmigration

Anadromous outmigrants have been caught in the lower Nooksack River smolt trap at Hovander Park from early April through late August (Lummi Nation, unpublished data 1994-2002). Most first time juvenile (sub-adult) outmigrants are believed to outmigrate as two year olds.

3.2.2.4.7. Estuarine/Nearshore

In marine waters, the principle forage is surf smelt and other small schooling fish (e.g., sandlance, herring, surf perch), and juvenile salmonids such as pink and chum smolts (Kraemer, 1994; H. Berge, King County Dept. of Natural Resources and Parks, pers. comm. 2003, as cited in USFWS 2004). Although foraging bull trout may tend to concentrate in forage fish spawning areas, they can be found throughout accessible estuarine and nearshore habitats. The maintenance of these forage species and marine foraging areas is key to maintaining the anadromous life form. Distributions in saltwater are closely tied to forage fish (including surf smelt and herring), and their spawning beaches are heavily used by bull trout when in marine areas (Kraemer 1994).

Table 3.1. Current and historic salmonid habitat in WRIA 1.

Species	Current Distribution		Historic Distribution	
	Kilometers	Miles	Kilometers	Miles
Chinook salmon	495	308	639	397
Coho salmon	1074	668	1721	1069
Chum salmon	503	313	1277	794
Pink salmon	273	169	517	322
Sockeye salmon	286	178	286	178
Steelhead trout	696	433	1680	1044
Cutthroat trout	1276	793	2138	1329
Bull trout	1189	739	1791	1113
Dolly Varden	56	35	56	35

Table 3.2. WRIA 1 Regions and Subbasins.

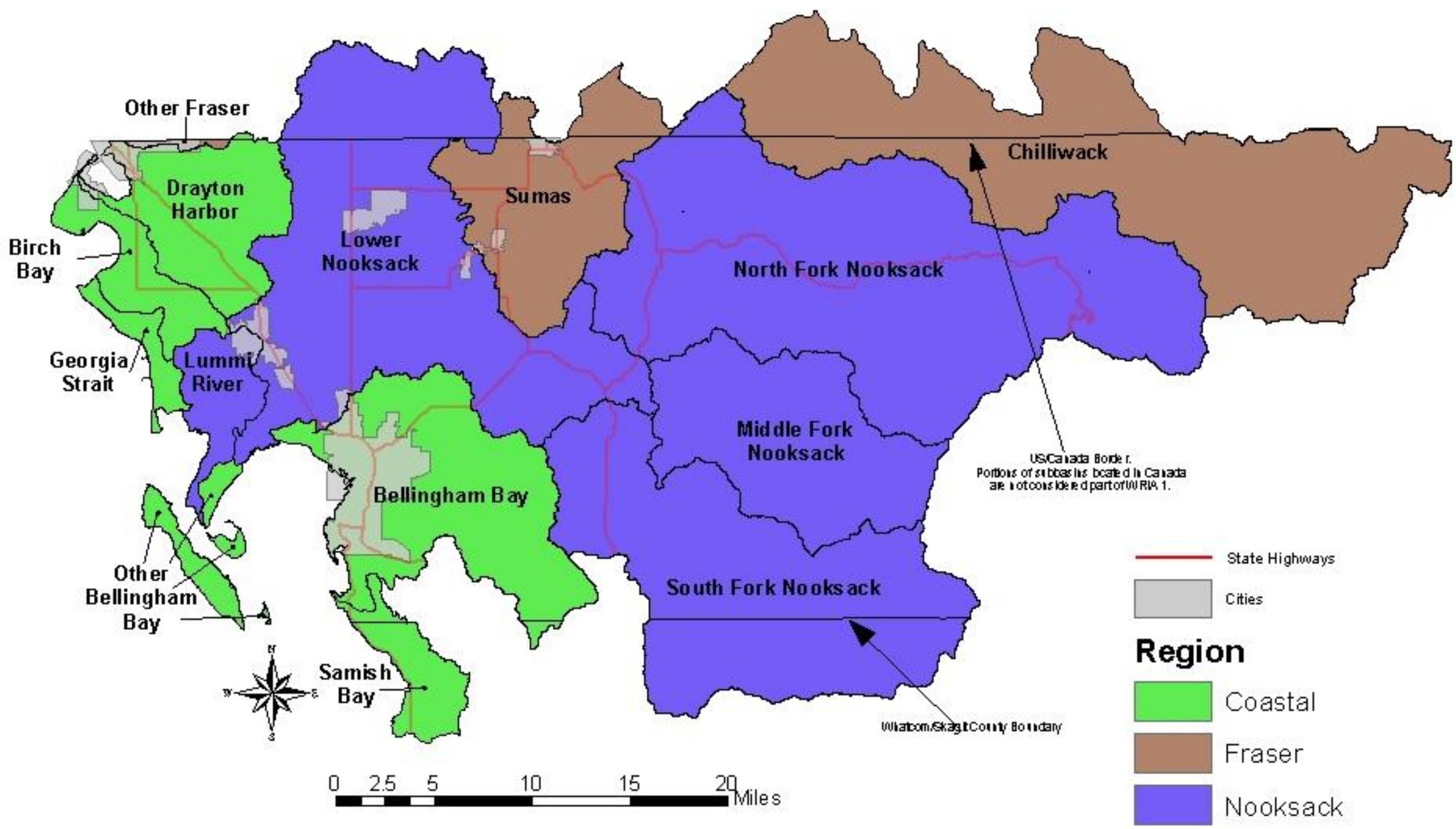
Region	Subbasin	% of Area
Nooksack	North Fork Nooksack	23
	Middle Fork Nooksack	8
	South Fork Nooksack	15
	Lower Nooksack	15
	Lummi River	2
Coastal	Drayton Harbor	5
	Birch Bay	2
	Georgia Strait	<1
	Bellingham Bay	9
	West Bellingham Bay	1
	Samish Bay	2
Fraser	Chilliwack	13
	Sumas	5
	Other Fraser	<1

Table 3.3. Escapements from 1993-2004 for Nooksack early chinook populations.

Year	North/Middle Fork Early Chinook			South Fork Early Chinook		
	Natural Origin	Kendall Hatchery Origin	Total NF/MF Escapement	South Fork Escapement	Kendall Origin Hatchery Strays (not included as part of escapement)	Other Hatchery Strays spawning by Sept. 30 (not included as part of escapement)
1993			449	235		
1994			45	118		
1995	171	59	230	290		
1996	209	326	535	203		
1997	74	543	617	180		
1998	37	333	370	157		
1999	85	738	823	166	87	37
2000	160	1082*	1242*	284	74	7
2001	240	1945*	2185*	267	138	15
2002	224	3517	3741*	289	289	44
2003	210	2647	2857*	204	217	148
2004	318	1428	1746*	130	20	20

Additional Notes:
2000: Additional to the total volitional spawners shown (which when combining natural origin and Kendall hatchery equal the co-manager N/M Fk. stock escapement estimates) there were 61 females, 785 males, and 40 jacks that were excess to hatchery needs, and returned to the North or Middle Fork (total of 886) from the Kendall Hatchery to spawn in the wild
2001: Additional to the total volitional spawners shown, there were 924 females, 3401 males, and 439 jacks (total 4,764) excess to hatchery needs that were returned to spawn in the wild.
2002: Additional to the total volitional spawners shown, there were 1835 females, 1896 males, and 29 jacks excess to hatchery needs that were returned to spawn in the wild
2003: Additional to the total volitional spawners shown, there were 1926 females, 1834 males, and 178 jacks excess to hatchery needs that were returned to spawn in the wild
2004: Additional to the total volitional spawners shown, there were 833 females, 955 males, and 13 jacks excess to hatchery needs that were returned to spawn in the wild
(Source of all five years of hatchery return to the river data is Ted Thygussen and Ed Argenio, Kendall Hatchery)

Figure 3.1. Water Resource Inventory Area (WRIA) 1 Subbasin Areas.



Data Sources: WRIA 1 Watershed Management Project delineated subbasins; WADOT Cities (2/2002) and State Highways (6/2003).
Cartography: T. Coe, Nooksack Natural Resources, 10/23/03.

Figure 3.2. Current and potential/historic salmonid-bearing streams in WRIA 1.

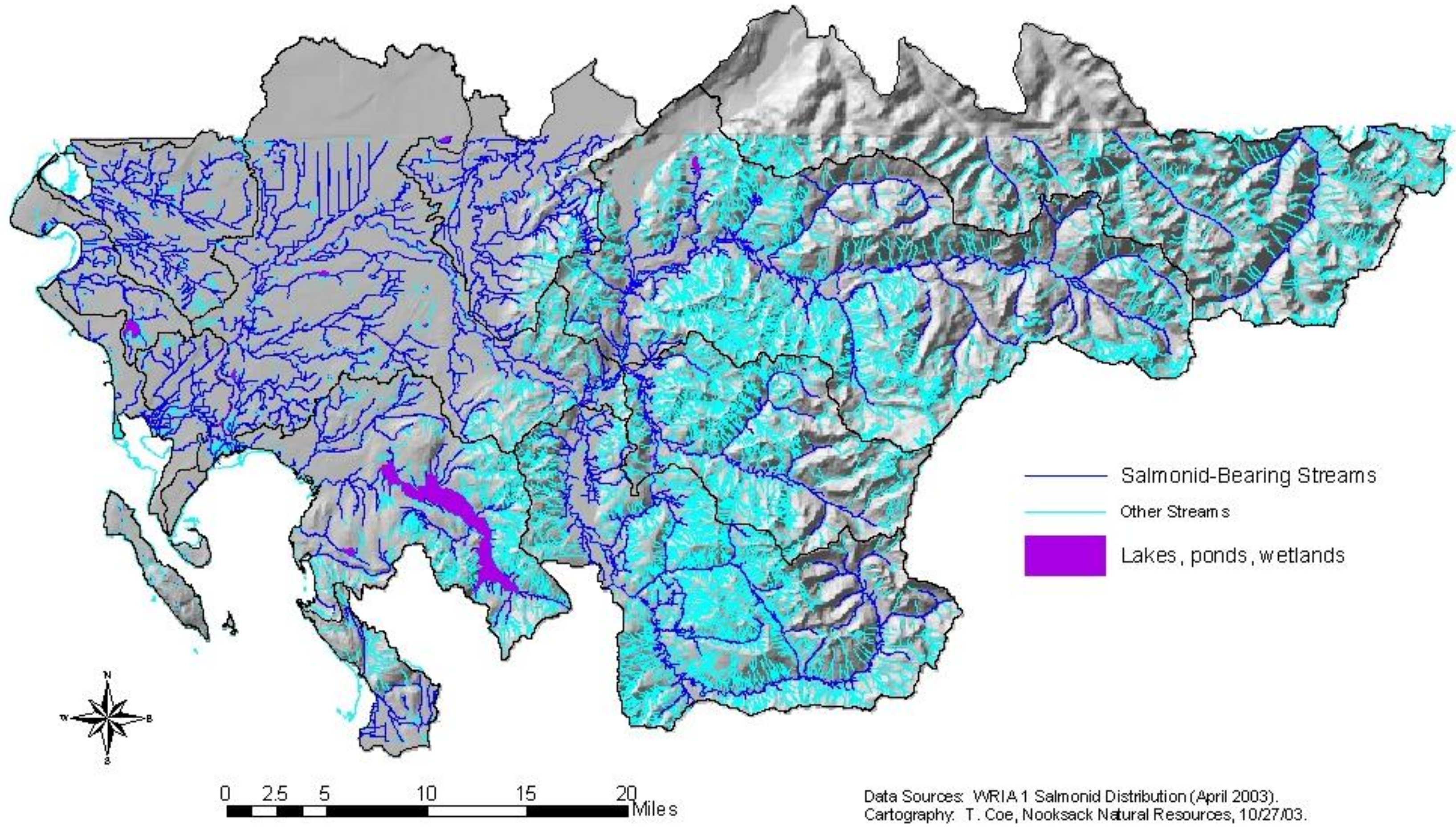


Figure 3.3. WRIA 1 Streams by Habitat Type.

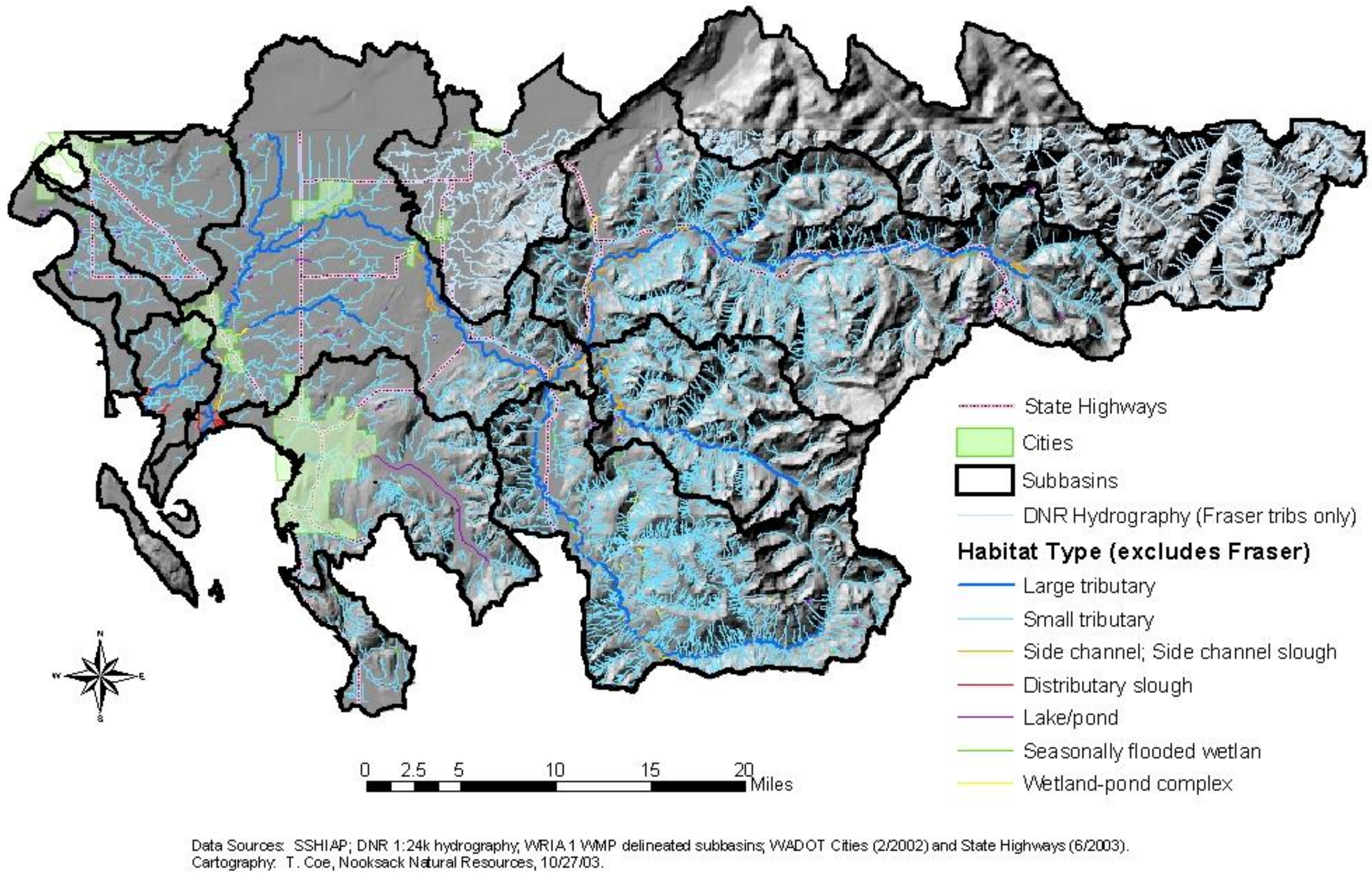


Figure 3.4. Chinook distribution in WRIA 1.

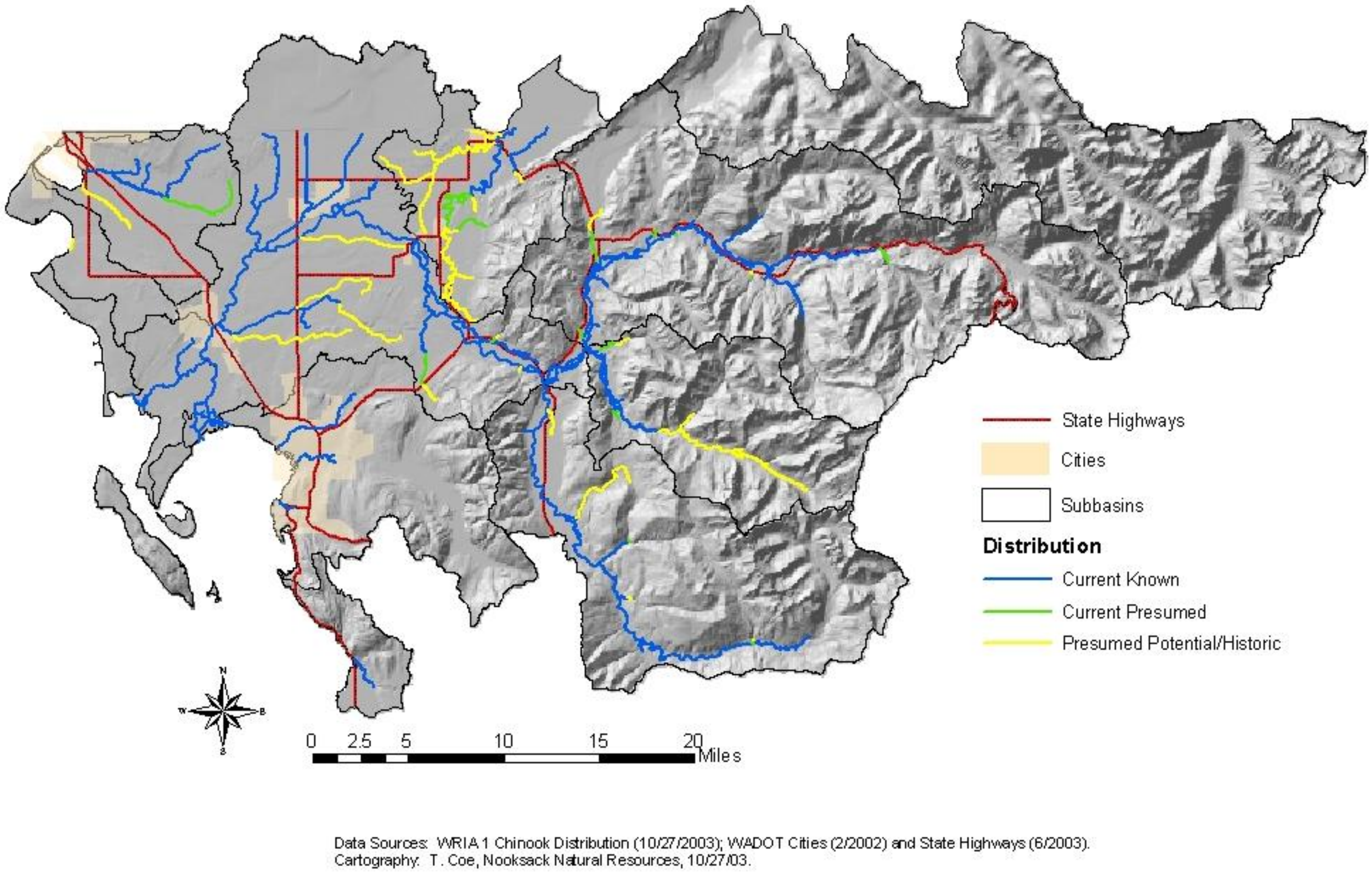
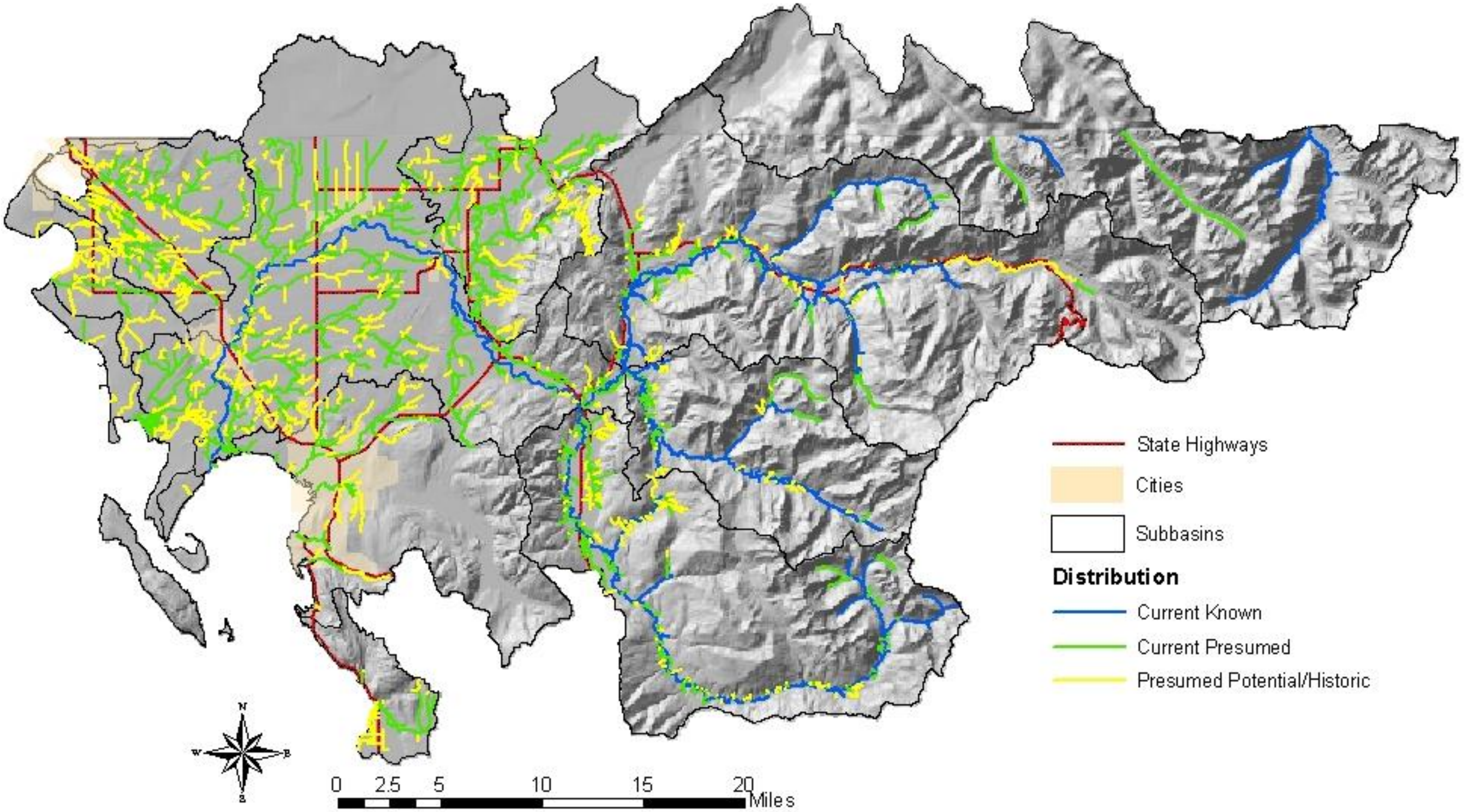


Figure 3.5. Native char (bull trout/Dolly Varden) distribution in WRIA 1.



Data Sources: WRIA 1 Native Char Distribution (10/27/2003); WADOT Cities (2/2002) and State Highways (6/2003).
Cartography: T. Coe, Nooksack Natural Resources, 10/27/03.

4. LIMITING FACTORS

The decline of Nooksack early chinook and other WRIA 1 salmonid populations is the result of a combination of habitat degradation, fishing, hatchery practices, hydropower operations, and negative ecological interactions. Developing and prioritizing recovery actions requires an understanding of the relative importance of multiple limiting factors, as well as how those factors function to affect the abundance, productivity, diversity and spatial structure of the salmonid populations of interest.

This section summarizes habitat, harvest, hatchery, and hydropower limiting factors and serves as the technical rationale for strategies and actions presented in subsequent sections. Effects on Nooksack early chinook populations are emphasized. Limiting factors are presented as hypotheses, along with syntheses of the supporting information and discussion of data gaps and uncertainties associated with the hypotheses. For the most part, more detailed supporting information is presented in Section 3: Technical Background. By explicitly acknowledging the uncertainty in local understanding of limiting factors, this section also provides the basis for research, monitoring, and adaptive management.

4.1. Habitat

Habitat degradation is considered the leading cause for the decline of WRIA 1 salmonid populations. Current habitat conditions are substantially less productive than historical conditions. Estimated current adult capacity for each Nooksack early chinook population is less than 10% of historic capacity; similarly, estimated current adult productivity and life history diversity are less than 15% and 45% of historic levels, respectively (Figure 4.1; Source: EDT Online, 2/22/05, www.mobrand.com/edt).

Salmonid populations are controlled by a hierarchy of physical, chemical, and biological processes operating at different time and space scales (Naiman et al. 1992). Tectonic and volcanic activity over millions of years, coupled with more recent glaciation events, have created the geology and topography that, together with climate, control soil and vegetation cover (Spence et al. 1996). Interactions among these watershed characteristics shape landscape processes that in turn form and maintain the habitat conditions to which organisms, populations, and communities respond (Naiman et al. 1992, Spence et al. 1996, Beechie et al. 2003). Land use affects habitat productivity directly, through destruction or isolation of habitat, or indirectly, through disruption of natural habitat-forming processes. Watershed processes that form and maintain habitat include those relating to the delivery and routing of sediment, water, wood and other organic matter, light, heat, nutrients, and chemicals. In turn, physical and chemical habitat conditions, moderated by biotic interactions, influence salmonid population viability through impacts to a population's spatial structure, abundance, productivity, and diversity (McElhany et al. 2000). Important habitat conditions for salmonid populations are access, substrate conditions, habitat structure and stability, flow regime and water quality. Biological processes include food webs, competition, predation, disease, and parasitism. A diagram of the linkages among watershed processes, land use, habitat conditions, biotic interactions, and salmonid populations is presented in Figure 4.2.

This section presents hypotheses for the factors most limiting Nooksack early chinook, as well as description of how limiting factors and habitats were identified and prioritized.

4.1.1. Identification and Prioritization of Limiting Factors and Habitats

Habitat limiting factors for Nooksack early chinook were identified and prioritized using the Ecosystem Diagnosis and Treatment (EDT) model, combined with qualitative and quantitative analyses based on scientific literature and local knowledge of land use, watershed processes, habitat conditions, and salmonid populations.

4.1.1.1. Ecosystem Diagnosis and Treatment

Ecosystem Diagnosis and Treatment (EDT) is a scientific model that relates local habitat conditions to salmonid population performance. Local input to the model consists of three components: (1) delineation of stream reaches; (2) characterization of salmonid populations of interest; and (3) characterization of habitat conditions. EDT translates input data into salmonid population performance in several steps (Lestelle et al. 2004):

(1) *Generation of life history trajectories*. Life history trajectories are generated randomly within constraints that are based upon the characteristics of the population of interest, including the timing and location of spawning and the proportion of the population outmigrating as fry, parr, and yearlings. A life history trajectory is the sequence of life stages and habitats that a fish moves through in completing its life cycle; each segment of the trajectory is defined by a specific life stage, stream reach location, and time span.

(2) *Calculation of capacity and productivity for each life stage in each reach*. For each trajectory segment, capacity and productivity are calculated based on reach habitat conditions using a set of species-specific rules. The rules are the foundation of the EDT model and were developed using scientific literature and expert opinion. Capacity depends on the quantity of habitat (area of key habitat types) in the reach with respect to a specific life stage, and is expressed as the number of individuals that the reach can support with the available habitat. Productivity is the survival rate without any density effects (density-independent survival) and is based on habitat quality in the reach with respect to a specific life stage. For example, survival of the egg incubation life stage depends on the levels of fine sediment in a reach.

(3) *Integration of reach- and life-stage-specific capacity and productivity to estimate overall population performance.* Capacity and productivity parameters are integrated over all reaches and life stages to estimate the overall capacity, productivity, abundance, and life history diversity index for the population. In the context of the population, capacity is the maximal number of adults or smolts that can be supported by the available habitat, while productivity is the number of adult progeny per spawner or number of smolts per spawner. Abundance, also referred to as population equilibrium abundance, is the average abundance of adults or smolts; analytically, it is the intersection of the replacement line with the spawner-recruitment curve, or the point on the curve where one adult produces one adult in the next generation. Life history diversity index is expressed as the percentage of possible (modeled) life history trajectories that are sustainable, i.e. for which productivity is at least 1.

In addition to the population parameters described above, the EDT model can also be used to diagnose the geographic areas and habitat attributes most limiting the population. Greater detail on the information structure, habitat condition rating, and biological rules for EDT can be found in *Information Structure of Ecosystem Diagnosis and Treatment (EDT) and Habitat Rating Rules for Chinook Salmon, Coho Salmon, and Steelhead Trout* (Lestelle et al. 2004; available at http://www.mobrand.com/MBI/library.html).

In the Nooksack River watershed, EDT has been run for the two early chinook populations. Biologists from the Nooksack Indian Tribe, Lummi Nation, and Washington Department of Fish and Wildlife who have knowledge of Nooksack River watershed conditions provided the model inputs. Early chinook habitat was delineated into self-similar stream reaches based on gradient, confinement, and the locations of tributary confluences using SSHIAP and stream hydrography data in GIS. There were 88 total reaches delineated, including: (1) one reach in the Nooksack/Lummi estuary; (2) 10 reaches in the Nooksack River downstream of the Forks; (3) 18 reaches in the North Fork Nooksack River; (4) 18 reaches in North Fork tributaries to the North Fork; (5) 13 reaches in the Middle Fork Nooksack River; (6) 8 reaches in Middle Fork tributaries; (7) 12 reaches in the South Fork Nooksack River; and (8) 8 reaches in South Fork tributaries. Population assumptions for the two populations were:

- North Fork/Middle Fork Nooksack chinook
    - Spawn in North and Middle Forks, North Fork tributary, and Middle Fork tributary reaches.
    - Spawn timing from week of 8/6 - 8/12 to 9/10 – 9/16.
    - Migration patterns: 14% fry migrants, 52% fingerling migrants, and 34% yearling migrants.
- South Fork Nooksack chinook
    - Spawn in South Fork and South Fork tributary reaches.
    - Spawn timing from week of 9/3 - 9/9 to 10/1 – 10/7.

- Migration patterns: 13% fry migrants, 51% fingerling migrants, and 35% yearling migrants.

Habitat characterization involved rating 46 habitat attributes for each reach. Attributes are listed in Table 4.1 and include those related to habitat diversity, proportion of key habitat types, channel stability, fine sediment load, temperature, flow, competition and predation, chemicals and pathogens, and fish passage obstructions. In general, attributes were rated on a scale of 0 to 4, either as integers or continuous values as appropriate. EDT provides guidance for rating each attribute; some attributes have quantitative values associated with each rating, while others are more qualitative (see Table 4.2 for examples of rating guidance). Local co-manager biologists rated the habitat using a combination of data and expert opinion. Attributes for which data were used were channel length, gradient, confinement, riparian function, bed scour (Forks only), fine sediment (Forks only), wood (South Fork only), and daily maximum temperature. Attributes were rated for both current and estimated historic conditions. The EDT model was run for both of these habitat condition scenarios (current and historic) as well as for the "PFC+ scenario", or properly functioning conditions (after NMFS 1996) in the freshwater environment and historical conditions in the estuarine environment. Local co-manager technical staff evaluated model output and determined that results were generally consistent with our understanding. In the Nooksack River watershed, EDT has been used to establish recovery goals for Nooksack early chinook (see Section 2, *Goals*), prioritize geographic areas for restoration and protection and identify and prioritize limiting factors (this Section), and estimate the effects of hypothetical recovery scenarios (see Section 5 *Actions*).

4.1.1.2. Other Information Sources

This section is also based on interpretation and synthesis by local technical experts of numerous reports, GIS layers, and datasets, especially:

- *Nooksack Chinook Spawning and Incubation Assessment* (Hyatt and Rabang 2003)
- *Nooksack Chinook Rearing Habitat Assessment* (Coe 2005)
- *Historical Riverine Dynamics and Habitats of the Nooksack River (Collins & Sheikh 2004b)*
- *Nooksack River Estuary Assessment* (Brown et al. 2005)
- Landslide inventories and road network inventories
- GIS layers: riparian function
- Reports of degraded habitat conditions and limiting factors largely from late 1980s

Salient details of these sources have been summarized in Section 3, *Technical Background*.

4.1.2. Description of Limiting Factors

For consistency and simplicity, presentation of limiting factors is organized around the EDT Level 3 Survival Factors, including those related to habitat structure (*Channel*

Stability, Habitat Diversity, Sediment Load, Key Habitat Quantity), access (*Obstructions*), water quantity and quality (*Flow, Temperature, Oxygen, Chemicals*), and biotic interactions (*Food, Competition with hatchery outplants, Competition with other species, Predation, Pathogens, and Harassment/poaching*).

4.1.2.1. Channel Stability

Channel Stability refers to the stability of the streambed, banks, and channel shape and location (Lestelle et al. 2004). Although unconfined channels are naturally dynamic environments, increases in natural rates of channel migration, bank erosion, and bedform mobility can lead to destruction of redds, either by scour and/or fill or dewatering, thereby reducing egg incubation survival. Abrupt changes in habitat and flow conditions associated with channel instability may also lead to mortality or downstream displacement of salmonids that are present, such as fry or overwintering juveniles. Debris flows that travel through salmonid habitats have similar if more catastrophic effects. Channel instability can also indirectly affect salmonids by simplifying holding and rearing habitat, through loss of pool habitats and reduced channel structure and complexity.

Causes of channel instability include: (1) increased magnitude and/or frequency of peak flows; (2) decreased flow resistance and in-channel sediment storage due to lack of large wood in the channel; (3) increased coarse sediment supply from mass wasting; (4) increased bank erosion due to loss of riparian vegetation that provides bank stability; and (5) hydromodifications that restrict access of flood flows to the floodplain. Increases in channel instability is also associated with conversion of historic anastomosing channel pattern to a more frequently shifting braided pattern, such as has occurred in the unconfined Forks and upper Mainstem Nooksack River.

4.1.2.2. Sediment Load

Sediment Load refers to the amount of fine sediment present in or passing through a reach (Lestelle et al. 2004), which can be manifest as high fine sediments in spawning gravels, high turbidity, or increased gravel embeddedness. High levels of fine sediments in spawning gravels can reduce survival to emergence by entombing embryos and reducing dissolved oxygen (Spence et al. 1996) or inhibiting emergence of fry from gravels. Embryo survival declines as percentage of fines (<0.85mm) increases above 11% (Peterson et al. 1992, cited in Spence et al. 1996). High turbidities can either kill, injure, or modify the behavior of rearing and holding salmonids, resulting in increased mortality and/or reduced productivity of habitats. The degree of impact depends on the duration, frequency of exposure, toxicity, temperature, life stage of fish, and natural background turbidity levels (Bash et al. 2001). Potential impacts of elevated turbidities include (1) gill trauma and disruption of osmoregulation, blood chemistry, and reproduction; (2) reduction of feeding efficiency for juvenile salmonids, which are visual predators, thereby reducing growth rates; (3) avoidance of habitats or delays in migration (Bash et al. 2001). Availability of turbidity refugia can help salmonids cope with short-term pulses of high turbidity (Bash et al. 2001). Increased gravel embeddedness can reduce the availability of substrate refugia for overwintering juveniles by reducing interstitial space that can be used during overwinter rearing (Spence et al. 1996). Entry into the substrate has been correlated with stream temperatures declining to 4 to 8°C (Bjornn 1971; Hillman et al. 1987). Indirect effects to salmonids of elevated fine sediment load include: (1) reduction of benthic macroinvertebrate production and thus reduced prey availability for juvenile salmonids (Spence et al. 1996); (2) reduction of hyporheic flow exchange, which can help moderate temperature extremes; and (3) infilling of pools (Spence et al. 1996), which reduces pool depth and thus quality.

Causes of high fine sediment load include: (1) increased fine sediment delivery due to mass wasting and surface erosion from managed forest lands; (2) increased bank erosion due to loss of riparian vegetation that provides bank stability; (3) disconnection of the channel from adjacent floodplain and wetlands, which can store fine sediments during overbank flows; and (4) loss of riparian vegetation that can trap fine sediment from upland runoff and overbank flows by slowing velocities and causing fine sediments to settle out. In agricultural and urban areas, increases in fine sediment delivery can also occur through dredging, surface erosion of cropland, construction sites, and unlined road and irrigation ditches, and bank erosion due to livestock access.

4.1.2.3. Habitat Diversity

Habitat Diversity refers to the extent of habitat complexity in the reach, including the presence of structural cover components (Lestelle et al. 2004). Cover provides refuge from predation, high velocities, and harassment or poaching for holding and rearing salmonids. Proximity of cover may also be a factor in selection of chinook spawning habitats (Spence et al. 1996; G. Pess, NWFSC, unpublished data). Complex cover is especially important for juvenile rearing: cover creates hydraulic heterogeneity that can increase feeding efficiency, i.e. an individual fish can reduce energy expenditure by maintaining position in slow current that is adjacent to faster current with higher rate of prey delivery (Fausch 1984); cover can also increase habitat capacity by increasing visual isolation for territorial juvenile salmonids, thus reducing effective territory size (Bjornn and Reiser 1991). Cover can be provided by wood jams, single logs, rootwads, undercut banks, large cobble or boulder substrates, overhanging vegetation, deep water, turbulence or turbidity (Bjornn and Reiser 1991). Another element of habitat diversity is the number and variety of habitat types available in a reach. In natural, unconfined rivers, the interaction of the channel with its forested floodplain, moderated by stable wood jams, created a dynamic mosaic of aquatic habitat types of different scales, including scour pools, stable side channels, braids, sloughs, backwaters, and edge habitats (Sedell and Luchessa 1982; Collins & Montgomery 2002).

Loss of habitat diversity is associated with the following: (1) loss of large in-channel wood; (2) disconnection of the channel from the floodplain due to channel incision or flood control; (3) simplification of bank condition through bank hardening; (4) loss of channel sinuosity through channelization; and (5) debris flows and frequent channel shifting. Large in-channel wood plays an especially important role; causes of decreased wood loading include (1) bank hardening that reduces bank erosion and thus wood recruitment; (2) clearing of floodplain forests that reduces sources of wood recruitment; (3) reductions in upslope and upstream wood sources; (4) historic and ongoing removal of wood from rivers and floodplains; (5) bridges, culverts or other artificial constrictions that interrupt the routing of large wood; and (6) reduced stability of wood jams as a result of smaller, more mobile wood and/or increased velocities associated with channel confinement.

4.1.2.4. Key Habitat Quantity

Key Habitat Quantity refers to the quantity, relative to other habitat types, of the primary habitat type(s) used by specific life stages (Lestelle et al. 2004). Habitat capacity, or the number of individuals of a life stage that a reach can support, is a function of both the relative proportion of different habitat types and streamflow, which controls the wetted surface area of the stream channel. Early chinook generally require deep, cool, primary pools with cover for holding, although glides can also be used. Spawning adults prefer pool tailouts, the transitional area between pools and riffles, although spawning also occurs in glides and riffles with appropriate substrate size. Large, deep pools may also be important for spawning; data from a reach of the North Fork Stillaguamish River indicate that more than two-thirds of the redds were located less than 70m from a pool (G. Pess, NWFSC unpublished data). Emergent fry initially seek habitats in slow current, such as shallow stream margins, backwater pools, and other edge habitats, moving into primary pools as they grow; floodplain habitats such as spring seeps and side channels (Castle and Huddle 1996b), and the lower ends of non-natal floodplain tributaries can also be important (Murray and Rosenau 1989), especially as refuges from high flows that can occur early in emergence. During summer, juvenile chinook densities are often highest in primary (main-channel) pools, although backwater pools and glides are also used (Hillman et al. 1987; Dewberry 2003). Overwintering juvenile chinook use primary pools or mainstem channel margins (Morgan and Hinojosa 1996); chinook also use interstitial spaces in the substrate, such as in large cobble riffles (Lestelle et al. 2004), during periods of cold temperature. As with fry, low-gradient tributaries and floodplain habitats may be important in providing refuge from high velocities, turbidity, and bedload movement associated with floods (Murray and Rosenau 1989). Fry that do not rear in freshwater but outmigrate soon after emergence rear in the Nooksack delta or in other WRIA 1 nearshore areas; those that rear in the delta require a system of blind tidal channels and distributary sloughs of various sizes, while those that rear along shorelines require shallow, low-water velocity, fine substrate habitats, such as pocket estuaries and non-natal deltas (K. Fresh, Northwest Fisheries Science Center, pers. comm. 2004).

Loss of key habitat is associated with: (1) loss of in-channel wood, which forms and maintains pool habitats; (2) loss of floodplain habitat-forming processes due to channel incision or artificial confinement that disconnects the channel from its floodplain; (3) pool infilling through increased coarse sediment delivery; and (4) loss of mainstem habitat and edge habitat length due to channel straightening, meander cutoffs, and conversion to single channels.

4.1.2.5. Obstructions

Obstructions refer to physical structures in the stream channel, such as culverts, dams, tidegates, and floodgates, that impede access to upstream habitats, thereby directly affecting prespawn migrants or fry or parr redistributing to oversummer or overwinter rearing habitats. Full barriers to passage strongly influence a population's spatial structure by eliminating upstream reaches from its spawning and rearing distribution. Abundance may be impacted when individuals that can ascend are delayed and thereby exposed to increased risk of prespawn mortality due to stress, disease, predation, or fishing. Obstructions can also affect productivity: (1) migration delays can reduce reproductive success (e.g. number of redds built); and/or (2) blocked access to abundant stocks such as pink or chum reduces the supply of marine derived nutrients upstream, thus limiting productivity of upstream habitat for rearing (i.e. feeding) life stages.

4.1.2.6. Withdrawals

Withdrawals refer to diversions and other water intake structures that facilitate the withdrawal of water from a stream, such as for irrigation. Withdrawals can kill or injure migrating and rearing juveniles due to entrainment or injury on screens.

4.1.2.7. Flow

Flow refers to the amount of stream flow, or the pattern and extent of flow fluctuations, within the stream reach (Lestelle at al. 2004). Stream flow exerts strong influence over salmonid habitat by regulating wetted surface area and thus the amount of available habitat, as well as by controlling the spatial distribution of depths and velocities. Anthropogenic changes to streamflow that affect salmonids include increases in magnitude and/or frequency of peak flows, decreases in magnitude of low flows, and rapid changes in streamflow due to withdrawals.

In addition to generally reducing habitat availability, low streamflows also affect salmonids as follows: (1) impeded upstream migration for prespawn migrants, especially in tributaries; (2) reduced availability of habitat for spawners, which require sufficient depth and velocities in areas with suitable spawning substrate; (3) redd dewatering, since incubating embryos require sufficient intragravel flow to maintain adequate temperature and dissolved oxygen and to eliminate waste; (4) dewatering and/or reduced connectivity of secondary channels and complex edge habitat, affecting fry; and (5) decreased survival of rearing juveniles due to increased vulnerability to terrestrial predators in shallow depths (Bjornn and Reiser 1991). Aggradation of channels and subsequent widening and shallowing from excessive sedimentation can exacerbate low flow concerns. Low streamflows are also associated with degraded water quality, including increased temperatures and concentration of contaminants and reduced dissolved oxygen.

Increases in peak flows can decrease survival to emergence by increasing the potential for redd scour and channel shifting. High velocities associated with peak flows can also lead to downstream displacement of fry or overwintering juveniles, especially in artificially confined channels where the availability of flow refugia is limited. Rapid changes in streamflow, which can occur when water withdrawals are activated or shut off without adequate ramping, are detrimental to downstream salmonids if they cannot respond quickly enough to the change to escape downstream displacement (associated with sudden increases in streamflow) or stranding (sudden drop in streamflow).

Anthropogenic causes of low streamflows include: (1) disconnection of channel from floodplain by channel incision and/or artificial confinement reduces groundwater discharge; floodplain provides storage for overbank flows that recharges the alluvial aquifer; (2) filling of floodplain wetlands reduces storage of overbank flows and upslope runoff, thereby reducing groundwater recharge that supports base flows; (3) ditching and draining of wetlands reduce storage and decrease base flows; and (4) water withdrawals for municipal, industrial or agricultural use. Aggradation and subsequent widening and shallowing of channels as a result of excess sedimentation, especially in the upper watershed, can exacerbate the effects of low flows.

Anthropogenic causes of high or more frequent flood flows include: (1) accelerated runoff due to decreased infiltration rates (e.g. related to impervious surfaces, land clearing, other changes in land cover); and (2) extension of the drainage network (e.g. through forest road building, ditching and drainage of wetlands) has changed the timing of runoff, which can increase peak flows. The effects of flood flows can be exacerbated by artificial confinement and/or channel incision that disconnects the channel from its floodplain, which reduces the available cross-sectional area, thereby increasing average velocity and decreasing the frequency of low velocities. Loss of floodplain vegetation, in-channel wood, and other roughness elements that dissipate high velocities can also reduce the availability of refuges from high flows.

4.1.2.8. Temperature

Temperature refers to the temperature regime in the reach, including maximum and minimum water temperatures, as well as spatial variation (Lestelle et al. 2004). Water temperature affects salmonids by influencing mortality, metabolism, growth rates, timing of life history events, biotic interactions, disease resistance, and behavior (Spence et al. 1996). Spatial variation in temperature throughout a reach can be important, as thermally stratified pools or cool tributary or groundwater inputs provide refuge from high temperatures in the reach.

High temperatures can stress holding and spawning fish, which can increase prespawn mortality and vulnerability to disease, or reduce egg survival. High temperatures can also delay or prevent migration upstream to spawning grounds, which can affect spatial structure. High temperatures during incubation can result in earlier fry emergence than under natural conditions, which can increase exposure of fry to larger floods that tend to occur early in their emergence period and lead to involuntary downstream displacement; early emergence can also reduce growth rates, if fry emergence is desynchronized from insect hatches that support rapid growth in spring and early summer (Spence et al. 1996). High temperatures can reduce productivity of oversummer rearing by reducing growth and metabolic efficiency and modifying behavior (Bjornn & Reiser 1991).

Anthropogenic causes of high temperatures include: (1) reduced stream shading due to degraded riparian function; (2) widening and shallowing of channels, which increases surface area for convective heat exchange, due to increased coarse sediment inputs and/or reduced bank stability; (3) reduced groundwater discharge to streams during summer months through impacts to infiltration and groundwater recharge, i.e. from changes to land cover, loss of wetlands, or disconnection of channel from floodplain; and (4) reduced hyporheic exchange[6], which can buffer or reduce high temperatures, due to loss of bedform diversity, siltation of gravels, and/or disconnection of the channel from its floodplain (Poole & Berman 2000).

4.1.2.9. Other Limiting Factors

The following potential limiting factors are either not considered to significantly impact Nooksack early chinook populations at this time or are indirect effects of factors that do present significant impact:

- *Oxygen* refers to dissolved oxygen concentration within the reach (Lestelle et al. 2004). Low dissolved oxygen concentrations can kill, disrupt physiological processes, and or modify the behavior of salmonids. Low dissolved oxygen in incubating redds, associated with low streamflows and/or high levels of fine sediments, reduces the survival and emergence of fry. Low dissolved oxygen can also can also adversely affect swimming performance of migrating and rearing salmonids and growth rates of rearing salmonids (Bjornn & Reiser 199). Low dissolved oxygen can be associated with high temperatures and low flows; it can also result from nutrient enrichment from agricultural, municipal or

[6] The hyporheic zone refers to the subsurface zone beneath or lateral to the stream channel (extending into the floodplain) that receives surface flow from stream and river channels (Edwards 1998). Hyporheic flow paths range in size from the streambed scale (e.g. pool and riffle sequence) to meander bend scale (e.g. through mid-channel gravel bars or abandoned channels) to floodplain scale (e.g. where unconfined floodplain reaches that alternate with bedrock-confined reaches; Poole & Berman 2000). Hyporheic exchange at the meander bend scale can buffer high temperatures, while hyporheic exchange at the floodplain scale can buffer or reduce high temperatures (Poole & Berman 2000).

industrial waste, which promotes algal growth than can deplete oxygen levels (Spence et al. 1996).

- *Chemicals* include toxic contaminants or toxic water quality conditions, such as heavy metals, low pH, and pesticides (Lestelle et al. 2004). Toxic contaminants can kill, injure or modify the behavior of salmonids, depending on concentration and length of exposure. Sources of toxic contaminants include runoff of agricultural and residential pesticides, municipal and industrial discharges, and stormwater runoff. Riparian buffers and wetlands can filter inputs.
- *Food* refers to the amount, diversity, and availability of food that can support chinook. Decreases in food availability are associated with (1) high fine sediment load, which reduces benthic macroinvertebrate production; (2) decreased spawner abundances and thus reduction in supply of marine derived nutrients that historically represented an important nutrient subsidy for stream systems; (3) degradation of riparian areas: vegetation overhanging the stream supplies terrestrial insects to streams that can be eaten by juvenile salmonids; riparian areas are also a source of organic inputs that support stream productivity; (4) loss of stream productivity due to lack of in-channel wood and other roughness elements that retain and trap organic matter; and (5) disconnection of channel and floodplain.
- *Biotic Interactions.* The presence of hatchery outplants and/or other fish, bird, and/or mammal species can negatively affect chinook through *predation* or *competition* with chinook for food or space. Low flows and lack of instream cover increase risk of predation. Many bacterial, viral, fungal, and microparasitic pathogens are naturally occurring in the wild, including bacterial kidney disease, columnaris, and infectious hepatopoietic necrosis (IHN;(Spence et al. 1996). However, disease outbreaks can occur in hatchery fish that can be transmitted to wild fish; disease outbreaks are also associated with high temperatures, which compromise immune systems. In addition to degrading habitat, humans negatively impact chinook through fishing, redd trampling, *harassment*, or other types of disturbance.

4.1.3. Nooksack Early Chinook

In this section, we present geographic priorities and limiting factors by geographic area for Nooksack early chinook. Geographic areas presented in this section are aggregations of the reaches and geographic areas defined for EDT.

4.1.3.1. Delineation of Geographic Areas

For the purposes of this Plan, Nooksack early chinook habitats were divided into the following:

- *Lower North Fork*: North Fork Nooksack, from South Fork confluence (RM 36.6) to Glacier Creek (RM 57.6)
- *Upper North Fork*: North Fork Nooksack, from Glacier Creek (RM 57.6) to Nooksack Falls (RM 65.1)

- *North Fork tributaries*[7]: Racehorse Creek; Bear Creek; Maple Creek; Boulder Creek; Canyon Creek; Cornell Creek; McDonald Creek; Glacier Creek; Boyd Creek; Deadhorse Creek; Wells Creek
- *Lower Middle Fork*: Middle Fork Nooksack, from mouth to Mosquito Lake Rd. bridge (RM 5)
- *Upper Middle Fork*: Middle Fork Nooksack, from Mosquito Lake Rd. bridge (RM 5) to Ridley Creek (RM 17.4)
- *Middle Fork tributaries*[8]: Canyon Lake Creek; Peat Bog Creek; Porter Creek; Clearwater Creek; Sisters Creek; Warm Creek; Wallace Creek
- *Lower South Fork*: South Fork Nooksack, from mouth to Skookum Creek (RM 14.3)
- *Upper South Fork*: South Fork Nooksack, Skookum Creek (RM 14.3) to upper extent chinook distribution (RM 31)
- *SF tributaries*[9]: Hutchinson Creek; Skookum Creek; Cavanaugh Creek; Plumbago Creek; Deer Creek
- *Lower Mainstem*: Mainstem Nooksack, Lummi River distributary (RM 4.5) to Everson (RM 24)
- *Upper Mainstem*: Mainstem Nooksack, Everson (RM 24) to South Fork confluence (RM 36.6)
- *Mainstem tributaries: Tenmile Creek, Bertrand Creek, Fishtrap Creek, Kamm Creek, Scott Ditch, Anderson Creek, Silver Creek, Smith Creek, McCauley Creek, Mitchell Creek.*
- *Estuary*: Nooksack/Lummi Estuary from Lummi River confluence to mudflats
- *Bellingham Bay:*
- *Other WRIA 1 Nearshore Areas*

Population and life stage use is presented in Table 4.3.

4.1.3.2. Geographic Priorities

As discussed above, EDT was used to identify the geographic areas that are most limiting each Nooksack early chinook population, as well as those that currently support the population. Results are presented in Figures 4.3 (South Fork Nooksack early chinook) and 4.4 (North Fork/Middle Fork Nooksack early chinook). The "tornado diagrams" indicate the expected change in population parameters if a reach were restored to historic conditions or, conversely, degraded to a hypothetical

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[7] Specified tributaries presented as modeled in EDT; not all tributary reaches that can support early chinook were modeled, although major tributary habitats are included.
[8] Specified tributaries presented as modeled in EDT; not all tributary reaches that can support early chinook were modeled, although major tributary habitats are included.
[9] Specified tributaries presented as modeled in EDT; not all tributary reaches that can support early chinook were modeled, although major tributary habitats are included.

urbanized scenario. Relative importance of each reach for restoration and protection is also provided, normalized to reach length[10].

Generalizing the tornado diagrams to geographic areas, for South Fork Nooksack early chinook, the highest priority geographic area for restoration is the lower South Fork, followed by the upper South Fork, then upper Mainstem, and Nooksack/Lummi Estuary. Highest priority for protection is the Nooksack/Lummi estuary, followed by the upper South Fork, lower South Fork, and upper Mainstem. For North Fork/Middle Fork Nooksack early chinook, the highest priority for restoration is the Middle Fork diversion dam, followed by the lower North Fork, lower Middle Fork, tributaries to the North Fork, and upper North Fork. The highest priorities for protection are the lower North Fork, Nooksack/Lummi estuary, upper North Fork, and upper Mainstem.

4.1.3.3. Limiting Factors by Geographic Area

The following section presents hypotheses for factors most limiting salmonid populations within each geographic area. Only those limiting factors that have a high or moderate impact on (i.e. that strongly or moderately limit) either Nooksack early chinook population are included. For each limiting factor in a geographic area, we discuss the supporting rationale (certainty of impact), specific impacts to early chinook populations (Early Chinook Impacts), and the important causal mechanisms. For the most part, EDT was used to quantify the relative importance (i.e. high, moderate) of various limiting factors (Figures 4.5, 4.6), although the presence of additional data and information improved the certainty of impact.

4.1.3.3.1. Lower North Fork

The lower North Fork is characterized by unconfined reaches alternating with short reaches confined by ancient landslide deposits. The historic channel migration zone of the lower North Fork nearly fills its floodplain, occupying about 74% of floodplain width (Collins & Sheikh 2004a). Historically, the channel pattern was anastomosing, with multiple channels, sloughs, and forested islands; a more frequently shifting braided pattern characterizes current conditions (Collins & Sheikh 2004b). Dominant land use in the watershed is commercial forestry, although much of the lower North Fork valley is zoned rural and rural forestry. Some bank hardening is present, especially associated with river-adjacent roads in the reach (Mt. Baker Highway, North Fork Rd., Truck Rd.). Bridges that constrain the lower North Fork include Highway 9 and Burlington Northern railroad bridges (RM 36.7), Mosquito Lake Road bridge (RM 40.7), and Mt. Baker Highway downstream of Canyon Creek (RM 54.8).

The lower North Fork represents 30% of the spawning distribution and 20% of the freshwater habitat for NF/MF Nooksack early chinook. Restoration of the lower North

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[10] Relative importance was calculated as the rank sum of individual parameter ranks, where individual parameter ranks were based on expected change to the population parameter divided by the reach length.

fork will be very important in recovering abundance and productivity, as well as life history diversity, of NF/MF Nooksack early chinook. After restoration of passage upstream of the Middle Fork diversion dam, the next most important reaches for restoration are in the lower North Fork, from the South Fork confluence to Maple Creek (Figure 4.4). The lower North Fork is also important in maintaining current abundance and productivity, especially the upstream reaches (Figure 4.4). Channel instability, leading to redd loss due to bed scour and channel shifting, is considered the most important factor limiting NF/MF Nooksack early chinook productivity in the geographic area. Egg incubation is the most limiting life stage, followed by fry. Fine sediment load, key habitat quantity, and to a lesser extent high temperatures, are considered to be limiting the population.

Channel Stability: High impact.

- *Certainty of Impact. High*. EDT reach diagnosis indicates that channel instability has a high impact on NF/MF Nooksack early chinook through ~25% of reach length and moderate impact through ~60% of length (Figure 4.6). Hyatt and Rabang (2003) found consistently high failure rates associated with scour chains in mainstem and braided reaches of the lower North Fork, even though relatively minor peak flows occurred during the study period. Failure rates ranged from 40-56% during the 2002-2003 season (highest flow <1 year recurrence interval) and 72-75% during the 2001-2002 season (highest flow 8-10 year recurrence interval). Failure was defined as scour greater than 20cm depth, fill greater than 30cm depth, or dewatering; bedload transport was the most common mechanism for failure, although channel shifting and dewatering was more of a concern in the higher flood year and in certain reaches. Failure rates were substantially lower in sloughs, tributary, and back channel habitats, especially during the higher flood season. Analysis of historic conditions (Collins & Sheikh 2004b) provides further evidence that the lower North Fork is less stable than current conditions. Between ~1880 and the 1930s, the lower North Fork changed from an anastomosing channel pattern with multiple channels, sloughs, and forested islands to a much simpler, wider, braided channel with extensive gravel bars (Collins & Sheikh 2004b). Further, average annual migration rates have doubled since 1933, increasing from 9.3 ± 5.0 m/yr (<1933) to 18.5 ± 8.6 m/yr (1933-2002) in the North Fork downstream of the Middle Fork confluence and from 3.9 ± 3.8 m/yr (<1933) to 8.3 ± 5.5 m/yr (1933-2002) in the North Fork upstream to RM 58 (Collins & Sheikh 2004a).
- *Early Chinook Impacts*: Channel instability, which is associated with destruction of redds either by scour and/or fill or dewatering, has the greatest impact on survival and thus productivity of the egg incubation stage, which is the most limiting life stage in 11 of 14 EDT reaches within the geographic area. Indeed, EDT estimates of productivity losses associated with egg incubation stage in these reaches range from 57.6% - 92.4%, due primarily to channel instability and secondarily to fine sediment load. Channel instability also impacts the survival

and thus productivity of other life stages present in the reach during high flow periods, including fry and overwintering juveniles, although to a much lesser degree than egg incubation. Channel instability may affect life history diversity: if mainstem spawning proves unsustainable in most years, i.e. productivity less than one, that life history strategy may become less common.

- *Relative Importance of Causal Mechanisms.*
    - *High Importance, High Certainty:* Reduced riparian function has increased channel instability by decreasing the abundance and size (stability) of in-channel wood and increasing bank erosion. Wood surveys found limited stable wood in the active channel area of the lower North Fork (Lummi Natural Resources, unpublished 2003 data). The future wood recruitment into the channel is limited by immature, deciduous-dominated riparian stands (Coe 2001); indeed, wood recruitment potential in riparian areas adjacent to the active channel of the lower North Fork is predominantly low (32%) or moderate (43%; Coe 2001). Causes of reduced riparian function in the reach include past riparian logging, stream-adjacent roads (especially SR542), and some development in lower reaches.
    - *High Importance, Moderate Certainty:* Historic wood removal from the channel increased channel instability. In-stream wood removal played a small part in the overall wood budget of the upper North Fork, although it was extensive in the lower reaches of tributaries following the storm of 1962 (USFS 1995a).
    - *Moderate Importance, High Certainty:* Elevated mass wasting frequency due to forestry management practices has increased coarse sediment supply to the lower North Fork. Recent landslide inventories in the North Fork watershed documented 632 mass wasting sites from 1940 through 1995; 36% and 28% were associated with roads and clearcuts, respectively, and a majority (74%) delivered sediment to stream channels (Watts 1997). Highest landslide densities were in Cornell, Racehorse, Gallop, Boulder, and Coal Creek watersheds, with 10.8, 10.6, 7.5, 5.7, 5.1 events $\cdot mi^2$, respectively. Management has increased landslide failure rates from background conditions; failure rates in unmanaged areas ranged from 0 to 6.8 landslides $\cdot acre^{-1} \cdot year^{-1} \cdot 10^{-4}$ in unmanaged areas of Cornell, Canyon, Boulder and Racehorse Creek watersheds, compared to 3.5 to 208 landslides $\cdot acre^{-1} \cdot year^{-1} \cdot 10^{-4}$ in timber-harvested areas and 0 to 700 landslides $\cdot acre^{-1} \cdot year^{-1} \cdot 10^{-4}$ in roaded areas (Peak Northwest 1986, cited in Smith 2002). The increase in sediment to the channel can lead to more active channel migration. Indeed, extensive channel shifting in the North Fork has been associated with sediment inputs from tributaries and upstream reaches, with Glacier, Canyon, Boulder and Racehorse Creeks being important contributors of sediment (Schuett-Hames & Schuett-Hames 1987; GeoEngineers 2001).
    - *Moderate Importance, Low Certainty.* Forest management has increased the frequency and magnitude of peak flows, primarily through extension of the drainage network by forest roads. Average road density in the North Fork

Nooksack watershed is 2.37 miles of road per square mile of watershed area; subbasins with high road density include Maple (3.17 mi/mi^2), Cornell (3.38 mi/mi^2), Kenny (3.58 mi/mi^2), Slide Mountain (4.05 mi/mi^2), Hedrick (4.14 mi/mi^2), Coal (4.79 mi/mi^2), Boulder (4.83 mi/mi^2), and Gallop Creeks (5.39 mi/mi^2; D. Coe, Nooksack Tribe, using DNR 2000 transportation and WRIA 1 basin shape files). Although evidence from the hydrologic record is lacking, high road densities in the contributing watersheds to the lower North Fork increases the likelihood of hydrologic effects. Recent research suggests that the hydrologic effects of roads may be more important than the hydrologic effects of timber harvest (Jones and Grant, 1996). Harr and others (1975) found no increase in peak flow response until more than 12% of the watershed was occupied by roads. Disconnecting road systems from the channel network can decrease peak flow response by 40% (Bowling and Lettenmaier, 2001).

Sediment Load: Moderate impact.

- *Certainty of Impact. Moderate*. EDT reach diagnosis indicates fine sediment impacts to NF/MF Nooksack early chinook increase downstream; impacts range from low in the upstream 5.4 miles of the geographic area, to moderate in the next 11.7 miles, and high in the lower 3.9 miles (Figure 4.6). Recent limited sampling of fine sediments in spawning gravels indicate high variability between samples and study sites (Hyatt and Rabang 2003). In the lower North Fork mainstem, average percentage fine sediments (<0.85mm) were high at 2 sites (18%, n=1; 22%, n=1), moderate at 2 sites (12%, n=5; 13%, n=1), and relatively low at 1 site (8%, n=1); fine sediments were relatively low (7%, n=2) at 1 braid site and high to moderate (17%, n=4; 14%, n=2; 11%, n=1) in 3 slough sites. Evidence of elevated turbidities in the lower North Fork relative to historical conditions is also limited. Naturally high turbidities occur in the North Fork during spring and early summer due to the glacial origin of flow. However, despite limited evidence, there is potential for management-induced increases in fine sediment delivery to the lower North Fork due to past and ongoing forest management, which may be manifest in either elevated proportions of fine sediments in spawning gravels or elevated turbidities during fall and winter storms.
- *Early Chinook Impacts.* Fine sediment load in the lower North Fork most limits productivity of the egg incubation stage due to high proportions of fine sediments in spawning gravels that reduce survival to emergence. According to EDT, spawning adults is the next most limited life stage, followed by fry and subyearling and yearling migrants; for these life stages, productivity may be limited by high turbidities. Gravel embeddedness also reduces productivity of the overwinter rearing life stage, as fine sediments reduce interstitial spaces that overwintering chinook can use for refuge as temperatures decrease.
- *Relative Importance of Causal Mechanisms.*

- *Moderate Importance, High Certainty:* Elevated mass wasting frequency due to forestry management practices has increased fine sediment supply to the lower North Fork. Forest management has increased landslide frequency in the North Fork basin (see evidence presented for *Channel Stability* above). Fine sediment can be delivered to the North Fork by erosion of recently disturbed slopes and/or from debris flow deposits in streams.
- *Low Importance, Moderate Certainty:* Surface erosion of forest roads increases fine sediment delivery to the North Fork. Surface erosion from forest management activities typically comprises a small proportion of the total sediment budget for watersheds in the Pacific Northwest (Swanson et al., 1982). However, surface erosion from roads may contribute as much as 50% of the management-induced fine sediment inputs (Cederholm et al., 1981). Average road density in the North Fork Nooksack watershed is 2.37 miles of road per square mile of watershed area. Subbasins with high road density include Maple (3.17 mi/mi^2), Cornell (3.38 mi/mi^2), Kenny (3.58 mi/mi^2), Slide Mountain (4.05 mi/mi^2), Hedrick (4.14 mi/mi^2), Coal (4.79 mi/mi^2), Boulder (4.83 mi/mi^2), and Gallop Creeks (5.39 mi/mi^2); subbasins with fair road density include Kendall (2.84 mi/mi^2), Racehorse (2.76 mi/mi^2), Canyon (2.34 mi/mi^2), and Swamp Creeks (2.30 mi/mi^2; D. Coe, Nooksack Tribe, using DNR 2000 transportation and WRIA 1 basin shape files).

Key Habitat Quantity: Moderate impact.

- *Certainty of Impact. Moderate.* EDT reach diagnosis indicates that the lack of key habitat in the lower North Fork has a moderate impact on NF/MF Nooksack early chinook (Figure 4.6). Quantitative habitat survey data for the lower North Fork are limited. GeoEngineers (2001) describes the habitat as mostly deep runs alternating with riffles, with few well-formed pools and woody debris common on gravel bars but no extensive wood jams. Changes in the availability of key habitat types is also expected given the observed changes in channel pattern from historical conditions. Between ~1880 and the 1930s, the lower North Fork changed from an anastomosing channel pattern with multiple channels, sloughs, stable log jams, and forested islands to a much simpler, wider, braided channel with extensive gravel bars (Collins & Sheikh 2004b). As a result, current proportions of primary pools, backwater pools, side channels, and complex edge habitats are likely less than under historical conditions. Lack of wood is also associated with loss of deep, complex pools.
- *Early Chinook Impacts.* The amount of key habitat types affects habitat capacity, which controls equilibrium abundances. According to EDT, lack of key habitat strongly impacts fry, oversummer and overwinter rearing, holding and spawning life stages, indicating that the habitat types most limiting in the reach are primary pools, backwater pools, complex edge habitats, side channels, and pool tailouts. Loss and simplification of fry and overwintering rearing habitat in the geographic area may also have affected NF/MF Nooksack early chinook

diversity by reducing the relative abundance of yearling or parr migrant life history strategy relative to historical conditions.

- *Relative Importance of Causal Mechanisms.*
    - *High Importance, High Certainty:* Loss of key habitat types is associated with the loss of stable wood in the lower North Fork. Wood distribution in the lower North Fork shows the effects of the immature riparian stands. Immature riparian zones no longer produce larger "key-piece" sized wood to the channel, which helps encourage the formation of persistent wood jams. Much of the lower North Fork is dominated by immature deciduous stands (Coe 2001); indeed, wood recruitment potential in riparian areas adjacent to the active channel of the lower North Fork is predominantly low (32%) or moderate (43%; Coe 2001).
    - *Low Importance, High Certainty.* Stream-adjacent roads constrain channel migration and/or reduce wood recruitment through bank hardening, leading to loss of wood function in the lower North Fork. The SR-9 bridge over the lower North Fork has reduced the North Fork's potential channel migration area by 96%; the Mosquito Lake Rd. bridge and the SR-542 bridge at RM 55 also constitute severe constraints on channel migration (GeoEngineers 2001). The Mt. Baker Highway isolates the lower North Fork from about a third of its floodplain from RM 50-52 and RM 44-45 (GeoEngineers 2001). Bank hardening is associated with the Mt. Baker Highway and the North Fork Road in several locations along the lower North Fork (GeoEngineers 2001).
    - *Moderate Importance, Low Certainty.* Increases in coarse sediment inputs to the lower North Fork, as a result of mass wasting, has led to aggradation, habitat simplification, and pool infilling. Recent inventories of landslides and forest road networks in the Nooksack basin (Watts 1996; Watts 1997; Watts 1998; Zander 1996; Zander 1997; Zander 1998), in concert with previous inventories conducted as part of the Watershed Analyses and graduate research (Kirtland 1995), indicate that landslides from roads and timber practices are common in the watershed and generate a large amount of sediment.

Temperature: Low impact some years, moderate during other years.

- *Certainty of Impact. Moderate.* EDT reach diagnosis indicates that temperature impacts increase downstream, ranging from low in the upstream 5.4 miles of the geographic area, to moderate for the next 11.7 miles, and high in the lower 3.9 miles (Figure 4.6). In 1996, peak high temperatures of 17°C were recorded in the lower North Fork (RM 41.6); 39% of July and August samples exceeded state water quality standard of 16°C (data from USGS 2001). Further downstream (RM 37.2), 59% of the samples in July and August of 1996 exceeded 16°C. More recent sampling of the North Fork at Mosquito Lake Rd. bridge (RM 40.7), however, indicate no exceedance of water quality standard during summer 2003, which was a warmer, lower flow year than average (Kopp 2004); further, temperatures remained within the optimal temperature ranges for chinook adult migration and juvenile rearing (Hicks 2000) during the sample period, although they averaged 3.3°C higher than the upper end of optimal temperature for incubation (12°C).

- *Early Chinook Impacts.* High temperatures may reduce productivity of several life history stages in the lower North Fork. According to EDT, spawning is the life stage most limited by temperature in the lower North Fork, followed by egg incubation, and to a lesser extent prespawning holding and migration. High temperatures in the lower North Fork may stress holding and spawning fish and increase susceptibility to disease, which can cause prespawn mortality or otherwise reduce reproductive success. In 2003, numerous pre-spawning mortalities were observed among early chinook spawning in the North Fork (D. Huddle, WDFW, pers. comm. 2003); later necropsies indicated that individuals had *Columnaris*, which is associated with higher mortality at temperatures greater than 15°C (Spence et al. 1996). It is not known whether the observed mortality was a result of exposures to high temperatures in the mainstem or North Fork or both. High temperatures during incubation result in earlier fry emergence than under natural conditions, which can increase exposure of fry to larger floods that tend to occur early in their emergence period and lead to involuntary downstream displacement. Early emergence can also reduce growth rates, if fry emergence is desynchronized from insect hatches that support rapid growth in spring and early summer.
- *Relative Importance of Causal Mechanisms.*
  - *Moderate Importance, Moderate Certainty:* Channel widening has increased the water surface area exposed to solar radiation. Channel widening in response to peak flows and sediment input have been identified in unconfined reaches of the North Fork (USFS 1995a, Indrebo 1998, Collins & Sheikh 2004b).
  - *High Importance, Moderate Certainty:* Riparian vegetation clearing reduces the bank cohesion and shading benefits of streamside vegetation. Current riparian shading is likely less than historical conditions; the current channel is a wider and simpler braided pattern (Collins & Sheikh 2004b) associated with less riparian shading than the historic branching with multiple sloughs and stable forested islands.

4.1.3.3.2. Upper North Fork

Gradient and valley confinement increase in the upper North Fork relative to the lower North Fork. The North Fork alternates in this reach between steep-gradient, bedrock-confined canyons and unconfined, frequently shifting reaches with numerous side channels (Schuett-Hames and Schuett-Hames 1987; GeoEngineers 2001). Nooksack Falls presents a complete anadromous barrier at RM 65.1. Adjacent ownership is largely federal (Mt. Baker-Snoqualmie National Forest), with some residential in-holdings. River-adjacent roads include the Mt. Baker Highway and Forest Service roads.

The upper North Fork represents 11% of the spawning distribution and 7% of the freshwater habitat for NF/MF Nooksack early chinook. Restoration of the upper North Fork to historic conditions is expected to contribute to recovery of NF/MF Nooksack early chinook abundance and productivity and, to a lesser extent, diversity, although its importance is less than other reaches (Figure 4.4). Accounting for differences in reach lengths, the upper North Fork is the third-most important geographic area for recovery of NF/MF Nooksack early chinook abundance and productivity. The upper North Fork also appears to support current diversity in the NF/MF population. Channel instability and loss of habitat diversity and key habitats are the dominant limiting factors in the upper North Fork. Egg incubation is the most limiting life stage, followed by fry.

Channel Stability: Moderate impact.

- *Certainty of Impact. High.* EDT reach diagnosis indicates that channel instability in the upper North Fork has a moderate impact on NF/MF Nooksack early chinook (Figure 4.6). See evidence (Hyatt and Rabang 2003) presented for channel stability impacts to lower North Fork. GeoEngineers (2001) also describes the reach from RM 61.75 to 64.5 as subject to frequent fluctuations in channel width and episodes of accelerated lateral migration, bank erosion and channel avulsion, while the channel planform of the reach upstream has been relatively stable since 1940.
- *Early Chinook Impacts.* Channel instability most strongly impacts productivity of the egg incubation stage, which is the most limiting life stage throughout the upper North Fork. According to EDT, there has been a 31 to 61% reduction in productivity of this life stage, due largely to channel instability and high fine sediment load. Fry and overwintering juveniles are limited to a lesser extent, most likely due to gravel embeddedness.
- *Relative Importance of Causal Mechanisms.*
    - *Moderate Importance, Low Certainty.* Forest management (especially road-building and harvest in the rain-on-snow zone) has increased the magnitude and frequency of peak flows, which has in turn increased channel instability (see also description for lower North Fork). The North Fork Watershed Analysis (USFS 1995a) found evidence of channel widening in response to peak flow events, which were commonly associated with rain-on-snow events. The USFS (1995a) determined that no change in peak flow is likely in the upper North Fork basin due to the relatively small clearcut area (4%). Also, it was expected that the impact from road drainage would show no net increase to flooding over the long term, due to road stabilization and decommissioning activities (USFS 1995a).
    - *Moderate Importance, High Certainty.* Elevated mass wasting frequency due to forestry management practices has increased coarse sediment supply to the upper North Fork. North Fork Landslide inventories (Watts 1997) identified road construction and clear-cutting as important mechanisms of shallow-rapid and small sporadic slope failures, accounting for nearly 65% of these

types of failures. A majority (74%) of these types of events delivered sediment to stream channels. Using aerial photos, Indrebo (1998) found a correlation between channel widening and peaks in landslide density. During these large storm events, tributaries contribute large amounts of debris and sediment directly into mainstem spawning reaches (USFS 1995a). This deposition results in mainstem channel widening and destabilization.

- *Moderate Importance, Moderate Certainty*. Lack of stable, in-channel wood has decreased channel stability. Instream wood that is present in the system is often in transient wood accumulations, with very few key-sized pieces (Lummi Natural Resources, 2003 unpublished data). Lack of wood may be due to wood removal (USFS 1995a). Riparian harvest does not appear to be a significant impact; assessment of riparian function along the upper North Fork active channel indicates that wood recruitment potential is largely high (78%; Coe 2001).

Habitat Diversity: Moderate impact.

- *Certainty of Impact. Moderate.* EDT reach diagnosis indicates that the lack of habitat diversity in the upper North Fork has a moderate impact on NF/MF Nooksack early chinook (Figure 4.6). Wood surveys found limited stable wood in the active channel of the upper North Fork; the wood that is present is both smaller and more transient and tends to be perched on gravel bars (Lummi Natural Resources, unpublished data). Habitat surveys of the upper part of the reach (Four Mile Flats; RM 61.2 to 64.2) indicate that dominant pool-forming feature is bedrock, which may be a change from historic conditions, where wood played a more active role in pool formation. Mapping also showed a low pool to riffle ratio for channel spanning habitat units. In braided reaches, smaller pocket pools were commonly formed by wood. Further, excess sedimentation and low wood loading has likely simplified habitat and reduced habitat unit diversity.
- *Early Chinook Impacts.* Lack of habitat diversity affects NF/MF Nooksack early chinook productivity, primarily the fry life stage, but also other juvenile rearing life history stages. Complex cover is an important habitat component for multiple chinook life stages (see 4.1.3.3. *Habitat Diversity* for description).
- *Relative Importance of Causal Mechanisms.*
  - *Moderate Importance, Moderate Certainty*: There is a lack of stable wood jams in the channel as a result of degraded riparian function. Instream wood that is present in the system is often in transient wood accumulations, with very few key-sized pieces (Lummi Natural Resources, unpublished data). Riparian function in the reach is degraded due to riparian harvest and, to a lesser extent, removal of large wood from the active channel (USFS 1995a). Forest fires have also reduced riparian stand size, historically limiting the size of trees present in the riparian zone (USFS 1995a). However, assessment of riparian function along the upper North Fork active channel indicates that wood recruitment potential is largely high (78%; Coe 2001).

  - *Moderate Importance, Moderate Certainty*. There has been a loss of complex edge and backwater habitat (e.g. undercut banks with fallen trees) as a result of degraded riparian function. Bank conditions are also simpler due to reduced bank stability associated with degraded riparian function.
  - *Moderate Importance, Low Certainty.* Increased coarse sediment delivery as a result of forest management-induced mass wasting has led to pool infilling and has reduced bedform and habitat diversity. Recent inventories of landslides and forest road networks in the Nooksack basin (Watts 1996; Watts 1997; Watts 1998; Zander 1996; Zander 1997; Zander 1998), in concert with previous inventories conducted as part of the Watershed Analyses (*USFS 1995a)* indicate that landslides from roads and timber practices are common in the watershed and generate a large amount of sediment.

Key Habitat Quantity: Moderate impact.

- *Certainty of Impact. Low.* EDT reach diagnosis indicates that the lack of key habitat in the upper North Fork has a moderate impact on NF/MF Nooksack early chinook (Figure 4.6). Quantitative habitat survey data for the lower North Fork are limited. Habitat surveys of the upper part of the reach (Four Mile Flats; RM 61.2 to 64.2) indicate low pool to riffle ratios, a lack of functioning wood prior to the USFS restoration project in the reach, and unstable edge areas in braided sections of the reach. Further, excess sedimentation and lack of wood has likely reduced the availability of wood-formed main-channel pools, as well as complex backwater and edge habitats.
- *Early Chinook Impacts.* According to EDT, lack of key habitats highly impacts fry, and oversummer rearing life stages, as well as prespawn holding, indicating that lack of primary pools, backwaters, and edge habitats are limiting.
- *Relative Importance of Causal Mechanisms.*
  - *Moderate Importance, Moderate Certainty.* There is a lack of stable wood jams in the channel to form and maintain pool habitats. Instream wood that is present in the system is often in transient wood accumulations, with very few key-sized pieces (Lummi Natural Resources, unpublished data). Riparian function in the reach is degraded due to riparian harvest and, to a lesser extent, removal of large wood from the active channel (USFS 1996). Forest fires have also reduced riparian stand size, historically limiting the size of trees present in the riparian zone (USFS 1995a). However, assessment of riparian function along the upper North Fork active channel indicates that wood recruitment potential is largely high (78%; Coe 2001).
    - *Moderate Importance, Low Certainty.* Increased coarse sediment delivery through mass wasting has led to pool infilling and otherwise simplified habitat in the reach.

4.1.3.3.3. North Fork tributaries

Tributaries to the North Fork largely drain commercial forest lands, although Maple and Kendall Creeks drain rural- and rural forestry-zone lands and the watersheds of Canyon, Glacier, Boyd, Deadhorse, and Wells Creeks largely fall within the national forest boundary. Tributary watersheds are characterized by high topographic relief, although chinook are generally confined to the low to moderate gradient reaches in the downstream reaches of tributaries. Forest management has increased the magnitude and frequency of mass wasting in tributary watersheds; in several tributaries, this has resulted in increased frequency of debris flows that pass through chinook habitats.

North Fork tributaries represent 25% of the spawning distribution and 17% of the freshwater habitat of NF/MF Nooksack early chinook. Accounting for differences in reach length, restoration of North Fork tributaries is the 4th priority for recovery of NF/MF Nooksack early chinook abundance, productivity, and diversity, after the Middle Fork diversion dam, lower North, and lower Middle Fork. Tributaries to the North Fork, especially those downstream of Glacier Creek, provide a different kind of habitat than that available in the North Fork mainstem – including, under natural conditions, more stable channels with lower turbidities – so are likely important in maintaining diversity and spatial structure of the NF/MF Nooksack early chinook population. Important limiting factors include channel instability, lack of habitat diversity and loss of key habitat types, high fine sediment load, high temperatures, and low flows, as well as the partial barrier at the lower end of Canyon Creek. Productivity of egg incubation and spawning life stages tend to be most limited, but juvenile and holding life stages are also impacted.

Channel stability: High impact (Racehorse/Bear, Boulder, Canyon, Cornell/Macdonald, Glacier Creeks).

- *Certainty of Impact. Moderate.* EDT reach diagnosis indicates that channel instability in Racehorse/Bear, Canyon, and Glacier Creeks has a high impact on NF/MF Nooksack early chinook; the impact in other tributaries is indicated as low (Figure 4.6) but is likely to be high; exceptions include Maple Creek, which is low gradient and associated with wetlands that would moderate the effects of debris flows, and Boyd and Wells Creeks. Recent debris flow history through anadromous salmonid habitat (R. Nichols, U.S. Forest Service, pers. comm. 2002) includes: Canyon Creek (1984, 1989), Boulder Creek (11 times from 1962-1989; Gowan 1989), Deadhorse Creek (1962, 1989), Glacier Creek (1962, 1989), and Cornell Creek (1989). Redd destruction and habitat loss were documented in the 1980s in most major chinook spawning tributaries in the North Fork, including Canyon, Boulder, Cornell, and Racehorse Creeks; indeed, serious redd loss associated with debris flows and subsequent channel instability is estimated to have occurred in 1982, 1983, 1985, and 1986 brood years (Schuett-Hames & Schuett-Hames 1987). Channel instability has also been observed in lower Glacier Creek (USFS 1995a). In Cornell Creek, 80% of more of the channel bottom substrate is estimated to have shifted at high flows, especially after debris flows (Schuett-Hames & Schuett-Hames 1984, cited in Smith 2002). Channel instability is further evidenced by the proliferation of channelization and dredging projects initiated to protect bridges and property from bank erosion and flood damage, for example in Boulder, Cornell, Glacier, Canyon, and Racehorse Creeks (Schuett-Hames & Schuett-Hames 1987). A recent study of bed scour in Nooksack early chinook habitats (Hyatt and Rabang 2003) found that redd failure rates (from scour, fill or dewatering, as indicated by scour chains) in pooled tributary sites were substantially less than in mainstem sites: 10% (2002-2003; highest flow <1 year recurrence interval) and 27% (2001-2002; highest flow 8-10 year recurrence interval), compared to the 56% and 72% failure rates, respectively, observed in mainstem habitats. Among North Fork tributaries, however, the study included sites in Racehorse, Maple, Thompson, and Boyd Creeks; Boulder, Canyon, Cornell, and Glacier Creeks were not included.

- *Early Chinook Impacts.* Channel instability has the greatest impact on survival and thus productivity of the egg incubation stage, which is the most limiting life stage in just over half of North Fork tributary reaches. Channel instability also impacts the productivity of other life stages present in the reach during high flow periods, including fry and overwintering juveniles, although to a much lesser degree than egg incubation.
- *Relative Importance of Causal Mechanisms.*
    - *High Importance, High Certainty:* Road fill failures and harvest-related slope failures have increased coarse sediment delivery to early chinook habitats throughout the tributaries of the North Fork. Recent inventories of landslides and forest road networks in the Nooksack basin (Watts 1996; Watts 1997; Watts 1998; Zander 1996; Zander 1997; Zander 1998), in concert with previous inventories conducted as part of the Watershed Analyses and graduate studies (USFS 1995a, USFS 1995b, DNR 1995, Gowan 1989, PEAK Northwest 1986) indicate that landslides from roads and timber practices are common in the watershed and generate a large amount of sediment.
    - *Moderate Importance, Moderate Certainty.* Lack of in-channel wood has contributed to channel instability in North Fork tributaries. Instream LWD levels were less than 10 pieces per mile in Glacier Creek, 20 pieces per mile in Canyon Creek, and were also low in Cornell Creek (data from U.S. Forest Service 1995a; cited in Smith 2002). Large stable wood can help moderate the effects of excess sedimentation.
    - *Moderate Importance, Low Certainty.* Forest management has increased the frequency and magnitude of peak flows, primarily through extension of the drainage network by forest roads and historic harvest in rain-on-snow zones of the watershed. Although evidence from the hydrologic record is lacking, high road densities in the contributing watersheds to the lower North Fork increases the likelihood of hydrologic effects. Road densities

(miles per square mile watershed area) in watersheds of early chinook tributaries to the North Fork are: 4.83 (Boulder Creek), 3.38 (Cornell Creek), 3.17 (Maple Creek), 2.76 (Racehorse Creek), 2.33 (Canyon Creek), 1.83 (Glacier Creek), 0.97 (Wells Creek), 0.72 (Deadhorse Creek) (D. Coe, Nooksack Tribe, using DNR 2000 transportation and WRIA 1 basin shape files).

Habitat Diversity: High impact (Boulder and Canyon Creeks) or moderate impact (Racehorse, Maple, Boyd, Deadhorse, and Wells Creeks).

Certainty of Impact. Moderate. EDT reach diagnosis indicates that the lack of habitat diversity in Boulder and Canyon Creeks has a high impact on NF/MF Nooksack early chinook, while in Racehorse/Bear, Maple, Boyd, Deadhorse, and Wells Creeks the impact is moderate (Figure 4.6). Simplified habitat (riffles and rapids with few pools) has been documented in Canyon Creek (USFS 1995b, cited in Smith 2002), Cornell Creek (USFS 1995a, cited in Smith 2002; DNR 1995), and Boulder Creek (Schuett-Hames and Schuett-Hames 1987). Low levels of instream wood to provide instream cover have been documented in Glacier Creek (USFS 1995a, cited in Smith 2002), Cornell Creek (DNR 1995), Canyon Creek (Smith 2002).

- *Early Chinook Impacts.* Lack of habitat diversity most strongly impacts productivity of juvenile rearing stages, especially fry, but also oversummer rearing. Complex cover is an important habitat component for multiple chinook life stages (see 4.1.3.3. *Habitat Diversity* for description).
- *Relative Importance of Causal Mechanisms.*
  - *High Importance, Low Certainty:* Loss of instream cover and habitat diversity is a result of a lack of stable wood in the channel, a result of degraded riparian function. Large woody debris recruitment potential in riparian areas of several North Fork tributary watersheds are predominantly low or moderate (Coe 2001), including Racehorse (57% low, 21% moderate), Maple (41% low, 33% moderate); Boulder (63% low, 15% moderate), and Cornell (48% low, 7.5% moderate).
  - *Moderate Importance, Moderate Certainty.* Increased sediment delivery to early chinook tributaries from upslope mass wasting, combined with the lack of instream wood, has simplified habitat, reducing habitat unit diversity and frequency of pools. Degradation and simplification of habitat has been documented as a result of excess sedimentation from debris flows in Canyon, Boulder, Cornell, Glacier, and other North Fork tributaries (Schuett-Hames & Schuett-Hames 1987; USFS 1995a, cited in Smith 2002).
  - *High Importance, High Certainty:* Wood removal for fish passage and flood conveyance was conducted through many of the lower reaches of major tributaries in the North Fork up until the 1980s. Salvage of wood from the channel occurred following floods in the early 1960s (USFS 1995a).

Sediment Load: Moderate impact

- *Certainty of Impact. Moderate*. EDT reach diagnosis indicates that high fine sediment load in Racehorse/Bear and Glacier Creeks has a high impact on NF/MF Nooksack early chinook, while in Cornell and MacDonald Creeks the impact is moderate (Figure 4.6). Racehorse Creek is on the 303d list for fine sediment (DOE 1998). However, while fine sediment (<0.85mm) levels in Racehorse Creek were high in the 1980s (17.5%, n=4; Schuett-Hames and Schuett-Hames 1984), more recent data indicate that levels have moderated (13%, n=4; Hyatt and Rabang 2003). Recent data also indicate low to moderate fine sediment levels in Boyd Creek (13%, n=1) and Maple Creek (8%, n=3; Hyatt and Rabang 2003). Although not sampled recently, fine sediment levels were low to moderate in the early to mid 1980s in Boulder Creek (n=2, 12.5%), Canyon Creek (8%, n=4), Cornell Creek (11%, n=3), and Deadhorse Creek (11%, n=1; Schuett-Hames and Schuett-Hames 1984). Impact is thus considered to be moderate. Fine sediment measurements can be problematic, however, as within-site variability in fine sediments is often as between site variability (Hyatt and Rabang 2003).
- *Early Chinook Impacts.* EDT indicates strong impacts of high fine sediment load to productivity of the egg incubation stage, since fine sediments in spawning gravels reduce survival to emergence. Fry life stages are also impacted; high fine sediment load is associated with high turbidities and gravel embeddedness. See Section 4.1.3.2 (*Sediment Load*) for further description of how high fine sediments affect these life stages.
- *Relative Importance of Causal Mechanisms.*
    - *High Importance, Moderate Certainty*: Sediment related to forest practices has increased the sediment load of forested tributaries in the North Fork Nooksack basin. USFS (1995) noted that many of the tributaries "flush-out" during storm events.

Temperature: High impact (Cornell/MacDonald, Racehorse Creeks); Moderate Impact (Canyon Creek)

- *Certainty of Impact. High.* EDT reach diagnosis indicates that high temperatures in Cornell, MacDonald, and Racehorse Creeks have a high impact on NF/MF Nooksack early chinook, while impact for Canyon Creek is moderate (Figure 4.6). Racehorse, Boulder, Canyon, and Cornell Creeks are on the 303(d) list for temperatures (DOE 1998). Continuous temperature monitoring during summer (June to September) 2003 indicate exceedances of DOE water quality standards at Cornell (60% of days monitored), lower Canyon (32%), and Racehorse Creeks (18%); among North Fork tributary sites, only Maple Creek met water quality standards (Kopp 2004). Upper ends of optimal temperature ranges for chinook were also exceeded at Cornell, Canyon, and Racehorse Creeks, especially for incubation, but also for migration and rearing. Temperatures exceeded the upper end of the optimal range for chinook incubation (12°C; Hicks 2000) during all days monitored by an average of 5.0°C in Racehorse Creek, 4.9°C in Cornell Creek, and 3.7°C in Canyon Creek; the monitoring period presented the first several weeks of incubation for early chinook. Temperatures exceeded the upper end of the optimal range for chinook migration and rearing (16.8°C; Hicks 2000) during substantial portions of the monitoring period (Kopp 2004); exceedances were documented at Racehorse Creek (average 1.18°C above threshold for 40% of days monitored), Cornell Creek (average 0.87°C above threshold for 41% of days monitored), and Canyon Creek (average 0.61°C above threshold for 15% of days monitored). Peak water temperatures approaching the lethal limit for salmonids have been recorded in Racehorse (24°C; Neff 1993) and Cornell Creeks (22.5°C; USFS 1995a, cited in Smith 2002).

- *Early Chinook Impacts.* EDT indicates temperature impacts productivity of the spawning life stage most, although egg incubation, prespawn migrant, and prespawn holding life stages are also impacted. See 4.1.3.8 *Temperature* for discussion of impacts.
- *Relative Importance of Causal Mechanisms.*
    - *High importance, Moderate Certainty*: High water temperatures in non-glacial tributaries to the North Fork are a result of reduced shading as a result of degraded riparian function. Stream shading levels are less than elevation-specific target shade levels in substantial proportions of Boulder (90% of riparian areas failed to meet target shade levels), Maple (61%), Racehorse (56%), Cornell (36%), and Canyon Creek (30%) watersheds (Coe 2001).
    - *Moderate Importance, Moderate Certainty*. Increased coarse sediment delivery from forest management-related mass wasting has led to aggradation and channel widening that increases surface area available for convective heat exchange (Poole and Berman 2000). Channel widening associated with coarse sediment inputs has been documented in Boulder (Schuett-Hames & Schuett-Hames 1987), Cornell Creek (DNR 1995, cited in Smith 2002), and Canyon Creek (USFS 1995b, cited in Smith 2002). As a result of the 1994 levee construction (see below), Canyon Creek has since incised.

Obstructions: Moderate impact (Canyon Creek)

- *Certainty of Impact. High.* The barrier at Canyon Creek ~RM 0.3 (location changes with channel changes) was not considered to be an obstruction at the time habitat was rated for EDT, so EDT reach diagnosis did not indicate an impact to NF/MF Nooksack early chinook (Figure 4.6). However, for the last several years, numerous early chinook have been observed holding in the pool downstream of the barrier and unsuccessfully attempting passage upstream during low-flow periods.
- *Early Chinook Impacts.* The lower Canyon Creek barrier partially blocks upstream access to 4.1 miles of anadromous habitat in Canyon Creek, which affects productivity, abundance, and spatial structure of NF/MF Nooksack early chinook (see 4.1.3.5 *Obstructions)*. The barrier also blocks access to abundant

pink salmon, thereby eliminating an important source of marine derived nutrients, which would otherwise boost productivity in upstream habitat.

- *Relative Importance of Causal Mechanisms.*
  - *High importance, High Certainty*: The barrier formed as a result of a large, long armored levee built by Whatcom County in 1994 to protect homes on the Canyon Creek alluvial fan. The levee significantly constrains Canyon Creek from the outlet of the canyon downstream; associated rock groins shifted the channel to the left side of the floodplain. A new channel has since incised into bedrock outcrops that form the barrier. The location and passability of the barrier shifts somewhat between years in response to channel changes.

Key Habitat Quantity: Moderate impact.

- *Certainty of Impact. Moderate.* EDT reach diagnosis indicates that lack of key habitat has a moderate impact on NF/MF Nooksack early chinook in all modeled North Fork tributaries, except Racehorse/Bear (high impact) and Boyd, Deadhorse, and Wells Creeks (low impact; Figure 4.6). Loss of key habitat has been documented in numerous tributaries, including: (1) lower Canyon Creek, which currently has virtually no optimal spawning sites, few holding pools, and little woody debris (D. Huddle, WDFW, pers. comm. 2004); (2) Boulder Creeks, which is dominated by riffles and rapids with coarse compacted substrates (Schuett-Hames and Schuett-Hames 1987); (3) Cornell Creek, also dominated by riffles and rapids (Schuett-Hames and Schuett-Hames 1987), with low frequency of pools (DNR 1995); and (4) Glacier Creek, where pool habitat availability is believed to be impacted by infilling from excess sedimentation (USFS 1995a, cited in Smith 2002).
- *Early Chinook Impacts.* EDT indicates that lack of key habitat types affects habitat capacity (and therefore abundance) for juvenile (fry, oversummer and overwinter rearing and yearling life stages) and holding life stages in Glacier, Canyon, Boulder, Racehorse/Bear, and Maple Creeks (except holding); spawning habitats are also limiting habitat capacity in Canyon, Boulder, and Racehorse/Bear creeks. This indicates that the habitat types most limiting in most North Fork tributaries are primary pools, backwater pools, complex edge habitats, side channels, and pool tailouts. Lack of habitat for overwintering and yearling life stages is likely less important, as chinook likely distribute downstream to mainstems for overwintering and beyond. See 4.1.3.4 *Key Habitat Quantity* for description of life-history specific habitat needs.
- *Relative Importance of Causal Mechanisms.*
  - *High Importance, Moderate Certainty:* Holding and juvenile rearing habitat quantity is limited by low quantities of stable wood in the anadromous zones of the North Fork tributaries, which scour pools and provides predation and high flow refuge. Large woody debris recruitment potential in riparian areas of several North Fork tributary watersheds are predominantly low or moderate (Coe 2001), including Racehorse (57% low, 21% moderate), Maple

(41% low, 33% moderate); Boulder (63% low, 15% moderate), and Cornell (48% low, 7.5% moderate).

- o *Moderate Importance, Moderate Certainty.* Increased sediment delivery to early chinook tributaries from upslope mass wasting, combined with the lack of instream wood, has simplified habitat, reducing habitat unit diversity and frequency of pools. Degradation and simplification of habitat has been documented as a result of excess sedimentation from debris flows in Canyon, Boulder, Cornell, Glacier, and other North Fork tributaries (Schuett-Hames & Schuett-Hames 1987; USFS 1995a, cited in Smith 2002).
- o *High Importance, High Certainty:* Wood removal for fish passage and flood conveyance was conducted through many of the lower reaches of major tributaries in the North Fork up until the 1980s. Salvage of wood from the channel occurred following floods in the early 1960s (USFS 1995a).

Flow: Moderate impact (Racehorse/Bear, Boulder, and Canyon Creeks).

- *Certainty of Impact. Low*. EDT reach diagnosis indicates that changes in flow regime in Racehorse/Bear, Boulder, and Canyon Creeks have a moderate impact on NF/MF Nooksack early chinook (Figure 4.6). Although empirical evidence of increases in frequency and/or magnitude of peak flows is lacking, the magnitude of impact is likely considering watershed conditions (high road densities, floodplain confinement; see below for description). Canyon, Thompson, Gallop, Cornell, Maple, and Racehorse Creeks are closed to further withdrawals during part of the year (DOE 1995, cited in Smith 2002).
- *Early Chinook Impacts.* Increases in magnitude, frequency, or effects (i.e. through floodplain confinement) of peak flows affects the spatial distribution of velocities in the channel, increasing average velocity and decreasing the availability of low velocities, which can lead to downstream displacement of fry or overwintering juveniles, especially where lack of wood and access to floodplain habitats further reduces the availability of hydraulic refugia. EDT indicates high flows in the named tributaries has the greatest impact on productivity of fry and overwintering juveniles; however, likelihood of impact to fry is greater as most overwintering occurs in unconfined reaches of the North Fork and mainstem. Increases in magnitude, frequency, or effects (i.e. through floodplain confinement) of peak flows affects the spatial distribution of velocities in the channel, increasing average velocity and decreasing the availability of low velocities, which can lead to downstream displacement of fry or overwintering juveniles, especially where lack of wood and access to floodplain habitats further reduces the availability of hydraulic refugia. Low flows can delay or prevent upstream migration in tributaries for spawners.
- *Relative Importance of Causal Mechanisms.*
  - o *Moderate Importance, Low Certainty.* Forest management has increased the frequency and magnitude of peak flows, primarily through extension of the drainage network by forest roads. Road-building associated with forest

management is considered to have the greatest effect on the hydrologic regime (Harr et al. 1975; Jones and Grant 1996); for instance, disconnecting road systems from the channel network can decrease peak flow response by 40% (Bowling and Lettenmaier, 2001). Although evidence from the hydrologic record is lacking due to lack of long-term stream gaging, high road densities in the contributing watersheds to the lower North Fork increases the likelihood of hydrologic effects, especially magnitude and frequency of peak flow events. Road densities (miles per square mile watershed area) in watersheds of early chinook tributaries to the North Fork are: 4.83 (Boulder Creek), 2.76 (Racehorse Creek), and 2.33 (Canyon Creek) (D. Coe, Nooksack Tribe, using DNR 2000 transportation and WRIA 1 basin shape files).

- *Moderate Importance, Moderate Certainty*: Floodplain confinement increases the effects of peak flows on chinook habitats, decreasing the cross-sectional area and thereby increasing the magnitude and reducing the diversity of velocities in-channel. The SR-542 bridges over Boulder Creek confine the channel, as does the extensive levee built along lower Canyon Creek.
- *Low Importance, Moderate Certainty*: Loss of in-channel wood reduces the availability of low-velocity refugia during peak flow events. Low levels of instream wood have been documented in Canyon Creek (Schuett-Hames & Schuett-Hames 1987).
- *Moderate Importance, Low Certainty.* Changes in hydrologic regime are exacerbated by sediment deposition in chinook reaches of tributaries, which compromises upstream fish access during low flow periods.

4.1.3.3.4. Lower Middle Fork

The lower Middle Fork is an unconfined, highly braided system. Like the lower North Fork, the channel pattern was historically anastomosing, with multiple channels, sloughs, and forested islands; a simpler, more frequently shifting braided pattern with fewer forested islands characterizes current conditions (Collins & Sheikh 2004b). The historic channel migration zone of the lower Middle Fork nearly fills its floodplain, occupying about 70% of floodplain width (Collins & Sheikh 2004a). The lower Middle Fork valley is largely zoned rural and rural forestry, while hillslopes are zoned commercial forestry. Stream-adjacent roads include Rutsatz Rd. and the Mosquito Lake Rd.; bank hardening is not extensive but is present at the edges of some meander bends.

The lower Middle Fork represents 19% of the spawning distribution and 12% of the freshwater habitat for NF/MF Nooksack early chinook. Restoration of the lower Middle Fork is expected to have a significant impact on recovery of NF/MF Nooksack early chinook abundance and productivity (Figure 4.4). Indeed, accounting for differences in reach length, it is the 3rd most important geographic area for restoration, after the Middle Fork diversion dam and the lower North Fork, and the 2nd most important geographic area for protection, after the lower North Fork. High temperatures, high fine sediment load, and lack of key habitats are the most significant limiting factors. Low flows have the potential for significant impact to the population, depending upon withdrawals at the Middle Fork diversion dam (which cannot ramp flows). Egg incubation is the most limiting life stage, followed by spawning, prespawning holding, and fry life stages.

Temperature: Low impact some years, moderate during other years.

- *Certainty of Impact. Low.* EDT reach diagnosis indicates that high temperatures in the lower Middle Fork have a high impact on NF/MF Nooksack early chinook (Figure 4.6). The Middle Fork is on the 303d list for temperature (DOE 1998). Peak water temperatures of 17.5°C have been measured in the lower Middle Fork (~RM 0.9), with 44% of samples warmer than 16°C; peak temperatures upstream tend to be cooler (16.4°C, RM 3.9; Neff 1993, cited in Smith 2002). In 1996, 80% of the water temperature samples at RM 4.8 were less than 14°C (USGS 2001, cited in Smith 2002). The effects of temperature on NF/MF Nooksack early chinook are considered to be low in some years but moderate in warmer, lower flow years. More water temperature monitoring of the lower Middle Fork is recommended.
- *Early Chinook Impacts.* EDT indicates that elevated late summer/ fall water temperature in the lower Middle Fork impacts productivity of spawning and egg incubation and, to a lesser extent, prespawn migrants and prespawn holding life stages. Temperatures may delay upstream migration, increase prespawn mortality, or otherwise reduce reproductive success. High temperatures during incubation may also decrease survival to emergence and/or result in earlier fry emergence. See 4.1.3.8 *Temperature* for further description of impacts.
- *Relative Importance of Causal Mechanisms.*
    - *High Importance, Low Certainty:* Increased summer water temperatures are the result of channel widening, coupled with the loss of stable forested islands and riparian stands that once shaded channels in the historically anastomosing section of the lower Middle Fork. A wider, simpler, more frequently shifting braided pattern with fewer forested islands characterizes current conditions in the lower Middle Fork; analysis of historical maps and aerial photos indicates that the Middle Fork has continued to widen from ~1880 to present (Collins & Sheikh 2004a).
    - *Moderate Importance, Moderate Certainty.* Increased summer water temperatures are the result of the loss of riparian shading in tributary watersheds. Stream shading levels fall short of elevation-specific target shade levels in a substantial portion of riparian areas of watersheds tributary to the Middle Fork; 47% of tributary riparian areas is at least 10% below target shading levels and 16% is at least 40% below target shading levels (Coe 2001).

Sediment Load: Moderate impact.

- *Certainty of Impact. Low.* EDT reach diagnosis indicates that high fine sediment load in the lower Middle Fork has a moderate impact on NF/MF Nooksack early chinook (Figure 4.6). No fine sediment data are available from the Middle Fork. Naturally high turbidities occur in the Middle Fork during spring and early summer due to the glacial origin of flow. However, despite limited evidence, there is potential for management-induced increases in fine sediment delivery to the lower North Fork due to past and ongoing forest management (Zander 1998), which may be manifest in either elevated proportions of fine sediments in spawning gravels or elevated turbidities during fall and winter storms.
- *Early Chinook Impacts.* EDT indicates that high fine sediment load in the lower Middle Fork impacts productivity of spawning and egg incubation life stages for NF/MF Nooksack early chinook. Spawning is most likely affected by high turbidities, while egg incubation is affected by high fine sediments in spawning gravels, which reduce survival to emergence.
- *Relative Importance of Causal Mechanisms.*
    - *High Importance, Moderate Certainty*: Elevated mass wasting frequency due to forestry management practices has increased fine sediment supply to the lower Middle Fork. Although the Middle Fork Nooksack River has a naturally high sediment yield from the Deming Glacier, past timber harvest activities have greatly increased sediment delivery to streams (Zander 1998, cited in Smith 2002). Overall, 480 landslides have been identified in the Middle Fork Nooksack Basin (Watts 1998, cited in Smith 2002). The majority of the landslides are shallow, rapid landslides (82%) that, together with the small, sporadic deep-seated slides, have the highest rate of sediment delivery to streams. Roads are associated with 36% of the landslides, while clearcuts are linked to 32% (Watts 1998, cited in Smith 2002). Landslide densities are greatest in Porter (15.7 events/mi^2), Canyon Lake (8.2), Falls (7.8), Clearwater (7.9), and Rocky Creek (7.6) watersheds (Watts 1998, cited in Smith 2002).
    - *Low Importance, Moderate Certainty:* Surface erosion of forest roads increases fine sediment delivery to the Middle Fork. Surface erosion from forest management activities typically comprises a small proportion of the total sediment budget for watersheds in the Pacific Northwest (Swanson et al., 1982). However, surface erosion from roads may contribute as much as 50% of the management-induced fine sediment inputs (Cederholm et al., 1981). Average road density in the Middle Fork Nooksack watershed is 2.16 miles of road per square mile of watershed area; subbasins with high road density include Canyon Lake (3.54 mi/mi^2), Heislers (5.03 mi/mi^2), and Galbraith Creek watersheds (5.58 mi/mi^2); road densities are fair (Smith 2002) in Falls (2.88 mi/mi^2), Porter (2.74 mi/mi^2), Clearwater (2.40 mi/mi^2), and Rankin Creek (2.28 mi/mi^2) watersheds (D. Coe, Nooksack Tribe, using DNR 2000 transportation and WRIA 1 basin shape files).

Key Habitat Quantity: Moderate impact.

- *Certainty of Impact. Moderate*. EDT reach diagnosis indicates that lack of key habitat in the lower Middle Fork has a moderate impact on NF/MF Nooksack early chinook (Figure 4.6). Quantitative habitat survey data for the lower Middle fork are limited. However, changes in the availability of key habitat types is expected given the observed changes in channel pattern and channel stability from historical conditions. Between ~1880 and the 1930s, the lower Middle Fork changed from an anastomosing channel pattern with multiple channels, sloughs, stable log jams, and forested islands to a much simpler, wider, braided channel with extensive gravel bars (Collins & Sheikh 2004b). The lower Middle Fork has also shown extensive lateral migration in recent years (Smith 2002); indeed, migration rates have systematically increased through time, from 2.9 ± 2.6 m/yr (<1933) to 9.2 ± 6.3 m/yr (1933-2002; Collins & Sheikh 2004a). As a result, current proportions of primary pools, backwater pools, side channels, and complex edge habitats are likely less than under historical conditions. Lack of wood is also associated with loss of deep, complex pools.
- *Early Chinook Impacts.* The amount of key habitat types affects habitat capacity, which controls equilibrium abundances. EDT indicates that lack of key habitat has a high impact on most life stages, especially fry, holding, oversummer rearing, and prespawn migrants, indicating that the habitat types most limiting in the reach are primary pools, backwater pools, complex edge habitats, side channels, and pool tailouts. Loss and simplification of fry and overwintering rearing habitat in the geographic area may also have affected NF/MF Nooksack early chinook diversity by reducing the relative abundance of yearling or parr migrant life history strategy relative to historical conditions.
- *Relative Importance of Causal Mechanisms.*
  - *Moderate Importance, High Certainty:* Loss of key habitat types is associated with the loss of stable wood in the lower Middle Fork due to degraded riparian function. Large wood is prevalent in the channel of the Lower Middle Fork immediately below Mosquito Lake Bridge, but in most cases, the wood provides little pool-forming function (Lummi Natural Resources, unpublished 2003 data). Riparian areas along the active channel of the lower Middle Fork have predominantly low (39%) or moderate (36%) large woody debris recruitment potential (Coe 2001).
  - *Moderate Importance, Moderate Certainty:* Loss of key habitat types is associated with the loss of stable wood in the lower Middle Fork due to removal of wood. Historically, wood has been removed from the channel and floodplain (Smith 2002). Even currently, firewood cutting is extensive on the open bars of the lower Middle Fork, where the river flows through rural residential areas.
  - *Low Importance, High Certainty.* Stream-adjacent roads constrain channel migration and/or reduce wood recruitment through bank hardening, leading

to loss of wood function in the lower Middle Fork. Mosquito Lake Rd. and Rutsatz Rd. partially constrain the lower Middle Fork.
    - *Moderate Importance, Moderate Certainty.* Increases in coarse sediment inputs to the lower North as a result of mass wasting has led to aggradation, habitat simplification, and pool infilling.

Flow: Moderate potential impact.

- *Certainty of Impact. Moderate*. Although EDT reach diagnosis indicates that the flow regime in the lower Middle Fork has a low impact on NF/MF Nooksack early chinook (Figure 4.6), the impact of the City of Bellingham water diversion is considered potentially moderate. Currently, the minimum instream flow in the Middle Fork is between 275-525 cfs; however, preliminary analysis of instream flow needs (USU, unpublished data) indicate that optimal flows for chinook would be higher than current levels. Although diversions in the past were substantial, the City has reduced the amount of water diverted since 1998 to maintain instream flows (Matthews et al. 2001, cited in Smith 2002). However, the City is not able to ramp flows with the current diversion structure, increasing the risk of stranding rearing juveniles.
- *Early Chinook Impacts.* Low flows in the Middle Fork limit productivity of multiple life stages of NF/MF Nooksack early chinook, including prespawn migrants, holding, spawning, egg incubation, and oversummer rearing (see 4.1.3.7 *Flow* for further description). Dewatering of redds is of particular concern. There may also be a legacy effect of the diversion. In past years, considerably more water was diverted, leaving little instream flow in the Middle Fork, which may have substantially reduced habitat capacity and productivity in the lower Middle Fork. Past diversions may also explain current spatial structure of the population – observed spawner escapements to the Middle Fork are lower than to the North Fork, although they appear to be increasing.
- *Relative Importance of Causal Mechanisms.*
    - *High Importance, High Certainty.* Diversion of water for the City of Bellingham can severely reduce in-stream flows downstream of the diversion dam. This can have a more severe impact with steep ramping rates.

4.1.3.3.5. Upper Middle Fork

Upstream of the Mosquito Lake Rd. bridge (RM 5), the Middle Fork becomes steeper and more confined, entering a box canyon ~1.5 miles upstream. The Diversion Dam, which diverts water from the Middle Fork to Lake Whatcom to augment the City of Bellingham's municipal water supply, blocks upstream passage almost completely, although the occasional salmon and trout have been observed jumping at or over the diversion (Currence 2000). Upstream of the diversion, the gradient moderates slightly, averaging 2 to 3% between Clearwater and Wallace Creeks and there are no natural barriers to upstream passage to at least RM 17.5. Habitat in the Upper Middle Fork Nooksack River is generally believed to be in good and improving condition, since 90 percent of the area is managed under U.S. Forest Service Late Successional Reserve or Washington Department of Natural Resource's Habitat Conservation Plan (Currence 2000).

The upper Middle Fork represents 7.4% of the spawning distribution and 4.9% of the freshwater habitat for NF/MF Nooksack early chinook. Restoration of passage at the Middle Fork diversion dam is considered to be the single most important action for recovery of NF/MF Nooksack early chinook, especially spatial structure and life history diversity, but also abundance and productivity. However, protection and restoration of habitat in the upper Middle Fork is not considered as important as in other geographic areas.

Obstructions (Middle Fork diversion dam): High impact.

- *Certainty of Impact. High.* EDT reach diagnosis indicates that the diversion dam at RM 7.2 has a high impact on NF/MF Nooksack early chinook (Figure 4.6). The Middle Fork diversion dam, which diverts water from the Middle Fork to Lake Whatcom to augment the City of Bellingham's municipal water supply, blocks upstream passage almost completely, although the occasional salmon and trout have been observed jumping at or over the diversion (Currence 2000). Potential anadromous habitat upstream of the diversion includes at least 10.2 miles in the Middle Fork and 6.9 miles in tributaries to the Middle Fork (Currence 2000). Historical and anecdotal evidence indicate that adult salmon were present above the dam site prior to construction (Currence 2000).
- *Early Chinook Impacts.* The Middle Fork diversion dam blocks upstream access to an estimated 17 miles of chinook habitat, or about 15% of the historically available habitat in the North and Middle Forks. This has strongly affected spatial structure, diversity, abundance, and productivity of the NF/MF Nooksack early chinook (Figure 4.4).
- *Relative Importance of Causal Mechanisms.*
    - *High Importance, High Certainty:* The Middle Fork Diversion is a documented passage barrier to most anadromous species. MF diversion dam is in place to divert water for City of Bellingham, but was built without provision for fish passage.

Habitat Diversity: Moderate impact.

- *Certainty of Impact. Low.* EDT reach diagnosis indicates that the lack of habitat diversity in most of the upper Middle Fork has a high impact on NF/MF Nooksack early chinook (Figure 4.6), but impact is considered moderate. Habitat condition ratings may have been underestimated, as the habitat is considered to be in fairly good condition and on a trajectory to recovery. Coe (2001) found mixed current riparian conditions and did NOT find a clear trend of improved riparian conditions moving up the fork, as occurs in North and South forks. STS Heislers Creek Hydro (1994) collected some data from Mosquito Lake Rd to

Wallace Creek (RM 5.0-14.5) and found 13.8% pools in the four reaches (reach results ranged from 34.2% to 0.0%), and overall gradient was 2.6%. Gravel formed 13.8% of dominate substrate, small cobbles 12.5% and large cobbles 32.7%.

- *Early Chinook Impacts.* Habitat diversity affects fry colonization and 0-age active rearing in the upper Middle Fork. Complex cover is an important habitat component for multiple chinook life stages (see 4.1.3.3 *Habitat Diversity* for further explanation).
- *Relative Importance of Causal Mechanisms.*
  - *High Importance, Low Certainty*. There is a lack of stable wood in the upper Middle Fork relative to historic conditions due to degraded riparian function. Riparian areas along the active channel of the upper Middle Fork have predominantly low (32%) or moderate (28%) large woody debris recruitment potential (Coe 2001).

4.1.3.3.6. Middle Fork tributaries

Tributaries to the Middle Fork largely drain commercial forest land. Land adjacent to the lower reaches of Canyon Lake, Porter, and Peat Bog Creeks are zoned rural and rural forest. Most of Warm, Sisters, and Wallace Creek watersheds and the upper portions of Rocky and Clearwater Creek watersheds are in the Mount Baker-Snoqualmie National Forest, with much of Wallace and Sisters Creeks watersheds in designated wilderness areas.

Tributaries to the Middle Fork represent 8.0% of the spawning distribution and 5.3% of the freshwater habitat for NF/MF Nooksack early chinook. Tributaries to the Middle Fork are not as important as other geographic areas for recovery of NF/MF Nooksack early chinook abundance, productivity, and diversity. Major limiting factors include lack of key habitats, high temperatures, loss of habitat diversity; high fine sediment load, channel instability, and change in flow regime are also a concern.

Key Habitat Quantity: High impact (Canyon Lake, Peat Bog, Porter Creeks); moderate Impact (Middle Fork tributaries upstream of diversion dam)

- *Certainty of Impact. Low.* EDT reach diagnosis indicates that the lack of key habitat in Canyon Lake, Peat Bog, and Porter Creeks has a high impact on NF/MF Nooksack early chinook, while in tributaries to the Middle Fork upstream of the diversion dam the impact is moderate (Figure 4.6). Habitat survey data for Middle Fork tributaries is limited, but impacts are likely given land use (sedimentation and loss of wood from forestry practices, degraded riparian conditions in lower reaches in rural areas).
- *Early Chinook Impacts.* EDT indicates that lack of key habitat strongly limits habitat capacity (and therefore abundance) of all life stages. See 4.1.3.4 *Key Habitat Quantity* for discussion of life-stage-specific habitat needs.
- *Relative Importance of Causal Mechanisms.*

- *High Importance, Moderate Certainty:* Availability of key habitats is limited by low quantities of stable wood in the anadromous zones of the Middle Fork tributaries, which scour pools and provides predation and high flow refuge. Although wood surveys are limited, large woody debris recruitment potential in riparian areas of Middle Fork tributaries is degraded (Coe 2001), including Canyon Lake (51% of riparian area has low lwd recruitment potential, 3% moderate), Porter (28% low, 11% moderate), Clearwater (11% low, 21% moderate), Sisters (37% low, 10% moderate), and Warm Creeks (18% low, 7% moderate).
- *Moderate Importance, Low Certainty.* Increased sediment delivery to early chinook tributaries from upslope mass wasting, combined with the lack of instream wood, has simplified habitat, reducing habitat unit diversity and frequency of pools.

Temperature: High impact (Canyon Lake, Porter Creeks); moderate impact (Peat Bog Creek, Middle Fork tributaries upstream of diversion dam)

- *Certainty of Impact. High (Canyon Lake), Moderate (others).* EDT reach diagnosis indicates that high temperature in Canyon Lake, Peat Bog, and Porter Creeks has a high impact on NF/MF Nooksack early chinook, while in Peat Bog Creek and tributaries to the Middle Fork upstream of the diversion dam the impact is moderate (Figure 4.6). Canyon Lake Creek is on the 303d list for temperature (DOE 1998). Continuous temperature monitoring during summer (June to September) 2003 indicate exceedances of DOE water quality standards at each of the Middle Fork tributaries monitored: Peat Bog Creek (92% of days monitored), Canyon Lake Creek (73%), and Porter Creek (23%; Kopp 2004). Upper ends of optimal temperature ranges for chinook were also exceeded at the three sites, especially for incubation, but also for migration and rearing. Temperatures exceeded the upper end of the optimal range for chinook incubation (12°C; Hicks 2000) during all days monitored by an average of 6.6°C in Canyon Lake Creek and 5.3°C in Peat Bog Creek; the monitoring period presented the first several weeks of incubation for early chinook. Temperatures also exceeded the upper end of the optimal range for chinook migration and rearing (16.8°C; Hicks 2000) during substantial portions of the monitoring period (Kopp 2004); exceedances were documented at Canyon Lake Creek (average 2.52°C above threshold for 65% of days monitored), Porter Creek (average 0.04°C above threshold for 3.8% of days monitored), and Peat Bog Creek (average 1.34°C above threshold for 79% of days monitored). Peak water temperatures approaching the lethal limit for salmonids have been recorded in Canyon Lake Creek (22.5°C; Neff 1993, cited in Smith 2002). No data are readily available for tributaries to the Middle Fork upstream of the diversion dam.
- *Early Chinook Impacts.* EDT indicates temperature impacts productivity of the spawning life stage most, although egg incubation, prespawn migrant, prespawn

holding, and oversummer rearing life stages are also impacted. See 4.1.3.8 *Temperature* for discussion of life-stage specific impacts of high temperatures.

- *Relative Importance of Causal Mechanisms.*
    - *High importance, Moderate Certainty*: High water temperatures in non-glacial tributaries to the Middle Fork are a result of reduced shading as a result of degraded riparian function. Stream shading levels are less than elevation-specific target shade levels in substantial proportions of Canyon Lake (95% of riparian areas failed to meet target shade levels), Porter (100%), and Sisters Creeks (63%); riparian shading is greater for Clearwater (30% below target shade levels) and Warm Creek (all riparian areas exceeded target shade levels by at least 10%) watersheds (Coe 2001).

Habitat Diversity: High impact (Porter Creek); moderate impact (Canyon Lake Creek, Middle Fork tributaries upstream of diversion dam).

- *Certainty of Impact.* EDT reach diagnosis indicates that the lack of habitat diversity in Porter Creek has a high impact on NF/MF Nooksack early chinook, while in Canyon Lake Creek and tributaries to Middle Fork upstream of diversion dam the impact is moderate (Figure 4.6). Habitat survey data for Middle Fork tributaries is limited, but impacts are likely given land use (sedimentation and loss of wood from forestry practices, degraded riparian conditions in lower reaches in rural areas).
- *Early* Chinook Impacts. EDT indicates that low habitat diversity strongly limits productivity of fry, oversummer and overwinter rearing, and holding life stages. See 4.1.3.3 *Habitat Diversity* for a discussion of life-stage-specific concerns with respect to habitat diversity.
- *Relative Importance of Causal Mechanisms.*
    - *High Importance, Moderate Certainty:* Habitat diversity is limited by low quantities of stable wood in the anadromous zones of the Middle Fork tributaries (see discussion for *Key Habitat* above).
    - *Moderate Importance, Low Certainty.* Increased sediment delivery to early chinook tributaries from upslope mass wasting, combined with the lack of instream wood, has simplified habitat, reducing habitat unit diversity and frequency of pools (see discussion for *Key Habitat* above).

Sediment Load: Moderate impact (Porter Creek, Canyon Lake Creek, Middle Fork tributaries upstream of diversion dam).

- *Certainty of Impact. Low*. EDT reach diagnosis indicates that high fine sediment load in Canyon Lake Creek and tributaries to Middle Fork upstream of diversion dam has a moderate impact on NF/MF Nooksack early chinook (Figure 4.6). However, the only available data on fine sediment levels in Middle Fork tributaries is a single sample from Porter Creek in 1982, for which fine sediment level (<0.85mm) was 11% (Schuett-Hames et al. 1988a). High total suspended solids and turbidities have been documented in Canyon Lake Creek (Smith 2002).

- *Early Chinook Impacts.* EDT indicates that high fine sediment load strongly limits productivity of spawning and egg incubation stages and moderately impacts productivity of prespawning migrant and holding life stages, indicating that fine sediments in spawning gravels and high turbidities are a concern. See *4.1.3.2* Sediment Load for discussion of life-stage-specific impacts.
- *Relative Importance of Causal Mechanisms.*
  - *High Importance, Moderate Certainty*: Elevated mass wasting frequency due to forestry management practices has increased fine sediment supply to Middle Fork tributaries. Landslide densities are high in Porter (15.7 events/mi^2), Canyon Lake (8.2), Falls (7.8), Clearwater (7.9), and Rocky Creek (7.6) watersheds (Watts 1998, cited in Smith 2002).
  - *Low Importance, Moderate Certainty:* Surface erosion of forest roads increases fine sediment delivery to the Middle Fork. Surface erosion from forest management activities typically comprises a small proportion of the total sediment budget for watersheds in the Pacific Northwest (Swanson et al., 1982). However, surface erosion from roads may contribute as much as 50% of the management-induced fine sediment inputs (Cederholm et al., 1981). Tributary watersheds with high road density include Canyon Lake (3.54 mi/mi^2), Heislers (5.03 mi/mi^2), and Galbraith Creek watersheds (5.58 mi/mi^2); road densities are fair (Smith 2002) in Falls (2.88 mi/mi^2), Porter (2.74 mi/mi^2), Clearwater (2.40 mi/mi^2), and Rankin Creek (2.28 mi/mi^2) watersheds (D. Coe, Nooksack Tribe, using DNR 2000 transportation and WRIA 1 basin shape files).

Channel Stability: Moderate impact (Canyon Lake and Porter Creeks).

- *Certainty of Impact.* EDT reach diagnosis indicates that channel instability in Canyon Lake Creek and Porter Creek has a moderate impact on NF/MF Nooksack early chinook (Figure 4.6). Recent debris flows have been recorded in Clearwater (1975, 1983, 1990), Porter (1989), and Canyon Lake Creeks (1989; R. Nichols, U.S. Forest Service, pers. comm. 2002, as cited in Smith 2002). Canyon Lake Creek and Porter Creeks were also described as unstable in the 1980s (Schuett-Hames et al. 1988a).
- *Early Chinook Impacts.* . Channel instability has the greatest impact on survival and thus productivity of the egg incubation stage. Channel instability also impacts the productivity of other life stages present in the reach during high flow periods, including fry and overwintering juveniles, although to a much lesser degree than egg incubation. See 4.1.3.1 *Channel Stability* for further description of impacts.
- *Relative Importance of Causal Mechanisms.*
  - *High Importance, Moderate Certainty:* Road fill failures and harvest-related slope failures have increased coarse sediment delivery to early chinook

habitats in Porter and Canyon Lake Creeks. Recent inventories of landslides and forest road networks in the Nooksack basin (Watts 1996; Watts 1997; Watts 1998; Zander 1996; Zander 1997; Zander 1998), in concert with previous inventories conducted as part of the Watershed Analyses, indicate that landslides from roads and timber practices are common in the watershed and generate a large amount of sediment.

- *Moderate Importance, Moderate Certainty.* Lack of in-channel wood has contributed to channel instability. Large stable wood can help moderate the effects of excess sedimentation.
- *Moderate Importance, Low Certainty.* Forest management has increased the frequency and magnitude of peak flows, primarily through extension of the drainage network by forest roads, thereby decreasing channel stability. Although evidence from the hydrologic record is lacking due to lack of long-term stream gaging, road densities (miles per square mile watershed area) are high (3.54 mi/mi^2) in the Canyon Lake Creek watershed and moderate (2.74 mi/mi^2) in the Porter Creek watershed (D. Coe, Nooksack Tribe, using DNR 2000 transportation and WRIA 1 basin shape files).

Flow: Moderate impact (Canyon Lake and Porter Creeks).

- *Certainty of Impact. Moderate.* EDT reach diagnosis indicates that flow in Canyon Lake Creek and Porter Creek has a moderate impact on NF/MF Nooksack early chinook (Figure 4.6). Porter and Canyon Lake Creeks are closed to further water allocations in the low flow period (DOE 1995, cited in Smith 2002).
- *Early Chinook Impacts.* Increases in magnitude, frequency, or effects (i.e. through floodplain confinement) of peak flows affects the spatial distribution of velocities in the channel, increasing average velocity and decreasing the availability of low velocities, which can lead to downstream displacement of fry or overwintering juveniles, especially where lack of wood and access to floodplain habitats further reduces the availability of hydraulic refugia. EDT indicates high flows in the named tributaries strongly impacts productivity of fry and overwintering juveniles; however, likelihood of impact to fry is greater as most overwintering occurs in unconfined reaches of the Middle Fork, lower North Fork, and mainstem. Increases in magnitude, frequency, or effects (i.e. through floodplain confinement) of peak flows affects the spatial distribution of velocities in the channel, increasing average velocity and decreasing the availability of low velocities, which can lead to downstream displacement of fry or overwintering juveniles, especially where lack of wood and access to floodplain habitats further reduces the availability of hydraulic refugia.
- *Relative Importance of Causal Mechanisms.*
  - *Moderate Importance, Low Certainty.* Forest management has increased the frequency and magnitude of peak flows, primarily through extension of the drainage network by forest roads. Road-building associated with

forest management is considered to have the greatest effect on the hydrologic regime (Harr et al. 1975; Jones and Grant 1996); for instance, disconnecting road systems from the channel network can decrease peak flow response by 40% (Bowling and Lettenmaier, 2001). Although evidence from the hydrologic record is lacking due to lack of long-term stream gaging, road densities (miles per square mile watershed area) are high (3.54 mi/mi^2) in the Canyon Lake Creek watershed and moderate (2.74 mi/mi^2) in the Porter Creek watershed (D. Coe, Nooksack Tribe, using DNR 2000 transportation and WRIA 1 basin shape files).

- *Moderate Importance, Low Certainty*: Loss of in-channel wood reduces the availability of low-velocity refugia during peak flow events. In the Middle Fork subbasin, Porter and Canyon Lake Creeks are also closed to further water allocations in the low flow period (DOE 1995).

4.1.3.3.7. Lower South Fork

Downstream of Skookum Creek, gradient and valley confinement of the South Fork decreases substantially. As described by Maudlin et al. (2002), the wide floodplain and low gradient make this reach an area of fine sediment deposition, channel migration and wood accumulation. The large amounts of wood described in early accounts (Morse 1883) would likely have caused frequent avulsions among a series of channel configurations. Channel movement through avulsion, coupled with logjams that functioned as hard-points across the floodplain, would likely have yielded a patchwork mosaic of mature forest and immature forest, as has been described in similar reaches that have not been as heavily impacted by land use activities (Fetherston et al. 1995). Evidence of such river dynamics is present in the pre-historic South Fork channels that dissect the valley floor, some now occupied by floodplain tributaries such as the Landingstrip Creek area and lower Hutchinson. An extensive system of wetlands, small channels, and ponds was historically associated with the lower South Fork, especially in the Black Slough area. Land use in the lower South Fork valley is predominantly zoned for agriculture, although rural and rural forest zoning is also present. Stream-adjacent roads that constrain the channel in sections include Highway 9, Mosquito Lake Rd. (near Acme), and the Burlington Northern railroad; bridges are associated with Potter Rd., Highway 9 at Acme, and Saxon Rd.

Riprap, which is prevalent from Acme downstream, has confined the channel to a single thread and greatly reduced the amount of slough and side-channel habitat. The City of Bellingham pipeline that carries the water from the Middle Fork diversion dam to Mirror Lake was buried under the South Fork Nooksack River and Hutchinson Creek, but without adequate accommodations for channel migration. Riprap placed to protect the pipeline where it crosses the South Fork (upstream from the Hutchinson Creek confluence) constrains the South Fork channel migration area width from 1200 feet to 200 feet, effectively halting the downstream migration of two meanders and severely impacting habitat-forming processes in the reach (Maudlin et al. 2002). The pipeline crossing of Hutchinson Creek further upstream also did not provide for channel movement.

The lower South Fork represents 36% of the spawning distribution and 19% of the freshwater habitat for SF Nooksack early chinook. Restoration of the lower South Fork is expected to have a very significant impact on recovery of SF Nooksack early chinook abundance and productivity; diversity would also be improved (Figure 4.3). Indeed, accounting for differences in reach length, it is the most important geographic area for restoration and the 3rd most important geographic area for protection, after the estuary and upper South Fork. High temperatures and lack of habitat diversity are the most significant limiting factors, followed by high fine sediment load, lack of key habitats, low flows, and human disturbance. Productivity of prespawn migrants, fry, egg incubation, and prespawn holding life stages are the most limited.

Temperature: High impact.

- *Certainty of Impact. High*. EDT reach diagnosis indicates that high water temperature in the lower South Fork has a high impact on SF Nooksack early chinook downstream of Jones Creek (Figure 4.5), although high temperatures have been well documented throughout the lower South Fork. The South Fork is on the 303d list for temperature (DOE 1998). Recently, summer temperatures in the lower South Fork have regularly exceeded water quality standards (WQS) of 18°C. Peak temperatures approaching the lethal limit have been recorded most years in the lower South Fork: 24°C in 1992 (Neff 1993), 21.8°C in 1995, 23.9°C in 1996 (USGS 2001, cited in Smith 2002), 22°C in 1998 (Soicher 2000), 19.4°C in 1999; 22.3°C in 2001 (Nooksack Tribe, unpublished data), and 24.3°C in 2003 (Kopp 2004). Continuous temperature monitoring during summer (June to September) 2003 indicate water temperatures exceeded DOE water quality standards at 8 sites in the lower South Fork on most days; the coolest site was 1.1 °C above threshold for 66% of the days monitored, while the warmest site was 3.4°C above threshold for 92% of days monitored. Monitored temperatures exceeded the upper ends of optimal temperature ranges for chinook incubation (12°C) and migration and rearing (16.8°C; Hicks 2000). Temperatures exceeded the upper end of the optimal range for chinook incubation by 5.1 to 8.2°C during all days monitored in August and September (Kopp 2004), which encompass the first several weeks of incubation for early chinook; Anchor Environmental 2003). Temperatures exceeded the upper end of the optimal range for chinook migration and rearing by several degrees during most days monitored (Kopp 2004); 7 of the 8 sites exceeded the threshold by 2.7°C to 3.6°C for 71% to 95% of the days monitored (Kopp 2004).
- *Early Chinook Impacts.* High temperatures reduce productivity of several life stages in the lower South Fork; EDT indicates that productivity of spawning, incubation, prespawn migrant and prespawn holding life stages are especially impacted, with moderate impact to oversummer rearing life stage. High

temperatures in the lower South Fork may stress holding and spawning fish and increase susceptibility to disease, which can cause prespawn mortality or otherwise reduce reproductive success. In 2003, numerous pre-spawning mortalities were observed among early chinook spawning in the South Fork (Nooksack Tribe, unpublished data); later necropsies indicated that individuals had *Columnaris*, which is associated with higher mortality at temperatures greater than 15°C (Spence et al. 1996). High temperatures during incubation result in earlier fry emergence than under natural conditions, which can increase exposure of fry to larger floods that tend to occur early in their emergence period and lead to involuntary downstream displacement. Early emergence can also reduce growth rates, if fry emergence is desynchronized from insect hatches that support rapid growth in spring and early summer. In addition to high temperatures, lack of deep pools and other potential thermal refugia to escape from high temperatures in the maisntem South Fork is also a concern. See also 4.1.3.8 *Temperature* for description of impacts.

- *Relative Importance of Causal Mechanisms.*
  - *High Importance, Low Certainty*. Disconnection of the South Fork from its floodplain through channel incision and channel confinement, coupled with draining of floodplain wetlands, has reduced groundwater discharge to the lower South Fork during summer low-flow periods. Between ~1880 and 1998, there has been a significant loss in the wetland area in the lower South Fork; loss of wetland area is especially pronounced in the Black Slough area, where only 19% of the historical wetland area remains (data from Collins & Sheikh 2004b). Over one-third of the lower South Fork is hydromodified (bank hardening and/or levees). Channel incision is also apparent in the lower South Fork (Maudlin et al. 2002).
  - *Moderate Importance, Low Certainty*. Changes in channel pattern of the lower South Fork have led to reduced riparian shading and hyporheic exchange, relative to historical conditions. Historically, the South Fork was a more complex, anastomosing system with numerous floodplain sloughs and side channels with stable log jams and forested islands; currently, the channel exhibits a simpler, braided pattern that has incised and effectively disconnected floodplain channels. The area in sloughs is 10% of historical conditions, while forested floodplain area is 36% of historical conditions (Collins & Sheikh 2004a, b). The historic anastomosing pattern, with numerous secondary channels interacting with the forested floodplain, would have effectively increased the channel area shaded by riparian vegetation. Further, there would have been greater hyporheic exchange at multiple scales (habitat unit, meander bend, and floodplain; Poole and Berman 2000), which would have moderated water temperatures in the reach.
  - *Moderate Importance, Moderate Certainty.* High temperatures in the South Fork mainstem are due to lack of riparian shading in tributary watersheds. Stream shading from riparian vegetation falls short of elevation-specific target shade

levels in 50% of riparian areas of tributaries to the South Fork (Coe 2001). Stream shading exceeds target shade levels in only 32% of riparian areas. High water temperatures are a concern in several South Fork tributaries (Smith 2002); further, Cavanaugh, Roaring, and Howard Creeks are on the 303d list for high temperatures (DOE 1998).

- o *Moderate Importance, Moderate Certainty.* Low flows in the lower South Fork exacerbate temperature problems during summer. The South Fork is on the 303d list for instream flows (DOE 1998).

Habitat Diversity: High impact

- *Certainty of Impact. High*. EDT reach diagnosis indicates that lack of habitat diversity in the lower South Fork (downstream of Jones Creek) has a high impact on SF Nooksack early chinook (Figure 4.5); however, impact is considered high throughout the lower South Fork. There is a general lack of complex pool and edge habitat in the lower South Fork (Doughty 1987; Smith 2002). Collins & Sheikh (2004b) documented the change from a more complex anastomosing channel pattern in ~1880 to a simpler channel pattern with substantial reduction in number of forested islands in 1998 throughout the upper mainstem and unconfined Forks. Since 1938, the channel has lost approximately 50% of its sharp-angled meander bends, which are associated with deep scour pools, and more than 37% of its channel length, primarily due to loss of secondary channels (Crown Pacific LP 1999). Although difficult to quantify, reductions in channel length (especially in secondary channels), gravel bar area, and slough length (Crown Pacific LP 1999) has likely reduced the frequency and diversity of other types of meso- and microhabitat units (e.g. lateral channel margins for fry, transverse riffles). Recent habitat surveys of the lower South Fork indicate that habitat unit diversity is low, especially in the lower reaches, with 14 habitat units/mile downstream of Acme and 30 units/mile upstream (Coe 2005). Maudlin et al. (2002) also found that habitat diversity was greater in the most upstream segment (15 units/km) of the Acme to Saxon reach than the downstream reaches (8.9 units/km in reach 1; 7 units/km in reach 2); secondary channel habitat was also more prevalent in the upstream reaches. Pools in the lower South Fork, especially downstream of Hutchinson Creek where the channel is more confined, are primarily formed by riprap, and the associated pools are larger and faster with less woody cover and hydraulic diversity than wood-formed pools (Maudlin et al. 2002; Coe 2005). Finally, pool depths have been widely reported as having decreased in recent years (e.g. Schuett-Hames et al. 1988b); there are anecdotal observations of 30 foot-deep pools earlier in the century, while the deepest pool in the Acme-Saxon reach was 9.7 feet (Maudlin et al. 2002). There is also a lack of complex woody cover in the lower South Fork. Wood jams, including channel-spanning jams, were historically abundant in the lower South Fork. Morse (1883) describes the presence of logjams "across the river nearly every mile." Current wood loading is low in the lower South Fork relative to historic conditions and there is a general lack of large, stable accumulations; indeed, the majority of wood is not interacting with the low-flow channel, where it could provide cover during summer months (DNR 1998; Maudlin et al. 2002). The predominance of riprap is also a concern: riprap bank conditions are simpler than natural bank conditions, especially natural banks on the outside edge of meander bends, which are often undercut and associated with wood and toppled trees; riprap also provides low quality cover for juvenile salmon.

- *Early Chinook Impacts.* EDT indicates that habitat diversity strongly limits productivity of adult holding, spawning and fry colonization life stages; productivity of oversummer and overwinter rearing and prespawning and juvenile migrants are also limited. Loss and simplification of fry and overwintering rearing habitat in the geographic area may also have affected SF Nooksack early chinook diversity by reducing the relative abundance of yearling or parr migrant life history strategy relative to historical conditions. The lack of deep, complex pool habitat – which affects holding and rearing chinook, is considered to be of greatest concern in the reach. In a study of South Fork chinook holding habitat in the South Fork, Schuett-Hames et al. (1988b) found that >98% of chinook held in areas with some cover (undercut bank, bedrock, wood, boulders, turbulence), although they preferred wood; chinook selected the deepest depths available. Most (76%) of the juvenile chinook enumerated during a snorkel survey of the upper Acme-Saxon reach was associated with wood cover, including 51% with complex cover (multiple logs; Ecotrust, unpublished data). Loss and simplification of edge and floodplain habitat is also a concern. For instance, several studies have shown that juvenile salmon prefer unaltered over riprapped stream banks (e.g. Hayman et al. 1996; Peters et al. 1998; Beamer and Henderson 1998). Loss of habitat complexity may also limit spawning in the reach; in Skagit River tributaries chinook spawning abundances were inversely related to pool spacing (Montgomery et al. 1999).
- *Relative Importance of Causal Mechanisms.*
    - *High Importance, High Certainty*: Channel confinement has reduced habitat diversity in the lower South Fork. Approximately one-third of the lower South Fork is hydromodified. Riprap contributes to habitat simplification by impeding the development of undercut banks with woody debris and overhead cover that are preferred by rearing salmonids, as well as reducing channel migration that recruits wood forms and maintains complex floodplain habitats (Schmetterling et al. 2001). Stream-adjacent roads and railroads also confine the channel, especially Hwy 9, Mosquito Lake Rd., and the Burlington Northern railroad.
    - *High Importance, High Certainty*: Habitat simplification is a result of degraded riparian function, which has reduced the supply of large wood to the channel and, where not associated with bank hardening, decreased bank stability. There are no riparian areas along the active channel of the lower South fork

with high large woody debris recruitment potential; large woody debris recruitment potential is either low (56%) or moderate (44%; Coe 2001). The loss of wood recruitment area and the immaturity of the riparian forests severely limits future wood levels in the river for at least the next 50 years (Lummi Natural Resources, unpublished data). The instream wood that is present is often in transient wood accumulations, with very few key-sized pieces associated with the active channel area.

- *Moderate Importance, High Certainty*: Loss of habitat diversity is a legacy of the removal of instream wood since the late 1800s. As cited in Maudlin et al. 2002: *During the twentieth century, logjams were actively removed from the channel, which resulted in virtually 100% of the large wood being taken from within the channel and floodplain of [the lower South Fork]… (Crown Pacific LP 1999)… There is also evidence of substantial transport of wood from logging operations down the river. A salmon hatchery egg eyeing station was built on the South Fork near Acme in 1908, but owing to winter freshets and the "immense quantity of shingle bolts driven down the river", the report discouraged any further attempts to rack the South Fork to obtain broodstock (20th and 21st Annual WDF Report, 1909).*

Sediment Load: Moderate impact.

- *Certainty of Impact. High.* EDT reach diagnosis indicates that high fine sediment load in the lower South Fork has a moderate impact on SF Nooksack early chinook (Figure 4.5). The South Fork is on the 303-d list for fine sediment (DOE 1998). Recent measurements of fine sediments in potential spawning areas indicate moderate to high levels of fine sediments (<0.85mm) in the lower South Fork; of 6 sites sampled from RM 1.4 through 10.6, percent fine sediments was low in 1 site (10%, n=1, RM 10.15), moderate in 2 sites (RM 5.9: 15%, n=1; RM 10.6: 16%, n=1), and high in 3 sites (RM 1.4: 19%, n=1; RM 6.1: 20%, n=1; RM 9.2: 19%, n=1; Hyatt and Rabang 2003). Schuett-Hames et al. (1988b) observed that 37% of the usable spawning habitat in the South fork was moderately embedded (25-50% embedded) and about 4% was >50% embedded. Hyatt and Rabang (2003) observed a slight downstream increase in fine sediments in spawning gravel samples through the South Fork. High turbidities, which persist relatively late into the spring and early summer, are also a concern. During high flow sampling in 2004/2005, Kopp (2005) measured higher turbidities and suspended solids in the South Fork (209.1 NTU; 264.6 mg/L) than in either the North (158 NTU; 120.7 mg/L) or Middle Forks (204.8 NTU; 182.1 mg/L). Soicher (2000) measured instantaneous turbidity at various locations during 1998 and 1999, including the South, Middle and North Forks, as well as tributaries to the South Fork. The lower South Fork (Potter Rd. Bridge) had the highest measured turbidity, at 632 nephelometric turbidity units (NTU), whereas maximum turbidity in the glacially turbid North and Middle Forks were 66 NTU and 36 NTU, respectively. Anecdotal observations indicate high turbidities, which limit spawn and snorkel surveying, can persist in the South Fork through mid to late summer.

- *Early Chinook Impacts.* EDT indicates that high fine sediment load has a high to extreme impact on productivity of egg incubation life stage, high impact to fry and overwinter rearing, and moderate to high impact on 0-age and 1-age migrant life stages. High proportions of fine sediments in spawning gravels reduce survival to emergence for egg incubation life stage, while gravel embeddedness reduces interstitial spaces used by fry and overwintering chinook. High turbidities may also alter timing of downstream migration. See also 4.1.3.2. *Sediment Load* for further description of impacts.
- *Relative Importance of Causal Mechanisms.*
  - o *High Importance, Moderate Certainty.* There are numerous mass wasting areas along the upper South Fork from ~RM 16.5 to RM ~36 (Schuett-Hames et al. 1988b; Osbaldiston 1995) that are delivering or have the potential to deliver substantial amounts of fine sediment directly to the South Fork. Just one of these landslides was estimated to have delivered 210,000 yd^3 of fine sediment in three years to one of the most heavily used spawning areas in the South Fork (Abbe 1999). Such slides also visibly contribute to high turbidities in the South Fork, as evidenced from aerial flights over the South Fork (D. Huddle, WDFW, pers. comm. 2003). Most are deep-seated rotational features (e.g. earth slumps), although secondary shallow features occur within the larger deep-seated landslides. All of these slides are associated with unconsolidated glacial sediments, most notably glacial outwash and glacial lacustrine sediments. Although the landforms are natural, loss of LWD roughness elements may lead to increased channel incision, oversteepening stream-adjacent valley walls and increasing rates of landsliding and bank erosion. Further, historically abundant wood likely buttressed the toe of such landslides, reducing bank erosion rates.
  - o *Moderate Importance, Low Certainty*. Levees and channel incision have isolated the floodplain, causing fine sediment deposition in the channel rather than on the floodplain. Over one third of the lower South Fork has been hydromodified; there is also evidence that the lower South Fork has incised (Maudlin et al. 2002). Potential causes of channel incision include loss of LWD roughness elements and artificial channel confinement.
  - o *Moderate Importance, Moderate Certainty*. Elevated mass wasting frequency due to forestry management practices has increased fine sediment supply to the lower South Fork. Kirtland (1995) estimated that landslides account for an estimated 72% of the sediment delivered to streams in the upper South Fork. Landslide inventories indicate that 81% of the 1216 landslides in the South Fork basin are shallow, rapid events that tend to deliver sediment to streams (Watts 1996, cited in Smith 2002). Most of the landslides are associated with forest management, with 37% related to clearcuts and 32%

associated with roads (DNR 1994, 1998; Kirtland 1995; Watts 1996, Benda and Coho 1999 draft; cited in Smith 2002).

- *Low Importance, Moderate Certainty:* Surface erosion of forest roads increases fine sediment delivery to the lower South Fork. Average road density in the South Fork subbasin is high at 3.38 miles of road per square mile of watershed area; watersheds with high road density include Hutchinson Creek (5.48 mi/mi^2), Deer/Roaring/Plumbago Creeks (4.54 mi/mi^2); Dye (3.98 mi/mi^2), Skookum Creek (3.56 mi/mi^2), and Cavanaugh Creek (3.56 mi/mi^2); watersheds with moderate road density include Howard (2.84 mi/mi^2) and Edfro Creeks (2.85 mi/mi^2); D. Coe, Nooksack Tribe, using DNR 2000 transportation and WRIA 1 basin shape files).

Key Habitat Quantity: Moderate impact.

- *Certainty of Impact. High.* EDT reach diagnosis indicates that lack of key habitat in the lower South Fork has a moderate impact on SF Nooksack early chinook (Figure 4.5). The lack of holding pool habitat in the lower South Fork has been widely reported (Smith 2002). Holding habitat is especially limiting in the lower 10 miles of the reach, where holding habitat area (scaled to reach length) is ~38% of that available from RM 10-15 (Schuett-Hames et al. 1988b). Pools comprise only 11% and 16% in the mouth to Acme reach (RM 0 – 8.5) and Acme to Saxon (RM 8.5 – 12.9) reach of the South Fork, respectively; pool frequencies were 4.4 pools/mile downstream and 9.3 pools/mile upstream of Acme (Coe 2005). It is worth noting that habitat surveys in the Acme to Saxon reach just distinguished between pools and riffles; many of the units classified as pools exhibited a "glide-like" character (D. Barker, Nooksack Salmon Enhancement Association, pers. comm. 2000). Floodplain habitat is also limited: the area in sloughs is 10% of historical conditions (Collins & Sheikh 2004a) and there has been a 37% reduction in channel length, primarily due to loss of secondary channels (Crown Pacific LP 1999). Currently, 95% of the floodplain channel length available in the lower South Fork is associated with tributaries rather than side channels, sloughs or other secondary channels (Coe 2005). Loss of key habitat types is confounded by the loss of habitat diversity in the reach; for example, current pools lack the cover, hydraulic complexity, depth, and – potentially – thermal stratification of historically available pools. See also *Habitat Diversity* limiting factor above.
- *Early Chinook Impacts.* The amount of key habitat affects habitat capacity, which controls equilibrium abundances. EDT indicates that lack of key habitat strongly limits juvenile rearing (oversummer, overwinter, yearling, and fry life stages) and prespawning adult (holding and upstream migration) life stages, indicating that the habitat types most limiting in the reach are primary (i.e. main channel) pools, and, to a lesser extent, backwater pools, complex edge habitats, and side channels. Lack of pools may also limit chinook spawning in the reach. Lack of pools and habitat complexity may also limit spawning by chinook in the reach. Through monitoring associated with logjam construction in the North Fork

Stillaguamish, it was observed that greater than 80% of chinook spawned within one channel width of a pool (Pess et al. 1998). In Skagit River tributaries, spawning abundances of both chinook and coho were inversely related to pool spacing (Montgomery et al. 1999). Loss and simplification of fry and overwintering rearing habitat in the geographic area may also have affected NF/MF Nooksack early chinook diversity by reducing the relative abundance of yearling or parr migrant life history strategy relative to historical conditions. See 4.1.3.4. *Key Habitat Quantity* for further description of life-stage-specific habitat needs.

- *Relative Importance of Causal Mechanisms.*
  - High Importance, High Certainty: Loss of in-channel wood due to wood removal and degraded riparian function has removed an important pool-forming element, which has reduced the quantity and quality of primary pools. See also discussion under *Habitat Diversity* for lower South Fork above.
  - *Moderate Importance, Moderate Certainty*. Excess sedimentation has led to pool infilling. Filling of deep holes in the South Fork was observed following extensive logging in the 1920s to 1930s (Doughty 1987); sedimentation and high rates of pool filling were also described in the upper South Fork in the early 1980s (Wunderlich 1983).
  - *Moderate Importance, Moderate Certainty*: Disconnection of the South Fork from its floodplain due to artificial channel confinement coupled with the lack of in-channel wood, has resulted in channel incision, which has reduced the availability and connectivity of floodplain habitats like side channels and sloughs. See also discussion under *Habitat Diversity* for lower South Fork above.
  - *Moderate Importance, Moderate Certainty*: Low stream flows reduce the total area and volume of wetted habitat during summer low-flow periods, reducing pool depths and dewatering side channels and complex edge habitats. See discussion under *Flow* below.

Flow: Moderate impact

- *Certainty of Impact. Moderate.* EDT reach diagnosis indicates that changes in flow regime in the lower South Fork (downstream of Jones Creek) has a moderate impact on productivity of SF Nooksack early chinook (Figure 4.5). Low flows are a major concern in the lower South Fork (Smith 2002), which is on the 303d list for low instream flows (DOE 1998). The hydrologic record is incomplete and does not predate anthropogenic impacts in the reach. However, peak flows are also a concern, given the habitat simplification and floodplain disconnection that has occurred in the lower South Fork; it is anticipated that such changes have both increased the magnitude and frequencies of high velocities and decreased the spatial variation in velocity during peak flow periods.
- *Early Chinook Impacts.* EDT indicates that changes in flow regime have moderately impact productivity of fry, overwinter rearing, and prespawn

holding. Low stream flows may block or hinder upstream migration, while high stream flows may kill or cause downstream displacement of fry and overwinter rearing life stages. See also 4.1.3.7 *Flow* for further description of life-stage specific impacts.

- *Relative Importance of Causal Mechanisms.*
    - *High Importance, Low Certainty*. Disconnection of the South Fork from its floodplain through channel incision and channel confinement, coupled with draining of floodplain wetlands, has reduced groundwater discharge to the lower South Fork during summer low-flow periods. See discussion under *Temperature* for lower South Fork above.
    - *Moderate Importance, Low Certainty.* Forest management has increased the frequency and magnitude of peak flows, primarily through extension of the drainage network by forest roads. Road-building associated with forest management is considered to have the greatest effect on the hydrologic regime (Harr et al. 1975; Jones and Grant 1996); for instance, disconnecting road systems from the channel network can decrease peak flow response by 40% (Bowling and Lettenmaier, 2001). Average road density in the South Fork subbasin is high at 3.38 miles of road per square mile of watershed area; watersheds with high road density include Hutchinson Creek (5.48 mi/mi^2), Deer/Roaring/Plumbago Creeks (4.54 mi/mi^2); Dye (3.98 mi/mi^2), Skookum Creek (3.56 mi/mi^2), and Cavanaugh Creek (3.56 mi/mi^2); watersheds with moderate road density include Howard (2.84 mi/mi^2) and Edfro Creeks (2.85 mi/mi$^{2)}$; D. Coe, Nooksack Tribe, using DNR 2000 transportation and WRIA 1 basin shape files).
    - *High Importance, Moderate Certainty*. Disconnection of the channel from its floodplain through artificial confinement and loss of in-channel wood has exacerbated the effects of peak flows in the main channel, reducing the availability of refuges from floods such as complex edge and floodplain habitats.

Harassment/poaching: Moderate impact.

- *Certainty of Impact. Moderate.* EDT reach diagnosis indicates that harassment and/or poaching in the lower South Fork (downstream of Jones Creek) has a moderate impact on SF Nooksack early chinook (Figure 4.5). The lower South Fork is a popular inner tubing destination during the summer low-flow period, when chinook are holding and spawning.
- *Early Chinook Impacts.* Harassment elicits avoidance behavior in upstream migrating, holding, and spawning chinook, which can use up limited energy stores or otherwise stress the fish and thereby reduce reproductive success. Redd trampling, which reduces survival to emergence, is also likely.
- *Relative Importance of Causal Mechanisms.*

- *High Importance, High Certainty*: Summer recreational use of the lower South Fork, especially inner tubing, increases human-chinook encounters, thereby stressing holding and spawning chinook.
- *High Importance, High Certainty*: The loss and simplification of holding habitat exacerbates the effects of human recreational use of the lower South Fork, as deep, complex pool habitat can function as refuge from harassment.

4.1.3.3.8. Upper South Fork

The lower reaches of the upper South Fork are relatively low gradient and unconfined, except for Dyes Canyon; gradient and confinement increase steadily in the upper half of the area. Stream-adjacent roads are minimal, although bridges constrain the channel at RM 20.6 and 30. There are multiple stream-adjacent landslides along the upper South Fork from ~RM 16.5 to RM ~36 (Schuett-Hames et al. 1988b; Osbaldiston 1995) that are delivering or have the potential to deliver substantial amounts of fine sediment directly to the South Fork. Most are deep-seated rotational features (e.g. earth slumps), although secondary shallow features occur within the larger deep-seated landslides. All of these slides are associated with unconsolidated glacial sediments, most notably glacial outwash and glacial lacustrine sediments. Land use adjacent to the upper South Fork is predominantly commercial forestry.

The upper South Fork represents 44% of the spawning distribution and 24% of the freshwater habitat for South Fork Nooksack early chinook. Restoration of the upper South Fork is expected to have a significant impact on SF Nooksack chinook abundance and productivity (Figure 4.3.). Accounting for differences in reach length, the upper South Fork is the 2nd most important geographic area for both restoration and protection for the SF Nooksack early chinook population. High temperatures and lack of habitat diversity are the most significant limiting factors, followed by high fine sediment load and lack of key habitats. Productivity of egg incubation, fry, prespawn holding and migration, spawning, and overwinter rearing life stages is most limited.

Habitat Diversity: High impact.

- *Certainty of Impact. Moderate*. EDT reach diagnosis indicates that lack of key habitat in the upper South Fork (RM 20.6 to 31) has a high impact on SF Nooksack early chinook (Figure 4.5). Instream wood, an important control on habitat diversity, is lacking in the upper South Fork relative to historic conditions, although stable accumulations do exist (Lummi Natural Resources, unpublished data). Pool depths have been widely reported as having decreased in recent years (e.g. Schuett-Hames et al. 1988b); there are anecdotal observations of 30 foot-deep pools earlier in the century. Channel incision due to loss of LWD roughness elements has also likely reduced interaction of the channel with its floodplain. Further, excess sedimentation and low wood loading has likely simplified habitat and reduced habitat unit diversity.

- *Early Chinook Impacts.* EDT indicates that lack of habitat diversity strongly limits productivity of fry, overwinter rearing and, to a lesser extent, prespawn holding and oversummer rearing life stages. Loss and simplification of fry and overwintering rearing habitat in the geographic area may also have affected SF Nooksack early chinook diversity by reducing the relative abundance of yearling or parr migrant life history strategy relative to historical conditions. The lack of deep, complex pool habitat – which affects holding and rearing chinook, is considered to be of greatest concern in the reach. In a study of South Fork chinook holding habitat in the South Fork, Schuett-Hames et al. (1988b) found that >98% of chinook held in areas with some cover (undercut bank, bedrock, wood, boulders, turbulence), although they preferred wood; chinook selected the deepest depths available. Loss of habitat complexity may also limit spawning in the reach; in Skagit River tributaries chinook spawning abundances were inversely related to pool spacing (Montgomery et al. 1999).
- *Relative Importance of Causal Mechanisms.*
    - *High Importance, High Certainty*: Habitat simplification is a result of degraded riparian function, which has reduced the supply of large wood to the channel and decreased bank stability. Riparian areas along the active channel of the upper South Fork have predominantly low (33%) or moderate (27%) large woody debris recruitment potential (Coe 2001).
    - *Moderate Importance, Low Certainty*: Lack of LWD roughness elements may be leading to increased channel incision, disconnecting the channel from its floodplain.
    - *Moderate Importance, Low Certainty*: Increased coarse sediment delivery as a result of forest management-induced mass wasting has led to pool infilling and has reduced bedform and habitat diversity. Recent inventories of landslides and forest road networks in the Nooksack basin (Watts 1996; Watts 1997; Watts 1998; Zander 1996; Zander 1997; Zander 1998), in concert with previous inventories conducted as part of the Watershed Analyses and graduate research (Kirtland 1995), indicate that landslides from roads and timber practices are common in the watershed and generate a large amount of sediment.

Sediment Load: Moderate impact.

- *Certainty of Impact. Moderate*. EDT reach diagnosis indicates that high fine sediment load in the upper South Fork has a moderate impact on SF Nooksack early chinook (Figure 4.5). Recent measurements of fine sediments in potential spawning areas indicate variable levels of fine sediments (<0.85mm) in the upper South Fork; of 7 sites sampled from RM 14.5 through 23, percent fine sediments was low in 2 sites (RM 17.7: 9%, n=1; RM 20.7: 9%, n=1), moderate in 3 sites (RM 14.5: 14%, n=1; RM 19.8: 12%, n=5; RM 23: 14%, n=1), and high in 2 sites (RM 19.5: 21%, n=1; RM 20: 23%, n=1; Hyatt and Rabang 2003). Schuett-Hames et al. (1988**b**) observed that 37% of the usable spawning habitat in the South fork was moderately embedded (25-50% embedded) and about 4% was >50% embedded. High turbidities have also been measured in the South Fork. During high flow sampling in 2004/2005, Kopp (2005) measured higher turbidities and suspended solids in the South Fork (209.1 NTU; 264.6 mg/L) than in either the North (158 NTU; 120.7 mg/L) or Middle Forks (204.8 NTU; 182.1 mg/L). Anecdotal observations indicate high turbidities, which limit spawn and snorkel surveying, can persist in the South Fork through mid to late summer.

- *Early Chinook Impacts.*
- EDT indicates that high fine sediment load has a high impact on productivity of egg incubation, and moderate impact on fry, overwintering, 0-age migrant, and 1-age migrant life stages. See discussion of impacts for sediment load in lower South Fork and under 4.1.3.2. *Sediment Load*.
- *Relative Importance of Causal Mechanisms.*
  - *High Importance, Moderate Certainty.* There are numerous mass wasting areas along the upper South Fork from ~RM 16.5 to RM ~36 (Schuett-Hames et al. 1988b; Osbaldiston 1995) that are delivering or have the potential to deliver substantial amounts of fine sediment directly to the South Fork (see discussion under for Sediment Load in lower South Fork).
  - *Moderate Importance, Moderate Certainty*. Elevated mass wasting frequency due to forestry management practices has increased fine sediment supply to the upper South Fork (see discussion under for Sediment Load in lower South Fork).
  - *Low Importance, Moderate Certainty:* Surface erosion of forest roads increases fine sediment delivery to the upper South Fork (see discussion under for Sediment Load in lower South Fork).

Temperature: High impact.

- *Certainty of Impact. High*. EDT reach diagnosis indicates that high temperature in sections of the upper South Fork (RM 14.3 to 20.6) has a moderate impact on SF Nooksack early chinook (Figure 4.5), although the impact is considered high. The South Fork is on the 303d list for temperature (DOE 1998). Recently, summer temperatures in the upper South Fork have regularly exceeded water quality standards (WQS) of 16°C. Peak temperatures approaching the lethal limit have been recorded during several years in the upper South Fork: 21.7°C in 1986 (Schuett-Hames et al. 1988c, cited in Neff 1993), 24°C in 1992 (Neff 1992, cited in Smith 2002), >20°C in 2001 (Nooksack Tribe, unpublished data), and 24.1°C in 2003 (Kopp 2004). Continuous temperature monitoring during summer (June to September) 2003 indicate water temperatures exceeded DOE water quality standards at a site in the upper South Fork (Dyes Canyon) on 81% of days monitored by an average 3.2°C above threshold (Kopp 2004). Monitored temperatures exceeded the upper ends of optimal temperature ranges for chinook incubation (12°C) and migration and rearing (16.8°C; Hicks 2000). Temperatures exceeded the upper end of the optimal range for chinook incubation by an average 7.5°C during all days monitored in August and September (Kopp 2004), which encompass the first several weeks of incubation for early chinook; Anchor Environmental 2003). Temperatures exceeded the upper end of the optimal range for chinook migration and rearing by an average 2.7°C during most 74% of days monitored (Kopp 2004).

- *Early Chinook Impacts.* High temperatures reduce productivity of several life stages in the upper South Fork. As with the lower South Fork, productivity of spawning, incubation, prespawn migrant, and prespawn holding life stages are expected to be especially impacted, with moderate impact to oversummer rearing life stage. See impacts for temperature in lower South Fork and 4.1.3.8 Temperature for further description.
- *Relative Importance of Causal Mechanisms.*
    - *Moderate Importance, Moderate Certainty.* High temperatures in the South Fork mainstem are due to lack of riparian shading in tributary watersheds. Stream shading from riparian vegetation falls short of elevation-specific target shade levels in 50% of riparian areas of tributaries to the South Fork (Coe 2001). Stream shading exceeds target shade levels in only 32% of riparian areas. High water temperatures are a concern in several South Fork tributaries (Smith 2002); further, Cavanaugh, Roaring, and Howard Creeks are on the 303d list for high temperatures (DOE 1998).
    - *Moderate Importance, High Certainty.* High temperatures in the upper South Fork are due to lack of riparian shading along the South Fork. Riparian zones for much of the main channel are dominated by young deciduous stands that provide little shading benefit to the channel (Coe 2001).
    - *Moderate Importance, Low Certainty.* Changes in channel pattern of the upper South Fork have led to reduced riparian shading and hyporheic exchange, relative to historical conditions. Evidence of incision is prevalent in the upper South Fork, where glacial lake deposits are exposed in the channel for several miles. Much of the channel appears to be confined between terraces, although the age of these and the type are unknown. These terraces may reflect historic floodplain, or may be much older. While extensive channel widening has not been noted in reaches that have been studied (Abbe 1999, Kirtland 1995), most of the anadromous portion of the South fork has not been thoroughly assessed.

Key Habitat Quantity: Moderate impact.

- *Certainty of Impact. Moderate*. EDT reach diagnosis indicates that lack of key habitat in sections of the upper South Fork (RM 14.3 to 20.6) has a moderate impact on SF Nooksack early chinook (Figure 4.5). An inventory of holding habitat in the South Fork found holding habitat to be limited in sections of the upper South Fork; volume of holding habitat (scaled to reach length) from RM 20 to 25 was less than half that from RM 15-20 and RM 25-30 (Schuett-Hames et al. 1988b). Schuett-Hames et al. (1988b) further asserted that, while the amount of holding and spawning habitat was not limiting at the time of the study (1986), both were of poor quality and likely to limit recovering populations. Loss of key habitat types is confounded by the loss of habitat diversity in the reach; for example, current pools lack the cover, hydraulic complexity, depth, and – potentially – thermal stratification of historically available pools. See also *Habitat Diversity* limiting factor above.

- *Early Chinook Impacts.* The amount of key habitat affects habitat capacity, which controls equilibrium abundances. EDT indicates that lack of key habitat most strongly limits prespawn holding, fry, and oversummer rearing life stages, followed by yearling and overwinter rearing life stages, indicating that the habitat types most limiting in the reach are primary (i.e. main channel) pools, and, to a lesser extent, backwater pools, complex edge habitats, and side channels. Lack of pools may also limit chinook spawning in the reach. Lack of pools and habitat complexity may also limit spawning by chinook in the reach. Through monitoring associated with logjam construction in the North Fork Stillaguamish, it was observed that greater than 80% of chinook spawned within one channel width of a pool (Pess et al. 1998). In Skagit River tributaries, spawning abundances of both chinook and coho were inversely related to pool spacing (Montgomery et al. 1999). See 4.1.3.4. *Key Habitat Quantity* for further description of life-stage-specific habitat needs.
- *Relative Importance of Causal Mechanisms.*
    - *High Importance, Moderate Certainty*: Wood serves as an important pool-forming mechanism in the Upper South Fork (Lummi Natural Resources, unpublished 2002 data). The loss of stable wood has increased pool spacing and reduced cover complexity for holding and migrating adults, as well as rearing habitat for juvenile salmon. Wood was actively removed from the channel up until the early 1990s to improve flood conveyance and facilitate fish migration in the upper South Fork. Riparian harvest has interrupted wood recruitment to the channel and slowed recovery from the channel cleaning operations. See also discussion under *Habitat Diversity* for upper South Fork above.
    - *Moderate Importance, Low Certainty*: Channel incision, possibly related to land management and wood removal from the channel, has isolated portions of the floodplain, reducing the connectivity of side channels and potential high flow refuge areas.
    - *Moderate Importance, Moderate Certainty*. Excess sedimentation has led to pool infilling. Filling of deep holes in the South Fork was observed following extensive logging in the 1920s to 1930s (Doughty 1987); sedimentation and high rates of pool filling were also described in the upper South Fork in the early 1980s (Wunderlich 1983).

4.1.3.3.9. South Fork tributaries

South Fork tributaries represent 21% of the spawning distribution and 11% of the freshwater habitat for South Fork Nooksack early chinook. Protection and restoration of South Fork tributaries is lower priority than the South Fork, upper Mainstem, and estuary, but South Fork tributaries represent an important component of the spatial structure and life history diversity of the population; cool tributaries such as Hutchinson and Skookum Creeks also provide refuge from high temperatures in the South Fork. Lack of habitat diversity and key habitat, as well as high fine sediment load, are important limiting factors. Tributaries to the South Fork largely drain commercial forest land.

Habitat Diversity: Moderate impact

- *Certainty of Impact. Low.* EDT reach diagnosis indicates that lack of habitat diversity in Skookum Creek has a high impact on SF Nooksack early chinook, while in Hutchinson, Cavanaugh, Plumbago and Deer Creeks the impact is moderate (Figure 4.5); however, the impact is considered moderate in all tributaries. Although habitat data is limited, reduced habitat diversity is expected given low wood loading and channel instability. Channel instability has been documented in lower Hutchinson Creek (DNR 1998, cited in Smith 2002), and much of the wood in Hutchinson Creek has been deposited outside the low-flow channel (DNR 1998, cited in Smith 2002). Skookum Creek is also considered to be unstable (Schuett-Hames et al. 1988a, DNR 1994, cited in Smith 2002) and low counts of wood have been documented in both Skookum and Cavanaugh Creeks (DNR 1994, cited in Smith 2002).
- *Early Chinook Impacts.* EDT indicates that lack of habitat diversity strongly limits productivity of fry and overwinter rearing life stages, as well as, to a lesser extent, oversummer rearing, spawning, and holding life stages. Complex cover is an important habitat component for multiple chinook life stages (see 4.1.3.3. *Habitat Diversity* for description).
- *Relative Importance of Causal Mechanisms.*
  - *High Importance, Moderate Certainty:* Loss of instream cover and habitat diversity is a result of a lack of stable wood in the channel, a result of degraded riparian function. Large woody debris recruitment potential in riparian areas of the tributary watersheds is substantially low or moderate (Coe 2001): Hutchinson (34% low, 22% moderate), Skookum (25% low, 20% moderate), Cavanaugh (30% low, 27% moderate), and Deer/Roaring Creeks (36% low, 13% moderate).
  - *Moderate Importance, Low Certainty.* Increased sediment delivery to early chinook tributaries from upslope mass wasting, combined with the lack of instream wood, has simplified habitat, reducing habitat unit diversity and frequency of pools.

Key Habitat Quantity: Moderate impact.

- *Certainty of Impact. Low.* EDT reach diagnosis indicates that the lack of key habitat in Hutchinson, Skookum, Cavanaugh, Plumbago, and Deer Creeks has a moderate impact on SF Nooksack early chinook (Figure 4.5). Filling of pools has been observed in Skookum and Cavanaugh Creeks (DNR 1994, cited in Smith 2002). Habitat surveys in subsampled reaches of Hutchinson Creek indicate that percent pool habitat was mostly poor (35%) or fair (26%; DNR 1998, cited in Smith 2002). Although habitat data is limited, reduced availability of key habitats is also expected given low wood loading and channel instability. See discussion under *Habitat Diversity* above.
- *Early Chinook Impacts.* EDT indicates that lack of key habitat types affects habitat capacity (and therefore abundance) of oversummer, overwinter, and yearling rearing life stages in the named tributaries, and holding, spawning, incubation, and fry life stages in Cavanaugh, Skookum and Hutchinson Creeks. See 4.1.3.4 *Key Habitat* for discussion of life-stage-specific habitat needs.
- *Relative Importance of Causal Mechanisms.*
    - *High Importance, Moderate Certainty:* Loss of instream cover and habitat diversity is a result of a lack of stable wood in the channel, a result of degraded riparian function. See discussion for *Habitat Diversity* above.
    - *Moderate Importance, Low Certainty.* Increased sediment delivery to early chinook tributaries from upslope mass wasting, combined with the lack of instream wood, has simplified habitat, reducing habitat unit diversity and frequency of pools. See discussion for *Habitat Diversity* above.

Sediment Load: Moderate impact

- *Certainty of Impact. Moderate.* EDT reach diagnosis indicates that high fine sediment load in Hutchinson, Cavanaugh, Plumbago and Deer Creeks has a moderate impact on SF Nooksack early chinook (Figure 4.5). Recent measurements indicate moderate levels of fine sediment in spawning gravels in Hutchinson Creek (15%, n=1; 12.7%, n=3; Hyatt and Rabang 2003). However, more extensive sampling in the mid 1990s indicates that most of the sampled sites have high levels of fine sediments (8 of 12 samples were >20%, 2 were 15-20%, and 2 were 10-15%; DNR 1998, cited in Smith 2002). Embeddedness was also high, averaging 25-50%, in Hutchinson Creek (DNR 1998, cited in Smith 2002). Measurements from the 1980s indicate fine sediment levels were high in Deer Creek (26% in 1983, 20% in 1984) and low to moderate in Skookum Creek (7-13%, 1982-1984; Schuett-Hames et al. 1988c). Fine sediment measurements can be problematic, however, as within-site variability in fine sediments is often as between site variability (Hyatt and Rabang 2003).
- *Early Chinook Impacts.* EDT indicates strong impacts of high fine sediment load to productivity of the egg incubation stage, since fine sediments in spawning gravels reduce survival to emergence. Fry and overwinter rearing life stages are also impacted; high fine sediment load is associated with high turbidities and

gravel embeddedness. See Section 4.1.3.2 (*Sediment Load*) for further description of how high fine sediments affect these life stages.

- *Relative Importance of Causal Mechanisms.*
  - *High Importance, Moderate Certainty*: Elevated mass wasting frequency due to forestry management practices has increased fine sediment supply to South Fork tributaries. Landslide densities are very high in upper Skookum (13.2 events/mi^2) and Cavanaugh Creek (10.8 events/mi^2) watersheds and moderate in Hutchinson WAU (DNR 1994, cited in Smith 2002). The majority of landslides in the South Fork basin are shallow, rapid events that tend to deliver sediment to streams; most (69%) are associated with forest practices (Smith 2002).

Low Importance, Moderate Certainty: Surface erosion of forest roads increases fine sediment delivery to South Fork tributaries. Surface erosion from roads may contribute as much as 50% of the management-induced fine sediment inputs (Cederholm et al., 1981). In the Acme WAU, gravel-surfaced logging roads were considered to generate and deliver substantial fine sediment, especially from wet-weather hauling (Crown Pacific LP 1999). Most roads in the Hutchinson WAU are unpaved (DNR 1998, cited in Smith 2002). Road densities are high in South Fork tributary watersheds, including Hutchinson (5.48 mi/mi^2), Deer/Roaring/Plumbago (4.54 mi/mi^2), Skookum (3.56 mi/mi^2), and Cavanaugh Creeks (3.56 mi/mi^2; D. Coe, Nooksack Tribe, using DNR 2000 transportation and WRIA 1 basin shape files).

4.1.3.3.10. Lower Mainstem

The lower mainstem flows through a broad low-gradient valley. Post-glacial deposition by the Nooksack River built up the river and its meander belt by about 3 to 4 meters above the valley bottom. Extensive wetlands, primarily with scrub-shrub vegetation and with numerous beaver dams, occupied low areas marginal to the meander belt. The river channel was a single-thread meandering channel with infrequent avulsions. Currently, the channel is tightly confined by levees; meanders have been cut off, wetlands largely ditched and drained for farmland, and wood removed from the channel. Land adjacent to the lower mainstem is predominantly zoned agriculture, except for the small cities of Ferndale, Everson, and Lynden. Little riparian vegetation remains adjacent to the channel.

The lower mainstem Nooksack River represents 17% and 13% of the freshwater habitat for SF and NF/MF Nooksack early chinook, respectively. Although the importance of lower Mainstem restoration to the recovery of SF and NF/MF Nooksack early chinook populations is relatively low, as an area of overlap for the two early chinook populations, it will benefit both. Although not reflected in EDT results, the lower mainstem has suffered the greatest loss of function from historical conditions and likely limits recovery of early chinook diversity and spatial structure. In particular, low-gradient unconfined systems such as the lower mainstem were historically highly productive habitats for rearing juveniles. Loss of habitat quantity and quality has likely reduced the prevalence of the yearling life history strategy among both populations. Loss of habitat diversity and key habitats are the most significant limiting factors. Productivity of prespawning migrant, overwinter rearing, and oversummer rearing life stages are the most limited.

Habitat Diversity: Moderate impact.

- *Certainty of Impact. Moderate.* EDT reach diagnosis indicates that the lack of habitat diversity in the lower Mainstem has a moderate impact on both Nooksack early chinook populations (Figures 4.5, 4.6). Although habitat surveys are lacking, the lower mainstem has been extensively hydromodified and there is a general dearth of large and stable wood, making it highly likely that habitat diversity is considerably reduced from historic conditions.
- *Early Chinook Impacts.* EDT indicates that habitat diversity strongly limits productivity of fry and moderately limits productivity of oversummer and overwinter rearing, prespawning migrant, and juvenile outmigrant life stages. Complex cover is an important habitat component for multiple chinook life stages (see 4.1.3.3. *Habitat Diversity* for description). The lower mainstem historically provided extensive fry and overwinter rearing habitat; loss of habitat diversity and flood refuge habitats may have reduced the proportion of yearling outmigrants among both early chinook populations, thereby reducing life history diversity.
- *Relative Importance of Causal Mechanisms.*
    - *High Importance, High Certainty*: Channel confinement and straightening has reduced habitat diversity in the lower Mainstem. Length of the lower mainstem from RM 15 to 19 decreased by 35% from ~1880 to 1938, largely due to meander cutoffs, resulting in a simpler, straighter channel associated with lower habitat diversity than a naturally meandering channel. Downstream of Everson, virtually the entire mainstem Nooksack River is leveed and/or riprapped. The levees between Everson and Marine Driver have reduced the floodplain area from 33.5 sq. mi to 2.5 sq. mi. downstream of Everson (based on mapping by Collins & Sheikh 2004b). Riprap contributes to habitat simplification by impeding the development of undercut banks with woody debris and overhead cover that are preferred by rearing salmonids, as well as reducing channel migration that recruits wood and forms and maintains complex floodplain habitats (Schmetterling et al. 2001). Although natural channel migration rates are low in the lower mainstem from RM 6-24, rates are lower than historically: 2 to 3 m/year before 1933 (prior to widespread or effective levees) and 0 to 2 m/year since 1933 (Collins & Sheikh 2004a).
    - *Moderate Importance, Moderate Certainty:* Floodplain development, including filling, ditching, and draining of wetlands and other floodplain habitats, has

reduced floodplain habitat diversity. Since ~1880, most of the native floodplain forest has been burned or logged and most wetlands in the lower mainstem has been diked and drained (Collins & Sheikh 2004b). Most of the floodplain has been converted to agriculture.

- *Moderate Importance, Moderate Certainty*: There is a lack of stable wood jams in the channel because of degraded riparian function and removal of wood. Wood jams were historically abundant and had a variety of geomorphic and habitat functions in the Nooksack, such as creating pools, causing avulsions and flow splits, and routing water and sediment at the valley scale (Collins & Sheikh 2004b). Instream wood that is currently present in the system is often in transient wood accumulations, with very few key-sized pieces (Lummi Natural Resources, unpublished data). Lummi Natural Resources (unpublished 2004 data) characterized wood distribution through the mainstem. Between Everson and Marine Drive Bridge, virtually no wood was present. The investigators concluded that the loss of wood recruitment area and the immaturity of the riparian forests marked a severe limitation to future wood levels in the river for at least the next 50 years.
- *Moderate Importance, Moderate Certainty*. There has been a loss of complex edge and backwater habitat (e.g. undercut banks with fallen trees) because of degraded riparian function. There are no riparian areas along the active channel of the lower Mainstem with high large woody debris recruitment potential; large woody debris recruitment potential is predominantly (81%) low (Coe 2001).

Key Habitat Quantity: Moderate impact.

- *Certainty of Impact. Moderate.* EDT reach diagnosis indicates that the lack of key habitat in the lower Mainstem has a moderate impact on both Nooksack early chinook populations (Figures 4.5, 4.6). Although mainstem habitat surveys are lacking, the lower mainstem has been extensively hydromodified, wetlands have been ditched and drained, and there is a general dearth of large and stable wood, making it highly likely that availability and connectivity of key habitats (e.g. primary pools, backwater pools, side channels, and complex edge habitats) is considerably reduced from historic conditions. High-flow habitat is especially limiting: low-flow channel area comprises 83% of the active channel area, and almost all (97%) of the floodplain channel length available in the valley bottom of the lower mainstem is associated with tributaries; side channels, sloughs, and other secondary channels are virtually absent. Indeed, the area in sloughs in the lower mainstem is 20% of that historically (Collins & Sheikh 2004a). Quantitative estimates using GLO notes indicate that winter inundated freshwater wetland in 1998 was about 5% of that in ~1880, and summer inundated freshwater wetland was about 1% that of the ~1880 estimate (Collins & Sheikh 2004b).
- *Early Chinook Impacts.* The amount of key habitat types affects habitat capacity, which controls equilibrium abundances. EDT indicates that lack of key habitat

strongly limits all life stages expected to use the lower mainstem, especially overwinter rearing, but also fry, oversummer, overwinter and yearling rearing, juvenile and prespawning migrants, and holding life stages. Reduction in high flow (i.e. overwinter rearing and early fry) habitat has likely changed the spatial structure (distribution of overwinter rearing) and life history diversity (proportion outmigrating as parr or yearlings) of both early chinook populations.

- *Relative Importance of Causal Mechanisms.*
  - *High Importance, High Certainty*: Channel confinement and straightening has reduced the amount of key habitats in the lower Mainstem. Length of the lower mainstem from RM 15 to 19 decreased by 35% from ~1880 to 1938, largely due to meander cutoffs. Loss of primary pools is associated with loss of steep-angled meander bends. See also discussion under *Habitat Diversity* above.
  - *Moderate Importance, Moderate Certainty:* Floodplain development, including filling, ditching, and draining of wetlands, side channels, and other floodplain habitats, has reduced the availability of floodplain habitats. See discussion under *Habitat Diversity* above.
  - *Moderate Importance, Moderate Certainty*: Loss of key habitats is associated with the loss of stable wood jams in the channel, a result of degraded riparian function and removal of wood. Stable wood jams form primary and backwater pools and promote channel-floodplain interaction that forms and maintains floodplain habitats. See discussion under *Habitat Diversity* above.

4.1.3.3.11. Upper Mainstem

The upper mainstem is considerably more dynamic than the lower mainstem. Similar to the lower North Fork, the historical channel pattern was anastomosing, with multiple channels, sloughs, forested islands, and wood jams (Collins & Sheikh 2004b). Currently, the channel exhibits a simpler, more frequently shifting braided pattern and stable wood jams are lacking. Although the channel migration zone is relatively wide, bank hardening degrades bank conditions through much of the length of the upper mainstem and especially confines the channel at the downstream end, just upstream of Everson. Adjacent land is predominantly zoned agriculture, with some rural and commercial forest land in the upper reaches.

The upper mainstem Nooksack River represents 29% and 21% of the freshwater habitat for SF and NF/MF Nooksack early chinook, respectively. Restoration of the upper mainstem to historic conditions is expected to contribute to abundance, productivity, and life history diversity of both Nooksack early chinook populations (Figures 4.3, 4.4). As an area of overlap for the two populations, restoration will benefit both populations. Accounting for differences in reach length, the upper mainstem is the third most important geographic area for recovery of SF Nooksack early chinook, after the lower and upper South Fork. Loss of habitat diversity and key habitats are the most significant limiting factors and may have reduced the prevalence of the yearling life history strategy among both populations. High temperatures are also a concern. Productivity of prespawning migrant, fry, oversummer rearing, and overwinter rearing life stages are the most limited.

Habitat Diversity: Moderate impact.

- *Certainty of Impact. Moderate*. EDT reach diagnosis indicates that the lack of habitat diversity in the upper Mainstem has a moderate impact on both Nooksack early chinook populations (Figures 4.5, 4.6). Although habitat surveys are lacking, loss of habitat diversity is expected given the observed changes in channel pattern from historical conditions. Between ~1880 and the 1930s, the upper mainstem changed from an anastomosing channel pattern with multiple channels, sloughs, stable log jams, and forested islands to a much simpler, wider, braided channel with extensive gravel bars and lacking large wood (Collins & Sheikh 2004b). As a result, current main channel and edge habitats are considerably less complex than historically. The predominance of riprap is also a concern: riprap bank conditions are simpler than natural bank conditions, especially natural banks on the outside edge of meander bends, which are often undercut and associated with wood and toppled trees; riprap also provides low quality cover for juvenile salmon.
- *Early Chinook Impacts.* EDT indicates that habitat diversity strongly limits productivity of fry and moderately limits productivity of oversummer and overwinter rearing, prespawning migrant, and juvenile outmigrant life stages. The upper mainstem historically provided diverse fry and overwinter rearing habitat; loss of habitat diversity may have reduced the proportion of yearling outmigrants among both early chinook populations, thereby reducing life history diversity. Edge and main channel habitat have been simplified and complex cover is lacking. Degradation of bank conditions through bank hardening negatively impacts juvenile chinook; several studies have shown that juvenile salmon prefer unaltered over riprapped stream banks (e.g. Hayman et al. 1996; Peters et al. 1998; Beamer and Henderson 1998). Where rearing habitat is limited, survival of juvenile salmon may decline where riprap has been installed. See 4.1.3.3. *Habitat Diversity* for further description of impacts.
- *Relative Importance of Causal Mechanisms.*
    - *Moderate Importance, Moderate Certainty*: There is a lack of stable wood jams in the channel because of degraded riparian function and removal of in-channel wood. Wood jams were historically abundant and had a variety of geomorphic and habitat functions in the Nooksack, such as creating pools, causing avulsions and flow splits, and routing water and sediment at the valley scale (Collins & Sheikh 2004b). Instream wood that is currently present in the system is often in transient wood accumulations, with very few key-sized pieces (Lummi Natural Resources, unpublished data).
    - *Moderate Importance, Moderate Certainty*. There has been a loss of complex edge and backwater habitat (e.g. undercut banks with fallen trees) because of

degraded riparian function. There are no riparian areas along the active channel of the upper Mainstem with high large woody debris recruitment potential; large woody debris recruitment potential is either low (47%) or moderate (53%; Coe 2001).

- *Moderate Importance, Moderate Certainty.* Bank hardening reduces habitat diversity in the upper mainstem. Upstream of Everson, there is bank hardening on at least one side of the channel for virtually the entire length Riprap contributes to habitat simplification by impeding the development of undercut banks with woody debris and overhead cover that are preferred by rearing salmonids, as well as reducing channel migration that recruits wood and forms and maintains complex floodplain habitats (Schmetterling et al. 2001).
- *Moderate Importance, Low Certainty.* Frequent channel shifting reduces habitat diversity in the upper mainstem. Potential causes of increased channel migration rates include reduced bank stability due to degraded riparian conditions, increased coarse sediment inputs from mass wasting, and loss of stable wood jams (Collins & Sheikh 2004b). Average annual migration rates have approximately doubled since 1933, increasing from 7.4 ± 4.8 m/yr (<1933) to 17.2 ± 7.8 m/yr (1933-2002) in the Mainstem Nooksack RM 24-31 and from 5.8 ± 4.0 m/yr (<1933) to 10.3 ± 5.5 m/yr (1933-2002) in the Mainstem Nooksack RM 31-37 (Collins & Sheikh 2004a).

Key Habitat Quantity: Moderate impact.

- *Certainty of Impact.* EDT reach diagnosis indicates that the lack of key habitat in the upper Mainstem has a moderate impact on both Nooksack early chinook populations (Figures 4.5, 4.6). *Although mainstem habitat surveys are lacking,* changes in the availability of key habitat types is expected given the observed changes in channel pattern from historical conditions, as well as hydromodification in the reach. Between ~1880 and the 1930s, the upper mainstem changed from an anastomosing channel pattern with multiple channels, sloughs, stable log jams, and forested islands to a much simpler, wider, braided channel with extensive gravel bars (Collins & Sheikh 2004b). As a result, current proportions of primary pools, backwater pools, side channels, and complex edge habitats are less than under historical conditions. The area in sloughs in the upper mainstem is 23% of that historically (Collins & Sheikh 2004a). Lack of wood and hardening of banks are also associated with loss of deep, complex pools.
- *Early Chinook Impacts.* The amount of key habitat types affects habitat capacity, which controls equilibrium abundances. EDT indicates that lack of key habitat strongly limits all life stages expected to use the lower mainstem, including fry, overwinter, oversummer, and yearling rearing, juvenile and prespawning migrants, and holding life stages. Limiting habitat types include primary pools, backwater pools, complex edge habitats, side channels, and pool tailouts. Loss of

fry and overwintering rearing habitat in the geographic area may also have affected SF and NF/MF Nooksack early chinook diversity by reducing the relative abundance of yearling or parr migrant life history strategy relative to historical conditions.

- *Relative Importance of Causal Mechanisms.*
    - *Moderate Importance, Moderate Certainty*: Loss of key habitats is associated with the loss of stable wood jams in the channel, a result of degraded riparian function and removal of wood. In the late 19th century, wood was systematically removed from the mainstem to increase navigability and provide for log transport. There are no riparian areas along the active channel of the upper Mainstem with high large woody debris recruitment potential; large woody debris recruitment potential is either low (47%) or moderate (53%; Coe 2001). Stable wood jams form primary and backwater pools and promotes channel-floodplain interaction that forms and maintains floodplain habitats. See discussion under *Habitat Diversity* above.
    - *Moderate Importance, Low Certainty.* Frequent channel shifting reduces availability of key habitats in the upper mainstem. See discussion under *Habitat Diversity* above.

Temperature: Moderate impact (Everson to Nugent's Corner).

- *Certainty of Impact. Low.* EDT reach diagnosis indicates that high temperature in the upper Mainstem (from Everson to Nugent's Corner) has a moderate impact on SF Nooksack early chinook (Figure 4.5). Water temperature data for the upper mainstem is lacking. Water temperatures in the Nooksack River near North Cedarville (RM 30.9) were warmer than 16oC for 54% of the samples in 1996 and 1997 (data from USGS 2001, cited in Smith 2002).
- *Early Chinook Impacts.* According to EDT, high temperatures moderately impact the productivity of the prespawning migrant life stage for both Nooksack early chinook populations. High temperatures may stress upstream migrating chinook and increase susceptibility to disease, which can cause prespawn mortality or otherwise reduce reproductive success. In 2003, numerous pre-spawning mortalities were observed among early chinook spawning in the North Fork (D. Huddle, WDFW, pers. comm. 2003); later necropsies indicated that individuals had *Columnaris*, which is associated with higher mortality at temperatures greater than 15°C (Spence et al. 1996). It is not known whether the observed mortality was a result of exposures to high temperatures in the mainstem or North Fork or both. .
- *Relative Importance of Causal Mechanisms.*
    - *Moderate Importance, Low Certainty:* Channel widening has increased the water surface area exposed to solar radiation. Collins and Sheikh (2004b) observed increases in channel area from historic conditions; channel widening was attributed to riparian logging that decreased bank stability, loss of stable

wood jams, or significant increases in coarse sediment supply from mass wasting.

- *High Importance, Moderate Certainty:* Clearing of the floodplain forest along the upper mainstem, coupled with the conversion from anastomosing channel pattern with stable forested islands, has reduced riparian shading of upper mainstem habitats. The current channel is a wider and simpler braided pattern (Collins & Sheikh 2004b) associated with less riparian shading than the historic branching with multiple sloughs and stable forested islands.
- *Moderate Importance, Moderate Certainty:* Loss of riparian shading in the upper watershed has increased the temperature of water from the North, Middle, and South Forks. Stream shading levels are less than elevation-specific target shade levels in substantial proportions of upper watershed riparian areas; 46% of riparian areas adjacent to tributaries to the Forks failed to meet target shade levels – 12% of riparian areas fell short of elevation-specific target shade levels by at least 40% (Coe 2001).

4.1.3.3.12. Mainstem tributaries

With the exception of Anderson and Smith Creek watersheds, which drain steeper forested slopes, chinook tributaries to the mainstem are low-gradient, unconfined systems draining agricultural- and rural-zoned areas. Historically, extensive wetlands were associated with several of these tributaries, including Bertrand and Fishtrap Creeks, but lowland forests have been cleared and wetlands ditched and drained to allow for agriculture. A substantial portion of lowland tributaries are incised and ditch-like with little riparian cover or instream wood.

Although stock origin is unknown, juvenile chinook that use tributaries to the lower mainstem are believed to be primarily Nooksack late-timed chinook, which spawn in those tributaries. However, mainstem tributaries likely historically provided important rearing and flood refuge habitat for juvenile Nooksack early chinook, especially in the lower reaches adjacent to the mainstem. Although mainstem tributaries were not modeled within EDT, the lower reaches of mainstem tributaries likely supported abundance, productivity, diversity, and spatial structure of Nooksack early chinook. Mainstem tributary habitat may be especially important in the lower mainstem, where 97% of the floodplain channel length available outside the main channel is in tributaries (as opposed to sloughs, side channels and other secondary channels; 49% of the floodplain channel length in the upper mainstem is in tributaries.
Indeed, loss and degradation of habitat in mainstem tributaries may have reduced the prevalence of the yearling outmigrant life history strategy among both early chinook populations.

Key Habitat Quantity: Moderate impact.

- *Certainty of Impact. Low.* Although habitat survey data is limited, reduced availability of key habitats is likely given impacts to tributaries. Tenmile, Fishtrap, and lower Bertrand Creeks have been straightened, re-routed, and dredged and levees exist along parts of Fishtrap and Bertrand Creeks (Whatcom County Dept. Public Works 1999, cited in Smith 2002). Bank erosion and dredging have been common in Kamm Creek (Smith 2002). Habitat surveys indicate few deep pools with very little large wood in Kamm, lower Bertrand Creeks, or Tenmile Creeks (Nooksack Salmon Enhancement Association data, cited in Smith 2002). In the more forested watersheds of Anderson, Smith, and McCauley creeks, debris flows have been common (Smith 2002). Additionally, historically extensive wetlands associated with the mainstem Nooksack River and its tributaries have been largely ditched and drained.

- *Early Chinook Impacts.* Juvenile chinook have been found in lower Smith, Anderson and Fishtrap Creeks during fall, in Smith Creek during winter, and Anderson and Fishtrap Creeks during summer (Coe 2005). However, stock origin of those juvenile chinook has not been determined. Use of non-natal tributaries for rearing or flood refuge has been documented in the lower Fraser River basin, where juvenile chinook were collected from May to June in seven of 21 non-natal tributaries sampled, ranging from 0.4 to 6.5 km upstream (Murray and Rosenau 1989). With respect to early chinook habitat needs, flood refuge habitat for fry and overwinter rearing life stages (i.e. complex, low-velocity habitat) is likely most limiting in lower mainstem tributaries. See also 4.1.3.4. *Key Habitat Quantity* for discussion of life-stage-specific habitat needs.
- *Relative Importance of Causal Mechanisms.*
    - *High Importance, Moderate Certainty.* Channelization and diking of the lower mainstem and its tributaries have reduced the availability of complex flood refuge habitat. Tenmile, Fishtrap, and Bertrand Creeks have been channelized and Fishtrap and Bertrand Creeks have been partially leveed. Hydromodification of the lower mainstem has also affected the processes that form and maintain complex, connected habitats at tributary junctions.
    - *Moderate Impact, Moderate Certainty.* Reduced availability of key habitats is a result of lack of stable wood in the channel, a result of degraded riparian function. Where habitat surveys have been conducted (Kamm, Bertrand, Tenmile Creeks), levels of instream wood are predominantly very low. Large woody debris recruitment potential in riparian areas of mainstem tributary watersheds is predominantly low or moderate (Coe 2001): Bertrand (74% low, 13% moderate), Tenmile (82% low, 12% moderate), Fishtrap (99% low, 1% moderate), Kamm (98% low, 2% moderate), Scott (100% low), Anderson (48% low, 31% moderate), Silver (71% low, 17% moderate), and Smith Creeks (69% low, 9% moderate).

Habitat Diversity: Moderate impact.

- *Certainty of Impact. Low.* See discussions under *Key Habitat Quantity* above.

- *Early Chinook Impacts.* See discussions under *Key Habitat Quantity* above and 4.1.3.3 *Habitat Diversity*.
- *Relative Importance of Causal Mechanisms.*
    - *High Importance, Moderate Certainty:* Channelization and diking of the lower mainstem and its tributaries has reduced the complexity and diversity of habitat available in mainstem tributaries. See discussion for *Key Habitat Quantity* above.
  - *Moderate Importance, Moderate Certainty:* Loss of instream cover and habitat diversity is a result of a lack of stable wood in the channel, a result of degraded riparian function. See discussion for *Key Habitat Quantity* above.

4.1.3.3.13. Estuary

The Nooksack estuary includes all of the tidally influenced freshwater areas of the Nooksack River, including the floodplain portions of tributaries and sloughs that directly contribute to the estuary. The upstream bound of the estuary is near the town of Ferndale, ~5 miles up the river. The Nooksack River delta is one of the fastest developing sedimentary features in the Puget Sound area. The delta has prograded rapidly into Bellingham Bay during the historic period and created a diverse and productive estuarine environment. In the earliest part of the historic record, the majority of the discharge of the Nooksack River flowed into Lummi Bay to the north of the Lummi Peninsula, then an island. Maps of the estuary in the late 1880s show broad wetlands and marshes dissected with numerous tidal and distributary channels draining into Lummi Bay and a relatively young delta forming in Bellingham where the main channel was discharging.

As the river was building the delta into Bellingham Bay, the floodplain draining into Lummi Bay was largely converted to agriculture and isolated from the main flow of the Nooksack River by levees. Drainage ditches were excavated through the floodplain to drain the historic marshes and tidal and distributary channels were filled to improve farmland. By the early 1930s, approximately 80% of the estuarine floodplain was converted to agriculture (Brown et al. 2005). Since the 1930s, the Nooksack River has recreated much of the diversity that was lost on the Lummi Bay delta to agricultural development. The estuary has seen a marked increase in saltmarsh, scrub-shrub, and forested floodplain habitat since the 1930s, making the active Nooksack delta one of the more pristine estuarine ecosystems in the Puget Sound.

As with other estuarine and nearshore areas, restoration of estuarine habitat will be important for recovery of Nooksack early chinook spatial structure and diversity. Estuarine restoration will also improve abundance and productivity (Figures 4.3, 4.4).

Key Habitat Quantity: Moderate impact.

- *Certainty of Impact. Low.* High quality rearing habitat is limited in the tidally influenced freshwater estuary between Ferndale and Kwina Slough. The mainstem channel is confined by armored levees with simplified edge habitat and is void of woody debris in the channel. Refuge from high flow and predation are both limited in this reach (Brown et al. 2005). Below Marine Drive, freshwater rearing habitat is abundant and transitioning habitat may become limiting. The saltwater-freshwater interface is likely narrow through the high-flow out-migration period, and occurs either on the sandflat, where habitat has low complexity and cover is limited, or in Bellingham Bay. This narrow zone of mixing between fresh and saltwater. EDT reach diagnosis indicates that the lack of key habitat in the Nooksack/Lummi estuary has a moderate impact on both Nooksack early chinook populations (Figures 4.5, 4.6).

- *Early Chinook Impacts.* The timing of chinook rearing and out-migration causes them to experience a wide range of conditions in the estuary. High discharge, when the majority of chinook leave the watershed, limits the area of the transitional zone. Also, chinook life history strategies that rear for extended periods of time in the estuarine environment may be limited by the reduced availability of rearing habitat late in the summer.
- *Relative Importance of Causal Mechanisms.*
    - *High.* Development of the estuary has led to a loss of historic habitats between early maps of the delta and the early 1930s. Wetland, scrub-shrub, and forested floodplain areas all saw a dramatic decrease in that time period, largely on the Lummi Bay delta of the river (Brown et al. 2005, Collins and Sheikh 2004b, Bortleson et al. 1980). Since the 1930s, the Bellingham Bay delta has prograded rapidly, recovering much of the habitat that was lost to diking and draining. In spite of this recovery, several habitat types are still less prevalent than under undisturbed conditions. This is particularly true of blind channel areas and salt marsh habitat. Wood removal and levee construction along the main channel upstream of Kwina Slough has further simplified in the in-stream habitat and likely reduced the quality of freshwater rearing habitat in the upper reaches of the estuary. Fish sampling focused on transition and rearing habitat has not been conducted and the residence time in these habitats is currently unknown.

Temperature: Moderate Impact

- *Certainty of Impact: Low.* Water temperature data was collected over the course of two years across habitat types in the estuary (Brown et al. 2005). It was found that temperature varies between habitat types, with most floodplain tributaries and sloughs reaching lethal temperatures in the summer. It is unknown how these habitats are used by migrating, rearing, and transitioning juvenile salmonids.
- *Early Chinook Impacts.* Elevated water temperature affects habitat types not directly influenced by mainstem flow or seawater as early as mid-May. Many

floodplain tributaries reach lethal temperatures during the out-migration and rearing period of juvenile chinook.

- *Relative Importance of Causal Mechanism:*
  - *Unknown.* Lack of riparian shading and low flow on floodplain tributaries and sloughs contributes to elevated water temperature in these habitats. In many cases, these channels reach lethal limits for rearing juveniles. The extensive sand flats on the delta front lead to extremely high temperatures in the distributary channels that cross the sand flats at ebb tide.

Habitat Diversity: Moderate impact.

- *Certainty of Impact. Low.* The distribution of channel and landscape habitat types has changed through time in the Nooksack estuary.
- *Early Chinook Impacts.* If chinook use these different habitat types for unique stages of the life-histories, then the changes in habitat distribution and abundance could negatively affect the population. To date, little is known about how juvenile salmon use these different habitats.
- *Relative Importance of Causal Mechanisms:*
  - *High:* Development of the floodplain for agriculture and delta progradation has been the driving force behind the change in landscape and channel habitat types. Diking and draining of the floodplain has decreased tidal and distributary channel lengths on the Lummi Bay delta, while delta progradation on the Bellingham Bay delta has increased these habitats. Loss of tidally influenced wetlands, scrub-shrub and saltmarsh habitats are being more slowly recreated by delta progradation, but are well below their historic abundance.

Obstructions: Moderate impact.

- *Certainty of Impact. Low.* Several floodplain channels, sloughs and distributaries were disconnected by levees to allow for development of the floodplain (Brown et al. 2005). In many cases, tidegates and floodgates were installed to protect the property from inundation. All of the flood protection infrastructure was in place by the first aerial photographs in 1933, disconnecting these habitat for the last 70 years. Sampling of similar habitats to those blocked has not been conducted to determine fish use of the habitat.
- *Early Chinook Impacts.* The loss of floodplain habitat may impact freshwater rearing habitat for early entrants into the estuary.
- *Relative Importance of Causal Mechanisms.*
  - *High:* Flood protection and reclamation activities have led to the disconnection of historic channel areas, either through channel filling, poorly functioning tidegates, culverts and floodgates.

4.1.3.3.14. Bellingham Bay

The heaviest development of the nearshore environment associated with the Nooksack River has occurred in Bellingham Bay related to the development of the port of Bellingham. A history of dredging, filling, armoring and over-water construction has led to the alteration of much of the nearshore environment in this area. The result is a long section of industrialized shoreline that has no nearshore habitat. Coupled with the loss of nearshore habitat, the bay has seen a history of waste discharge and dumping that has prompted an extensive clean-up effort.

As with other estuarine and nearshore areas, restoration of Bellingham Bay will be important to recover spatial structure and diversity of Nooksack early chinook populations. Since non-natal and other pocket estuaries historically available in Bellingham Bay provided a proximal (within 5 miles) alternative to rearing in the delta, Bellingham Bay restoration may also improve abundance and productivity.

Key Habitat Quantity: Moderate impact.

- *Certainty of Impact. Low.* Development of the Port of Bellingham shoreline has led to a loss of nearshore habitat in much of the bay. Nearshore habitat has been systematically developed since the mid-1800s. Over-water structures, filling and dredging have all contributed to the conversion of the nearshore. The conversion of the nearshore likely reduced the quality of sheltered nearshore migration habitat.
- *Early Chinook Impacts.* Development of the nearshore likely affected feeding and migrating juvenile salmon that would have used the shallow nearshore as they migrated from the Nooksack River. Vegetation in the nearshore environment would have provided cover from predation and a source of food for the migrating juveniles.
- *Relative Importance of Causal Mechanisms.*
  - *High:* Dredging and filling of the near-shore have reduced the amount of nearshore habitat in Bellingham Bay.

Habitat Diversity: Moderate impact.

- *Certainty of Impact. Low.* Loss of shallow water habitats associated with the development of the port and development of non-natal estuaries has reduced the habitat diversity of the Bellingham Bay nearshore environment. The loss of shallow water habitat has likely altered the submerged aquatic vegetation and substrate characteristics in the nearshore, which are important aspects of habitat diversity.
- *Early Chinook Impacts.* A lack of habitat diversity can affect the life-history strategy of migrating, rearing and transitioning juvenile salmon.
- *Relative Importance of Causal Mechanisms.*

- Industrial development of the nearshore has reduced habitat diversity in the nearshore. A history of filling and dredging tidelands has severely altered the nearshore environment of Bellingham Bay. Shoreline armoring has further interrupted habitat-forming processes, by halting sediment sources that provide material to adjacent drift cells.

Chemicals: Moderate impact.

- *Certainty of Impact. Low.* Discharge and dumping of waste in Bellingham Bay has impacted the water and substrate quality in Port of Bellingham area of Bellingham Bay. Contaminants, such as mercury, PCB and phenol, are present in Bellingham Bay.
- *Early Chinook Impacts.* These chemicals can affect the reproductive and immune systems of fish and have been shown to cause weight loss and early death in some instances. While bioassay work is being conducted to assess the accumulation of chemicals in fish and shellfish, the extent that chemicals limit salmon development is unknown.
- *Relative Importance of Causal Mechanisms.*
  - *High:* Industrial development in the nearshore and discharge is the dominant source of chemicals in Bellingham Bay.
  - *Moderate:* Development in the watersheds of Squalicum and Whatcom creeks contributes chemicals to Bellingham Bay.

Food: Moderate impact.

- *Certainty of Impact. Low.* Loss of nearshore environment in Bellingham Bay has likely reduced the extent of eelgrass and other submerged aquatic vegetation available to migrating juvenile salmon. The loss of this habitat has likely affected prey species, such as surf smelt, sandlance, and herring that juvenile fish will feed on as they migrate and rear in the nearshore. Saltmarsh and scrub-shrub environments associated with the non-natal estuaries in the Bellingham Bay nearshore were likely another source of food for rearing and transitioning juvenile salmon. Development and filling of these estuaries have likely reduced the amount of food produced by these areas.
- *Early Chinook Impacts.* Reduced food resources can slow growth and alter migration patterns of juvenile fish.
- *Relative Importance of Causal Mechanisms.*
  - *Moderate:* Development of nearshore and non-natal estuaries has likely reduced the food available to migrating, rearing and transitioning juvenile salmon in Bellingham Bay.

4.1.3.3.15. Other WRIA 1 Nearshore Areas

Before upland and shoreline development began in the 1850s, the shoreline flanked cliffs composed of sandstone and glacial deposits, either glacial marine drift or glacial outwash. The natural erosion that pulls sediment and other materials from the cliffs to nourish the beaches below and feed the alongshore drift cells is an important process in the sustenance of complex nearshore habitat. When cliff erosion and sediment transport processes are disrupted by the construction of over-water structures or artificial armoring with riprap, nearshore habitat-forming processes, in turn, can be disrupted. Disruptions in habitat-forming processes can cause shifts in biotic communities, reductions in juvenile salmonid prey resources, changes in migratory behavior, and loss of rearing habitat (Levings 1980, Waldichuk 1993, Thom 1994, Simenstad and Fresh 1995 cited in Aitkin 1998).

Industrial shoreline development began in the 1880s, on the beachfronts of what is now the City of Bellingham (Wahl 2004). Activities included dredging sediment for transportation, dumping municipal wastes, dock and pier construction, bulkheading, and shore stabilization with rock and wood structures. Nearly one-third of shoreline habitat within the estuary has been modified by artificial means, which is consistent with the amount of shoreline modified statewide (DNR 1996).

Habitat Diversity: Moderate impact.

- *Certainty of Impact. Low.* Loss of shallow water habitats associated with the development of the shoreline and fill of non-natal estuaries has reduced the habitat diversity of the WRIA 01 nearshore environment. The loss of shallow water habitat has likely altered the submerged aquatic vegetation and substrate characteristics in the nearshore, which are important aspects of habitat diversity.
- *Early Chinook Impacts.* A lack of habitat diversity can affect the life-history strategy of migrating, rearing and transitioning juvenile salmon.
- *Relative Importance of Causal Mechanisms.*
    - High: Industrial development of the nearshore has reduced habitat diversity in the nearshore. A history of filling and dredging tidelands has severely altered the nearshore environment of WRIA 01. Shoreline armoring has further interrupted habitat-forming processes, by halting sediment sources that provide material to adjacent drift cells.
    - Moderate: Loss of riparian contributions to the nearshore due to land clearing and shoreline armoring have reduced the local sources of wood to the nearshore. Wood can play an important ecological role in the upper nearshore environment (Sedell and Maser 1994).

4.1.4. Nooksack Bull trout

In this section we discuss priority areas for bull trout, and add limiting factors to the extent that those previously described for early chinook do not capture the factors for decline for bull trout. There is a great deal of geographic overlap by bull trout and the early chinook populations for spawning and rearing, although bull trout also use smaller tributaries to the forks, and in some cases occupy habitats higher in the watershed (i.e. South Fork) . Because Chilliwack core area bull trout that spawn and rear in the U.S. are essentially located in Federally protected pristine habitat, the discussion, and higher priority area is limited to the Nooksack core area.

4.1.4.1. Nooksack Geographic Local Population Areas

Consistent with the draft bull trout recovery plan (USFWS 2004), spawning and rearing local population areas in the Nooksack core area are listed below. For more specific information on use of these areas see section 3.2.2, or the draft recovery plan.

- Lower Canyon Creek (downstream of long-term barrier at mile 4.4)
- Glacier Creek watershed (including accessible tributaries)
- Lower Middle Fork Nooksack River (from diversion dam to confluence with North Fork, including accessible tributaries)
- Upper Middle Fork Nooksack River (upstream of diversion dam, including accessible tributaries)
- Lower North Fork Nooksack River (North Fork and accessible tributaries between Canyon and Maple creeks)
- Middle North Fork (North Fork and accessible tributaries between Canyon and Glacier creeks)
- Upper North Fork (North Fork and accessible tributaries from Glacier Creek to Nooksack Falls)
- Upper South Fork (South Fork and accessible tributaries from confluence with Wanlick Creek to approximately river mile 39)
- Lower South Fork (South Fork and accessible tributaries from confluence with Wanlick Creek to confluence with Hutchinson Creek)

4.1.4.2. Geographic Priorities

The geographic priority areas are the local population spawning and early rearing areas described above, the migratory and foraging corridors downstream from these (the lower North Fork, lower South Fork, and mainstem Nooksack River), and forage fish production areas of the nearshore that provide the prey base critical for supporting this species.

4.1.4.3. Limiting Factors

There are enough similarities in the life history requirements of bull trout and early chinook that the description of limiting factors in section 4.1.3 generally apply for bull trout as well. While EDT has not been run for bull trout and consequently there are not geographic results for bull trout, the specific habitat conditions for respective geographic areas described in section 4.1.4.3 are also generally applicable, and the reader is referred to those sections.

For the spawning and rearing areas located higher, or in smaller tributaries, than early chinook use, the land management is primarily forestry, and general habitat deficiencies are related to disruption of habitat forming processes, including lack of functional LWD, degraded riparian areas, and increased coarse and fine sediment delivery related to accelerated mass wasting, including debris flows.

Consistent with chinook, the Middle Fork diversion dam and Canyon Creek passage barriers block migratory access to the largest quantity of habitat. There are additional passage barriers on smaller streams within the local population geographic areas that are not used by chinook. These include Hedrick Creek (SR542), an unnamed RB tributary just downstream of Boulder Creek (SR542), "Chainup" Creek (SR542), Loomis Creek (USFS 12 Rd) and Kenny Creek (North Fork Rd, and additionally on a private road). Three additional tributaries to the upper Middle Fork (USFS 38 Rd) are scheduled to have passage corrected in 2005, and passage was also recently restored under the Mosquito Lake Road crossing of Johnson Creek.

Migratory corridors are very important for bull trout as they repeatedly forage in and migrate through these areas. The degraded conditions of the forks and mainstem downstream from spawning and rearing areas, and lost salmon productivity here, and in other foraging areas, have also contributed to the decline. Thermal impairment of the South Fork is of particular concern.

Figure 4.1. EDT estimates of current and historic habitat potential with respect to Nooksack early chinook adult capacity, adult productivity, and life history diversity. (Source: EDT Online baseline report, 2/22/05; www.mobrand.com/edt).

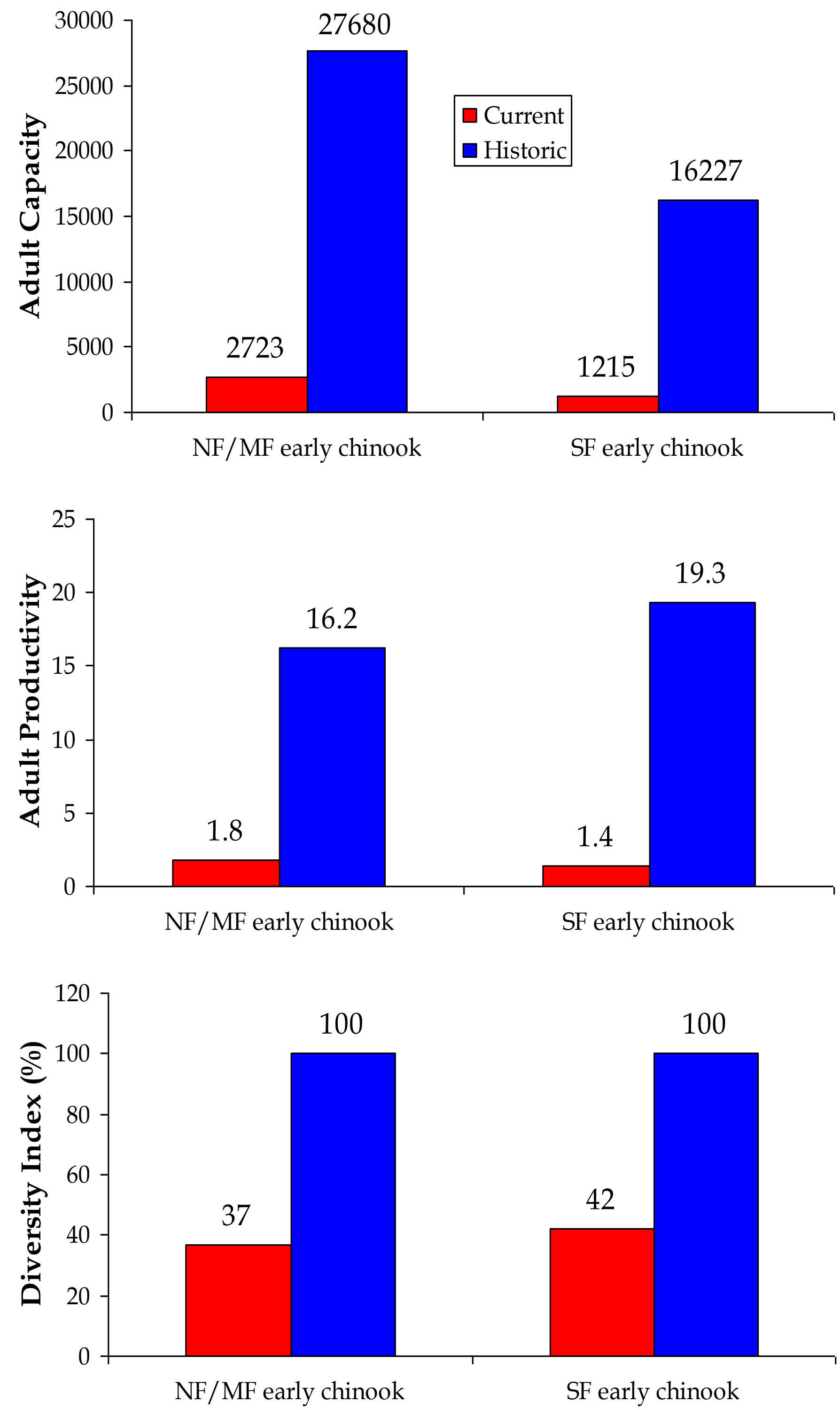


Figure 4.2. Diagram of interactions among watershed processes, habitat conditions, anthropogenic impacts, and salmonid population viability.
Note: Adapted from Beechie et al. 2003.

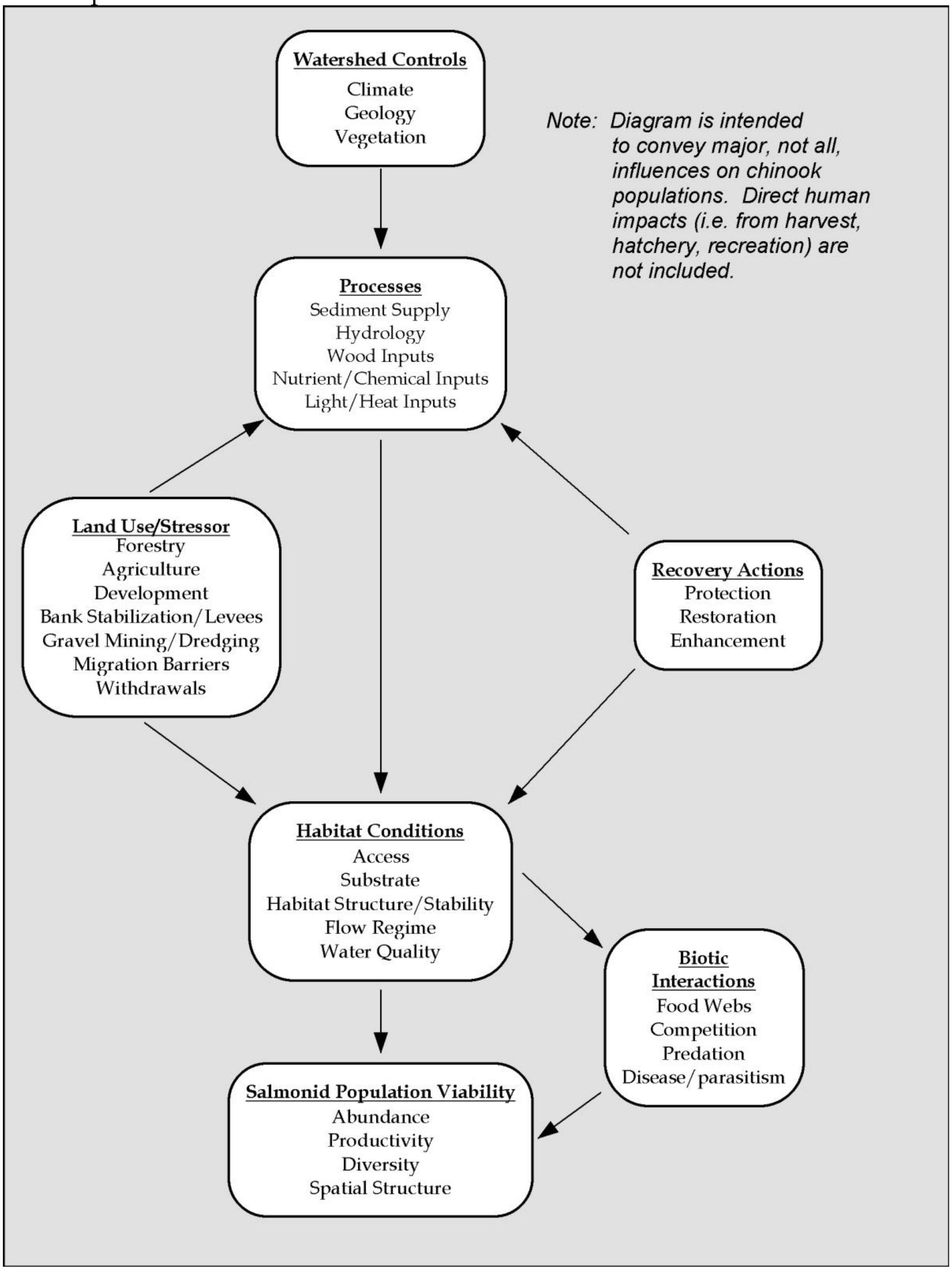


Table 4.1. Environmental attributes rated for each of 88 reaches in the Nooksack River watershed for input into EDT.

Source: Lestelle et al. 2004.

Environmental Attributes (Level 2)	
1 Hydrologic Characteristics	
1.1 Flow variation	Flow - change in interannual variability in high flows
	Flow - changes in interannual variability in low flows
	Flow - Intra daily (diel) variation
	Flow - intra-annual flow pattern
	Water withdrawals
1.2 Hydrologic regime	Hydrologic regime - natural
	Hydrologic regime - regulated
2 Stream Corridor Structure	
2.1 Channel morphometry	Channel length
	Channel width - month maximum width
	Channel width - month minimum width
	Gradient
2.2 Confinement	Confinement - hydromodifications
	Confinement - natural
2.3 Habitat type	Habitat type - backwater pools
	Habitat type - beaver ponds
	Habitat type - glides
	Habitat type - large cobble/boulder riffles
	Habitat type - off-channel habitat factor
	Habitat type - pool tailouts
	Habitat type - primary pools
	Habitat type - small cobble/gravel riffles
2.4 Obstruction	Obstructions to fish migration
2.5 Riparian and channel integrity	Bed scour
	Icing
	Riparian function
	Wood
2.6 Sediment type	Embeddedness
	Fine sediment (intragravel)
	Turbidity (suspended sediment)
3 Water Quality	
3.1 Chemistry	Alkalinity
	Dissolved oxygen
	Metals - in water column
	Metals/Pollutants - in sediments/soils
	Miscellaneous toxic pollutants - water column
	Nutrient enrichment
3.2 Temperature variation	Temperature - daily maximum (by month)
	Temperature - daily minimum (by month)
	Temperature - spatial variation
4 Biological Community	
4.1 Community effects	Fish community richness
	Fish pathogens
	Fish species introductions
	Harassment
	Hatchery fish outplants
	Predation risk
	Salmonid carcasses
4.2 Macroinvertebrates	Benthos diversity and production

Table 4.2. Examples of guidance for rating of EDT environmental attributes.

Source: EDT Stream Reach Editor version 3.1; **www.mobrand.com/edt**).

Attribute	Rating	Guidance
Fine sediment (intragravel)	0	Particle sizes <0.85 mm: < 6% OR Particle sizes <6.3 mm: <10%
	1	Particle sizes <0.85 mm: > 6% and < 11% OR Particle sizes <6.3 mm: >10% and <25%
	2	Particle sizes <0.85 mm: > 11% and < 18% OR Particle sizes <6.3 mm: >25% and <40%
	3	Particle sizes <0.85 mm: > 18% and < 30% OR Particle sizes <6.3 mm: >40% and <60%
	4	Particle sizes <0.85 mm: > 30% fines OR Particle sizes <6.3 mm: >60%
Temperature - spatial variation	0	Super abundant sites of groundwater discharge into surface waters (primary source of stream flow), tributaries entering reach, or deep pools that provide abundant temperature variation in reach.
	1	Abundant sites of groundwater discharge into surface waters, tributaries entering reach, or deep pools that provide abundant temperature variation in reach.
	2	Occasional sites of groundwater discharge into surface waters, tributaries entering reach or deep pools that provide intermittent temperature variation in reach.
	3	Infrequent sites of groundwater discharge into surface waters, tributaries entering reach or deep pools that provide infrequent temperature variation in reach.
	4	No evidence of temperature variation in reach.

Table 4.3. Life stage use of Nooksack Early Chinook Geographic Areas.

(S= use by SF early chinook; N= use by NF/MF early chinook; B= use by both; lower case with italics indicate use is marginal or uncertain).

		Geographic Area														
	Life Stage	Lower North Fork	Upper North Fork	North Fork tribs	Lower Middle Fork	Upper Middle Fork	Middle Fork tribs	Lower South Fork	Upper South Fork	South Fork tribs	Lower Mainstem	Upper Mainstem	Mainstem tribs	Estuary	Bellingham Bay	Other Nearshore
Freshwater	Adult migration	N	N	N	N	N	N	S	S	S	B	B	B			
	Adult holding	N	N	N	N	N	N	S	S	S		*s*				
	Spawning	N	N	N	N	N	N	S	S	S						
	Incubation	N	N	N	N	N	N	S	S	S						
	Fry	N	N	N	N	N	N	S	S	S	B	B	B			
	Oversummer rearing	N	N	N	N	N	N	S	S	S	*b*	B				
	Overwinter rearing/ flood refuge	N	*n*	*n*	N	*n*	*n*	S	S	*S*	*B*	B	*b*			
	Juvenile migration	N	N	N	N	N	N	S	S	S	B	B				
Estuary/Nearshore	Delta fry rearing													B	B	
	Fry migrant rearing														B	B
	Parr migrant rearing													*b*	*b*	
	Yearling migrant rearing															
	Adult migration													B	B	B

Figure 4.3. Geographic priorities for South Fork Nooksack early chinook using EDT.

South Fork Nooksack Early Chinook

Relative Importance Of Geographic Areas For Protection and Restoration Measures

Geographic Area	Protection benefit Rank	Restoration benefit Rank
Bellingham Bay	12	12
Nooksack/Lummi Estuary	4	6
MS Lower	10	10
MS Upper: Everson to Nugents	8	5
MS Upper: Nugents to Forks	7	6
SF Lower: Mouth to Jones Cr	9	1
SF Lower: Jones Cr to Skookum Cr	2	2
SF Upper: Skookum Cr to RM 20.6	1	3
SF Upper: RM 20.6 to RM 31	6	4
SF Tribs: Hutchinson Creek	11	9
SF Tribs: Skookum Creek	4	11
SF Tribs: Cavanaugh-Plumbago-Deer	3	6

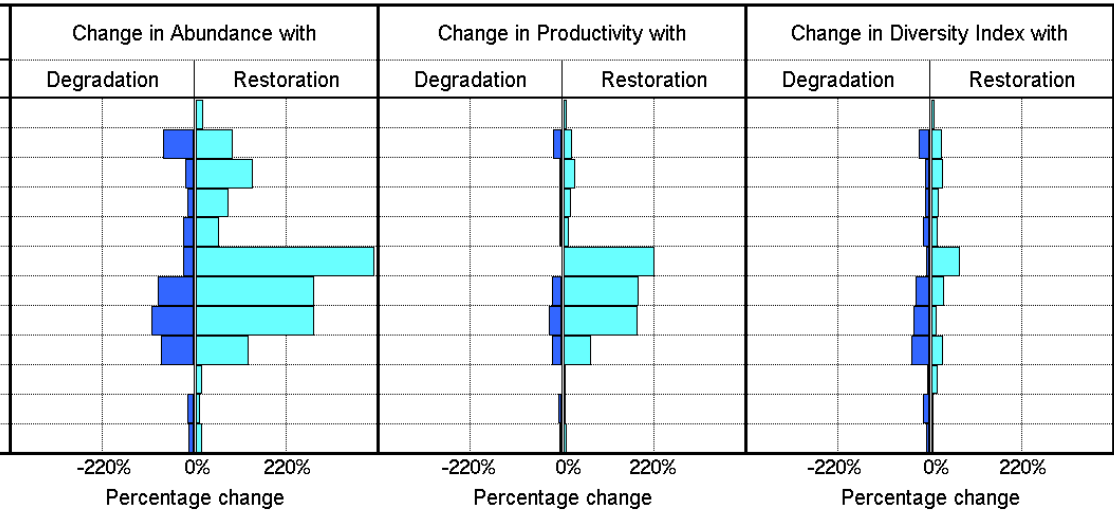


Figure 4.4. Geographic priorities North Fork/Middle Fork Nooksack early chinook using EDT.

North Fork/Middle Fork Nooksack Early Chinook

Relative Importance Of Geographic Areas For Protection and Restoration Measures

Geographic Area	Protection benefit Rank	Restoration benefit Rank
Bellingham Bay	27	29
Nooksack/Lummi Estuary	10	24
MS Lower	23	25
MS Upper: Everson to Nugents	20	23
MS Upper: Nugents to Forks	17	19
NF Lower: below Middle Fork	14	2
NF Lower: MF to RM 43	16	6
NF Lower: RM 43 to Racehorse Cr	7	2
NF Lower: Racehorse to RM 46.7	4	4
NF Lower: RM 46.7 to Maple Cr	5	5
NF Lower: Maple Cr to Boulder Cr	2	14
NF Lower: Boulder to RM 55.1	15	10
NF Lower: RM 55.1 to Glacier Cr	1	11
NF Upper: Glacier Cr to Falls	13	19
NF Tribs: Racehorse and Bear Creeks	26	15
NF Tribs: Maple Creek	6	18
NF Tribs: Boulder Creek	21	21
NF Tribs: Canyon Creek	18	13
NF Tribs: Cornell and McDonald Creeks	18	17
NF Tribs: Glacier Creek	27	22
NF Tribs: Boyd, Deadhorse, Wells Creek	8	27
MF Lower: Mouth to RM 0.9	12	9
MF Lower: RM 0.9. to RM 5	9	12
MF Upper: RM 5 to Diversion	11	25
MF Upper: Diversion Dam	27	1
MF Upper: Diversion to RM 17.4	27	30
MF Tribs: Canyon Lake Creek	23	7
MF Tribs: Peat Bog Creek	3	28
MF Tribs: Porter Creek	25	8
MF Tribs: upstream of Diversion	27	30

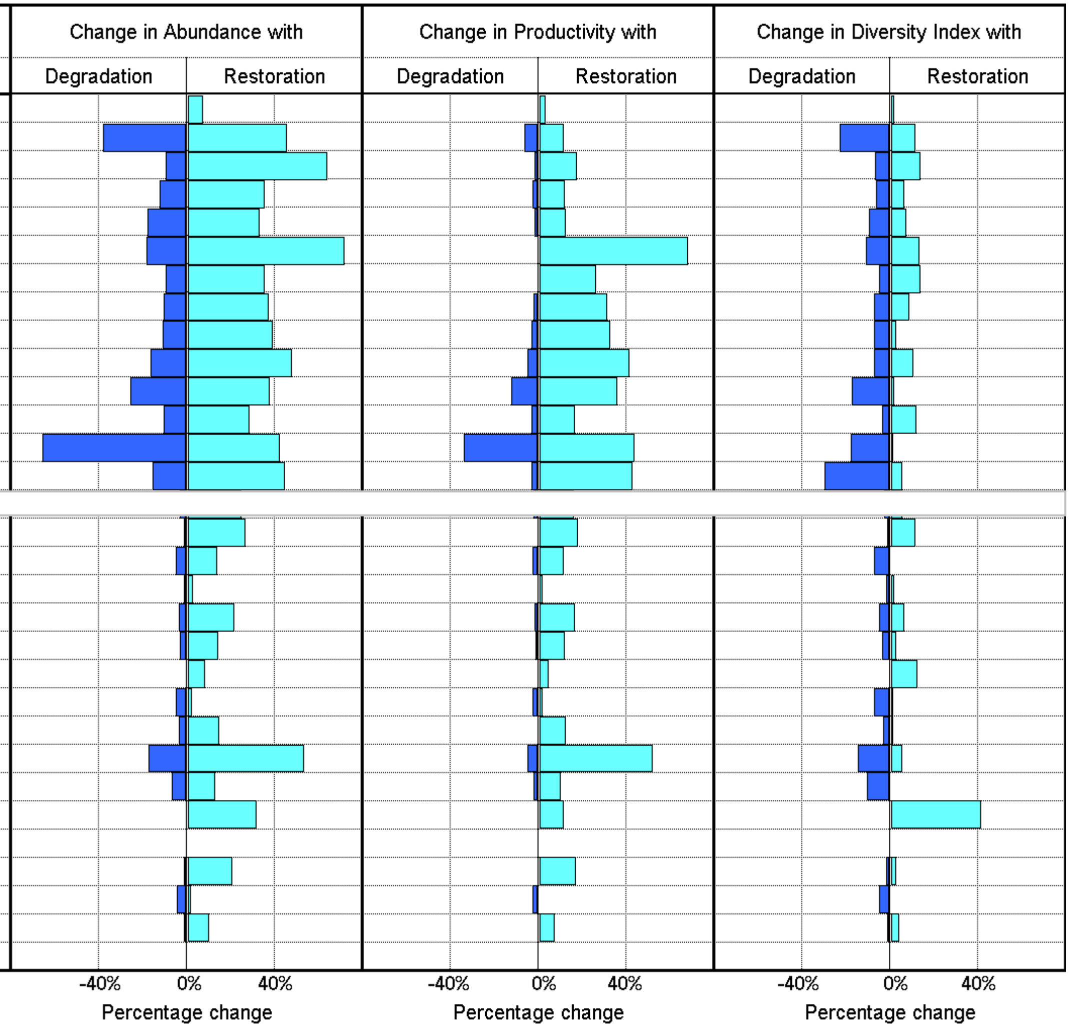


Figure 4.5. Limiting factor priorities for South Fork Nooksack early chinook using EDT.

South Fork Nooksack Early Chinook
Protection and Restoration Strategic Priority Summary

Geographic area	Attribute class priority for restoration															
	Channel stability	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
Bellingham Bay		•	•			•	•									
Nooksack/Lummi Estuary		•	•	•	•	•	•					•	•	•		●
MS Lower	•		•		•	•	●						•	•		●
MS Upper: Everson to Nugents	•		•		•	•	●						•	●		●
MS Upper: Nugents to Forks	•		•		•	•	●					•		•		●
SF Lower: Mouth to Jones Cr	•				●	•	⬤	●				•	●	⬤		●
SF Lower: Jones Cr to Skookum Cr	•				•	•	•	•				•	●	●		●
SF Upper: Skookum Cr to RM 20.6	•				•	•	•					•	●	●		●
SF Upper: RM 20.6 to RM 31	•				•	•	⬤	•				•	●	•		•
SF Tribs: Hutchinson Creek	•				•	•	●	•				•	●			●
SF Tribs: Skookum Creek	•		•		•		⬤									●
SF Tribs: Cavanaugh-Plumbago-Deer	•				•	•	●						●			●

1/ "Channel stability" applies to freshwater areas only.

Key to strategic priority (corresponding Benefit Category letter also shown)

A		B		C		D & E	
◯ / ⬤	High	○ / ●	Medium	∘ / •	Low	(blank)	Indirect or General

Figure 4.6. Limiting factor priorities for North Fork/Middle Fork Nooksack early chinook using EDT.

North Fork/Middle Fork Nooksack Early Chinook
Protection and Restoration Strategic Priority Summary

Geographic area	Attribute class priority for restoration															
	Channel stability	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
Bellingham Bay		•	•			•	•									
Nooksack/Lummi Estuary		•	•	•	•	•	•					•	•	•		●
MS Lower	•		•		•	•	●						•	•		●
MS Upper: Everson to Nugents	•		•		•	•	●							•		●
MS Upper: Nugents to Forks	•		•		•	•	●							•		●
NF Lower: below Middle Fork	●				•	•	•	•				•	⬤	⬤		●
NF Lower: MF to RM 43	⬤				•	•	●	•				•	●	●		●
NF Lower: RM 43 to Racehorse Cr	●				•	•	•	•				•	●	●		●
NF Lower: Racehorse to RM 46.7	●				•		●	•				●	●	●		●
NF Lower: RM 46.7 to Maple Cr	⬤				•	•	•					•	●	●		●
NF Lower: Maple Cr to Boulder Cr	●				•		•						●	●		●
NF Lower: Boulder to RM 55.1	●		•		•	●	●	•				●	•	•		●
NF Lower: RM 55.1 to Glacier Cr	•				•		•						•	•		●
NF Upper: Glacier Cr to Falls	●				•		●					•	●			●
NF Tribs: Racehorse and Bear Creeks	⬤				●	•	●					●	⬤	⬤		⬤
NF Tribs: Maple Creek	•		•		•		●					⬤		•		●
NF Tribs: Boulder Creek	•				●	•	⬤							•		●
NF Tribs: Canyon Creek	⬤				●	•	⬤	•				●	•	●		●
NF Tribs: Cornell and McDonald Creeks					•	•	•						●	⬤		●
NF Tribs: Glacier Creek	⬤				•		•						⬤			●
NF Tribs: Boyd, Deadhorse, Wells Creeks					•		●									•
MF Lower: Mouth to RM 0.9	●				•	•	•					•	●	⬤		●
MF Lower: RM 0.9. to RM 5	•				•	•	•						●	⬤		●
MF Upper: RM 5 to Diversion	•				•	•	●						●	•		●
MF Upper: Diversion Dam									⬤							
MF Upper: Diversion to RM 17.4					•	•	⬤						•			●
MF Tribs: Canyon Lake Creek	●				●	•	●					●	●	⬤		⬤
MF Tribs: Peat Bog Creek							•							●		⬤
MF Tribs: Porter Creek	●		•		●	•	⬤					●	•	⬤		⬤
MF Tribs: upstream of Diversion					•	•	●						●	●		●

Key to strategic priority (corresponding Benefit Category letter also shown)

A		B		C		D & E	
◯ / ⬤	High	○ / ●	Medium	∘ / •	Low		Indirect or General

1/ "Channel stability" applies to freshwater areas only.

4.2. Harvest

Improperly managed harvest that causes mortality in excess of 50% of the total population can have a variety of impacts on the ability of the population to survive over time. This section identifies the effects of harvest on the abundance and genetic diversity of the early chinook population, as well as potential effects on the ecosystem, such as changes in marine-derived nutrients. The hypothesis is that the current exploitation rate has as low impact on the recovery with a moderate degree of certainty.

4.2.1. Abundance Impacts

In this section, the current abundance of the Nooksack early chinook stocks is described and potential harvest impacts are discussed. If the total harvest is not managed to provide an escapement of spawning adults required to sustain harvest at maximum levels over time, the abundance of the population will decline. Fisheries managers use several models based on representative data on stock escapement and subsequent harvest by brood years to calculate the escapement that will provide the Maximum Sustainable Yield. Since the problem with the Nooksack Early Chinook management unit was identified in the 1970s, efforts have been made to collect the information required to develop these models for this management unit. In 1977, a coast-wide coded wire tag (CWT) program was established to provide coordination of CWT release and recovery efforts. Standards were established for catch sampling rates, release, and reporting to a centralized site, access and ability to extract data of interest, and methods of analysis among managers. The Fisheries Resource Assessment Model (FRAM) based upon estimated fisheries mortalities derived from CWT information has estimated that the current exploitation rates from all fisheries has been at or below 20% since 1996 (Figure 4.7). While there is no specific estimate of the exploitation rates on this management unit in the 1970s, a period of increased catches on chinook salmon in the West Coast Vancouver Island fisheries and Strait of Georgia was associated with the negotiation of the Pacific Salmon Treaty.

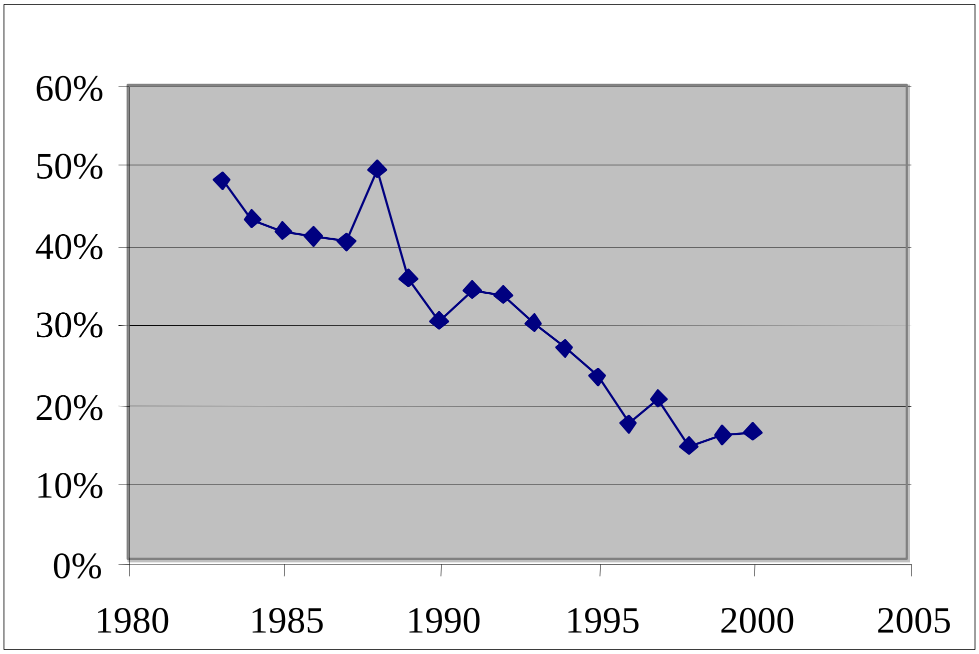


Figure 4.7. Total adult equivalent Exploitation rate of Nooksack early chinook for management years 1983 – 2000, estimated by post-season FRAM runs.

The current status of the Nooksack early chinook populations is critical. The geometric mean number of natural-origin spawners in the North / Middle Fork, for 1998 – 2002, was 124. The NOR escapement has increased slightly in recent years from very low levels in the late 1990's (Table 4.4). The number of native, natural-origin spawners in the South Fork remains low, but is also apparently stable. The geometric mean NOR escapement in South Fork, for 1998 – 2002, was 224.

Table 4.4. Natural-origin escapement of early chinook to the North / Middle Forks and South Fork of the Nooksack River.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
No/Mid Fork	335	8	171	209	74	37	85	160	264	224
South Fork	235	118	290	203	180	157	166	284	267	289

The natural spawning escapement has been substantially higher in recent years, due to volunteers from the Kendall Creek Hatchery supplementation program. In the North / Middle Fork, escapement has increased markedly since 1998, and exceeded 3,700 in 2002. The number of natural spawners in the South Fork has also increased, and reached 625 in 2002 (Table 4.5).

Table 4.5. The total number of natural early chinook spawners (i.e., hatchery- and natural-origin) in the North / Middle and South Forks of the Nooksack River.

Note: North / Middle Fork estimates exclude hatchery turnbacks.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
No Mid Fk	445	45	224	537	574	370	823	1242	2185	3741
South Fk	235	118	290	203	180	157	290	373	420	625

North/Middle Fork escapement in the last three years has been more than three times the average for the preceding five-year period (1992-96), while South Fork populations escapement has been stable at about 200 for the last five years. Recruits per natural-origin spawner in the North and Middle Forks have consistently remained below one recruit per spawners. Results from otolith studies, indicate that the return rate of natural origin spawners in the North Fork for brood years 1992 through 1995 ranged from 0.08 to 0.59 per spawner (Table 4.7), well below the replacement rate.

The large and increasing number of hatchery-origin fish (Table 4.6)escaping to the North and Middle Forks suggests that harvest in the southern U.S. specifically, and all fisheries generally, are not impeding the rebuilding of the abundance of natural origin spawners. The failure of the NORs to show a substantial increase in abundance similar to that of hatchery-origin fish, during the restricted fisheries in the late 1990s, suggests limitations in the ability of existing habitat conditions to support substantial productivity from the increased spawner abundance.

Table 4.6: Origin of Spawners in the North/Middle Forks of the Nooksack River (Source: Co-Manager unpublished data).

Return Year	Natural Origin	Cultured Origin	Hatchery Turnbacks	Total
1995	171	53		228
1996	209	328		537
1997	74	500		574
1998	37	333		370
1999	85	738		823
2000	160	1082	3760	5002
2001	264	1921	4801	6986
2002	224	3517	4188	7482
2003	210	2467	3937	5714
2004	318	1428	1801	2547

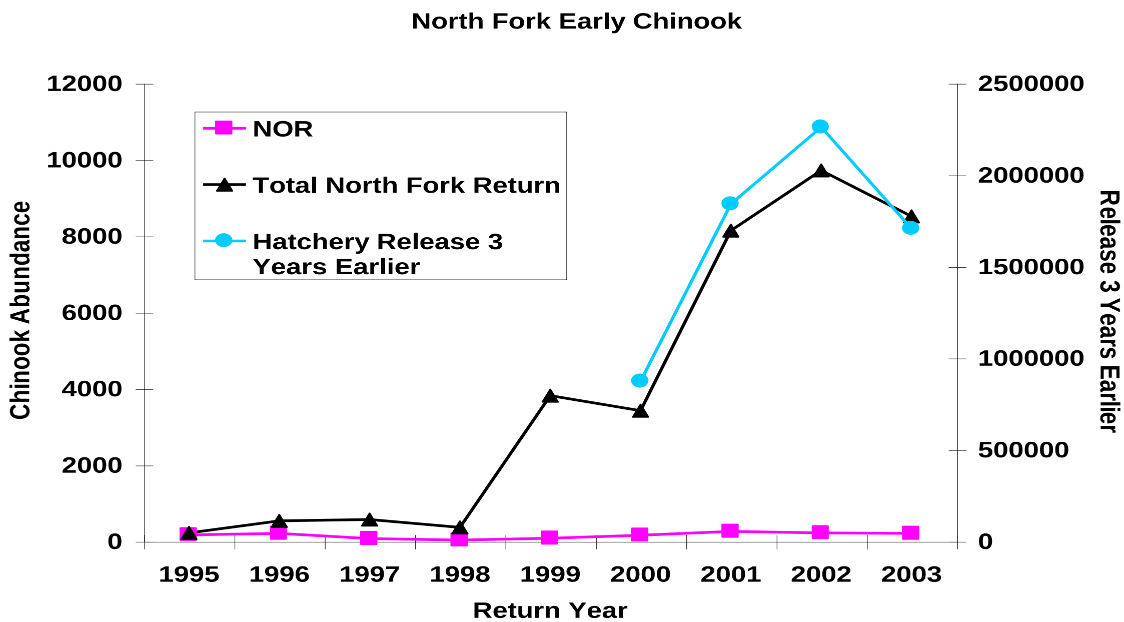


Figure 4.8. Natural-origin and total natural escapement to the North / Middle Fork of the Nooksack River, and Kendall Creek Hatchery releases three years prior.

Table 4.7. Natural origin return per spawner rates for early chinook in the North/Middle Fork of the Nooksack River (Co-Manager unpublished data).

Brood year	Natural spawners	Total age 3 - 6 Returns	Return per Spawner
1992	493	174	0.373
1993	445	77	0.164
1994	45	25	0.556
1995	230	18	0.078
1996	533	248	0.464
1997	617	344	0.558
1998	370	119	0.324
1999	823	196	0.238
2000*	823	325	0.262

** Age 3 and 4 returns only*

While there is high variability in the relationship between natural-origin spawners and subsequent returns per spawner for the North / Middle Fork population, and statistical relationship is not significant, the data suggest that the recruitment rate is lower at higher spawner abundance. With the significant increase in natural spawners in recent years, the next four years will provide a clearer picture of the relationship between the number of spawners in the wild and the subsequent recruitment.

The EDT results for the North/Middle Forks under current conditions estimate capacity at 2,059 adults, equilibrium (i.e. replacement) abundance at 760, and productivity 1.6 adult recruits per spawner, without consideration of fisheries mortality. These results largely agree with observations of the NOR spawners in the river, but suggest slightly higher productivity than the production calculated from NOR escapements (Table 4.7). The EDT analysis indicates that productivity under recovered habitat conditions would be much greater (Figure 4.9).

Figure 4.9. Spawner-recruit relationships under current, recovered, and historical habitat conditions in the North / Middle Fork of the Nooksack River, as estimated by EDT analysis.

A similar analysis of the current productivity in the South Fork indicates adult capacity of 885, equilibrium (i.e., replacement) abundance of 80,and a return of 1.1 recruits per spawner. Productivity under recovered conditions would be far in excess of the current level. (Figure 4.10)

Figure 4.10. The spawner – recruit functions for South Fork Nooksack early chinook under current, recovered, and historic habitat conditions, from the EDT model.

The status of the South Fork stock is more difficult to determine in the absence of a reliable brood year return per spawner. The comparison of South Fork early escapement to the early escapement four years later suggest an average spawner replacement rate of 1.21 (Table 4.8). With the advent of otolith marks for each release strategy in the Kendall Creek Hatchery Program, the North/Middle Fork stock has been identified in the early chinook spawners in the South Fork. Because the 1991 release was the first to be otolith marked and pre-dated the substantial releases of cultured fish in the North and Middle Forks, it is assumed that the straying of North/Middle Fork chinook into the South Fork was low prior to 1995.

Table 4.8. Origin and replacement rate of early chinook spawners in the South Fork Nooksack River.

Brood Year	South Fk Stock (no mark)	North Fk Stock	Stray Other or Unknown	Total	NOR BY+4	*Replacement* Rate
1991	365			365	290	0.79
1992	103			103	203	1.97
1993	235			235	180	0.77
1994	118			118	157	1.33
1995	166	87	37	290	166	0.57
1996	284	74	14	373	284	1.40
1997	267	138	15	420	267	1.48
1998	289	289	44	625	289	1.84
1999	204	217	148	570	204	0.70
					Average	1.21

Recent information indicates that as much as 46% of the early chinook spawners in the South Fork have been strays from the Kendall Creek Hatchery program.

Table 4.9. Estimates of the contributions of the native South Fork stock to natural spawning in the South Fork of the Nooksack River, 1999 - 2003.

Return Year	Total Early Number	South Fork Stock	
		Number	Percent
1999	290	166	57%
2000	373	284	76%
2001	420	267	64%
2002	625	289	46%
2003	570	204	36%

The relationship between the number of early chinook spawners in the South Fork and the number of natural origin recruits to the spawning grounds 4 years after the brood year strongly suggests that habitat conditions constrain productivity in the South Fork. This relationship assumes that the reproductive success of the North Fork and other strays is similar to that of the South Fork population and that the unmarked fish represent only NORs returning to the South Fork, regardless of the origin of the stock.

4.2.2. Genetic Diversity Impacts

Fisheries that take a high proportion of the production may exert a significant influence on the genetic diversity of a population.

Harvest related mortality in the troll fisheries may affect the age and size composition of the adults that survive to the spawning grounds because chinook may be available to the fishery for more than one year. To a certain extent, as similar situation might occur in hook and line sport fisheries on fish in internal waters as well as in the ocean when fish under a size limit must be released.

Harvest related mortality in the gill net fisheries may affect the age and size composition of the adults that survive to the spawning grounds because the size of the net mesh will select for a narrow range of sizes.

Harvest related mortality in all fisheries may affect the timing characteristics of the populations surviving to the spawning grounds if they do not access all portions of the returning populations with a similar exploitation rate.

The information does not exist to comment on the impact of fisheries on the genetic diversity of the Nooksack Early Chinook Management Unit. The hypothesis, with modest certainty, is that current fisheries have a low impact on the recovery of the Nooksack Early Chinook Management Unit because of the low overall exploitation rat, and low proportion of the total harvest taken in net fisheries.

Table 4.10. Average harvest distribution of Nooksack early chinook, for management years indicated, as percent of total adult equivalent fishery mortality (CTC 2003).

	Alaska	B.C.	Wa troll	PS net	Wa sport
1995-1999 yearlings	0.0%	67.4%	1.9%	6.4%	24.3%
1997-2001 fingerlings	21.5%	65.8%	3.0%	1.5%	8.2%

Coded-wire tag recoveries indicate that, in Washington waters, Nooksack early chinook have been caught in the Strait of Juan de Fuca troll fishery, recreational fisheries in southern and northern Puget Sound, and net fisheries (primarily in Areas 7 and 7A, Bellingham Bay, and the Nooksack River) in northern Puget Sound. The Kendall Creek facility currently releases only fingerling early chinook.

4.2.3. Ecosystem Impacts

Fisheries that take a high proportion of the production may exert a significant influence on the ecosystem processes that could influence the productivity of the habitat by limiting the volume of marine derived nutrients represented by the numbers of adults that doe not survive to the spawning grounds.

This is not thought to be a significant factor in the recovery of the Nooksack Early Chinook Management Unit, because:

1. The large numbers of chinook spawners present in the North and Middle Forks in recent years,
2. The numbers of late chinook observed in the South Fork in recent years.
3. Substantial chum escapements in chinook sections of the river
4. Substantial odd year pink salmon escapements
5. Distribution of healthy surplus hatchery carcasses from chinook and coho programs in the region.

Table 4.11. Current Estimates of Escapements of Salmon Contributing Significant Marine Derived Nutrients to the Nooksack System.

	South Fork Chinook			**North Fork Chinook**			**Pink**	**Chum**
	NF Origin	Native	Late	HOR	NOR	HOR Turnback		
Return Year								
1990		142		10				27995
1991		365		108			24000	27888

1992		103		498				29137
1993		235		449			56000	19855
1994		118		45				83503
1995		290		230	171[A]		22000	30621
1996		203		535	209[A]			31969
1997		180		617	74		26000	13198
1998		157		370	37			50911
1999	87	166	305	823	85		95000	17570
2000	74	284	263	1242	160	3760		3760
2001	138	267	303	2185	264	4801	226000	26943
2002	289	289	1583	3741	224	4188		46449
2003	217	204	93	2857	210	3937	51000	95898
2004	40	130		1746	318	1801		36697

HOR = Hatchery Origin, NOR=Natural Origin, HOR Turnbacks = Returned to the river from the Hatchery.

4.2.4. Bull Trout

Bull trout are not considered particularly desirable to eat, and are not targeted for harvest. While not targeted, larger individuals may be incidentally harvested in small numbers when local fisheries occur for other species where large bull trout are present. Harvest is undoubtedly limited by the fisheries management plans and restrictions in place for other species. While considered to be low impact, the level of harvest is unknown.

Marine and freshwater sport regulations have required all bull trout to be released since 1994. Sport fishermen may catch and release bull trout during the winter steelhead season, or the coho season, or upstream migrating sub-adults or adults during the summer "trout" fisheries. During mid-to late summer, adults can hold, or "stage" prior to spawning, and these aggregations can be vulnerable to anglers or poachers. Additionally, holding or foraging in thermally impaired waters including the South Fork Nooksack River may increase stress and susceptibility to hook and line mortality.

In Canada, sport fishing regulations were changed in 1989 reducing the allowable bull trout limit from eight per day, with two fish greater than 500 mm (19.7 inches) to a maxim of four per day, with one greater than 500mm (USFWS 2004). In 1998 a lake angler survey estimated 731 bull trout were caught in the lake from May 23 to Sept. 29, with 90% greater than 350 mm in length (13.8 inches), and a key fishery in April and most of May was not included (Nelson and Caverhill 1999).

Because migratory bull trout are long lived, repeat spawners with anadromous individuals repeatedly foraging and migrating up and down rivers, they are potentially more exposed to fishing than most species. They are also aggressive feeders, prone to sport fisheries. Catch monitoring should be more formally conducted for recreational and commercial fisheries. The summer recreational "trout" fishery in the South Fork should be evaluated, as temperatures can approach lethal conditions.

4.3. Hatcheries

The scientific literature indicates that artificial production risks to wild salmonid populations include: 1) genetic impacts, which affect the loss of diversity within and among populations and reproductive success in the wild; 2) ecological impacts, such as competition, predation, and disease; and 3) demographic impacts, which directly affect the physical condition, abundance, distribution, and survival of wild fish (WDFW and PSTT 2004). Many potential or actual hatchery impacts to WRIA 1 salmonid stocks are legacies of the lengthy hatchery history in WRIA 1 rather than effects from current operations. The hypothesis developed below attempt to make these distinctions.

The history of hatchery supplementation in WRIA 1 varies tremendously by species, with chinook having a discontinuous, but lengthy history, and bull trout having no history of hatchery supplementation. Appendix C includes an overview of the chinook release history, which will only be briefly reviewed here. Kendall and Samish Hatcheries began operations in 1899, eggs or fry have frequently been exchanged between these facilities. Kendall Hatchery and Samish Hatchery did not initially culture chinook, but Kendall Hatchery had some chinook supplementation by at least the mid-1920's, apparently mostly using local stock. The hatchery burned in 1934, was re-built, and chinook eggs were again taken at Kendall from 1935-1937. Then no chinook were cultured from 1938-1950, as the hatchery closed in 1939. Small chinook transfers from other facilities likely occurred in at least the mid to late 1940's. Kendall Hatchery restarted operations after 1950 with a very small egg take of what was likely two early-timed and two late-timed female chinook in 1951. Much larger chinook releases began in 1953 with late- timed chinook from Spring Creek (Lower Columbia River.) After this, late-timed chinook production at Kendall Hatchery essentially was reinitiated with Green River stock (starting 1954) and Samish River chinook (starting 1955). This Samish chinook stock was transplanted to Samish Hatchery in the late 1930's from Green River broodstock.

Kendall and/or Samish Hatchery late-timed chinook were also released from Bellingham Technical College's Maritime Heritage Hatchery into Whatcom Creek starting in 1985 and ending with 2001 Squalicum Harbor net pen releases. The Kendall Creek hatchery late-timed chinook program was terminated in 1998. In 1993 late-timed chinook release goals were 5.0 million fingerlings released from Kendall Hatchery, 2.0 million into the lower Nooksack River and 2.0 million to Lummi Bay, 5.2 million fingerlings to the Samish River, 700,000 to Whatcom Creek, 100,000 to Padden Creek, 50,000 to Squalicum Creek and 75,000 to Squalicum Harbor (Co-manager Equilibrium Brood Document 1993). Currently all late-timed chinook releases in or near the Nooksack River are from broodstock collected at the Samish Hatchery, then released into the lower Nooksack River and Lummi Bay or from the Samish Hatchery. Releases have been greatly reduced over approximately the past decade, and now consist of 4.0

million fingerlings and 100,000 yearlings to the Samish River, 500,000 fingerlings to lower Nooksack River and 500,000 fingerlings to Lummi Bay (WDFW and PSTT 2004).

In contrast to the extensive history of non-native fall chinook releases since 1952, the only known non-native early-timed chinook releases in the Nooksack basin were small numbers of Sol Duc early-timed chinook in 1977, 1978 and 1980 (Young and Shaklee 2002). Then the North Fork early-timed chinook run rebuilding program began using local broodstock collected from 1980-1982 from Wick's Slough. This program slowly increased abundances, with rapid increases observed in the 1990's in response to program growth. The Kendall chinook release goal was reduced from 2.1 million to 800,000 beginning in 2003 to address concerns regarding straying and competition. There was an egg eying station near Hutchinson Creek on the South Fork from 1908-1915 and local chinook were among the fish spawned. The Skookum Creek Hatchery attempted a rebuilding program for the South Fork early-timed chinook population, with small releases occurring between 1982 and 1994 (Young and Shaklee 2002). The release goal was 100,000 juveniles, and most years releases were smaller than this. Adult mortality, low returns from juvenile releases, and broodstock collection problems led to termination of this program (WDFW and PSTT 2004).

4.3.1. Genetic Diversity

As we do not have historical data on original genetic composition of WRIA 1 salmonids, one cannot know with certainty how much change in genetic diversity has occurred as legacy effects from former or current artificial propagation. However, one can infer the changes to some extent from the extent to which stock compositions are similar or different from other stocks. Nooksack salmonid stocks or populations that lack extensive out-of basin stock transfer histories are, in general, genetic outliers compared to other Puget Sound stocks.

Hatchery practices limit genetic diversity of South Fork early chinook: Moderate Impact.

- *Certainty of Impact. Moderate.* Until very recently, genetic diversity of Nooksack early-timed chinook populations had not been seriously compromised by legacy effects of the small number of years of non-native early chinook releases to the North Fork, or from genetic exchange between the two populations, however the South Fork population is currently at high risk of loss of among-population genetic uniqueness from recent, but recurring hatchery strays from the Kendall Hatchery North/Middle Fork early chinook rebuilding program, from current late-timed hatchery strays of unknown origin, and from late-timed chinook from past releases that are now reproducing successfully in the South Fork.

  The WDFW again found that South Fork and North/Middle Fork early-timed chinook populations are genetically divergent (Young and Shaklee 2002). Genetic population differentiation between these populations was one of the largest observed between spawning aggregations within a river basin in the

Puget Sound (PSTRT 2004). The release of Sol Duc spring chinook for three years at Kendall Hatchery apparently did not substantially affect either of the two Nooksack early-timed chinook populations, as allozyme analysis comparing both populations to Sol Duc chinook found little evidence of genetic similarity between the Sol Duc stock and either Nooksack population (Anne Marshall, WDFW, unpublished data, as described in Young and Shaklee 2002).

- *Early Chinook Impacts:* A recent and current concern is possible inter-stock hybridization with effects on genetic integrity and health of the South Fork Nooksack early population. While substantial straying had not been detected prior to 1999, appreciable numbers have been recorded spawning in the South Fork since that time, primarily from the Kendall Hatchery s North/Middle Fork rebuilding program. WDFW conducted stock of origin assignments for juveniles sampled at the lower South Fork smolt trap, and determined that about 84% of South Fork smolt trap's juvenile outmigrants in 2000 were assigned to the Kendall Creek Hatchery fall chinook stock, about 7% were NF/MF stock and about 9% were SF stock (Young and Shaklee 2002). As no artificially propagated late-timed chinook have been released into the South Fork since 1987, the high percentage of outmigrants being assigned to the late-timed chinook was unexpected. This demonstrates that substantial fall chinook natural production, and some North/Middle Fork early-timed chinook production is occurring in the South Fork. Results from Young and Shaklee's (2002) analysis of S.F. Nooksack spring chinook samples from several years between 1993 and 1998 suggested that fall chinook introgression, if it was occurring, had not eliminated the spring stock's genetic distinctiveness, but hybridization was not explicitly tested.

  The North/Middle Fork population has greater spawn timing separation from the late-timed stock than the South Fork population. As such, the North/Middle Fork population is considered to be at less risk of inter-stock hybridization with late-timed chinook. The South Fork population also has spawn timing overlap with North/Middle Fork early chinook during mid-August through late September, and with the late-timed stock from mid-September through the end of their spawning period. In 2004, the number of detected Kendall Hatchery origin strays was much lower.

  Recent mass marking of late chinook from local releases has enabled them to be detected as adults when carcasses are evaluated in the South Fork. While sampling is limited, a substantial proportion of late-chinook spawners in the South Fork were hatchery origin. Differential marking is planned for late-timed chinook releases to each location for future years, and this will enable specific release contributions to be evaluated.

  The HSRG (2003) concluded that there did not appear to be significant straying of Samish Hatchery late chinook on-station releases to other areas, and this was likely after reviewing results from Vander Haegen and Doty (1995). However, a cursory review of South Fork Nooksack spawn survey efforts for late timed chinook during the years that this report reviewed few coded wire tag recoveries indicates that very little effort occurred in the South Fork, so the history of straying into this population actually appears to be uncertain.

The present genetic baselines are probably inadequate to test for hybridization, although if hybridization is recent, pre-hybridization baseline data (such as testing DNA from old fish scale collections) for all three stocks might make is possible to detect and quantify hybridization (Young and Shaklee 2002). Given the duration and magnitude of direct releases of hatchery late-timed chinook into the Nooksack River starting in 1954, and into the South Fork starting in 1957, it may be difficult to obtain scales from the era before the potential for hybridization existed between the South Fork early population and late-timed chinook.

Hatchery practices limit genetic diversity of North/Middle Fork early chinook: Moderate Impact.

- *Certainty of Impact. Moderate.* The North/Middle Fork chinook population has likely lost some within-population genetic diversity (the amount of genetic information within a population), with possible inbreeding depression (reduced individual fitness from mating of closely related individuals) as a *legacy effect* due to relatively small population size prior to initiating the Kendall rebuilding program, and from obtaining original Kendall Hatchery program broodstock from a small number of adults from a restricted geographic area. Additionally, North/Middle Fork population is *currently at risk* of domestication (intentional or unintentional selection for adaptation to an artificial environment such as hatcheries), and this is created in part, by the very low abundance of wild fish relative to hatchery returns to facilities.

Hatchery practices increase the abundance of North Fork/Middle Fork early chinook: High Impact

- *Certainty of Impact: High.* The Kendall Hatchery North/Middle Fork chinook rebuilding program is successfully protecting the remaining genetic resources and increasing absolute abundances (HSRG 2003), but has not substantially increased the number of natural origin chinook in this population (see Table 4.7.). No natural origin chinook have returned to Kendall Hatchery for incorporation into the broodstock (WDFW 2002c). So few, if any, natural origin recruits are being incorporated into the broodstock, which increases the risks from domestication (HSRG 2003). Since 1996 the number of Kendall Hatchery origin spawners has exceeded the number of wild spawners, generally by a large margin.

  While total escapements have dramatically increased, this is primarily the result of increased returns of hatchery fish, and abundances of natural origin chinook have increased much more modestly. This strongly suggests freshwater and/or estuarine habitat spawning and/or rearing capacity limitations that are affecting wild fish much more than the hatchery fish. The lower rate of adult returns per spawner for the North/Middle Fork population also suggests capacity limitations. NOAA Fisheries has concluded that there is unknown overall effectiveness of supplementation programs in maintaining a population until underlying factors for decline are corrected (Flagg et al. 2000. This suggests an urgency in improving habitat capacity and productivity, as increased natural origin abundances in this population could help reduce domestication risks. In programs culturing listed fish to aid in recovery including the Kendall Hatchery program, while there is risk of domestication, the benefits of using artificial propagation to prevent extinction outweigh the risks of domestication (WDFW and PSTT 2004). While increased abundances are primarily attributable to the Kendall Hatchery program, population abundances are much higher now than prior to initiation of the rebuilding program.

While estimating escapements in glacial systems is challenging due to obscured visibility, escapement estimates for North/Middle Fork chinook in years before, and shortly after, initiation of the Kendall Hatchery rebuilding program were 10 fish in 1990 and 45 fish in 1984 and 1994. Abundances in all other years from 1984 to present were always at least 100 chinook, and the diverse age composition of natural origin returns (3, 4, and 5 years olds with very small numbers of 2 and 6 years olds) results in genetic exchange occurs between brood years. Initial broodstock spawned for the Kendall hatchery program was a total of about 111 adults, collected from Wicks Slough (RM 46.8-47) in 1980 and 1981, with a few fish from 1982 (Nooksack Tribe, unpublished file data). This is a very small area in comparison to the total geographic spawning distribution of this population.

- *Early Chinook Impact*: A natural population continually receiving hatchery introductions is essentially selecting for performance in two different environments, with the possible outcome of reduced fitness in the wild (Busack and Currens 1995). Domestication selection can occur through intentional selection (i.e. selecting early spawners), unintentional selection, or through biased sampling (i.e. how broodstock selection occurs) (Busack and Currens 1995). There are ways that domestication can be reduced but it should be considered a ubiquitous phenomenon in hatchery operations, and to some extent is one of the costs of running hatcheries (Busack and Currens 1995). The very small number of wild chinook in the population relative to hatchery chinook contributes appreciably to the concern. Intentional gene flow from wild fish into hatchery broodstock may reduce the inevitable loss of diversity due to non-random sampling (Busack and Currens 1995).

Genetic diversity of Nooksack late-timed chinook has been highly limited by past non-native releases and continues to be limited by hatchery practices: High Impact

- *Certainty of Impact: High*. Genetic diversity has been seriously reduced or lost as a legacy effect of the past releases of non-native late-timed chinook, primarily since 1952 and originating from Green River stock. We know little about historical late-timed chinook in the Nooksack watershed except that they were historically part of the life-history diversity of Nooksack chinook, but are now considered to be non-native (WDFW 2002a). While the Nooksack drainage has a more extensive history of non-native late-timed chinook releases than most rivers, substantial releases of non-native late-timed chinook (frequently Green River origin) have occurred throughout most Puget Sound rivers (Myers et al. 1998). Hatchery late-timed chinook populations that have been tested from many WDFW hatcheries in Puget Sound that historically used Green River origin broodstock have failed to reveal statistically significant differences among them (Anne Marshall, WDFW unpublished data as described in Young and Shaklee 2002).

  Despite the use of Green River origin broodstock in the Nooksack basin, Kendall Hatchery strain late-timed chinook were found to be significantly different than the population currently reared at Sooes Creek Hatchery on Green River (Young and Shaklee 2002). However, allozyme analysis of Kendall Hatchery late-timed chinook showed them to be closely related to other hatchery stocks such as Hoodsport and Deschutes which at least partially obtained their broodstock from Green River (WDFW 2002a). While Nooksack adult late-timed chinook collections from spawning grounds were limited, and hatchery or wild origin could not be identified at the time of the collections due to a lack of external mass marking (adipose fin clip) , WDFW found no compelling evidence for a late stock in the Nooksack basin that is unique from Kendall Hatchery late-timed chinook (Young and Shaklee 2002).

- *Early Chinook Impacts:* There is much remaining to be learned about Nooksack late-timed chinook, including more clearly determining what proportion of adults are naturally produced and what are artificially propagated. While carcass recoveries have been limited, in 2003 and 2004 late chinook (encountered after Oct. 7) appeared to be a fairly even mixture of natural origin and hatchery origin adults. While Young and Shaklee (2002) determined that successful natural reproduction is occurring, these results also show that hatchery contributions to spawning grounds are continuing despite dramatically reduced late timed chinook releases. While fall chinook continue to be released in Lummi Bay, and in the lower river, numbers released to the Nooksack watershed area have been reduced approximately 90% in the past decade.

As all late-chinook hatchery releases are now mass marked, future spawn survey efforts may (or may not) reveal geographic areas that primarily support wild late-timed chinook.

Past releases of non-native brook trout have a low negative impact on bull trout and Dolly Varden genetic diversity. Moderate Impact.

- *Certainty if Impact: Low.* There is a *legacy effect* from former releases of non-native brook trout that are now successfully established and apparently expanding their distributions for potential hybridization with bull trout and Dolly Varden where either species' distribution overlaps with the non-native brook trout. Brook trout have been widely introduced throughout the state of Washington and in 1992 approximately 10 percent of current range of bull trout also contained brook trout (Mongillo and Hallock 1993). Naturalized populations of brook trout within the Nooksack core area overlap with bull trout spawning and rearing habitats. Although hybridization with brook trout has been identified as a significant threat to bull trout in other parts of its range, it is currently unknown to what degree brook trout introductions have impacted Nooksack bull trout abundance and distribution. Because the replacement of bull trout populations by brook trout has been documented in other parts of their range (MBTSG 1996), the potential for hybridization remains a concern.

  Current brook trout distributions appear to have expanded downstream from former release locations in the Nooksack basin. Brook trout are distributed in the upper North Fork (upstream of Wells Creek) and major tributaries thereto, including, Bagley Creek, Swamp Creek, Ruth Creek, and Anderson Creek, and downstream from the falls in Wells Creek (NWIFC 2004). They are also mapped in upper Maple Creek, upper Kenny Creek, and in a tributary to Canyon Creek (Bald Lake outlet) in the North Fork and upper Hutchinson and upper Howard Creek in the South Fork watershed. Hybridization between a Dolly Varden trout and a brook trout has been observed in Canyon Creek.

4.3.2. Ecological Interactions

Ecological interactions between hatchery and non-hatchery chinook can affect the productivity of wild stocks. Competition and predation impacts to wild early chinook populations and bull trout are the two primary impacts discussed below.

4.3.2.1. Hatchery Chinook Competition

Artificially propagated chinook compete with wild chinook, resulting in negative impacts to both North Fork/Middle Fork and South Fork early chinook productivity. Level of Impact: Moderate.

- *Certainty of Impact: Low.* Artificially propagated chinook may be competing with wild chinook for limited food and space with the consequence of reducing wild abundances of the two populations. This is both a *legacy effect and to a lesser* *extent, a current concern.* The *legacy effect* is from past releases of non-native late timed chinook that are now successfully reproducing in the Nooksack basin. The *current concern* is for in-river competition from North Fork early chinook population artificial propagation, for estuary competition from these and late chinook releases to the lower Nooksack River, and for nearshore marine competition from both of these programs as well as Lummi Bay late chinook releases. While a current concern, program reductions in the 1990's and early this decade, and other changes including delaying releases have reduced the concern. An additional *current concern* is potential redd superimposition and freshwater and estuary competition from late chinook hatchery strays, from their offspring, and competition in the South Fork from late chinook strays and Kendall program strays and their offspring.

Adult hatchery origin chinook spawning in the wild may compete with wild fish for holding areas, mates, and spawning sites (WDFW and PSTT 2004). Holding habitats appear to be quite degraded in the South Fork, including elevated summer temperatures and a loss of deep pools with cover (Maudlin et al. 2002). North/Middle Fork early chinook have similar migration and pre-spawn holding periods as South Fork early chinook, and a substantial proportion of early timed spawners in the South Fork have been determined to be Kendall Hatchery origin strays since 1999. These fish likely compete with South Fork native, wild chinook for the most suitable holding and spawning areas. Additionally, about 84% of South Fork smolt trap's juvenile outmigrants in 2000 were assigned to the Kendall Creek Hatchery fall chinook stock, about 7% were NF/MF stock and about 9% were SF stock (Young and Shaklee 2002). This suggests juvenile competition between South Fork population juveniles and offspring from hatchery strays is likely a problem, especially with the late-timed stock.

- *Early Chinook Impacts:* Hatchery juvenile fish may compete with wild fish for food and space in areas where they interact during downstream migration, in estuarine, and marine areas (WDFW and PSTT 2004). Food may be a limiting resource that creates competition in marine waters. When juvenile chinook have recently entered estuaries and are concentrated in a relatively small area, there may be short term instances where food is in short supply and growth and survival declines as a result (SWIG 1984 as discussed in WDFW and PSTT 2004). However, due to the difficulty in studying salmonids in marine habitats, so far it hasn't been possible to define the extent of competitive interactions between wild and hatchery origin chinook salmon. Hatchery origin North Fork early chinook did not have a detectible external mark until 2005 (although they were otolith marked), so hatchery juveniles or smolts could not confidently be distinguished from wild smolts. The recent mass marking of all hatchery origin chinook should aid in evaluating post-release outmigration rates, the potential for competition, and ecological interactions between wild and hatchery fish.

However, determining stock compositions of the wild outmigrants will only be possible through microsatellite DNA analysis, and this is unlikely to be possible for estuarine or nearshore areas.

Competition between North/Middle Fork hatchery releases and the small wild population is a concern, although this is substantially diminished with the program size reductions from 2.1 million fish to about 750,000 beginning in 2003. However, fry (fingerlings) produced and released are larger than natural origin fry, potentially producing competition risk to the wild chinook (HSRG 2003). Hatchery juvenile salmonids can have higher levels of aggression than wild fish, and this may have a genetic basis (Flagg et al. 2000). As juveniles establish and defend territories through agonistic contests, and aggressive behaviors have been positively associated with dominance in these contests, fish with relatively high levels of aggression may have a competitive advantage (Flagg et al. 2000).

Comparing Hovander trap outmigration timing with Kendall Hatchery releases suggests that the April Kendall Hatchery releases may reside in the river for about a month on average before outmigrating through the Hovander smolt trap, and that the June releases may reside for an average of about two weeks (A. Chapman, Lummi Natural Resources, pers. comm. 2003). Comparing chinook outmigration timing between the lower South Fork smolt trap and the lower mainstem smolt trap suggests that South Fork Chinook outmigrants probably rear for a period of weeks in the mainstem, and competition with Kendall Hatchery smolts is a concern for this population as well, as is competition with this population and the lower mainstem late-timed chinook releases that occur at RM 1.5. Starvation is a primary cause of poor post release survival in hatchery fish (Flagg et al. 2000), and Myers (1980) found that hatchery chinook, shortly after release were inept foragers compared to wild fish, but stomach contents of wild and hatchery chinook converged after extended residence in the estuary (Flagg et al. 2000).

4.3.2.2. Hatchery Chinook Predation

Yearling coho and steelhead may prey on native salmonids including chinook, resulting in a negative impact to early chinook abundance. Level of Impact: Low.

- *Certainty of Impact: Moderate.* Yearling coho and steelhead releases may be preying on native wild juveniles including chinook, reducing their abundances, and while a low impact current concern, historically it may have been greater. Yearling coho and steelhead are much larger than sub-yearling chinook juveniles, and may prey on these and other small juvenile salmonids where their rearing areas overlap spatially and temporally. Impacts are thought to be low for a number of reasons, including that hatchery fish do not eat natural prey, and are unaccustomed to it when first released. Starvation is a primary cause of poor post release survival in hatchery fish (Flagg et al. 2000). Additionally, coho program sizes are much smaller now than even a decade ago, and all Nooksack steelhead releases are now in the North Fork. There have also been other program adjustments to reduce the likelihood of predation, including delaying releases until most chinook have outmigrated to estuarine areas, and releasing them in a condition when they are ready to out-migrate. Data from the South Fork smolt trap indicates most chinook have already outmigrated before hatchery coho are released, and that most coho outmigrate in a week or less (Nooksack Tribe, unpublished data). Additional investigations of prey items in hatchery fish caught in seining in freshwater and estuarine areas have found few juveniles ingested, and very few chinook (A. Chapman, Lummi Natural Resources, pers. comm. 2005). Young bull trout are unlikely to be consumed by these fish juveniles in their first year generally rear in or near their natal streams, which are mostly or entirely upstream from hatchery release locations.

4.3.2.3. Hatchery Brook Trout Competition and Predation

Larger brook trout, established from past releases may prey on native salmonids, resulting in a negative impact to bull trout from competition and predation. Level of Impact: Low.

- *Certainty of Impact: Low.* Former releases of brook trout have resulted in locally successful colonization and apparent expansion of distributions, and larger individuals may be preying on, or competing with, native bull trout diminishing their abundances. This is a *legacy effect* from former hatchery releases, with low certainty. Brook trout are successfully established in geographic areas used by migratory bull trout including in tributaries to the North Fork downstream of Nooksack Falls, in Hutchinson Creek, and in other locations. Brook trout appear to adapt better to degraded habitat conditions (USFWS 2004). Brook trout growth rates were greater than for bull trout at higher water temperatures. While brook trout distributions have expanded, the impacts to bull trout are unclear.

4.4. Hydropower

Hydropower projects can impact anadromous salmon in a variety of ways, including alteration of the flow regime and barrier to access. In the Nooksack basin, limited development for hydropower has occurred to date, although several small hydro projects have been studied in several of the tributaries of the North and Middle forks. The Middle Fork Diversion Dam, while not a hydropower dam, has many of the same impacts as hydropower development.

4.4.1. Existing Projects

4.4.1.1. Excelsior/ Nooksack Falls hydropower facility

At Excelsior/Nooksack Falls (North Fork Nooksack River), there is a very old hydropower facility that was damaged in a fire in the 1990's, and abandoned, but restarted in 2003 without appreciable upgrades that are needed to adequately protect salmon and anadromous and resident trout. The intake is located upstream from

Nooksack Falls, and the powerhouse and tailrace are located on the North Fork Nooksack River downstream of Wells Creek. The facility, as it is currently operated, probably impacts chinook and bull trout in several ways. First, the facility lacks tailrace protection to exclude fish that are likely to be attracted to it. Pink salmon have been observed congregating in the tailrace outfall flow when the facility was formerly operating (D. Schuett-Hames, NWIFC/Cooperative Monitoring and Evaluation Committee, pers. comm. 2003). Additionally, minimum instream flows need to be established and implemented to assure that all life stages of anadromous salmon and trout are adequately protected. The water intake above the falls also lacks adequate screening to prevent entrainment of resident fish. The Federal Energy Regulatory Commission recently decided that the project was grandfathered, and does not require license.

Flow: Moderate impact.

- *Certainty of Impact. Moderate.* The facility lacks more recent improvements that would enable ramping the changes in flow, and likely strands juveniles downstream when operations cease, and possibly fish within the bypass reach when operations commence. The bypass reach appears to be an adult staging area for bull trout, and spawning may also occur in this reach. It is unclear what volume of water is diverted through the penstock, or what volume is retained in the bypass reach including the contribution from Wells Creek, so the magnitude of impact is currently unclear.

4.4.1.2. Small Hydroelectric Facilities

While the number of small hydroelectric facilities in salmonid streams is comparatively small in WRIA 1, they do exist in a few areas including Kenney Creek and Sygitowicz Creek. A substantial number of projects have been proposed in recent years in fish bearing portions of important salmon and trout streams, including Glacier, Wells, Boulder, Canyon, Clearwater, Warm, and Skookum Creeks. While these proposals have not been granted licenses to date, the interest in small hydroelectric production is likely to continue. If facilities are proposed in salmonid streams, they are likely to be detrimental to fish.

Flow: Moderate impact

- *Certainty of Impact. Low:* The facility on Sygitowicz Creek was damaged in a debris flow late 2004, and is being repaired. It is in an unusual setting in that the intake generally retains flow during the summer while the tailrace area dries up. There is apparently no ability to ramp changes in flow when operations start or stop.

4.4.1.3. Middle Fork Diversion Dam

The City of Bellingham operates a water diversion facility on the Middle Fork Nooksack River (river mile 7.2) that diverts water to Lake Whatcom to augment the city's municipal water supply. The diversion dam is 12 to 14 feet high and was built in 1960 without provisions for fish passage. The dam is located approximately 250 feet upstream of Box Canyon, a 0.8 km (0.5 mi) bedrock gorge that is considered passable at discharges below 1000 to 1500 cubic feet per second, based on limited numeric modeling of discharges and velocity refuges continuing to exist behind large boulders (E. Zapel, Northwest Hydraulic Consultants, pers. comm. 2003). There are no other natural barriers to adult migration in the Middle Fork Nooksack River to at least river mile 17.5, approximately 0.4 kilometers (0.25 mile) upstream of Ridley Creek, and the average gradient over its lower 17.4 miles is 2.4% (STS Heislers Creek Hydro L.P. 1994). The lowest gradient river reach upstream of the dam is between Clearwater and Wallace Creeks, averaging 2 to 3 percent (STS Heislers Creek Hydro L.P. 1994). Habitat in the Upper Middle Fork Nooksack River is generally believed to be in good and improving condition, since 90 percent of the area is managed under U.S. Forest Service Late Successional Reserves or Washington Department of Natural Resource's Habitat Conservation Plan (Currence 2000).

While the diversion dam does not have a reservoir behind it, nor interrupts routing of sediment or large woody debris, it blocks most upstream migration and use of the majority of the Middle Fork's former habitat for chinook, anadromous bull trout, steelhead, and probably coho. Potential chinook and steelhead habitat has been estimated to extend to the confluence of the Middle Fork and Rankin Creek (9 miles above the diversion dam), and Clearwater, Warm and Wallace Creeks were also considered suitable for chinook (STS Heislers Creek Hydro L.P. 1994). An additional 1.6 miles of habitat was considered coho habitat, and Sisters Creek is suitable for chinook. Recent surveys of additional tributaries have found additional streams that are suitable and accessible for anadromous fish, such as Ridley Creek (Nooksack Tribe, unpublished data). While a pink salmon was observed jumping at the dam in 1993, chum and pink salmon are not expected to have substantially utilized the upper Middle Fork, due to their reluctance to ascend the cascades and the Box Canyon.

Access: High Impact

- *Certainty of Impact: High.* See Section 4.1 for Middle Fork Habitat Limitations.
- *Early Chinook Impacts:* Salmon and trout, including a pink salmon, what were presumably chinook and steelhead, what appeared to be a bull trout, and possibly a coho (based on November timing), have been incidentally observed jumping at or over the diversion dam in 1986, 1992, 1993 (STS Heislers Creek Hydro L.P. 1994; Currence 2000), and in 2001 (del Corral 2001; E. Zapel, Northwest Hydraulic Consultants, pers. comm. 2001). Additionally, there are anecdotal reports of early timed chinook use in the upper Middle Fork in the 1930's and 1940's (STS Heislers Creek Hydro L.P. 1994), and coho were also reported to use the upper Middle Fork (B. Kelly Sr., Nooksack Indian Tribe, pers. comm. 2000; D. Huddle, WDFW, pers. comm. 2000). While two of these adults were observed successfully getting over the dam, the dam essentially precludes

use of the upper Middle Fork by stronger anadromous fish. It also separates a once connected population of bull trout into two separate groups, one primarily isolated above the facility and one containing anadromous bull trout below.

Flow: High Impact

- *Certainty of Impact: High.* See Section 4.1 for Middle Fork Habitat Limitations.
- *Early Chinook Impacts:* While the diversion dam is screened, these are not to current standards, and may entrain outmigrating juvenile fish including bull trout. Additionally, 67 cubic feet per second is diverted from the river when in operation (and initially more when first diverting), and the current facility does not have the ability to ramp changes in flow. This may adversely affect salmonids in reaches downstream through stranding juveniles when the diversion is started. The degree of downstream stranding and even redd loss from not ramping were likely higher in the past, before the existing instream flow requirements were established in 1985. Increased temperatures in the lower Middle Fork may have also have resulted. The lower Middle Fork is currently included on the Department of Ecology's 303(d) list. The diversion of water may also contribute to thermal problems in the lower river, or even the lower North Fork and mainstem, although low instream flows during this period may preclude diverting water.

  *S*ubstantial increases in minimum flows in the lower Middle Fork resulted after establishment of the minimum flows in 1985, and from voluntary agreements between resource agencies, the Tribes and the City in recent years. However, the recommended flows do not explicitly consider the needs of either listed species (chinook or bull trout), and almost certainly need to be revised for both, as the minimum instream flows are lower during the period when chinook spawning occurs. Diverting water during earlier years when less instream flow was agreed to be retained in the lower Middle Fork likely substantially reduced salmon production as the water right issued to the City was established, but not the instream flows to protect aquatic species in the Middle Fork.

5. MANAGEMENT STRATEGIES AND ACTIONS

5.1. Habitat

5.1.1. Recovery Objectives

- Protect and restore freshwater, estuarine, and nearshore marine habitat, including water quantity and water quality conditions, in WRIA 1 sufficient to meet recovery goals for WRIA 1 salmonid populations, prioritizing as follows:
  1. South Fork Nooksack early chinook and North Fork/Middle Fork Nooksack early chinook.
  2. WRIA 1 bull trout
  3. WRIA 1 wild late-timed chinook
  4. WRIA 1 wild-spawning coho salmon
  5. Other WRIA 1 salmonid populations
- Identify and prioritize the sequencing and location of habitat protection and restoration efforts using the *WRIA 1 Salmonid Habitat Restoration Strategy.*
- Protect and restore the natural watershed processes that form and maintain the habitat to which WRIA 1 salmonid stocks are adapted.
- Maintain or increase the quality and quantity of habitat necessary to sustain healthy, self-sustaining runs of other WRIA 1 salmonids to provide for harvest, as well as cultural and social values.
- Retain or provide adequate quantity and quality of water in streams for salmonids.
- Restore access to isolated habitat.

5.1.2. Other Objectives

- Ensure programs and actions are consistent with Endangered Species Act and Clean Water Act requirements.
- Maintain viable forestry, agricultural, and other industries and provide long-term regulatory certainty.
- Ensure that citizens and stakeholders are actively engaged in salmon conservation efforts.
- Uphold existing federal, state, tribal, and local laws and implementation authorities.

5.1.3. Coordination with Watershed Management Plan

The WRIA 1 Watershed Management Project was established in response to the Watershed Management Act, passed in 1998 as Engrossed Substitute House Bill 2514 (ESHB 2514) and codified into state law as RCW 90.82. The Watershed Management Act requires that water quantity issues be addressed, and gives local governments the option of addressing three other issue areas—water quality, fish habitat, and instream flows. The Watershed Management Project will prepare a Watershed Management Plan (WMP) that addresses all four issue areas.

To date, the Watershed Management Project has entailed detailed assessment of surface water and groundwater quantity and quality, as well as actual and projected human water uses and instream flow needs for salmonids. Due to be adopted by 2005, the WMP will suggest strategies for increasing water supplies in the management area, including water conservation, water reuse, voluntary water transfers of existing water rights and claims, aquifer recharge and recovery, additional new water allocations, and new or enhanced water storage. These strategies should provide for both instream flows for fish, and for future out-of-stream uses of water such as agriculture, energy production, and population and economic growth.

The WRIA 1 Salmonid Recovery Plan will:

- ***Defer*** to the Watershed Management Plan for implementing management strategies and action items related to **low instream flows**.
- ***Coordinate*** with the Watershed Plan for implementing management strategies and action items related to **water quality**.
- Be the ***primary mechanism*** for implementing management strategies and action items related to salmonid habitat and high flows.
- Be the ***primary mechanism*** for integration, monitoring and adaptive management for actions affecting salmon recovery.

5.1.4. Guiding Principles for Habitat Restoration and Protection [11]

- Recovery of salmonid habitats will require *both* protection of baseline conditions *and* substantial active restoration of lost and damaged habitat.
- Success of salmonid recovery efforts depends on our ability to protect and restore the natural watershed processes that form and maintain the habitat to which WRIA 1 salmonid stocks are adapted.
- Particular emphasis should be placed on protecting areas where salmon populations are healthy and where existing habitat conditions are considered good to excellent. Protecting and preventing degradation of habitats is far more reliable and less expensive than restoration.
- Voluntary and incentive-based projects and programs should be used to the greatest extent possible, but strong regulatory standards and protections will be necessary to protect the baseline. Continual restoration of unmitigated impacts to wild salmonid habitat is undesirable, ineffective, and costly.
- Restoration of habitat-forming processes and reconnecting isolated and/or fragmented high quality habitat should be emphasized in habitat restoration. For stocks and species at critically low abundances (i.e. North Fork/Middle Fork and South Fork early chinook), interim measures (e.g. large wood placement) will also be necessary that can provide more immediate benefit than restoration of processes.

[11] Additional ecological principles guiding habitat restoration and protection projects are presented in the *WRIA 1 Salmonid Habitat Restoration Strategy.*

- Habitat restoration on private lands will be more readily accepted and implemented if the cost of restoration includes some level of public financing, if restoration provides flexibility to the landowner, and if restoration addresses, at least in part, relief from regulatory processes.
- Investment and use of government resources should be coordinated and used in a cost effective and efficient manner.
- Land use management and habitat restoration and protection should be based on the most current scientific information.
- The effects of individual and cumulative actions should be comprehensively monitored and appropriate corrective measures taken as necessary to achieve the recovery goals.

5.1.5. Habitat Targets

Habitat targets for WRIA 1 salmonid habitats are presented in Table 5.1. Habitat targets were derived from a combination of the "Properly Functioning Conditions, or "PFC" matrix (NMFS 1996) as interpreted for EDT by Blair (2001), USFWS guidance for what constitutes conditions that are "functioning appropriately" for bull trout (USFWS 1998), standards adopted by the Washington Conservation Commission for what constitutes "good" salmonid habitat conditions (Smith 2002). All of the above were generally developed based upon the principle of "properly functioning conditions", defined by NOAA (NMFS 1999) as:

> *the sustained presence of natural habitat-forming processes in a watershed (e.g. riparian community succession, bedload transport, precipitation runoff pattern, channel migration) that are necessary for the long-term survival of the species through the full range of environmental variation.*

Along with information on the current condition of habitat attributes within specific stream reaches, these targets are intended to indicate which and to what degree habitat attributes are degraded. Habitat targets should be used as guidance on the direction and magnitude of habitat change needed. The ultimate objective is to protect and restore the natural range and variability of habitats required to sustain and recovery salmonid populations, rather than as static conditions to be managed for.

5.1.6. Early Chinook Strategy

5.1.6.1. Conceptual Approach

- Since abundance and productivity are important to buffer against extinction in the short term, the strategy for Nooksack early chinook recovery prioritizes actions that will address the habitat attributes and stream reaches that are most limiting abundance and productivity.
- Over the longer term, recovery of Nooksack early chinook will require implementation of actions that improve the populations' spatial structure and diversity, thus contributing to their ability to persist through environmental fluctuations over the long term (McElhany et al. 2000).

- The strategy for chinook recovery should be based on a life-cycle approach to restoration, which recognizes the need to provide sufficient habitat quantity and quality for a population to successfully complete each life stage, including holding, spawning, incubation, post- emergence/ summer/ overwinter freshwater rearing, estuarine and nearshore marine rearing, and migration. The life-cycle approach will generally require a diverse array of spatially distributed habitats, as well as preservation of the life history types to use those habitats.

5.1.6.2. Prioritization and Sequencing

Potential habitat restoration projects will be prioritized for salmon recovery funding using the *WRIA 01 Salmonid Habitat Restoration Strategy*. The version used in the Salmon Recovery Funding Board 5th Round grant cycle (2004) is presented in Appendix E. Projects were prioritized based on the following general criteria:

- Salmonid population priorities
- Magnitude of benefit
  - Project location relative to geographic priority areas
  - Importance of Limiting Factor that project is designed to address
  - Magnitude of effect project will have on limiting factor
  - Lifespan of benefit
  - Timing of benefit (i.e. how soon the benefits will begin to accrue)
- Certainty of Success
  - Readiness to proceed
  - Extent to which project addresses habitat-forming processes
  - Likelihood of meeting objectives (i.e. level of design, expertise of project participants, use of proven methods).
- Cost-effectiveness

The *Strategy* will be updated later this year to reflect the priorities and recommendations presented in this *Plan*. Sequencing of projects will follow the "critical pathways" methodology to ensure projects function in relation to each other and address root causes of degradation.

5.1.6.3. Whatcom County/WRIA-wide Actions

5.1.6.3.1. Existing Actions

Forest and Fish Rules

In 1999, after two years of preparation and negotiation, five stakeholder groups, including the Department of Ecology (Ecology) and EPA, produced a plan for protection of water quality and fish habitat covering eight million acres of non-federal forestland in Washington State. The Plan, the *Forests & Fish Report* (FFR), represents a significant improvement to the state's forest practices rules. The state Forest Practices Board promulgated emergency rules consistent with the FFR recommendations in January 2000 and passed permanent forest practices rules in May 2001.

Overall performance goals of forest practice rules are:

1. Support harvestable levels of salmonids;
2. Support the long-term viability of covered species; or
3. Meet or exceed water quality standards (protection of designated uses, narrative and numeric criteria, and anti-degradation).

To achieve these performance goals, the Forest and Fish Report (FFR) set functional objectives for various resource issues such as water temperature, LWD loading, sediment, etc (Table 5.2). The functional objectives are achieved through the implementation of the forest practice rules. Salient details of the rules are below:

- **Riparian Buffers:** Riparian management zones on both sides of fish-habitat streams are managed to provide near-maximum shade at levels that approach or exceed the amounts provided by mature conditions. West of the Cascade crest (Westside), fish-habitat streams are protected with buffers that extend up to a site-potential tree height from the outer edge of the stream or channel migration zone. This distance is 90 to 200 feet, depending on the productivity of the land near the stream. Timber management within buffers is progressively more restrictive in the zones closer to the stream with a no-harvest zone of 50′ and a shade requirement to leave all available shade using the approved shade model out to 75′.
- **Road Maintenance:** FFR-based forest practices rules require that all existing forest roads must be improved and maintained to provide fish passage to fish in all life stages, prevent landslides, limit delivery of sediment and surface runoff water to streams and avoid capture or redirection of surface or ground water. To accomplish these goals, industrial landowners are required to bring all of their forest roads into an approved road maintenance plan within five years and complete improvements within fifteen years. Small landowners are also required to complete road maintenance plan checklists and to maintain roads to avoid damage to public resources. Improvements on small landowner roads are required at the time of harvest to ensure that costs associated with road improvements can be offset by revenues from the harvests. The DNR is responsible for tracking landowner compliance with road maintenance planning requirements. Landowners must also complete road repairs on a "worst first" basis (i.e. where roads create fish passage barriers, fish passage improvements are completed on streams that open the most habitat first). Standards, priorities and implementation guidelines are established in the rule. The FFR-based forest practices rules also include new road construction standards to meet water quality goals and, specifically, to reduce sediment inputs to the stream.
- **Unstable Slopes:** In addition to the forest practices rules for road maintenance and management practices outlined above, protections for unstable slopes and wetlands will help ensure that hydrologic regimes for surface and groundwater are maintained. The forest practices rules require considerable improvements to permitting processes with the goal of preventing forest practices from causing an

increased rate of landslide-related sediment delivery. Improved topographic and geologic mapping will provide landowners and the Department of Natural Resources (DNR) with more accurate tools to predict where landslides may occur. Detailed standards are being established to field-identify the most hazardous areas. Local slope stability issues are being identified through regional efforts. Resource professionals representing agencies, tribes, and landowners are being trained to recognize potentially unstable slopes and geologists are mapping hazard areas and assisting resource professionals in assessing slope stability issues on the ground.

DNR HCP (DNR 1997b)

The DNR HCP is a 70-year multi-species Habitat Conservation Plan (HCP) to address state trust land management issues relating to compliance with the Endangered Species Act. The plan covers about 1.6 million acres of forested state trust lands, mostly in western Washington. The HCP provides mitigation for incidental take permits for the northern spotted owl and the marbled murrelet, but also conserves habitat for several runs of salmonids that were not listed at the time of Plan adoption (November 1996). Protections relevant to salmonids are presented below.

- **Riparian Protection**: Riparian protections consist of an inner riparian buffer to protect salmonid habitat and an outer wind buffer to protect the riparian buffer.
    - *Riparian buffers* Riparian buffers along types 1, 2, and 3 waters are equal to one site-potential-tree-height in a mature conifer stand or 100 feet, whichever is greater. Riparian buffers along type 4 waters are 100 feet. Buffers apply to both sides of stream and are measured from the outer margin of the 100-year floodplain. Buffer widths average about 150 feet for types 1 and 2 and 100 feet for types 3 and 4 waters. Activities within the buffer are restricted thus: (1) no timber harvest is allowed for the first 25 feet from the stream; (2) for the next 75 feet, minimal harvest is allowed provided there is no reduction in stream shading or the ability of the buffer to intercept sediment or contribute nutrients or wood; such harvest is likely to include only selective removal of single trees; (3) in the remaining buffer, low levels of harvest are allowed, e.g. selective removal of single trees, selective removal of groups of trees, thinning operations and salvage operations.
    - *Wind buffers*: Wind buffers are applied to types 1, 2, and 3 waters in areas that are prone to windthrow. For types 1 and 2 waters, wind buffers are 100-foot along the windward side; for type 3 waters wider than 5 feet and with at least moderate potential for windthrow, buffers are 50 feet.
- **Unstable Slopes Protection**. Unstable slopes are identified through field reconnaissance or identified with slope geomorphology models and verified through field reconnaissance. Activities on unstable slopes are avoided that would increase the severity or frequency of slope failure or severely alter the natural input of wood, sediment and nutrients to the stream network.

- **Road Network Management**: On a Watershed Administrative Unit (WAU) basis, DNR shall minimize adverse impacts to salmonid habitat caused by the road network by developing and instituting a comprehensive landscape-based road network management process. Major components of the process include:
  - Minimization of active road density
  - Site-specific assessment and, where practicable and consistent with conservation objectives, implementation of alternatives to new road construction
  - Baseline inventory of all roads and stream crossings
  - Prioritization of roads for decommissioning, upgrading, and maintenance
  - Identification of fish blockages caused by stream crossings and a prioritization of their retrofitting or removal.
- **Hydrologic Maturity in Rain-on-Snow (ROS) zone**: Two-thirds of DNR-managed forest lands in drainage basins (>1000 acre in size) in the significant ROS zone shall be maintained in forest that is hydrologically mature. Hydrologic maturity is defined on the west side of Cascades as a well-stocked conifer stand at age 25 or older. Exceptions are allowed where:
  - Less than 1/3 of drainage basin area is in significant ROS zone
  - At least 2/3 of the drainage basin area in the significant ROS zone is covered by hydrologically mature forest and there is reasonable assurance it will remain in that condition (e.g. National Park or National Forest Late Successional Reserve)
  - Less than 1/2 of the drainage basin area in the significant ROS zone is under DNR management and there is no reasonable assurance that other landowners will contribute hydrologically mature forests; in such cases, an interdisciplinary team of scientists will be convened to develop a prescription for DNR-managed land within the basin.
- **Wetlands:** Wetlands protection consists of buffers on wetlands at least 0.25 acres in size. For wetlands up to 1 acre in size, 100-foot buffers are applied. For wetlands larger than 1 acre, the buffer is equal to 1 site-potential-tree height in a mature conifer stand or 100 feet, whichever is greater. Within wetlands and wetland buffers, no road building is allowed without mitigation and other forestry operations are to be implemented in accordance with DNR's policy of no overall net loss of wetland function.

Concerns with the DNR HCP include:

- Riparian restoration strategy allows for too much thinning in Riparian Management Zones.
- Water typing of perennial non-fish-bearing streams were changed to the current FFR standards without going through the HCP revision process.

Northwest Forest Plan
Federal lands in the Nooksack River watershed are managed under the Northwest Forest Plan, which allocates land among seven categories. Timber harvesting is limited to thinning and salvage for all categories, except for the matrix. The matrix area is reserved for intensive timber management. Federal lands in the Nooksack River watershed are designated Late Successional Reserve (79,625 acres or 51% of area), Congressionally Reserved Areas (61,427 acres, or 39% of area), Administratively Withdrawn Areas (8,681 acres, or 5.5% of area), and Matrix (7,685 acres, or 4.9% of area); these numbers exclude Riparian Reserves.

- **Congressionally Reserved Areas** – Lands that have been reserved by an act of Congress. These include National Parks and Monuments, Wilderness Areas, Wild and Scenic River corridors, National Wildlife Refuges, Department of Defense lands, and other lands with congressional designations.
- **Late Successional Reserves** – Reserves that will maintain a functional, interactive, late-successional and old-growth forest ecosystem. They are designed to serves as habitat for late-seral and old-growth dependent species including the northern spotted owl.
- **Adaptive Management Areas** – These areas are designed to develop and test state-of-the-art management approaches that integrate and achieve ecological, economic, and social objectives. The federal agencies will use a multi-stakeholder approach to accomplish these objectives. There are 10 Adaptive Management Areas, each with a different emphasis for its prescriptions. Management approaches include maximizing late-seral characteristics, improving riparian conditions through silvicultural treatments, and maintaining a predictable flow of harvestable timber.
- **Managed Late Successional Areas** – Lands are either mapped managed pair areas or unmapped protection buffers. Managed pair areas are delineated for known northern spotted owl activity centers. Protection buffers are designed to protect certain rare and locally endemic species.
- **Administratively Withdrawn Areas –** Includes recreational, visual areas, back country, and other areas not scheduled for timber harvest.
- **Riparian Reserves** – Riparian reserves are areas along streams, wetlands, ponds, lakes, and unstable or potentially unstable areas where the conservation of aquatic and riparian-dependent terrestrial resources is important. These reserves protect aquatic habitat and its dependent species, and provides greater connectivity to late-successional forest habitat.
- **Matrix** – Matrix is the federal land outside the six categories listed above. It is the area in which most timber harvest and silvicultural activity takes place.

5.1.6.3.2. 10-year Actions

Cities and counties required to plan under the State of Washington Growth Management Act are also required to update both Critical Areas Ordinances (CAO) and

Shoreline Master Programs (SMP) every seven years. Some communities, such as Lynden, completed a CAO update in 2004. Whatcom County and City of Bellingham updates to both the CAO and SMP are slated for completion by the end of 2005. The intent of WRIA 1 local governments is to strive for consistency between each jurisdiction during future updates to meet the needs of both salmon recovery and the individual communities

Whatcom County Critical Areas Ordinance

Specific to Whatcom County CAO updates, new Growth Management Act guidelines required that Whatcom County make specific changes to the previous version of the CAO including:

- The County must use "best available science" in developing policies and regulations to protect the functions and values of Critical Areas (RCW 36.70A.172(1))
- "Special consideration" must be give to conservation or protection measures necessary to preserve or enhance anadromous fisheries (RCW 36.70A.172(1)).
- The County must record all sources considered in the development of policies and regulations and explain any deviation from best available science.
- The County must ensure "no net loss" of ecological function.

The County had previously contracted an ESA evaluation report for County programs and regulations (URS Corporation 2001) to identify areas where improvements were necessary. The City of Bellingham, under contract with Whatcom County, completed a similar evaluation for their programs and for those at the small cities. Some important changes and additions to the County CAO are proposed based on the study outcomes and the new GMA guidelines. A public review draft of the updated CAO was released on February 8, 2005, and the public comment period ended on March 4, 2005. A brief overview of the proposed County CAO changes is provided below. A description of the update process, full copies of revised ordinances, and supporting materials can be found at: http://www.co.whatcom.wa.us/pds/shorelines_critical_areas/index.jsp

- o **Administration.** A suite of administrative changes is being made to improve the efficiency and accountability of the permitting process. Changes include:
    - More detailed standards for permit applicants, county staff and consultants to improve consistency and predictability,
    - Technical analyses will provide greater detail to ensure sound decision-making and predictability of outcomes.
    - Special provisions are provided for agriculture (Conservation Program for Agricultural Lands). Farm plan requirements have been updated based on new information from Natural Resource Conservation Service and other applicable resources.
    - Reasonable use exceptions are a key element for landowners, but will be subject to a more effective process and criteria for review.

- Integration, as part of an integration strategy, with other regulations will be ensured and will produce a reduction in conflicts between regulations and an assurance that all applicants will meet the same standards.
- Recognition of watershed processes and a clear emphasis on impact avoidance will be employed as first steps in protection critical areas.
- Mitigation banking is offered as a means to provide flexibility to property owners to compensate for critical areas impacts within mitigations banks in Whatcom County. WRIA 1 salmonid recovery priorities and needs will be considered as mitigation banks are instituted.

o **Wetlands.** Wetlands categories are assigned based on the Western Washington Wetland Rating System. This system rates wetlands from Category I (exceptional resource value) to Category IV (limited resource value). The range of standard buffer size is based on the wetland category (Category I wetlands have the largest buffers), the habitat function score (high quality habitat is protected with a larger buffer), and the adjacent land-use intensity (high intensity land-use requires a larger buffer). The final buffer size will be determined by the Critical Areas administrator based on the site conditions and the outcome of an evaluation of the above factors (category, function, adjacent land-use). The range of standard buffers for each wetland category is:

- Category I: 50 – 300 feet
- Category II: 50 – 275 feet
- Category III: 50 – 150 feet
- Category IV: 25 - 50 feet

o **Fish and Wildlife Habitat Conservation Areas.** A number of improvements and changes have been made to the Fish and Wildlife Habitat Conservation Areas section of the CAO. Endangered Species Act listed, priority, and locally important species are distinguished and anadromous fish are given special consideration. Refinements have been made in how development is regulated in and adjacent to streams and other related habitats such as wetlands in continuity with a river or stream. Other changes include new standards for culverts, storm water facilities, and stream bank and shoreline protection. Finally, beaches and the Chuckanut Corridor (wildlife) are designated as locally important habitats. This designation will be important to protecting and reinforcing to the public the importance and interconnection of freshwater and marine components of the ecosystem. Stream and marine shoreline buffers are described under the Fish and Wildlife Habitat Conservation Areas section.. The buffers are:

  - Streams
    - Shorelines of the State (mean annual flow greater than 20 cfs) – 150 feet
    - Other fish bearing streams (current, presumed, historic use) - 100 feet
    - Non-fish bearing streams – 50 feet
  - Marine Shorelines – 150 feet

  - Other habitats – to be evaluated on a case-by-case basis usually based on State Department of Fish and Wildlife recommendations.
- **Frequently Flooded Areas.** Improvements to the Frequently Flooded Areas section includes better protection of floodplain ecology and management of flood hazards in a manner beneficial to the floodplain functions. Mitigation for floodplain impacts can be required where the impact is unavoidable and is consistent with health and safety standards. Finally, the roles and responsibilities between County departments are clarified to ensure consistency in project evaluation and permitting.
- **Geologically Hazardous Areas.** A number of improvements and changes to the Geologically Hazardous Areas section have been made. The primary driver for these changes is the protection of human life and safety. Yet benefits to protecting human lives are often consistent with and provide a compelling reason to plan for the outcomes of the myriad natural processes that also form and maintain salmon habitats. Further restriction of development on alluvial fans is provided. Many if not all tributaries to the Nooksack forks cross alluvial fans before entering the Nooksack. While attractive for home site development by those unaware of the danger to life and limb, these areas most often provide crucial spawning and rearing habitats. Development is also regulated within 300 feet of potential landslide areas and no new structures are allowed in channel migration zones where maps have been adopted. Riparian buffers begin at the edge of the channel migration zone where those have been mapped and adopted. Critical facilities (such as fire stations, schools, or hospitals) are prohibited in all hazard areas including tsunami, volcanic, and seiche hazards areas. An evaluation of tsunami and volcanic hazards affords the regulator the opportunity to consider not only the human safety perspective, but also the larger ecological context. This has the benefit of providing a compelling reason the public understands to stay back from a given hazard areas, such as a shoreline bluff, while also providing a stronger basis for improved habitat protection.

Salmon in general and chinook salmon and bull trout, in particular, will be clearly be better protected once the updates are completed and fully implemented. However, the CAO and SMP are just two tools in the regulatory toolbox and are designed to produce a "no net loss" of ecological function. They are not primary restoration tools. The intent is to ensure that they contribute appropriately to the protection of existing habitat functions and that this will assist in recovery when implemented against a backdrop of other local regulations (such as clearing and grading permits, flood permits) and state and federal regulatory requirements such as the Washington State Hydraulics Code, Forest Practice Applications, or Army Corps of Engineers permits and a whole suite of voluntary actions.

Whatcom County Shoreline Master Program Updates
Whatcom County is scheduled to update its Shoreline Management Program by December 1, 2005. The SMP will be updated consistent with the Department of Ecology's *Shoreline Master Program Guidelines*. A Technical Advisory Committee convened for the CAO and SMP updates will provide input and review of work products during the update process; members include technical staff from Whatcom County, Lummi Nation, Nooksack Tribe, Washington Department of Fish and Wildlife, Washington Department of Ecology, Washington Department of Natural Resources, Port of Bellingham, City of Everson, Whatcom Conservation District, and Puget Sound Action Team. The update process will entail: (1) coordination with partner jurisdictions, agencies, and districts to integrate parallel projects and planning processes; (2) providing opportunities for public involvement, such as: open houses, workshops, stakeholder meetings, Citizen Advisory Committee meetings, work sessions, and public hearings; (3) inventory and characterization of the shoreline landscape by maximizing use of available information and resources; (4) integration of shoreline policies and regulations with parallel planning efforts and development regulations; (5) identification and documentation of ecological functions and values of shorelines; (6) coordination of shoreline restoration planning with current restoration programs and efforts; (7)evaluation and update of existing shoreline designations; (8) evaluation and update of policies and development standards; and (9) cumulative impact analysis of potential effects to shoreline ecological functions based on future growth projections and predicted development demands.

5.1.6.4. Lower North Fork

The proposed actions for the lower North Fork include:

- Riparian planting of the channel migration area for wood recruitment
- Riparian planting for shading benefits
- Construction of stable in-stream wood structures
- Protection of existing in-stream wood
- Monitoring of forest practice activities
- Relocation of stream-adjacent roads and infrastructure

5.1.6.4.1. 10-year Actions

Riparian planting of the channel migration area for wood recruitment
Riparian planting throughout the channel migration area of the North Fork and its tributaries will encourage long-term recovery of wood recruitment to the channel. Priorities for planting should be given to areas where the wood recruitment function is currently classified as "low" (Duck Creek, Assoc. 2001), is located where the channel can access the wood through channel erosion, but lies in a protected enough location that the trees can grow to a substantial size.

Riparian planting for shading benefits
Riparian planting in the Lower North Fork is expected to highly improve both the maximum monthly and spatial variation of the water temperature in the river. It is expected that upstream shading will have modest downstream benefits to stream temperature, as the water warms more slowly as it loses elevation.

Construction of stable in-stream wood structures
Restoration opportunities also exist to construct stable accumulations of wood in confined, low gradient reaches of the North Fork Nooksack. These reaches should be prioritized because wood is more likely to persist in the lower energy sections of the river. Further, these are the reaches with the greatest potential for habitat diversity as the channel migrates across the floodplain, creating secondary channels and potentially floodplain islands. There may be restoration opportunities in the channel to address the legacy effects of channel instability by constructing stable habitat features in the low gradient, unconfined reaches of the North Fork Nooksack. Since the channel actively migrates across the channel migration area, projects will need to treat the entire width of the channel migration area to ensure habitat stability into the future. In-stream restoration projects that focus on stabilizing bars and narrowing the active channel area in unconfined reaches will address channel widening in response to elevated sediment load.

5.1.6.4.2. Long-Term Actions

Protection of existing in-stream wood
Regulatory protection of wood in the channel exists and will need to be enforced to reduce the loss of wood from the channel. In some reaches of the lower North Fork wood cutting on the gravel bars reduces the function of wood, either by direct removal, or by reducing the size and therefore the potential stability of wood moving through the system.

Monitoring of forest practice activities
Extensive storm proofing and abandonment of forest roads has been conducted in the Lower North Fork and its tributaries and continues to be monitored for effectiveness by Lummi Natural Resources and Nooksack Indian Tribe staff. There is the need to continue this monitoring into the future. Forest and Fish regulations will likely have a positive effect on reducing the impacts of forest practices in the Lower North Fork and will need to be monitored for long-term effectiveness. Opportunities for restoration may exist as roads are identified for abandonment and storm-proofing. In places, it may be possible to directly treat slope failures as they are identified. Long-term monitoring of Forest and Fish will work to reduce forest practices impacts on in-stream habitat.

Relocation of stream-adjacent roads and infrastructure
Opportunities to relocate stream adjacent roads and infrastructure outside of the channel migration area exist and need to be evaluated. In addition to the loss of wood recruitment, stream adjacent roads have a direct impact on the loss of habitat diversity due to bank protection, which often accompanies roads and infrastructure within the channel migration zone. Roads should be prioritized for relocation by whether it represents critical infrastructure (i.e. is the only access), or secondary and by how strongly it confines the channel migration area of the river. The Mount Baker Highway (RM 44 to 45, RM 50.25-52 and RM 53.5-56) and Truck Road infringe on the channel migration area of the North Fork Nooksack River. The bridges at RM 55 on the Mount Baker Highway and RM 36.8 on State Route 9 should also be replaced with wider spans.

Monitor Shorelines and Critical Areas Ordinance
The Whatcom County Shorelines regulations and Critical Areas Ordinance will likely have a positive effect on reducing the impacts of floodplain development in the lower North Fork and will need to be monitored for long-term effectiveness. Critical areas will include channel migration zone and riparian protection, which are critical to the recovery of habitat-forming processes in the river.

5.1.6.5. Upper North Fork

The proposed actions for the upper North Fork include:

- Large-scale LWD placement
- Riparian restoration to improve wood delivery to the channel
- Riparian restoration to improve channel shading
- Set back infrastructure from the channel

5.1.6.5.1. 10-year Actions

Large-scale LWD placement
The primary objective of wood placement in the upper North Fork is to slow wood transport through the river and trap the mobile debris on stable wood structures in unconfined reaches. Much of the unconfined area of the upper North Fork has already been treated by the U.S. Forest Service and currently being monitored for effectiveness. It is expected that the wood accumulations will help stabilize bars in the channel and slow the process of channel migration and avulsion. In reaches where channel incision has degraded habitat, the increased flow resistance of the wood in the channel is expected to slow the incision and improve floodplain connectivity. It is expected that several of these projects could be implemented to provide a variety of habitat values to the channel. Over a longer timeframe as the logjams grow and stabilize, this project is designed to directly address habitat diversity and key habitat quantity for adult holding and spawning in the upper North Fork. Large-scale wood placement in sections of the upper North Fork Nooksack is expected to fully restore wood function in the channel. This will have a high impact on the formation of pools, pool tail-outs and backwater pools. The structures would also be expected to have a minor impact on off channel

habitat and a negligible impact on the formation of beaver ponds. The creation of more pools with complex cover will have a high impact on benthic community richness, a moderate impact on harassment of fish, as well as a minor impact on the retention of salmon carcasses. Spatial variation of temperature is expected to see an improvement from better interaction of pools with groundwater. During high flow, the project would be expected to moderately increase channel width, with a negligible impact on minimum width. The impact of the project on high flow, low flow and intra-annual flow variability would be a negligible benefit.

Riparian restoration to improve wood delivery to the channel
By restoring and protecting riparian areas adjacent to the river, this project seeks to reduce bed scour, sediment impacts, and provide more diverse habitat over the long term. By proper management of timberlands, the channel is expected to see moderate decreases in bed scour, embeddedness and fine sediment, as well as a high impact on turbidity. The improvements in pools, backwaters pools, pool tail-outs and beaver ponds are expected to be high with a better functioning riparian ecosystem. A functioning riparian ecosystem is also expected to increasing the minimum (moderate impact) and maximum (high impact) channel width. The riparian functions and woody debris levels of the channel would both have an extreme benefit from the project. It is expected that improving the interface between the terrestrial and aquatic environments would have a moderate impact on salmon carcass retention. Wood delivered to the channel in the upper North Fork would be expected to eventually be transported into the lower North Fork reaches, improving downstream habitat over a longer timeframe.

Riparian restoration to improve channel shading
Riparian planting in the Upper North Fork is expected to highly improve both the maximum monthly and spatial variation of the water temperature in the river. It is expected that upstream shading will have modest downstream benefits to stream temperature, as the water warms more slowly as it loses elevation.

5.1.6.5.2. Long-Term Actions

Set back infrastructure from the channel
Sections of the Mount Baker Highway and Forest Road 37 impinge on the channel migration area of the North Fork River through this reach. Several chronic repair sites were identified by the Department of Transportation in the reach. While the roads have only a modest impact on confining the channel, these repairs periodically degrade habitat and relocating the channel away from the river will reduce the impacts of highway maintenance on the channel.

5.1.6.6. North Fork Tributaries

The proposed actions for the North Fork tributaries include:
- Riparian restoration to improve wood delivery to the channel
- Riparian restoration to improve channel shading

- Canyon Creek fish passage improvement
- Canyon Creek habitat restoration

5.1.6.6.1. 10-year Actions

Riparian restoration to improve wood delivery to the channel
By restoring riparian areas adjacent to the river, this project seeks to reduce bed scour, sediment impacts, and provide more diverse habitat over the long term. By proper management of timberlands, the channel is expected to see moderate decreases in bed scour, embeddedness and fine sediment, as well as a high impact on turbidity. The improvements in pools, backwaters pools, pool tail-outs and beaver ponds are expected to be high with a better functioning riparian ecosystem. A functioning riparian ecosystem is also expected to increasing the minimum (moderate impact) and maximum (high impact) channel width. The riparian functions and woody debris levels of the channel would both have an extreme benefit from the project. It is expected that improving the interface between the terrestrial and aquatic environments would have a moderate impact on salmon carcass retention. In more confined reaches of tributaries wood can provide an important sediment storage function in the channel, as it creates lower gradient steps in the channel. Addition of recruited wood to the North Fork tributaries will have a longer-term benefit to habitat conditions below the confluence as the wood is slowly transported down to the mainstem North Fork River. Protection of in-channel wood will ensure that the functions that recruited wood provide will be maintained. Priorities for wood recruitment should be given to places were the channel has access to the riparian zone infrequently enough that the trees can grow to a sufficient size to provide functional “key pieces” to the channel.

Riparian restoration to improve channel shading
Riparian planting in the North Fork tributaries is expected to highly improve both the maximum monthly and spatial variation of the water temperature in the various creeks. Priorities should be given to narrower channels, which can more quickly be shaded by smaller trees.

Canyon Creek fish passage improvement
As necessary, and consistent with longer-term restoration plan for lower Canyon Creek (see below), short-term improvements will be made to the barrier at RM 0.3 to ensure that early chinook can access upstream habitat.

Canyon Creek habitat restoration
Canyon Creek restoration focuses on dike setback, large woody debris placement, as well as riparian restoration. The project is expected to remove the impacts of the rock revetment on the alluvial fan of Canyon Creek, and fully restore the historic channel width. The project will have a moderate impact on wood function in the channel, including the formation of pools through the treated reach. Riparian function will be restored to a moderate degree, with shading benefits to the maximum temperature and

the spatial variation of the temperature, which currently exceeds water quality standards. The project will complement upstream sediment management and landslide stabilization work that was recently completed by the USFS.

5.1.6.6.2. Long-Term Actions

Monitoring of forest practice activities

Extensive storm proofing and abandonment of forest roads has been conducted in the North Fork and its tributaries and continues to be monitored for effectiveness by Lummi Natural Resources and Nooksack Indian Tribe staff. There is the need to continue this monitoring into the future. Forest and Fish regulations will likely have a positive effect on reducing the impacts of forest practices in the North Fork tributaries and will need to be monitored for long-term effectiveness. Opportunities for restoration may exist as roads are identified for abandonment and storm-proofing. In places, it may be possible to directly treat slope failures as they are identified. Long-term monitoring of Forest and Fish will work to reduce forest practices impacts on in-stream habitat.

Set back infrastructure from the channel

Sections of the Mount Baker Highway and various forestry roads cross the lower alluvial fan, or debris flow deposition areas, of important tributaries such as Boulder Creek and Racehorse Creek. When these streams have had debris flows, past responses have included channel cleanout and armoring road crossings. For Mt Baker Highway, WSDOT reports have recommended road relocation as the best long-term maintenance solution, and road relocations and replacing bridges that constrict tributary channels in these and other areas will restore important habitat forming processes.

5.1.6.7. Lower Middle Fork

The proposed actions for the lower Middle Fork include:

- Upland forest management
- Riparian timber managed lands
- Riparian planting of the channel migration area for wood recruitment
- Riparian planting for shading benefits

5.1.6.7.1. 10-year Actions

Upland forest management

This action continues the program to upgrade or decommission forest roads on state and federal forests and eliminates logging of unstable slopes in the Middle Fork watershed. It is expected that this action will continue to reduce anthropogenic sediment sources to the river and changes in flow caused by forest management.

Riparian timber managed lands
This action includes the natural regeneration of the riparian corridor under current Forest and Fish regulations. Actions include monitoring of forest practices and ensuring Best Management Practices are implemented and adequate to protect the riparian zone.

Riparian planting of the channel migration area for wood recruitment
Riparian planting throughout the channel migration area of the Middle Fork and its tributaries will encourage long-term recovery of wood recruitment to the channel. Priorities for planting should be given to areas where the wood recruitment function is currently classified as "low" (Duck Creek, Assoc. 2001), is located where the channel can access the wood through channel erosion, but lies in a protected enough location that the trees can grow to a substantial size. Wood recruited to the channel in this reach would benefit downstream reaches of the lower North Fork Nooksack as well.

Riparian planting for shading benefits
Riparian planting in the Lower Middle Fork is expected to highly improve both the maximum monthly and spatial variation of the water temperature in the river. It is expected that upstream shading will have modest downstream benefits to stream temperature, as the water warms more slowly as it loses elevation.

5.1.6.7.2. Long-Term Actions

Protection of existing in-stream wood
Regulatory protection of wood in the channel exists and will need to be enforced to reduce the loss of wood from the channel. In some reaches of the lower Middle Fork wood cutting on the gravel bars reduces the function of wood, either by direct removal, or by reducing the size and therefore the potential stability of wood moving through the system.

Large-scale LWD placement
The primary objective of wood placement in the lower Middle Fork would be to slow wood transport through the river and trap the mobile debris on stable wood structures in unconfined reaches. It is expected that the wood accumulations will help stabilize bars in the channel and slow the process of channel migration and avulsion. It will also help form and maintain side channels and other floodplain habitats. While this reach has not yet been assessed for specific restoration actions and priorities, it is expected that several of these projects could be implemented to provide a variety of habitat values to the channel. Over a longer timeframe as the logjams grow and stabilize, this would help address habitat diversity and key habitat quantity for adult holding and spawning chinook. This will also help form and maintain pools, pool tail-outs and backwater pools.

Continued monitoring of forest practice activities

There is the need to continue this monitoring into the future. Forest and Fish regulations will likely have a positive effect on reducing the impacts of forest practices in the Middle Fork and its tributaries and will need to be monitored for long-term effectiveness. Opportunities for restoration may exist as roads are identified for abandonment and storm-proofing. In places, it may be possible to directly treat slope failures as they are identified. Long-term monitoring of Forest and Fish will work to reduce forest practices impacts on in-stream habitat.

Monitor Shorelines and Critical Areas Ordinance

The Whatcom County Shorelines regulations and Critical Areas Ordinance will likely have a positive effect on reducing the impacts of floodplain development in the lower Middle Fork and will need to be monitored for long-term effectiveness. Critical areas will include channel migration zone and riparian protection, which are critical to the recovery of habitat-forming processes in the river.

5.1.6.8. Upper Middle Fork

The proposed actions for the upper Middle Fork include:

- Restore Passage at Middle Fork Diversion Dam
- Establish and manage for sufficient instream flow at the Middle Fork Diversion Dam
- Upland forest management
- Riparian timber managed lands

5.1.6.8.1. 10-year Actions

Restore Passage at Middle Fork Diversion Dam

The project includes the installation of a fish ladder and water intake screen at the Middle Fork Diversion Dam. It is expected that the project will allow passage for all anadromous species into the upper Middle Fork basin.

Establish and manage for sufficient instream flow at the Middle Fork Diversion Dam

This project will ensure adequate flows in the Middle Fork Nooksack River downstream of the diversion dam in summer and early fall for spawning early chinook. A combination of minimum in-stream flows and control of the ramping rate at the dam will ensure stable flows downstream of the dam.

Upland forest management

This action continues the program to upgrade or decommission forest roads on state and federal forests and eliminates logging of unstable slopes in the Middle Fork watershed. It is expected that this action will continue to reduce anthropogenic sediment sources to the river and changes in flow caused by forest management.

Riparian timber managed lands
This action includes the natural regeneration of the riparian corridor under current Forest and Fish regulations. Actions include monitoring of forest practices and ensuring Best Management Practices are implemented and adequate to protect the riparian zone.

5.1.6.8.2. Long-Term Actions

Continued monitoring of forest management
This action continues the program to upgrade or decommission forest roads on state and federal forests and eliminates logging of unstable slopes in the Middle Fork watershed. It is expected that this action will continue to reduce anthropogenic sediment sources to the river and changes in flow caused by forest management. This action includes the natural regeneration of the riparian corridor under current Forest and Fish regulations. Actions include monitoring of forest practices and ensuring Best Management Practices are implemented and adequate to protect the riparian zone.

5.1.6.9. Middle Fork Tributaries

The proposed actions for the Middle Fork tributaries include:
- Riparian timber managed lands

5.1.6.9.1. 10-year Actions

Riparian timber managed lands
This action includes the natural regeneration of the riparian corridor under current Forest and Fish regulations. Actions include monitoring of forest practices and ensuring Best Management Practices are implemented and adequate to protect the riparian zone.

5.1.6.9.2. Long-Term Actions

Monitoring of forest practice activities
Forest and Fish regulations and USFS Forest Plan will likely have a positive effect on reducing the impacts of forest practices in the Middle Fork tributaries and will need to be monitored for long-term effectiveness. Opportunities for restoration may exist as roads are identified for abandonment and storm-proofing. In places, it may be possible to directly treat slope failures as they are identified. Long-term monitoring of Forest and Fish and the USFS Forest Plan will work to reduce forest practices impacts on in-stream habitat.

5.1.6.10. Lower South Fork

The proposed actions for the lower South Fork include:
- Upland forest management through Forest and Fish, Northwest Forest Plan, including forest road maintenance and monitoring, riparian management, and avoidance of unstable slopes
- Protect existing function through CAO/SMP
- Acquisition of priority habitats
- Large-scale LWD placement

- Restoration of channel migration area
- Riparian restoration to improve wood delivery
- Riparian restoration to improve riparian shading
- Set back infrastructure from the channel
- Wetland restoration to improve baseflow, temperature maintenance

5.1.6.10.1. 10-year Actions

Acquisition of priority habitats
Continued protection of priority habitat in the lower South Fork will continue through a variety of programs including purchase, acquisition of conservation easements, and voluntary enrollment in the Conservation Reserve Enhancement Program. It is expected that by protecting existing refuge areas in the lower South Fork, restoration activities can work to connect and expand high quality habitat. Acquisition sites further facilitate restoration actions on the property.

Large-scale LWD placement
Building on the results of the Acme-Saxon In-stream Assessment (Maudlin et al. 2002) and the Acme to Confluence Assessment (NNR in prep.), several areas for in-stream wood placement were identified and prioritized. It is expected that several of these projects could be implemented to provide a variety of habitat values to the channel. This project is designed to directly address habitat diversity and key habitat quantity for adult holding and spawning in the lower South Fork. The project will also have benefits to channel stability. Large-scale wood placement in sections of the lower South Fork Nooksack is expected to fully restore wood function in the channel. This will have an extreme impact on the formation of pools, pool tail-outs and backwater pools. The structures would also be expected to have a minor impact on off channel habitat and a negligible impact on the formation of beaver ponds. The creation of more pools with complex cover will have a high impact on benthic community richness, a moderate impact on harassment of fish, as well as a minor impact on the retention of salmon carcasses. Maximum temperature and spatial variation of temperature is expected to see an improvement from better interaction of pools with groundwater and by providing refuge habitat in known cool water influence areas. During high flow, the project would be expected to moderately increase channel width, with a negligible impact on minimum width. The impact of the project on high flow, low flow and intra-annual flow variability would be a negligible benefit.

Restoration of channel migration area
By removing constraints to channel migration in the lower South Fork, it is expected that the negative habitat effects associated with hydro-modifications would be reversed in treated reaches. Further, the projects would be expected to have a moderate influence on low flow, high flow and intra-annual flow variation. These benefits would be realized by allowing the channel better access to its floodplain.

Riparian restoration to improve wood delivery to the channel
By restoring riparian areas adjacent to the river, this project seeks to reduce bed scour, sediment impacts, and provide more diverse habitat over the long term. By proper management of timberlands, the channel is expected to see moderate decreases in bed scour, embeddedness and fine sediment, as well as a high impact on turbidity. The improvements in pools, backwaters pools, pool tail-outs and beaver ponds are expected to be high with a better functioning riparian ecosystem. A functioning riparian ecosystem is also expected to increasing the minimum (moderate impact) and maximum (high impact) channel width. The riparian functions and woody debris levels of the channel would both have an extreme benefit from the project. It is expected that improving the interface between the terrestrial and aquatic environments would have a moderate impact on salmon carcass retention. Addition of wood to the lower South Fork will have a longer-term benefit to habitat conditions below the confluence as the wood is slowly transported out of the South Fork and into the mainstem Nooksack River.

Riparian restoration to improve channel shading
Riparian planting in the Lower South Fork is expected to highly improve both the maximum monthly and spatial variation of the water temperature in the river.

5.1.6.10.2. Long-Term Actions

Set back infrastructure from the channel
In the Lower South Fork, the channel is confined by several pipeline crossings (Williams natural gas pipeline and City of Bellingham water pipeline), a railroad, State Route 9, Mosquito Lake Road and Saxon Road. Both pipeline crossings should be widened to accommodate the channel migration width, and transportation routes relocated where possible away from the channel. It is expected that these actions will reduce channel confinement and restore floodplain connectivity as the channel is allowed to migrate across its floodplain. These actions would further allow other restoration opportunities as critical infrastructure is moved to a safer location.

Wetland Restoration to improve baseflow and temperature maintenance
In the Lower South Fork, extensive wetlands occupied the floodplain of the channel. The largest of these is the Black Slough wetland, near Van Zandt, which likely provided substantial summer inflow to the river before much of it's area was converted to agriculture. The slough currently has a slight cooling effect on the South Fork that could likely be improved with restoration. In other places, drainage ditches have reduced the capacity of floodplain wetlands, such as the Foxglove wetland complex near Acme, and changed the outflow of the wetland. Restoration efforts focused on restoring natural hydrology will greatly improve wetland function in the lower South Fork.

Protection of existing in-stream wood
Regulatory protection of wood in the channel exists and will need to be enforced to reduce the loss of wood from the channel. In some reaches of the lower South Fork wood cutting on the gravel bars reduces the function of wood, either by direct removal, or by reducing the size and therefore the potential stability of wood moving through the system.
Monitor Shorelines and Critical Areas Ordinance
The Whatcom County Shorelines regulations and Critical Areas Ordinance will likely have a positive effect on reducing the impacts of floodplain development in the lower South Fork and will need to be monitored for long-term effectiveness. Critical areas will include channel migration zone and riparian protection, which are critical to the recovery of habitat-forming processes in the river.

5.1.6.11. Upper South Fork

The proposed actions for the upper South Fork include:

- Upland forest management through Forest and Fish, Northwest Forest Plan, including forest road maintenance and monitoring, riparian management, and avoidance of unstable slopes
- Priority habitat acquisition
- Large-scale wood placement
- Decrease river-adjacent sediment inputs to South Fork Mainstem
- Riparian restoration to improve channel shading and wood delivery to the channel

5.1.6.11.1. 10-year Actions

Upland Forest Management- Forest roads
Forest road management is expected to improve habitat impacts from high winter flow and sediment generated from road failures. Road management in the South Fork basin is expected to show a moderate reduction in interannual variability in high flow and low flow and intra-annual flow pattern. These changes should be associated with a minor reduction in fine sediment, embeddedness and turbidity. Changing the flow patterns should also have a moderate impact on reducing bed scour.

Priority Property Acquisition
The Whatcom Land Trust is in the process of acquiring the floodplain of the South Fork Nooksack River from timber interests. This acquisition, along with mitigation property owned by Seattle City Light, will provide protection for the South River from the Acme Valley upstream to the USFS property boundary. This will include all of the most heavily used areas for holding and spawning chinook.

Upland Forest Management-Protection of unstable slopes
Elimination of logging on unstable slopes is expected to reduce is expected to reduce sediment contributed to the river from forest practice activities. The reduced sediment will benefit habitat for the length of the South Fork Nooksack River.

Priority Habitat Acquisition
Acquisition and protection of the floodplain will allow natural recovery of habitat-forming processes, such as channel migration and riparian functions. This acquisition will also facilitate near-term restoration projects, such as those described under the 10-year implementation strategy. The upper South Fork is considered a high priority for preservation.

Large scale LWD placement
This project is designed to directly address habitat diversity and key habitat quantity for fry colonization in the upper South Fork. The project will also have benefits to channel stability. Large-scale wood placement in sections of the upper South Fork Nooksack is expected to fully restore wood function in the channel. This will have an extreme impact on the formation of pools, pool tail-outs and backwater pools. The structures would also be expected to have a minor impact on off channel habitat and a negligible impact on the formation of beaver ponds. The creation of more pools with complex cover will have a high impact on benthic community richness, a moderate impact on harassment of fish, as well as a minor impact on the retention of salmon carcasses. The project is further expected to result in a high reduction of bed scour and a minor improvement in gravel embeddedness and fine sediment impacts. Maximum temperature and spatial variation of temperature is expected to see a minor improvement from better interaction of pools with groundwater. During high flow, the project would be expected to moderately increase channel width, with a negligible impact on minimum width. The impact of the project on high flow, low flow and intra-annual flow variability would be negligible. Since the logjams will be an engineering tool to meet habitat objectives, the number of structures in a reach is expected to vary depending on the goals of the project. Based on a previous wood placement project that met similar habitat limitations as those described for the upper South Fork Geographic Area, we estimate 10 logjams per mile across the channel migration zone would be necessary. The expected length treated for the upper South Fork is 10 miles of channel.

Decrease river-adjacent sediment inputs to South Fork Mainstem
This project is designed to directly address sediment impacts on sediment impacts on egg incubation by applying source controls to major sediment sources in the upper South Fork. It is expected that reducing sediment delivery from landslides will have a minor impact on reducing embeddedness and fine sediment, but will have a moderate impact on reducing turbidity in the river. It is expected that the project will also minor impact on pools and pool tail-out abundance, which have been lost to filling. The project is expected to have a negligible benefit to wood levels in the channel. These

projects would be expected to improve fine sediment conditions in the lower South Fork Geographic Area.

Riparian restoration to improve wood delivery to the channel
By restoring riparian areas adjacent to the river, this project seeks to reduce bed scour, sediment impacts, and provide more diverse habitat over the long term. By proper management of timberlands, the channel is expected to see moderate decreases in bed scour, embeddedness and fine sediment, as well as a high impact on turbidity. The improvements in pools, backwaters pools, pool tail-outs and beaver ponds are expected to be high with a better functioning riparian ecosystem. A functioning riparian ecosystem is also expected to increasing the minimum (moderate impact) and maximum (high impact) channel width. The riparian functions and woody debris levels of the channel would both have an extreme benefit from the project. It is expected that improving the interface between the terrestrial and aquatic environments would have a moderate impact on salmon carcass retention. Wood delivered to the channel in the upper South Fork would be expected to eventually be transported into the lower South Fork reaches, improving downstream habitat over a longer timeframe.

Riparian restoration to improve channel shading
Riparian planting in the Upper South Fork is expected to highly improve both the maximum monthly and spatial variation of the water temperature in the river. It is expected that upstream shading will have modest downstream benefits to stream temperature, as the water warms more slowly as it loses elevation.

5.1.6.11.2. Long-Term Actions

Riparian timber managed lands (Upper SF Nooksack and major tributaries)
By restoring riparian areas adjacent to the river, this project seeks to reduce bed scour, sediment impacts, and provide more diverse habitat over the long term. By proper management of timberlands, the channel is expected to see moderate decreases in bed scour, embeddedness and fine sediment, as well as a high impact on turbidity. The improvements in pools, backwaters pools, pool tail-outs and beaver ponds are expected to be high with a better functioning riparian ecosystem. A functioning riparian ecosystem is also expected to highly improve both the maximum monthly and spatial variation of the water temperature, in addition to increasing the minimum (moderate impact) and maximum (high impact) channel width. The riparian functions and woody debris levels of the channel would both have an extreme benefit from the project. It is expected that improving the interface between the terrestrial and aquatic environments would have a moderate impact on salmon carcass retention.

Set back infrastructure from the channel (Upper South Fork)
There is a Seattle City Light bridge across the river at RM 29.8 that constrains the channel and that likely contributes to recent movements on a deep seated landslide

landform that is active along the river. Removing this bridge would restore channel width, and may reduce sediment input.

5.1.6.12. South Fork Tributaries

The proposed actions for the South Fork tributaries include:

- Riparian restoration to improve wood delivery to the channel
- Riparian restoration to improve channel shading

5.1.6.12.1. 10-year Actions

Riparian restoration to improve wood delivery to the channel

By restoring riparian areas adjacent to the river, this project seeks to reduce bed scour, sediment impacts, and provide more diverse habitat over the long term. By proper management of timberlands, the channel is expected to see moderate decreases in bed scour, embeddedness and fine sediment, as well as a high impact on turbidity. The improvements in pools, backwaters pools, pool tail-outs and beaver ponds are expected to be high with a better functioning riparian ecosystem. A functioning riparian ecosystem is also expected to increasing the minimum (moderate impact) and maximum (high impact) channel width. The riparian functions and woody debris levels of the channel would both have an extreme benefit from the project. It is expected that improving the interface between the terrestrial and aquatic environments would have a moderate impact on salmon carcass retention. In more confined reaches of tributaries wood can provide an important sediment storage function in the channel, as it creates lower gradient steps in the channel. Addition of wood to the South Fork tributaries will have a longer-term benefit to habitat conditions below the confluence as the wood is slowly transported down to the mainstem South Fork River.

Riparian restoration to improve channel shading

Riparian planting in the South Fork tributaries is expected to highly improve both the maximum monthly and spatial variation of the water temperature in the various creeks. Priorities should be given to narrower channels, which can more quickly be shaded by smaller trees.

5.1.6.12.2. Long-Term Actions

Monitoring of forest practice activities

Forest and Fish regulations and USFS Forest Plan will likely have a positive effect on reducing the impacts of forest practices in the South Fork tributaries and will need to be monitored for long-term effectiveness. Opportunities for restoration may exist as roads are identified for abandonment and storm-proofing. In places, it may be possible to directly treat slope failures as they are identified. Long-term monitoring of Forest and Fish and the USFS Forest Plan will work to reduce forest practices impacts on in-stream habitat.

5.1.6.13. Upper Mainstem

The proposed actions for the upper Mainstem include:

- Riparian and floodplain habitat acquisition
- Riparian restoration for shading in the Upper Mainstem Area
- Riparian restoration for wood recruitment in the Upper Mainstem Area
- Levee setback and removal of bank protection along the Upper Mainstem Nooksack
- Large wood placement

5.1.6.13.1. 10-year Actions

Riparian and floodplain habitat acquisition

This action includes locating opportunities to purchase and restore floodplain habitat. Acquisition will be achieved using a combination of conservation easements and purchases. It is expected that the action will facilitate future restoration actions such as levee setbacks and bank protection removal.

Riparian restoration for shading in the Upper Mainstem Area

Riparian planting in the upper mainstem is expected to highly improve both the maximum monthly and spatial variation of the water temperature in the river. It is expected that upstream shading will have modest downstream benefits to stream temperature. The focus of the planting will be on cooling smaller sloughs and side channels, which will more quickly achieve a full canopy. These smaller channels will be the highest priority for planting.

Riparian restoration for wood recruitment in the Upper Mainstem Area

Riparian planting throughout the channel migration area of the upper mainstem will encourage long-term recovery of wood recruitment to the channel. Priorities for planting should be given to areas where the wood recruitment function is currently classified as "low" (Duck Creek, Assoc. 2001), is located where the channel can access the wood through channel erosion, but lies in a protected enough location that the trees can grow to a substantial size. Wood recruited to the channel in this reach would benefit downstream reaches of the lower North Fork Nooksack as well.

Levee setback and removal of bank protection along the Upper Mainstem Nooksack

Setting back levees and removing bank protection should provide a variety of habitat benefits to the upper mainstem Nooksack River. The action is expected to improve floodplain connectivity and restore channel migration where it is limited by bank protection.

Large wood placement

This action focuses on the placement of large woody debris to provide deep, complex pools and help restore the historic anastomosing channel form above the town of Everson. Wood structures will be sited to protect maturing mid-channel bars and allow vegetation to colonize the sites. The structures will also provide deep and complex pools, which will be ideal habitat for migrating and holding adults, as well as out-migrating juveniles. The structures would be sited across the channel migration area to meet a variety of habitat objectives, such as bar stabilization and pool development. The number of structures will ultimately be related to the habitat objectives identified for the reach.

5.1.6.13.2. Long-Term Actions

Monitor Shorelines and Critical Areas Ordinance

The Whatcom County Shorelines regulations and Critical Areas Ordinance will likely have a positive effect on reducing the impacts of floodplain development in the upper mainstem Nooksack and will need to be monitored for long-term effectiveness. Critical areas will include channel migration zone and riparian protection, which are critical to the recovery of habitat-forming processes in the river.

5.1.6.14. Lower Mainstem

The proposed actions for the lower Mainstem include:

- Early action projects that integrate floodplain management with habitat recovery: Bertrand Creek area; Whiskey-Schneider Creek area
- Implementation of Best Management Practices on urban and agricultural lands
- Restore mainstem channel complexity
- Systematically integrate flood planning with habitat recovery

5.1.6.14.1. 10-year Actions

Integrate floodplain management with habitat recovery: Bertrand Creek area

Integrate flood hazard management with salmon recovery (i.e. pursue opportunities to setback levees for multiple benefits). Nooksack River between Fishtrap and Bertrand creeks has been identified as potential location for levee setback for flood hazard management. Integrate flood hazard with fish habitat restoration by creating side channel sloughs, off-channel wetlands and riparian vegetation. Include large scale LWD placement with project to promote instream complexity. Increase channel width and complexity. Restore channel meander and connection to off-channel wetlands. Provide clear water habitat in the lower river for juvenile chinook rearing.

Integrate floodplain management with habitat recovery: Whiskey-Schneider Creek area

Integrate flood hazard management with salmon recovery (i.e. pursue opportunities to setback levees for multiple benefits). Nooksack at Whisky and Schneider creeks has been identified as potential location for levee setback for flood hazard management. Integrate flood hazard with fish habitat restoration by creating side channel sloughs, off-channel wetlands and riparian vegetation. Include large scale LWD placement with project to promote instream complexity. The objectives of the project is to increase channel width and complexity, restore channel meander and connection to off-channel wetlands and provide clear water habitat in the lower river for juvenile chinook rearing.

Implementation of Best Management Practices on urban and agricultural lands
Implement BMP's re: filter strips, stormwater management, pesticide application in agricultural and urban areas. Decrease input of toxic contaminants, nutrients, fine sediments; increase riparian filtration.

Restore mainstem channel complexity
Placement of wood along river margins; anchored to piling wing walls or other instream structures. Structures placed to increase channel complexity along bank of river at multiple locations. LWD to improve complexity along edge of channel, increase habitat quality for juvenile rearing.

5.1.6.14.2. Long-Term Actions

Integrate flood planning with habitat recovery
Integrate flood hazard management with salmon recovery (i.e. pursue opportunities to setback levees for multiple benefits). Integrate flood hazard with fish habitat restoration by creating side channel sloughs and off-channel wetlands. Include large scale LWD placement with project to promote instream complexity. Identify opportunities to connect existing floodplain habitat; improve riparian vegetation and provide wider channel migration zone.

Monitor Shorelines and Critical Areas Ordinance
The Whatcom County Shorelines regulations and Critical Areas Ordinance will likely have a positive effect on reducing the impacts of floodplain development in the lower mainstem Nooksack and will need to be monitored for long-term effectiveness. Critical areas will include channel migration zone and riparian protection, which are critical to the recovery of habitat-forming processes in the river.

5.1.6.15. Mainstem Tributaries

The proposed actions for the mainstem tributaries include:

- Restoration of tributary slough habitat to provide flood refuge for fry and overwintering juveniles in the lower mainstem.
- Small-scale riparian restoration through CREP, voluntary stewardship, or community-based programs that do not compete with early chinook projects.
- Establish and manage for instream flows through Watershed Management Project.
- Implement best management practices to maintain water quality for downstream habitats.
- Restore fish passage using funding sources specifically targeted for fish passage improvements.
- Implement Forest and Fish rules (applies to Smith and Anderson Creek watersheds).

5.1.6.15.1. 10-year Actions

Whiskey-Schneider Creek restoration
Multiple lower tributary slough habitat restoration. Whiskey Creek: remove flood gate, daylight slough/creek, improve channel to expand habitat and connect flood plain wetlands. Schneider Creek: remove / relocate flood gate to connect Keefe Lake Complex to river. Improve Lower mainstem habitat complexity by restoring tributary slough habitat.

Kamm Creek restoration
Small-scale riparian restoration with a few CREP projects; restore Northwood wetland. Increase riparian shading, overhanging vegetation and leaf litter (improve benthos production, water temperatures but narrow buffer width, small-scale treatment so limited improvement in riparian function). Primary benefit to late timed chinook and coho utilizing off-channel habitat. Include side-channel/slough habitat to benefit juvenile rearing early timed chinook.

Fishtrap Creek restoration
Limited riparian improvement expected given existing land use, but some CREP likely. Set back levee on 2 mile reach between Guide and River road. Increase riparian shading, overhanging vegetation and leaf litter (improve benthos production, water temperatures but narrow buffer width, small-scale treatment so limited improvement in riparian function). Primary benefit to late timed chinook and coho utilizing off-channel habitat. Include side-channel/slough habitat to benefit juvenile rearing early timed chinook.

Bertrand Creek restoration
Bertrand CIDMP/Watershed Improvement District to facilitate limited riparian improvement - anticipate some small-scale improvement (I.e. narrow buffer width, smaller vegetation) over 30% of length. Set Back BC levees on lower 0.5 mile of channel to increase slough habitat area/complexity. Increase riparian shading, overhanging vegetation and leaf litter (improve benthos production, water temperatures but narrow buffer width, small-scale treatment so limited improvement in riparian function).

Tenmile Creek restoration
Community-based restoration with Tenmile Creek partnership - anticipate 20-30' riparian buffer over ~70% of length. Increase riparian shading, overhanging vegetation and leaf litter (improve benthos production, water temperatures but narrow buffer width, small-scale treatment so limited improvement in riparian function). Primary benefit to late timed chinook and coho utilizing off-channel habitat. Include side-channel/slough habitat to benefit juvenile rearing early timed chinook. Consider improving channel complexity / open water habitats in 1.5 miles of Barrett lake.

Anderson Creek restoration
Active and passive riparian restoration possible in lower reaches. Increase riparian shading, overhanging vegetation and leaf litter (improve benthos production, water temperatures but narrow buffer width, small-scale treatment so limited improvement in riparian function)

Anderson Creek fish passage
Regular maintenance of fishway to ensure passage. Restore full passage to upper Anderson Creek

Smith Creek restoration
Active riparian restoration possible. Increase riparian shading, overhanging vegetation and leaf litter (improve benthos production, water temperatures but narrow buffer width, small-scale treatment so limited improvement in riparian function).

Riparian restoration of managed forest lands
Implement elements of Forest and Fish. Riparian restoration; reduce sediment input, etc.

5.1.6.15.2. Long-Term Actions

Monitor Shorelines and Critical Areas Ordinance
The Whatcom County Shorelines regulations and Critical Areas Ordinance will likely have a positive effect on reducing the impacts of floodplain development in the tributaries of the mainstem Nooksack and will need to be monitored for long-term effectiveness. Critical areas will include channel migration zone and riparian protection, which are critical to the recovery of habitat-forming processes in the river.

5.1.6.16. Estuary

The proposed actions of the estuary include:

- Restore riverine-tidal blind channel network: Marietta Slough
- Restore riverine-tidal blind channel network: Marietta Slough
- Setback levees on LB of river between Slater Road and Ferndale
- Restore channel complexity

5.1.6.16.1. 10-year Actions

Restore riverine-tidal blind channel network: Marietta Slough
Setback levees on LB of river between mouth of river and Slater Road, and seaward dikes.

Restore riverine-tidal blind channel network: Tennant Wetland
Project proposes to enhance floodplain tributary channels by redesigning the channel, introducing wood and planting riparian vegetation on Tennant Creek. This creek drains

the wetlands on the eastern side of the floodplain of the mainstem downstream of Ferndale.

Setback/ remove levees on LB of river between Slater Road and Ferndale
Levee setback and removal will encourage floodwater and sediment deposition on the estuarine floodplain above Slater Road. Slater Road will be raised to accommodate flooding and infrastructure will be protected. It is expected that the project will enhance wetland functions on the floodplain and encourage more flow into the Tennant Creek area.

Restore channel complexity
Placement of wood along river margins; anchored to piling wing walls or other instream structures. Structures placed to increase channel complexity along bank of river at multiple locations. LWD to improve complexity along edge of channel, increase habitat quality for juvenile rearing.

5.1.6.16.2. Long-Term Actions

Reconnect slough and floodplain habitat
Reconnection of floodplain sloughs, such as Smuggler's Slough and Slater Slough, will provide enhanced freshwater rearing habitat for juvenile salmon. The project also provides a freshwater transit between the Bellingham Bay delta and the Lummi Bay delta.

Reconnect distributary habitat
In places where tidal and distributary channels have been truncated by non-passable tidegates and levees, restoration opportunities exist to improve passage into these habitat areas by updating the or removing the tidegates.

5.1.6.17. Bellingham Bay

5.1.6.17.1. 10-year Actions

Prioritize and implement relevant recommendations from the Bellingham Bay Pilot Project
The Bellingham Bay Pilot Project developed a list of restoration and enhancement projects for the developed portion of Bellingham Bay. These projects could be evaluated and prioritized for their benefit to target species and implemented. Focus should be placed on projects that improve habitat diversity and quantity in the nearshore areas and non-natal estuaries of Padden Creek, Whatcom Creek and Squalicum Creek.

5.1.6.17.2. Long-Term Actions

Monitor Shorelines and Critical Areas Ordinance
The Whatcom County Shorelines regulations and Critical Areas Ordinance will likely have a positive effect on reducing the impacts of shoreline development along the nearshore areas of Bellingham Bay and will need to be monitored for long-term

effectiveness. Critical areas will include a geotechnical setback for bluffs and riparian protection, which are important to the recovery of habitat-forming processes such as sediment transport and natural beach protection in the nearshore.

5.1.6.18. Other WRIA 1 Nearshore Areas

5.1.6.18.1. 10-year Actions

There are currently no proposed actions outside of the Bellingham Bay nearshore area.

5.1.6.18.2. Long-Term Actions

Restore beach habitat-forming processes

Restoring beach processes may include removing unnecessary bulkheads, or artificially nourishing the beach where bulkheads cannot be removed. Benefits include reducing beach scour, restoration of littoral sediment supply and movement, restoration of backshore vegetation and the accumulation of driftwood.

Monitor Shorelines and Critical Areas Ordinance

The Whatcom County Shorelines regulations and Critical Areas Ordinance will likely have a positive effect on reducing the impacts of shoreline development along the nearshore areas of WRIA 1 and will need to be monitored for long-term effectiveness. Critical areas will include a geotechnical setback for bluffs and riparian protection, which are important to the recovery of habitat-forming processes such as sediment transport and natural beach protection in the nearshore.

5.1.7. Bull Trout Strategy

As described in Section 2.2 *Near Term Priorities,* the near-term strategy for bull trout recovery is to implement actions with mutual benefit to both early chinook and bull trout and also to remove fish passage barriers in presumed bull trout spawning and rearing habitats in the upper Nooksack River watershed. In addition to the Middle Fork diversion dam and the lower Canyon Creek barrier, which hinder upstream access of both early chinook and bull trout, bull trout passage barriers include: Hedrick Creek (SR542), an unnamed RB tributary just downstream of Boulder Creek (SR542), “Chainup” Creek (SR542), Loomis Creek (USFS 12 Rd) and Kenny Creek (North Fork Rd, and additionally on a private road). Three additional tributaries to the upper Middle Fork (USFS 38 Rd) are scheduled to have passage corrected in 2005, and passage was also recently restored under the Mosquito Lake Road crossing of Johnson Creek.

5.1.8. General Salmonid Recovery Strategies

- Implement local land use regulations, permits, policies, or programs to maintain, prevent further degradation, and restore to target levels the habitat parameters identified above.
- Emphasize voluntary and incentive-based actions in salmon recovery efforts, but use regulatory actions if non-regulatory actions are not being taken or are insufficient to achieve recovery.

- Use the following hierarchy of approaches in undertaking actions that impact salmonid habitat:
  - Avoid impact by not taking an action or part of an action that would cause adverse impacts;
  - Minimize adverse impacts by limiting the degree or magnitude of the action and its implementation;
  - Rectify adverse impacts by utilizing proven methods that demonstrate success of repairing, rehabilitation, or restoring the affected habitat to its full productive capacity;
  - Reduce or eliminate adverse impacts over time by preservation and maintenance operations during the life of the action; and/or
  - Monitor the impact and take appropriate corrective measures to achieve the identified goal.
  - Seek full restoration, where feasible, or monetary compensation from responsible parties for direct loss of salmonids or adverse impacts to salmonid habitat.
- Implement, adapt, and enforce compliance of existing regulations for the protection and restoration of salmonid habitat. Integrate incentives and other non-regulatory approaches within existing regulatory programs may improve compliance (i.e. use incentives to promote protection and restoration, apply penalty to discourage degradation).
- Develop non-regulatory strategies to motivate landowners and developers to engage in salmonid habitat protection and restoration. Examples include direct financial assistance, credits or rebates, cost-sharing agreements, stewardship agreements, purchase or transfer of development/access/ mineral/timber rights, technical assistance, education and outreach, Public Benefit Rating System-tax incentives programs, purchase of priority lands, land trades, and conservation easements.
- Coordinate salmon recovery planning efforts with other planning processes, including Growth Management, Shorelines Management, and flood control.
- Identify, develop, review, revise, and implement best management practices that limit impacts to salmonid habitats of forestry, agriculture, construction, road maintenance, etc..
- Manage growth wisely:
  - Reduce urban sprawl by concentrate residential, commercial, and industrial growth in urban growth areas.

- Minimize road density across the landscape by discouraging settlement patterns that promote road building and developing alternatives to automobile use (e.g. bicycle paths, mass transportation).
- Develop mechanisms to prevent or slow land use conversion to more intensive land uses (e.g. forested, agricultural, or rural lands converted to urban or suburban uses). Potential examples include incentives, technical assistance, zoning, re-aggregation of small parcels, and clustering.

- Use education and outreach to increase awareness of human impacts to salmonids, foster land stewardship, and encourage behavior changes to reduce impacts.
- Develop and propose rule changes or legislative changes as needed to improve likelihood of success of salmon recovery.
- Evaluate new regulations, permits, policies or programs for the potential to lead to conservation of salmon habitat by avoiding, minimizing or mitigating human impacts on salmon habitat. Use the following evaluation questions:
  - Would the policy or program lead to degradation of habitat processes and functions?
  - Would the policy or program help develop and implement salmon-friendly best management practices?
  - Would the policy or program result in better knowledge or understanding of the issues surrounding the decline and recovery of salmon populations and their habitat?
  - Would the policy or program contribute to restoration of degraded habitat processes or functions?
  - Would the impacts of the policy or program be temporary and reversible? Or would they be irreversible?
  - What would it take to avoid or mitigate the potential impacts of the policy or program?
  - Does the policy or program identify standards, procedures or guidelines that are accepted as good management practices that protect salmon and habitat?
- Identify and minimize inconsistencies between and within current and new policies that relate to salmonid habitat protection and restoration.
- Develop an organizational structure that can facilitate the technical review of policies, programs, projects, and permits that affect salmonid habitat by local experts. Establish formal pathways for technical input by establishing committees for joint review and/or distribution lists for individual review.

- Create tax breaks and/or market incentives to encourage the development and implementation of economically and ecologically sustainable land use practices that maximize positive and/or minimize adverse impacts to WRIA 1 salmonids and salmonid habitats.
- Amend zoning regulations to minimize development in and near salmonid habitats, especially priority species:
  - Develop density and open space requirements
  - Employ density transfer procedures to allow for the transfer of development rights from one property to another
  - Prevent parcel splitting, encourage parcel reaggregation
  - Impose moratoriums in new development where appropriate
- Ensure that permitting departments have sufficient levels of staff, expertise, and training to effectively implement regulations.

5.1.8.1. Access

- Systematically inventory, assess, prioritize, and correct: (1) fish passage barriers, which block access including tributary, floodplain, and estuarine habitats; and (2) surface water diversions, which have the potential to entrain salmonids. Use WDFW's *Fish Passage Barrier and Surface Water Diversion Screening Assessment and Prioritization Manual* (available at http://wdfw.wa.gov/hab/engineer/habeng.htm).
- Enforce and monitor compliance of existing laws that mandate the maintenance or restoration of fish access and passage for man-made structures, such as diversion dams, culverts, levees, dikes, flood gates, tide gates, surface water diversions, pump stations, or bridges (e.g. WAC 220-110-070, RCW 77.55.040, RCW 77.55.060, RCW 77.55.070, RCW 77.16.220).
- Ensure that new stream crossings, fishways, and surface water diversions that are installed conform to WDFW design guidance and standards, including *Fish Passage Design at Road Culverts; Fishways – Design, Operation, and Evaluation; Screening Requirements for Water Diversions* (available at http://wdfw.wa.gov/hab/engineer/habeng.htm). All species and life stages expected to use the reach should be considered.
- Ensure that new flood control structures maintain passage into floodplain habitats (e.g. side channels and overflow channels).
- Manage impoundments to minimize the ponded area necessary for surface water diversion

- Develop and implement regular and effective monitoring and maintenance programs to ensure that fish passage is maintained at stream crossings and fishways.
- Develop education and outreach programs to educate small forest and other private landowners regarding salmonid migration habits and passage issues. When stream crossings are in place or unavoidable, provide technical assistance in the design and construction of structures to facilitate passage.
- Secure long-term funding and develop incentives and cost-sharing programs to help defray and equitably distribute the costs of fish passage restoration.
- Integrate fish passage and screening needs into land and water use planning to reduce the opportunity for additional problems to develop.

5.1.8.2. Channel Conditions

Sediment Supply

- Evaluate and adapt land use management policies, practices and plans that prevent disturbances to natural rates of sediment supply, deposition, and routing.
- Employ best management practices and implement activity limitations to control surface erosion and fine sediment delivery to streams. Examples of activity limitations include avoiding or minimizing land clearing, timber harvest, and use of unpaved roads during wet weather. Examples of sediment control methods include cover crops, sediment fences, stormwater detention facilities, vegetated buffer strips, and adequate cross drain spacing for road ditches.
- Reduce frequency and magnitude of anthropogenically-induced mass wasting events, including landslides and debris flows:
    - Minimize or avoid land-use activities (logging, yarding, grazing, farming, mining, road construction) on unstable slopes.
    - Inventory and upgrade – or where possible, decommission – roads that have potential to increase mass wasting (e.g. unstable areas, inadequate road drainage, blocked stream crossings, and road fill and sidecast failure). Prioritize roads and road systems with demonstrated problems and that continue to pose a threat to important salmonid habitats downstream.
    - Develop and implement timely monitoring and maintenance of road drainage conditions
    - Consider seasonal road closures
- Maintain and, where possible restore, road densities within watersheds to target levels

- Develop incentives to manage for cumulative impacts at the watershed scale and encourage long-range strategic planning for roads within a watershed
- Retain roadless areas.
- Avoid construction of new roads
- Decommission existing roads.

LWD

- Add large woody debris to streams to increase channel complexity, cover, spawning gravel retention, channel stability, pool frequency and depth, and habitat diversity.
- Maintain and restore natural large woody debris recruitment and routing processes by maintaining and restoring riparian buffers, avoiding and reducing artificial channel confinement, and ensuring that instream structures convey wood (culverts, bridges, diversion dams).
- Prevent removal of wood from rivers and streams:
  - Educate public and road and bridge maintenance crews of importance of wood to salmonid habitat.
  - Develop and enforce regulations to restrict removal of wood from rivers, gravel bars, and floodplains.
  - Where wood removal is unavoidable due to public safety or risk to public or private infrastructure, relocate wood to other areas within the channel.

Channel

- Maintain and restore habitats and habitat elements needed by species and life history stages that use a reach, e.g. edge and backwater habitat for fry; undercut banks and pools with cover for summer rearing; floodplain and edge habitats that provide low-flow refuges for overwintering; large, deep pools with cover for holding, and pool tailouts and riffles with adequate spawning gravels for spawning.
- Emphasize restoration of processes that form and maintain historic channel patterns. In highly managed systems where restoration to historic conditions is impossible or infeasible, instream habitat enhancement may also be the only viable alternative.
- In addition to managing upslope sediment supply, reduce fine sediment levels (where elevated) by improving channel complexity, natural bank stability, and channel/floodplain connectivity. Increased in-channel complexity changes the spatial distribution of fine sediment deposition (i.e. deposition in slower pool habitats, transport in faster riffle habitats). Stabilizing stream banks by restoring

natural riparian vegetation reduces bank erosion that can be significant source of fine sediments. Reconnecting channels and floodplains increases fine sediment deposition and storage on floodplain during floods.

- Evaluate alternatives to channel dredging. For example, the need for continuous, intensive channel dredging could be avoided or minimized by identifying and managing upstream and upslope sediment sources, limiting the spread of reed canarygrass that retains fine sediment, and improving storage capacity by promoting channel/floodplain connectivity.

- Avoid gravel mining and dredging in chinook and bull trout habitats. Where channel dredging and gravel mining are unavoidable, minimize negative effects to salmonids and salmonid habitats, by limiting the intensity, location, and/or timing of dredging activities. In particular, avoid: (1) disturbance of salmon redds; (2) increases in downstream turbidity and fine sediment levels; and (3) disruptions to channel equilibrium that can lead to downcutting and channel instability. Fully mitigate impacts using proven methods.

- Remove or set back existing bank hardening that impedes channel migration. Avoid or minimize new channelization projects or encroachments (e.g. bank hardening, narrow bridge or culvert crossing, roads parallel to the stream) that will simplify the channel structure and/or result in a loss of salmonid habitat function. Where bank stabilization is unavoidable, employ softer alternatives to traditional riprap (e.g. incorporate complex wood jams), follow Washington's *Integrated Streambank Protection Guidelines* (WDFW et al. 2003), and fully mitigate impacts using proven methods.

5.1.8.2.1. Floodplain Conditions

- Conduct comprehensive inventory of man-made structures that constrain the channel or restrict flood flow access to the floodplain and carry out feasibility analyses for their removal or relocation.

- Restore floodplain habitats and habitat-forming processes in WRIA 1 floodplains, especially along the Nooksack River and Forks, using historic conditions as reference:

- Remove or setback bank hardening, dikes and levees, stream-adjacent roads, bridges, buildings, and other infrastructure that constrain the channel or restrict flood flow access to the floodplain.

- Restore connectivity to floodplain habitats (side channels, sloughs, oxbows, wetlands, etc.) that are isolated by hydromodifications and bank stabilization (e.g. Rothenbuhler Slough in lower South Fork, to which fish passage is currently blocked by riprap). Reconnection of floodplain habitats may be a feasible method of improving floodplain habitat connectivity even where removal or setback of these structures is currently infeasible.

- Add wood at upstream ends of overflow channels to meter flow and increase floodplain habitat stability.
- Restore riparian forests within channel migration zones.
- Implement projects that can promote channel aggradation where channel incision has effectively disconnected the channel from its floodplain (e.g. lower South Fork, Acme to Saxon reach). Installing channel roughness (large wood and wood jams) may prove effective to this end.

- Develop a strategic Flood Hazard Management Plan for the Nooksack River and Forks that integrates salmonid habitat and human needs and prioritizes projects that maximize mutual benefit.
  - Establish floodplain meander limits informed by historic conditions channel migration areas to the extent possible. Delay non-emergency flood projects until meander limits are in place and the project's relevance to the larger context is clear.
  - Explicitly incorporate chinook and other salmonid habitat needs into flood hazard management planning and implementation by establishing a Technical Advisory Committee that includes state and tribal biologists with expertise in salmon and salmonid habitat.
  - Conduct economic analysis that considers costs of flood control and lost salmonid production and the value destroyed or damaged land or infrastructure.
  - Identify flood-prone properties that should be acquired to avoid future flood damage and/or need for flood control, especially within meander belts.
  - Where flood control is necessary, employ softer alternatives to traditional riprap (e.g. incorporate complex wood jams), follow Washington's *Integrated Streambank Protection Guidelines* (WDFW et al. 2003), and fully mitigate impacts using proven methods.
  - Identify feasible restoration projects (in conjunction with floodplain restoration recommendations described above).
- Protect Nooksack River and other floodplain habitat in WRIA 1 by preventing further encroachment into the floodplain.
  - Enact land use regulations (i.e. Shorelines) to prevent new development and detrimental activities in the 100-year floodplain. In addition to the immediate effects, such development often leads to increased demand and need for flood protection and bank hardening.
  - Acquire undeveloped lands or development rights to protect existing habitat.

- Maintain and develop incentives and buyback programs to facilitate removal of existing buildings and structures within the floodplain.
- Reduce adverse impacts of transportation network to channel and floodplain condition and function by working with WSDOT and County and City public works departments to:
- Identify roads and bridges that pose severe constraints to channel width and migration and/or disrupt the routing of flood flow.
- Minimize construction of new roads in floodplains. If construction is necessary, minimize increases in flood elevations and disruptions to flood flow routing.
- Relocate or remove stream-adjacent roads and railroads to provide for salmonid habitat-forming processes. Encourage transportation planners to consider the long-term costs associated with road repair and bank stabilization for stream-adjacent roads due to floods. Examples of stream-adjacent roads and railroads include SR-542 (North Fork), Mosquito Lake Road (Middle Fork, South Fork), Rutsatz Road (Middle Fork), and the railroad (South Fork). The SR-9 bridges across the South Fork and the North Fork are examples of constraining bridges.
- Implement a policy of "no net loss" of area or function for wetlands that provide or support salmonid habitat.
- Develop a mechanism for inventory and monitoring of wetland conditions and functions.
- Develop critical areas ordinances to enforce adequate buffers for development and activities that can adversely impact wetlands. Use best available science in establishing buffers (e.g. Sheldon et al. 2003).
- Avoid adverse impacts to wetlands. If alterations are unavoidable, minimize adverse impacts and fully mitigate using proven methods. Wetlands replacement is highly discouraged because of the difficulty of providing adequate replacement of functions and values.
- Off-site mitigation, where necessary, should occur within the affected watershed if possible. Develop wetland mitigation banking program that can guide such off-site mitigation and explicitly incorporates salmonid habitat and habitat needs and the technical expertise of state and tribal experts.
- Over the long term, increase the extent and functionality of wetlands in WRIA 1 that either directly provide salmonid habitat or indirectly support salmonid habitat through fine sediment filtration, groundwater recharge, and stormwater retention):
    - Restore lost or degraded wetlands.

  - Remove wetland fill.
  - Restore wetland vegetation.
  - Reconnect isolated wetlands.
  - Reintroduce beavers and/or discourage removal of beavers or destruction of beaver dams. Beaver ponds serve as overwinter rearing and flood refuge habitat for coho and other juvenile salmonids, increase habitat complexity, slow stream incision, increase flood storage, and increase flows during the dry season.

5.1.8.3. Riparian Conditions

- Protect existing riparian areas and functions along WRIA 1 streams, rivers, and floodplain habitats, as well as recovering riparian areas.
  - Maintain the full array of existing riparian functions (shading, large wood recruitment potential, leaf litter and other organic inputs, bank stability, sediment control, and nutrient and chemical filtration).
  - Develop and enforce land use regulations that prohibit development, roadbuilding, and detrimental activities within as much of the target riparian area width as possible (See *Section 5.1.5* above). If adverse impacts are unavoidable, fully mitigate impacts with proven methods.
  - Establish buffers outside regulated "no-touch" riparian areas in which low impact activities are allowed.
  - Develop and implement non-regulatory measures (e.g. incentives, lease or purchase of land or development rights, tax breaks) that support and complement regulatory measures to prevent loss and degradation of riparian areas (within target width).
- Restore degraded riparian areas where possible along streams, rivers, floodplain habitats, and wetlands throughout WRIA 1:
  - Prioritize riparian restoration in floodplain areas available for channel migration.
  - Focus on restoring structural and functional integrity of riparian areas: (1) establish or expand riparian vegetation zone width to target level (See *Section 5.1.5.* above); (2) restore riparian areas to provide the full array of functions, including shading, large wood recruitment potential, leaf litter and other organic inputs, bank stability, sediment control, and nutrient and chemical filtration.
  - Allow for passive restoration of riparian areas where natural vegetational successional processes are operational, such as in forested uplands of the Nooksack River and Forks.

  - Promote and accelerate successional processes by thinning and underplanting desired plant species (e.g. underplanting conifers where historically abundant conifers are absent or in low density).
  - Remove non-native invasive plants that hinder natural successional processes and impair riparian function
  - Plant native plant species, using historic information from the same or similar system, to restore the natural vegetation composition for the site
  - Remove or setback structures that constrain the channel and prevent channel migration and wood recruitment
- If adequate vegetated riparian buffers are infeasible, emphasize activities and land uses that are compatible with or that minimize impacts to salmonids and salmonid habitat, including (in decreasing order of desirability):
  - non-use
  - farm woodlots/non-farmed fields
  - fence rows, ditches, and unpaved roadsides with abundant shrubs, trees, or emergent
  - wetland vegetation
  - low impact recreation (hiking trails, camp, and picnic sites)
  - hay fields or other crops with infrequent tillage
  - corn and grain plantations
  - tree farming
  - moderately-grazed livestock pasture
  - urban parks
  - landscaping (preferably with abundant shrubbery, berries, and/or native vegetation).
- Restrict livestock access to avoid or minimize adverse impacts to streams and riparian areas: (1) install fencing and stream crossings (that maintain full fish passage); and (2) develop watering areas away from streams and riparian areas (i.e. outside of target riparian area widths).
- Develop program for early detection and monitoring of the distribution of non-native invading plant species and act aggressively to eliminate or prevent the spread of such species (e.g. Japanese or other knotweed species; Himalayan blackberry; reed canarygrass; and butterfly bush). Disseminate information on noxious weeds to landowners, public, and nurseries.

- Encourage Army Corps of Engineers (Emergency Management Section) to reverse its policy of requiring that levee maintenance activities remove vegetation.
- Develop programs and zoning ordinances to prevent or discourage land conversions that degrade habitat conditions, e.g. conversion from forested to agriculture, or from agriculture to industrial or residential development.
- Avoid construction of roads, utility lines, or stream crossings that encroach upon riparian areas; if road construction is unavoidable, align roads perpendicular to streams to minimize riparian vegetation loss. Modify vegetation management programs along existing roads and utility lines to minimize loss of riparian vegetation to the extent possible.
- Limit recreation or design use areas to minimize degradation of riparian habitat (vegetation trampling, soil compaction, and streambank erosion).
- Develop and implement education and outreach materials to communicate to the public the importance of riparian habitat for salmonids.

5.1.8.4. Water Quality

General

- Employ regulatory and voluntary measures to maintain and restore properly functioning water quality conditions for all WRIA 1 salmonid streams (see *Habitat targets*).
- Seek rigorous enforcement of Clean Water Act:
  - Monitor water quality throughout WRIA 1 salmonid streams to document exceedances of water quality standards for 303d listing (emphasize temperature, dissolved oxygen, and turbidity, as well as toxic contaminants)
  - Work with Ecology to prioritize, schedule and implement water cleanup plans (TMDL). Prioritize timely completion of TMDLs for early chinook and bull trout habitats.
- Monitor and implement measures to ensure that irrigation return flows, water conveyance systems (e.g. road ditches), and stormwater inputs meet applicable water quality standards for receiving waters (temperature, sediment, nutrients, pollutants). Control measures can include settling ponds and water treatment.
- Deny, defer, or condition all permits that will adversely impact water quality in WRIA 1 salmonid streams.
- Ensure best available management practices (BMP) are employed to reduce nonpoint source pollution and other adverse impacts of land uses on water quality

  - Identify and adapt existing BMPs from federal, state, and local resource and governmental agencies
  - Support applied research and otherwise encourage the development of new BMPs and technologies
  - Encourage BMP implementation through regulatory or non-regulatory measures, combined with education and outreach
  - Monitor effectiveness and adapt BMPs accordingly
- Restore wetlands and riparian areas to enhance their capacity to moderate sediment, chemical, and nutrient delivery to streams.
- Evaluate influence of insufficient instream flows on degraded water quality (e.g. elevated temperature, low dissolved oxygen) and incorporate into instream flow planning efforts (see *Water Quantity* section)

Temperature

- Protect and restore vegetation along riparian areas of WRIA 1 salmonid streams to provide adequate shading
- Restore natural hydrologic regime, especially conditions that support increased summer base flows (see *Water Quantity* section)
- Identify and protect or restore both unique cold water features (e.g. springs, cold water tributaries, hyporheic and groundwater upwelling zones) and the processes that support them

Turbidity

- Control fine sediment sources (see Channel Conditions) section
- Regulate in-channel activities that can suspend sediment (e.g. dredging, gravel mining, instream restoration projects):
  - Enforce standards for turbidity and suspended sediment to avoid conditions that will injure or alter the migration behavior of downstream salmonids
  - Prohibit certain activities
  - Restrict activity timing and location,
  - Employ measures to control downstream routing (e.g. temporary berms and flow diversions)

Toxic Contaminants

- Develop and enforce applicable laws and land use regulations to restrict application and runoff of chemicals that have known or likely deleterious effects to salmonids (direct lethal and sublethal effects) and stream habitat (i.e. reduced riparian function) and productivity (e.g. invertebrates that are prey for juvenile salmonids):

  - Conduct regular water quality monitoring to detect where levels of contaminants exceed standards.
  - Compile and keep up-to-date with information on banned and restricted chemicals (pesticides, herbicides, fertilizers, etc.) from EPA, NRCS, product labels, and relevant court orders (e.g. 1/22/04 federal court order banning application of 38 pesticides within 100 yards of Northwest salmon streams, except for mosquito prevention and other human-health applications).
  - Prohibit aerial and ground spraying within recommended distances of streams and irrigation ditches (accounting for drift).
  - Mandate widths and vegetation requirements in riparian areas to provide functional filter strips.
  - Avoid, to the extent possible, chemical application during icy or wet weather conditions or on bare ground or immature crops, where elevated runoff increases the likelihood of chemical delivery to streams. Also, avoid aerial application during windy conditions.
  - Develop incentives and other non-regulatory measures to encourage alternatives to chemical treatment for forestry, agriculture, and residential use (e.g. organic farming, Integrated Pest Management).
  - Use best available technology to maximize efficient use of chemicals and reduce overapplication.
  - Evaluate the benefits and risks of chemical control of noxious weeds that impair riparian function and act accordingly.
- Use best available technology to reduce industrial and urban pollution inputs from stormwater, road drainage, and point discharges into WRIA 1 salmonid streams.
- Minimize use and potential for delivery to streams of materials used during road and bridge construction and repair
- Support and facilitate state and federal efforts to fund and implement cleanup of toxic areas
- Clean up and remove dumped material from streams and riparian areas (e.g. large pile of tires in Anderson Creek watershed; creosote-treated wood).

Dissolved Oxygen

- Manage land use practices to avoid nutrient concentrations in salmonid streams that increase biological oxygen demand and can lead to critically low dissolved oxygen levels

  - Minimize runoff of fertilizer and livestock waste into streams, by restrict quantities and timing of manure spraying or spreading
  - Develop comprehensive plan to evaluate and correct the effects of failing septic systems on stream water quality throughout WRIA 1
  - Manage effluent discharge from wastewater treatment plants to minimize nutrient concentrations to the extent possible
  - Restrict livestock access to streams and riparian areas to prevent concentration of livestock waste and delivery to streams

5.1.8.5. Water Quantity

- Maintain and restore natural hydrologic regimes to properly functioning conditions for WRIA 1 salmonids
- Restore processes and conditions that support summer base flows for WRIA 1 salmonid streams
  - Restore wetlands
  - Reconnect and revegetated floodplains
  - Protect aquifer recharge areas
- Ensure that sufficient instream flows are provided to protect and restore upstream and downstream passage for all lifestages of chinook salmon and other salmonid within the limits of the natural hydrology.
- Work through Watershed Management Project and Comprehensive Irrigation District and Management Plan process to manage water use to provide adequate instream flows to meet salmonid needs, as well as channel-formation and maintenance flows
- Restore hydrologic maturity (especially within rain-on-snow zones):
  - Establish standards for hydrologic maturity of watershed units
  - Develop nonregulatory mechanisms to meet the standards and to manage for cumulative impacts at the watershed-scale
  - Reduce forest harvest rates and cut areas within watersheds
  - Minimize clearcut patch size and cumulative area
  - Transition to longer rotations between timber harvest
  - Replant or reseed harvested areas
- Reduce hydrologic effects of forest roads
  - Establish standards for forest road densities within watershed units

- Encourage long-range planning for road networks within a watershed to minimize road densities, stream crossings, stream-adjacent road construction
- Maintain roadless areas
- Develop nonregulatory mechanisms to meet road density standards
- Disconnect road drainage networks from stream channel networks by:
    - Constructing frequent cross drains and ditch outlets
    - Designing and building road stream crossings to minimize accumulation of runoff that is delivered directly to the stream

- Minimize effective impervious surface area
    - Establish effective impervious surface area thresholds and adapt and enforce zoning ordinances accordingly
    - Provide incentives to discourage land use conversion from forest, agricultural and rural to urban and industrial land uses
    - Encourage development and application of alternatives to impervious surface materials for construction and development
    - Protect hydrologically mature forest cover to the maximum extent feasible
- Develop and implement best management practices to minimize soil compaction and vegetation disturbance in forestry, agriculture, and grazing practices, especially proximal to stream
- Increase flood water storage capacity and groundwater recharge, especially in the Nooksack River and Forks
    - Restore hydrologic connectivity between channels and floodplains and wetlands
    - Remove or setback dikes, levees and channel constraints
    - Address and correct land use-induced channel incision that effectively disconnects channels and floodplains
    - Protect and restore wetlands and riparian areas
    - Remove floodplain fill
- Prevent channelization and ditching; restore historical channel, floodplain, and wetland morphologies where possible
- Develop Stormwater Management plans that minimize, to the maximum extent feasible, the effects of stormwater on the hydrologic regime (e.g. stormwater detention/retention and infiltration systems)

- Restore channel conditions and habitat elements that will buffer the negative effects of peak flows on salmonid habitat, especially in the Nooksack River and Forks (see also Channel Conditions)
    - Improve incubation success by: (1) reducing lateral and vertical channel instability associated with peak flows, e.g. by adding large wood, reducing channel confinement, and improving channel/floodplain connectivity; and (2) protect and restore the floodplain and tributary habitats that function as spawning refuges (reduced scour during peak flows).
    - Improve juvenile overwintering habitat: (1) reduce channel confinement (reduces mean water column velocity and decreases likelihood that flood flow will flush rearing salmonids); (2) restore connectivity to and encourage formation and maintenance of floodplain, edge, and backwater habitats that serve as flood refuges; and (3) increase instream habitat complexity (i.e. by adding wood and restoring multiple channel and/or meandering channel pattern) to increase hydraulic heterogeneity and the availability of low-flow microhabitats.

5.1.8.6. Estuarine and Nearshore Marine Habitat

- Address water quality degradation in streams and rivers flowing to WRIA 1 estuarine and nearshore marine waters (see *Water Quality Conditions*)
- Protect and restore estuaries associated with coastal independent tributaries (especially in Bellingham Bay), especially those have been determined to provide important non-natal estuary habitat to Nooksack River salmonids
- Protect and restore, to the extent feasible, the processes regulating the supply, transport, and deposition of sediment, water, large wood, and nutrients in the estuarine and nearshore marine environment.
    - Use historic conditions as reference
    - Identify sediment sources and sinks, drift cells and prevailing current patterns
    - Inventory anthropogenic uses and structures that disrupt habitat-forming processes (e.g. shoreline modifications, docks and piers)
- Protect and restore nearshore marine habitat structure and function
    - Ensure no net loss of eelgrass habitats, macroalgae habitats, intertidal forage fish spawning habitats (e.g. surf smelt and sandlance), intertidal wetlands, and intertidal mudflats, salt marsh.
    - Avoid or limit dredging activities, and minimize and fully mitigate for adverse impacts (eelgrass destruction, bathymetric changes, resuspension of contaminated sediments)

    - Avoid or limit placement of fill, and minimize and fully mitigate for adverse impacts
    - Restore bathymetry where feasible (e.g. remove fill; the Cornwall Landfill has been identified as a high priority through the Bellingham Bay Demonstration Pilot.
    - Plant native vegetation
- Protect and restore shoreline conditions
    - Develop and enforce land use regulations (Shorelines Master Plan) to protect and restore marine bluffs (i.e. limit construction, removal of vegetation, new roadbuilding)
    - Prevent new shoreline armaments
    - Develop incentives and identify opportunities to remove, set back, or replace shoreline armoring and bulkheading with softer alternatives
    - Identify opportunities to remove fill and overwater structures in the nearshore environment
    - Restore vegetation along shorelines to provide shoreline stabilization, shading of upper intertidal, and inputs of organic matter and woody debris
- Protect and restore forage fish spawning areas
    - Prohibit development or activities that would adversely impact known forage fish spawning beaches
    - Avoid destruction of eelgrass beds; where infeasible, minimize and fully mitigate for adverse impacts
    - Minimize disturbance in herring pre-spawn holding areas to the extent possible
    - Implement beach nourishment activities to restore forage fish spawning areas:
        - Although not process-based, May be the only available option when restoration of sediment regime is infeasible (i.e. inner Bellingham Bay, other highly modified shorelines)
        - Consider physical context (wave and current patterns) in site selection to minimize the need for costly, frequent maintenance
        - Consider specific substrate size and tidal elevation requirements
        - Secure funding for long-term maintenance
- Improve migratory corridors in estuarine and nearshore marine environment

    - Maintain adequate flows through estuaries to ensure optimal and timely downstream migration for smolts.
    - Identify timing, location, and characteristics of migration routes for chinook and other salmonids
    - Identify existing structures and shoreline conditions that disrupt or otherwise adversely impact migrating salmonids
    - Avoid adverse impacts of new activities and development on migratory corridors
    - Restore or enhance conditions in migratory corridors, e.g. by placement of cover, grading to create shallow shelf habitats, restoring eelgrass and other intertidal and subtidal vegetation

- Ensure coordination and cooperation with and among various organizations and committees working within the estuarine and nearshore marine environments of WRIA 1 (e.g. Whatcom Marine Resources Committee, Bellingham Bay Pilot Project, Puget Sound Nearshore Ecosystem Restoration Program, Waterfront Futures) to achieve recovery of estuary and nearshore marine ecological functions beneficial to recovery of chinook salmon and other salmonids.
- Work with the Burlington Northern railroad to seek solutions to reduce impacts to WRIA 1 shorelines (especially Chuckanut Bay)
- Reduce occurrence of treated wood structures in nearshore
    - Use less toxic alternatives to wood treatment
    - Identify, prioritize, and remove or replace existing treated timber structures
- Evaluate, address, and avoid or minimize impacts of industrial and municipal discharges in cherry point to water and sediment quality
- Evaluate and remove creosote logs in WRIA 1 estuaries and nearshore marine habitats
- Promote oil and hazardous substance spill prevention, contingency, and response planning to reduce risk, minimize exposures, remediate contaminated areas, and restore lost resource functions and services.
- Regularly monitor for presence of *Spartina* and other invasive species in WRIA 1, especially on the Lummi Bay and Bellingham Bay mudflats, and develop a plan to quickly respond with control efforts if detected
- Continue to address the cleanup and disposal or appropriate capping of contaminated sediments in inner Bellingham Bay according to the prioritization by the Bellingham Bay Demonstration Pilot

Table 5.1: Habitat targets for Nooksack early chinook freshwater habitats.

(Note: Apply to or adjacent to early chinook habitats, except Watershed Conditions, which apply to watershed upstream.)

Category	EDT Attribute	Definition	Target	
Access	Migration Obstructions[1]	Obstructions to fish passage by physical barriers.	None, or existing obstructions allow full upstream and downstream passage of juveniles and adults .	
Channel Conditions	Fine Sediment[1]	Percentage of fine sediment (<0.85mm)	Riffles	< 11%
	Embeddedness[1]	Extent that larger cobbles or gravel are surrounded by or covered by fine sediment	Riffle and tailout habitat units (where cobble, gravel substrates occur).	< 25 % covered by fine sediment
	Wood Debris[1]	Large Wood Function	Complex array of large wood pieces (>50cm diameter) but fewer cross channel bars and fewer pieces of sound large wood due to less recruitment than historic conditions; large wood, jams are a prevalent influence on channel morphology.	
		Large woody debris (LWD, i.e., pieces >0.1 m diameter and >2m in length) density in pieces per channel width (CW, i.e., average wetted width during high flow month that is less thank bankfull)	CW <25 ft	2 to 3
			CW 25 - 50 ft	2 to 4
			CW 50 - 150 ft	3 to 7
			CW 150 - 400 ft	10 to 20 (excluding large jams), plus large jams where accumulations occur.
			CW >400 ft	8 to 15 (excluding large jams), plus large jams where accumulations occur.
	Bed Scour[1]	Average depth of bed scour during annual peak flow event over ~ a 10-year period.	Spawning areas (i.e., in pool-tailouts and small cobble-gravel riffles)	Frequent scour of depths < 10 cm.
	Quantity and Quality of Pools[1]	Pool Frequency (pools per mile)	Width 5'	184
			Width 10'	95
			Width 15'	20
			Width 20'	56
			Width 50'	26

Category	EDT Attribute	Definition	Target	
			Width 75'	23
			Width 100'	18
		Pool Quality	Pools > 1 meter depth (holding pools) with good cover and cool water, minor reduction of pool volume by fine sediment	
Floodplain Conditions	Hydromodifications[1]	Extent that man-made structures constrict flow (e.g., bridges) or restrict flow access to floodplain (e.g., streamside roads, riprap, levees); extent of ditching or channelization.	Stream channel is fully connected to the floodplain although very minor structures may exist that do not result in flow restriction or constriction.	
	Floodplain Connectivity[2]	Ability of flood flows to access floodplain	Off-channel areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession.	
	Habitat Type – Off Channel[1]	Off-channel habitats, as a proportion of the total wetted area	Use historic conditions as reference	
Riparian Conditions	Riparian Function[1]	Degree to which riparian function has been altered within the reach.	> 70% of functional attributes present	
	Riparian Buffer Width and Composition[3]	Width of riparian zone measured horizontally from the channel migration zone on each side of the stream; species composition and stand age of vegetation.	>150 ft or site potential tree height (whichever is greater) *and* dominated (>70%) by mature conifers unless hardwoods were dominant historically	
Water Quantity	Annual Variation in Peak Flow[1]	Relative change in average peak annual discharge, as inferred from historical flow data or indicator metrics.	Peak annual flows typical of an undisturbed watershed of similar size, geology, orientation, topography, and geography; OR <20% change in Q2yr based on historical record	
	Intra-Annual Variation in Peak Flow[1]	Intra-annual flow variation during the wet season (i.e., "flashiness") as indicated by flow data or watershed condition metrics (e.g., road density, % impervious surface).	Storm runoff response (rates of change in flow) typical of undisturbed watershed of similar size, geology, orientation, topography, and geography; OR <5% reduction in average TQmean compared to the undeveloped watershed state.	
	Annual Variation in Low Flow[1]	Relative change in average daily flow during the normal low flow period, as indicated by historical flow data or inferred from watershed metrics.	Average daily low flows expected to be comparable to an undisturbed watershed of similar size, geology, and flow regime (or the pristine state for the watershed of interest); OR <20% change in the 45 or 60-day consecutive lowest average daily flow.	

<table>
<tr><th>Category</th><th>EDT Attribute</th><th>Definition</th><th colspan="4">Target</th></tr>
<tr><td></td><td>Diel Variation in Flow[1]</td><td>Average diel variation in flow level during a season or month.</td><td colspan="4">Slight to low variation in flow stage during an average 24-hr period during season or month. This pattern typical of routine slight to low ramping condition associated with flow regulation, averaging <2 inches change in stage per hour.</td></tr>
<tr><td rowspan="16">Water Quality</td><td>General Water Quality[2]</td><td>Includes all water quality parameters regulated through the Clean Water Act that affect salmonids.</td><td colspan="4">Low levels of contamination from agricultural, industrial, and other sources; no excess nutrients; no 303-d listed reaches.</td></tr>
<tr><td rowspan="10">Temperature - daily maximum[4]</td><td rowspan="10">Maximum water temperatures (7-day average of daily maximum) within the stream reach during the period should not exceed:</td><td></td><td>Incubation</td><td>Juvenile Rearing</td><td>Adult Migration</td></tr>
<tr><td>Chinook</td><td>11 - 12</td><td>14.2 - 16.8</td><td>14.2 - 16.8</td></tr>
<tr><td>Coho</td><td>9 - 12</td><td>14 - 17</td><td>14 - 17</td></tr>
<tr><td>Chum</td><td>10.5 - 12</td><td>N/A</td><td>Insuff. Data</td></tr>
<tr><td>Pink</td><td>10 - 12</td><td>12.5 - 14.5</td><td>12.5 - 14.5</td></tr>
<tr><td>Sockeye</td><td>10.5 - 12</td><td>12 - 16</td><td>13 - 14.5</td></tr>
<tr><td>Steelhead</td><td>13 - 14</td><td>16.5 - 17.5</td><td>16 - 17</td></tr>
<tr><td>Bull Trout/Dolly Varden[a]</td><td>5.5 - 6.5</td><td>10 - 12</td><td>14 - 17</td></tr>
<tr><td>Rainbow Trout</td><td>9 - 12</td><td>15.5 - 18</td><td></td></tr>
<tr><td>Cutthroat Trout</td><td>10 - 11</td><td>13 - 15.5</td><td>14.5 - 17.5</td></tr>
<tr><td>Temperature - spatial variation[1]</td><td>Water temperature variation within the reach as influenced by inputs of groundwater.</td><td colspan="4">Intermittent sites of groundwater discharge into surface waters and total quantity of groundwater discharge not a major source of flow in reach.</td></tr>
<tr><td>Dissolved Oxygen[1]</td><td>Average dissolved oxygen within the water column.</td><td colspan="4">>8 mg/L</td></tr>
<tr><td>Turbidity[1]</td><td>The severity of suspended sediment episodes within the stream reach (Scale of Severity, or SEV[3]).</td><td colspan="4">SEV Index ≤ 6; Occasional episodes with low to moderate concentrations (<250 mg/L) of suspended sediment. Concentrations are sublethal, although slight behavioral modification may occur.</td></tr>
<tr><td>Pollutants[1]</td><td>The extent of dissolved heavy metals and other toxic pollutants within the water column.</td><td colspan="4">No toxicity expected due to dissolved heavy metals to salmonids under prolonged exposure (1 month exposure assumed).</td></tr>
</table>

Category	EDT Attribute	Definition	Target
Watershed Conditions	Mass Wasting	Occurrence of mass wasting events (e.g., debris flows, shallow-rapid landslides).	No evident impact of land use on the frequency and magnitude of mass wasting events that deliver sediment to streams.
	Road Network Impacts	Measures of the impact of the road network to the stream system, e.g., the length of road network per unit watershed area, number stream crossings per unit channel length, proportion of stream network with stream-adjacent roads.	Road Density[3]: <2 mi/mi^2; other thresholds to be developed based on best available science.
	Increase in Drainage Network[2]	Extension of stream network by land use practices, e.g., ditching/draining of wetlands, road ditches that intercept precipitation or groundwater flow and deliver directly to stream network	Zero or minimum increases in active channel length correlated with human-caused disturbance.
	Riparian Areas[3]	Condition of riparian areas adjacent to stream reaches upstream of but hydrologically connected to Nooksack early chinook habitats	Streams more than 2 ft bankfull width: >100 ft buffer width dominated by mature trees of historically dominant species Streams* less than 2 ft bankfull width: >50 ft buffer width dominated by mature trees of historically dominant species *Applies to streams for which wood is important in sediment storage. Research is underway locally to characterize such streams.
	Hydrologic Maturity[3]	Proportion of watershed area with forest stands aged 25 or more	>60%
	Impervious Surface Area[3]	Percentage impervious surface in the watershed (e.g., calculated by applying effective impervious surface % to land use/land cover types and averaging over watershed	≤ 3%

Category	EDT Attribute	Definition	Target
Ecological Interactions	Salmon Carcasses[1]	Relative abundance of anadromous salmonid carcasses within watershed that can serve as nutrient sources for juvenile salmonid production and other organisms.	Very abundant -- on average 400 carcasses/mile of main channel habitat

[1] Source: Blair, G. 2001. Puget Sound PFC Rules. May 2001 Memorandum. Mobrand Biometrics, Vashon, WA.
[2] Source: USFWS. 1998. A Framework to Assist in Making Endangered Species Act Determinations of Effect for Individual or Grouped Actions at the Bull Trout Subpopulation Watershed Scale. February 1998.
[3] Source: Smith, C. 2002. Habitat Condition Standards (Table 13) *in* Salmon and Steelhead Habitat Limiting Factors in WRIA 1, the Nooksack Basin. July 2002. Washington State Conservation Commission. Lacey, WA. *Note: Standards for good conditions were used.*
[4] Source: Hicks, M. 2000. Preliminary Review Draft Discussion Paper Evaluating Standards for Protecting Aquatic Life In Washington's Surface Water Quality Standards Temperature Criteria. Washington State Department of Ecology, Water Quality Program, Watershed Management Section. Olympia, Washington.

Table 5.2. Functional objectives for resource issues under the Forest and Fish Rules.

Resource Issues	**Functional Objective**	**Forest Practice Rules to Achieve Objectives**	**Gaps in the Forest Practice Rules**
Heat / Water Temperature	Provide cool water by maintaining shade, groundwater temperature, flow, and other watershed processes controlling stream temperature.	1. Achieving desired future conditions (DFC) in Riparian Management Zones (RMZs) for fish-bearing waters; 2. Partial buffering of non-fish-bearing perennial surface waters.	1. Small forest landowner exemptions for riparian buffers; 2. Non-fish-bearing surface waters are only buffered for 50% of their length; 3. Inadequate 4. No buffers for seasonal streams
LWD / Organic Inputs	Develop riparian conditions that provide complex habitats for recruiting large woody debris and litter.	1. Achieving desired future conditions (DFC) in Riparian Management Zones (RMZs) for fish-bearing waters; 2. Partial buffering of non-fish-bearing perennial surface waters.	1. Small forest landowner exemptions for riparian buffers; 2. Non-fish-bearing surface waters are only buffered for 50% of their length; 3. No buffers for seasonal streams.
Sediment	Provide clean water and substrate and maintain channel forming processes by minimizing to the maximum extent practicable, the delivery of management-induced coarse and fine sediment to streams (including timing and quantity) by protecting stream bank integrity, providing vegetative filtering, protecting unstable slopes, and preventing the routing of sediment to streams	1. SEPA process for harvesting on unstable slopes; 2. Mass-wasting buffer prescriptions; 3. Rule standards for new road construction; 4. Road maintenance and abandonment plans (RMAPs)	1. Small forest landowner exemptions for RMAP; 2. Lack of wood recruitment for non-fish bearing streams increases sediment transport capacity for headwater streams; 3. Lack of wet season hauling restrictions for forest roads;
Hydrology	Maintain surface and groundwater hydrologic regimes (magnitude, frequency, timing, and routing of stream flows) by disconnecting road drainage from the stream network, preventing increases in peak flows causing scour, and	1. Rule standards for new road construction; 2. RMAPs; 3. Logging restrictions for wetlands.	1. Small forest landowner exemptions for RMAP; 2. No logging restrictions for hydrologic maturity (i.e. cumulative effects).

	maintaining the hydrologic continuity of wetlands.		
Chemical Inputs	Provide for clean water and native vegetation (in the core and inner zones) by using forest chemicals in a manner that meets or exceeds water quality standards and label requirements by buffering surface water and otherwise using best management practices.	1. Rules for the handling, storage, and application of chemicals.	.
Stream Typing	Type "fish habitat" streams to include habitat which is used by fish at any life stage at any time of the year, including potential habitat likely to be used by fish which could be recovered by restoration or management, and including off-channel habitat, by using a multi-parameter, field-verified, peer reviewed, GIS logistic regression model using geomorphic parameters such as basin size, gradient, elevation, and other indicators.	1. Interim water typing system based on physical criteria ; 2. Water typing model for fish habitat in validation.	1. Water typing model under predicts low gradient, floodplain anadromous fish habitat.
Fish Passage	Maintain or restore passage for fish in all life stages and provide for the passage of some woody debris by building an maintaining roads with adequate stream crossings.	1. Rule standards for new road construction; 2. RMAP	1. Small forest landowner exemptions.

5.2. Harvest

5.2.1. Recovery Objectives

The initial objective for harvest (direct or incidental harvest) is that the Nooksack Early Chinook Management unit will increase to the level that would sustain harvests below the agreed Recovery Exploitation Rate (RER) level which will allow incidental impacts sufficient to allow achieving harvest objectives on fisheries with harvestable surpluses. This will allow:

- Annual directed harvest opportunity for the ceremonial ,and eventually subsistence, treaty-reserved fishing rights and , non-treaty fishing opportunities, and harvest in Canada.
- Fisheries in Areas 7 and 7A not constrained by the exploitation rate limit on the Nooksack Early Chinook Management Unit.
- Incidental mortality in mixed stock sport fisheries not constrained by the exploitation rate limit on the Nooksack Early Chinook Management Unit.

The Long term objective will be have the populations recover to the level where they would produce three recruits for each spawner, allowing a spawning population of 3,000 to produce a harvestable surplus 6,000 in each of the populations in the Nooksack Early Chinook management unit.

- The Washington Departments of Fisheries and Game (WDFG 1948) estimated Nooksack River annual commercial salmon production contributions to in-river, Puget Sound, and Coastal commercial catches from 1938-1944 as 13,289 chinook. They also estimated that 40% of the chinook run was caught on the Coast, and 10% of the equivalent of 10% of the in-river numeric catch was caught in Puget Sound. When sport estimates are added, annual Nooksack origin chinook catches in Washington were 15,289. The annual river catch of chinook in the river, predominately representing the catch from April through July, averaged 3,800 chinook. Assuming that the primitive fishing gear of the day would be unlikely to harvest 50% of the run entering the river, we would suggest that the average productivity of the populations during that time period was on the order of 4 recruits per spawner. This would suggest that three recruits per spawner is not an unreasonable number, though the population size was apparently 20% lower than the long term goal. It should be noted that commercial catches for Chinook from this period are diminished from Puget Sound District catches from 1913-1928 (WDFG 1930).
- The Beverton Holt production function relates the number of recruits expected given a number of spawners, or parents and a given set of habitat conditions. When the habitat conditions approximating the properly function conditions for survival of chinook are input into the EDT model for each of the two populations

in the Nooksack Early Chinook Management Unit, a population specific estimate of recruits per spawner is generated over a range of spawner populations. It is assumed that the habitat characteristics are limited and that as the population increases the recruits per spawner decreases and eventually levels off so the number of recruits does not increase with increasing spawners.

When the rate of the increase in the population reaches its maximum value relative to the number of spawners, additional spawners are less efficient at increasing the population numbers. This point of diminishing return is the escapement that on average, under average habitat conditions will provide the maximum sustainable yield from the population. The model output provides estimates listed in Table 5.3.

A graphic display of the relationship between spawners and recruits, or total population prior to fishing, the relationship between the return per spawner and the number of spawners is provided in Figure 5.1

5.2.2. History of Harvest Management

Prior to the 1970s, salmon fisheries were concentrated where the highest quality fish could be caught, which was generally on the approaches from the oceans to the internal waters leading to the natal rivers. Salmon traps on the these routes were major fisheries until they were outlawed in 1935. Purse Seine gear evolved considerably from the turn of the century through the development of the power block and nylon net became the dominant gear operating in the approach fisheries. Substantial troll fisheries had developed along the coasts of Washington, Oregon and the West Coast of Vancouver Island developed in the late 60s and the 70s. The impact of these fisheries on the numbers of salmon returning to the natal streams was not unnoticed.

A variety of factors during the 70s led to investigations that would identify the origin of stocks taken in fisheries and the development of management tools that would allow management of fisheries so the numbers of chinook of each stock taken in each fishery could be estimated. Developing international agreement on the Law of the Sea inflamed the smoldering discontent in Canada concerning the interception of Canadian origin salmon by United States fisheries. The Boldt decision, requiring allocation of harvestable surplus of stocks on a region by region or stock by stock basis equally between tribal and non-tribal parties in Puget Sound also required this information and tools.

The basic information required to accomplish new management objectives was the ability to identify the natal stream of each salmon killed by fishing activity. Successful generation of this data allows a calculation of the total survival of a brood stock, and the identification of the stock composition of each fishery. With information on the numbers of brood production (spawners, potential egg deposition, or in the case of hatcheries releases) and the total mortality over time allows insight into the variations in survival and perhaps causes of survival which leads to the ability to make useful forecasts of the numbers of adults returning from the ocean each year. The identification of the origins of chinook caught in each fishery also allowed evaluation of fisheries regulations that would be required to meet agreed or required catch allocation objectives as well as providing information on where chinook were at different times in their marine life history phase.

Initial research was based upon placing plastic disk tags on fish taken in fishing areas where large numbers of tags could be applied, and then surveying likely spawning areas to determine where the tags were found and from the information on the tag, the times and locations the fish were tagged. Much of this work was conducted by the International Pacific Fisheries Commission (IPSFC) created in 1938 to manage the sockeye stocks from the Fraser River passing through US and Canadian territories by the Sockeye Salmon Convention of 1938. A number of assumptions concerning the ability of the fish tagged to represent the fish taken in the fishery and the ability of the tags recovered on the spawning ground to represent all of the tags in the spawning population and the statistical methods of the day allowed the IPSFC to manage the harvest of sockeye with allocation of the harvestable surplus, that which would provide spawning escapements that would provide for the maximum sustainable harvest over time, equally between Canadian and American fisheries.

This line of research was very expensive and was not able to track all fish in all fisheries. New technologies were developed to identify fish identified by stock as juveniles and then to identify them in the catch of fisheries. Initially, information on the survival of juvenile fish, too small for the tags of the day, was obtained from clipping various combinations of fins. The invention of micro-sized coded wire tags (CWTs), up to 1.5 mm length, that could be easily implanted into the tough nasal cartilage of juvenile salmonids greatly changed juvenile marking studies because of the numerous advantages over fin clipping. Binary coded tags were introduced in 1971. The new tags had an exceptional number of available codes. Standard length binary tags (1mm, 6-bit word) for example, have 63 possible agency codes and 3,969 codes per agency (not using zero), for an overall total of 250,047 unique codes.

CWT applications were initially developed in the 1960s to investigate the effectiveness of different hatchery practices. In 1977 a coast wide CWT program was established to provide coordination of CWT release and recovery efforts. Standards were established catch sampling rates, release and reporting to a centralized site, access and ability to extract data of interest, and methods of analysis among managers.

The coded wire tag (CWT) is now widely used by fisheries agencies on the West Coast as a major information collection tool for stocks of salmon. Resource management problems addressed include hatchery contribution studies, differential treatment studies, fishery contribution studies, and a variety of other related studies which are important for fisheries management and research. The Pacific States Marine Fisheries Commission hosts the Regional Mark Processing Center (RMPC) and maintains an on-line Regional Mark Information System (RMIS) to facilitate exchange of CWT data between release agencies and the sampling/recovery agencies, and other data users. The RMPC also serves as the U.S. site for exchanging U.S. CWT data with Canada for Pacific Salmon Treaty purposes. The CWT database houses information relating to the release, sample, and recovery of coded wire tagged salmonids throughout the Pacific region. These data must meet stringent validation criteria for inclusion in the permanent database.

The estimation of the contribution of stocks to the catch of each in the fishery, requires CWT release groups to represent the component stocks, a statistically adequate number of recoveries, a ratio of the sample for CWTs to the catch in each fishery or group of fisheries is known, and the escapement ratio of tagged to untagged population components. To fully estimate the fishing associated mortality, it is necessary to develop estimates of the non-landed fisheries mortality, i.e. net drop, troll shakers or releases of hooked fish. Chinook are exposed to the fisheries mortality over a number of years due to their range of ages of maturity. This requires estimates of the age specific fisheries mortality to determine brood year production necessary for evaluating productivity

When fisheries are sampled in known proportions, number of individual with a CWT code in a sample of a known proportion of a catch, can be expanded to estimate total numbers of individuals with that CWT code taken in the fishery. The number of tags of a CWT released, the sum of estimated numbers of the CWT code in each fishery's catch, and the total numbers of CWTs recovered in the hatchery or the spawning grounds, an estimate can be made of the survival from release into the river to the return from the ocean. The proportion of the total accounted for CWTs (all fisheries and hatcheries) accounted for in all fisheries estimates the total exploitation rate on that stock. The proportion of the total accounted for CWTs (all fisheries and hatcheries) estimated in a fishery provides an estimate of a fishery specific exploitation rate. With known proportion of the population represented by the individuals with CWTs, the numbers of CWTs estimated in a fishery, and the total catch of that fishery, and estimate of the fishery specific harvest rate on a population can be made. The life history trajectories of the chinook as indicated in Table 1 complicates the extrapolation of annual fisheries data to brood year exploitation rates. In order to estimate the effect of fisheries on the survival of a population, the estimates based on the landed catch must be adjusted by estimates of mortalities caused by the actions of the fishery but included in the estimates of the landed catch.

5.2.3. Management Processes

Because the coded wire tag information indicated that fisheries in other jurisdictions intercepted significant quantities of Puget Sound chinook, Nooksack stocks included, it was necessary for the co-managers to cooperate in national and international management processes in order to ensure that local management objectives are met. The Pacific Fisheries Management manages the fisheries in the Extended Economic Zone of the United States off of the States of Washington, Oregon and California. The PFMC is responsible for regulation of ocean fisheries to ensure an escapement of chinook, on a stock by stock basis, from the ocean fisheries to the state coastal and internal waters to required to meet biological and legal requirements for conservation and allocation objective. The co-managers provide the PFMC, through the North of Falcon process, the information required to manage ocean fisheries to meet the requirement of conservation and allocation of Puget Sound Stocks. The Pacific Salmon Treaty (1985) created the Pacific Salmon Commission to prevent overfishing, provide for optimum production, and provide for each party to receive benefits equivalent to the production of salmon originating in its waters where intercepting fisheries of one nation affected the ability of the other to achieve conservation and management objectives.

5.2.3.1. The Co-managers

The Boldt Decision (*U.S. v Washington)* interpreted the language of the treaties made with Washington tribes "the right of taking fish at all usual and accustomed grounds and stations is further secured to said Indians in common with all citizens of the Territory" to mean sharing equally in the opportunity to take fish sharing means the opportunity to take up to 50% of the allowable harvest. Prior to the Decision in 1974, most commercial fisheries on Puget Sound salmon were conducted in marine waters, with no explicit management units or escapement goals. The Boldt Decision encouraged the development of significant tribal fisheries at the mouths of Puget Sound rivers, and required the development of spawning escapement goals for each management unit. The court maintained continuing jurisdiction over the implementation of the decision.

The Fish and Wildlife Service initially provided technical assistance to the tribes to develop the information and management skills required to ensure identification of conservation objectives, identification of harvestable surplus and the allocation of the allowable harvest between tribes and the citizens of the State. The Tribes developed programs to provide them with the ability to make responsible management decisions affecting the treaty reserved natural resources. The tribes, in consultation with the State of Washington were responsible to see that fisheries under their respective jurisdictions were regulated to ensure that the spawning escapements (the numbers of spawning adults), and respective 50% shares on a stock by stock, region by region, basis were met or any differences were agreed.

Initially, the State of Washington did not trust the tribes, and much time and money was spent arguing issued before a federal mediator. In the early 80s the State of

Washington decided that more could be accomplished by cooperation than by litigation, and co-management was born. The Puget Sound Salmon Management Plan (PSSMP 1985) set out agreed management objectives and protocols for developing agreed run forecasts and fishing regimes. The PSSMP identified management units no smaller than a system that flows into saltwater, unless component populations exhibit a difference in migration timing, or as otherwise agreed by the co-managers. The implementation of the PSSMP is now integrated with other management processes.

5.2.3.2. Pacific Fisheries Management Council

The Fisheries Management and Conservation Act (FCMA) of 1976 (last revised as the Sustainable Fisheries Act of 1999) extended the fisheries jurisdiction of the United States to the Extended Economic Zone, and established regional fish management councils to manage fisheries off shore from 3 to 200 miles. The Pacific Fisheries Management Council is responsible fisheries off the coast of California, Oregon and Washington. The Council recommends fisheries management measures to the National Marine Fisheries Service (NMFS). The Council has 14 voting representatives from Oregon, Washington, Idaho and California chosen by the Governors of each state to represent state or tribal agencies and recreational and commercial fishing and marine conservation.

The directions to the Council are that conservation and management issues shall:

1. Prevent overfishing while achieving optimum yield.
2. Use best available science.
3. Manage stocks through their range as a unit, with interrelated stocks .
4. Not discriminate between residents of different states and contain fair and equitable allocation of opportunity.
5. Promote efficiency without relying solely on economic allocation.
6. Allow for variations in fisheries, resources and catches.
7. Minimize costs and avoid duplications
8. Take into account the importance of fisheries to communities.
9. Minimize bycatch.
10. Promote safety of life at sea.

U.S. fishery regulations must comply with many other laws including the National Environmental Policy Act (NEPA), the Marine Mammal Protection Act (MMPA), The Endangered Species Act (ESA), the Coastal Zone Management Act (CZMA), and the National Marine Sanctuaries Act. International agreements and organizations, and the United Nations Code of Conduct for Responsible Fisheries also play a role in the shaping of U.S. fisheries.

The council is composed of Council members, staff, advisory bodies, and the public. Pacific coast salmon fisheries in Council managed waters focus on chinook and coho salmon. The Councils Salmon Fisheries Management Plan describes the goals and methods of salmon management. The plan has an annual goal for spawner escapement goals and provides for the allocation of harvest.

The basic theory of conservation included in the plan is the Optimum Yield, the catch that will provide the greatest overall benefit to the nation. The Optimum Yield is the Maxim Sustainable Yield (MSY), the largest long term average catch that can be taken from a stock under prevailing ecological and environmental condition, reduced by economic, social and ecological factors. MSY is associated with the number of spawners required on average to achieve this goal. The MSY is based on long term average that can only be calculated from historical data that might not reflect MSY under current or future conditions.

Most of the conservation objectives for stocks north of Cape Falcon have been included in U.S. District Court Orders. Under these orders for Washington Coastal and Puget Sound Stocks (US v Washington 626 F. Supp. 1405 (1985) and Hoh v Baldridge No. 81 [R] C) the Treaty Tribes and the WDFW agree to annual spawner targets. Because some of the stock components present in waters under the jurisdiction of the Council are subject to minimal harvest impacts because of migration timing or distribution, the Council ability to affect the overall trend in abundance through harvest restrictions is negligible. While harvest has contributed to the declines in salmon abundance, the primary reason for their decline has been the degradation and loss of freshwater spawning, rearing and migration habitats, key factors in determining the MSY of salmon populations. The Council chooses not to reduce the MSY to account for the new degraded freshwater habitat conditions.

The Council follows a pre-season process to develop recommendations for the ocean fisheries. In February, reports of the previous season and forecasts of abundance for the coming season are released. The Council meets in March to develop season options. Hearings are held between March and April to review options and final recommendations are recommended during an April meeting and adopted by NMFS on May 1. There is an iterative process between the levels set by the PFMC for the ocean fisheries and the escapement of salmon required in the coastal and internal waters to meet conservation and allocation objectives. Agreement to a nominal fisheries plan occurs during the North of Falcon (NOF) process within the PFMC process. The specific fisheries in the plan are adjusted during the year when new information generated during fisheries suggests that conservation or allocations objectives will not be met.

5.2.3.3. Pacific Salmon Commission
The Pacific Salmon Commission (PSC) succeeded the IPSFC in 1985 with the conclusion of the Pacific Salmon Treaty, an agreement between the United States and Canada concerning the management of their salmon fisheries. In order to fulfill the obligation to prevent over fishing, provide for optimum production and ensure that both countries

receive benefits equal to the production of salmon from their waters, it was necessary to establish agreed programs to provide the information on interceptions by each country on stocks originating in the waters of the other. The Southern Panel was established to coordinate the management of chinook, coho and chum salmon on the southern U.S. Canada region, and the Fraser Panel retained the management functions of the IPSFC for sockeye and pink salmon fisheries in the Fraser Panel Area which included Point Roberts, San Juan Islands and the Strait of Juan de Fuca.
The PSC established a Joint Data Sharing Committee, reporting to the Standing Committee on Research and Statistics to facilitate data exchange between the two parties and develop standard methods of reporting and analyzing CWT data. The U.S. repository for this data is the RMIS at the PSFMC facility. The Chinook Technical Committee (CTC) developed a model to estimate stock-age-specific exploitation rates from a cohort analysis of CWT recovery data. The initial single stock multiple brood and fishery model was developed in 1984 to reduce harvest rates to a level that would allow rebuilding by 1998. This model underestimated the time required for recovery because of the affect of aggregated stocks under the ceiling management. The final model during the 1984 negotiations incorporated four stocks and nine fisheries. As the need for added stratification of fisheries was determined the model was modified in 1987 to simulate 26 stocks and 25 fisheries and by 1994 increased to 30 stocks and 29 fisheries. The University of Washington developed a user friendly version of the CTC model named CRiSP Harvest, based on the 1995 CTC model to explore the effects of various harvest management regulations on chinook stock rebuilding.

The 1999 Annex to the Treaty established chinook fisheries regimes designed to constrain fisheries exploitation to meet spawning escapement goals. Abundance based regimes were established for Southeast Alaska, Northern British Columbia, and the West Coast of Vancouver Island fisheries complexes because of their impacts on mixtures of chinook populations. An abundance Index is the ratio between the projected age specific abundance of natural and hatchery stocks and the abundance observed during a base period (1979-1982). The allowable harvest will vary up or down based on the relationship of the abundance index. The fishery specific exploitation rate each year will be scaled to the same proportion of the base year rate as the projected abundance is related to the base year abundance. Individual Stock Based Management Regimes (ISBM) constrains impacts on individual stocks of naturally spawning chinook. For stocks not achieving escapement goals, there is a general obligation for Canada to reduce its adult equivalent mortality rates by 36.5% from the base period rate and the US to reduce its of the parties adult equivalent mortality rates by 40% from the base period rate.

CWT information the ocean migration patterns and vulnerability of the Nooksack chinook stocks demonstrated that Canadian fisheries in the Strait of Georgia and the Southern West Coast of Vancouver Islands were major harvesters of Nooksack Chinook. The realities of the chinook management in fisheries in the Southern Panel area is that, as in the PFMC management, the contributions of the Nooksack Early Management Unit represented a negligible contribution to the harvest in those fisheries, but those fisheries accounted for a significant portion of the total exploitation on the stock. As a result most of the time and energy of the PSC is devoted to the larger stocks that contribute a significant portion of the catches in a fishery as a single stock or a group of stocks. The Biological Opinion by the National Marine Fisheries Service concerning the 1999 amendments to the PST acknowledged that it would be difficult to meet the Recovery Exploitation Rate (RER) the level of allowable harvest that would ensure rebuilding of the Nooksack Early Chinook Management Unit with all harvest in US waters south of Canada eliminated given the expected exploitation rates in the Canadian fisheries. The present agreement for conservation and management of salmon between the United States and Canada expires at the end of 2008 except for management of Fraser River sockeye and pink salmon which expire at the end of 2010.

Control of fishing mortality becomes easier as the proportion of the stock of concern in the harvest becomes larger. The limitation of fishing mortality can be implemented in several ways. Where there is sufficient information on the timing and relative abundance of a stock of concern through a particular fishing area, time and area closures become the method of choice. The more precise the information of timing an stock contributions is, the more restricted the time and area closures can be without disrupting the harvest on other stocks with harvestable surplus. In those instances where the chinook of concern may be taken during the course of fisheries on other salmon species, and the fish are alive at capture, chinook may be returned to the water. Although there is fishing mortality in these cases, it is much less the total chinook handled.

It is in this context that the Nooksack Harvest Management plan, a component of the Regional Management Plan governing fisheries in Puget Sound was developed. The Regional Management Plan concerning harvest was submitted to the National Marine Fisheries Service in 2004 for as a limit on the application of the Endangered Species Act take prohibitions imposed by the Secretary of Commerce on activities affecting the Puget Sound Chinook Evolutionarily Significant Unit (ESU) under Section 4d.

5.2.4. Harvest Management Tools

5.2.4.1. Fisheries Resource Allocation Model (FRAM)

The Co-managers developed a Fisheries Resource Allocation Model (FRAM) which combined agreed information on the contributions of salmon stocks to fisheries in a manner that would allow an estimate of the stock contribution to each fishery given pre-season forecasts of each stock abundance, and estimated levels of effort in each fishery by treaty and non-treaty fishers. The summation of the of estimated fisheries mortalities by stock group and allocation group provided the basis for determining whether a particular fishing scenario provided the agreed escapements and allocations on a stock by stock basis.

In the late 1970s, the Washington Department of Fisheries (Now WDFW) and the US National Bureau of Standards (NBS) developed a model for evaluating alternative fishery regulatory packages coded in FORTRAN and run on a mainframe. In the 1980s, the proliferation and development of personal computers allowed the model to be converted into spreadsheet models. The initial conversion, the Coho Assessment Model (CAM) was used until the mid 90s and its report generation capability was improved and a Terminal Area Management Module (TAMM) provided more detailed information on terminal area fisheries. As the demand for information increased, it became difficult to evaluate fisheries regimes in the spreadsheet models, and in the mid 90s the CAM was reprogrammed in Quick BASIC and renamed FRAM. Because common algorithms in the spread sheet models were used to manage both coho and chinook, the new FRAM was developed to evaluate fisheries regimes for either chinook or coho by using different input file configurations. In 1998 FRAM was converted to Visual BASIC to use the user interfaces in MS Windows. A multi Agency Model Evaluation subgroup reviewed model performance and parameter estimation methods and revisions were made between 1998 and 2000.

FRAM is a discrete, time-oriented, age structured, deterministic computer model intended to predict the impacts from a variety of proposed fishery regulation schemes during a single management year. It produces point estimates of fishery impacts by stock for specific time periods and age classes. It tracks the progress of individual stock groups as the fisheries in each time step exploit them. In each time step, all pre-terminal fisheries operate on the entire cohort and all terminal fisheries operate on mature fish.

There are 33 stock groups currently represented in the Chinook FRAM. Each of these groups have adipose clipped and non-clipped components to allow assessment of mark–selective fishery regulations. The model then processes clipped and un-clipped fish as separate stocks, expanding the number of chinook stock groups to 66. The stocks represented in FRAM were chosen based on the level of management interest, their contribution rate to fisheries and the availability of representative CWT recoveries in the fisheries. There are 73 fisheries in the Chinook FRAM including pre-terminal and terminal fisheries in Alaska, Canada, Washington , Oregon and California to allow assessment of and account for all fishing related impacts to the stocks. The time step structure in FRAM provides a level of resolution that corresponds to management planning seasons, and species specific migration and maturation schedules. The number of time steps was restricted to four in the Chinook FRAM those necessary for fish management purposes, October to April 1, May-June, July September and October-April 2 . The time step resolution is limited by the CWT database. Increasing the time steps, decreases the CWT recoveries in a time-area strata and increases the variance of the exploitation rates in those strata. At each time step, a cohort is subjected to natural mortality, pre-terminal fisheries, and maturation.

5.2.4.1.1. FRAM Assumptions

The value of FRAM are based on the following assumptions:

1. CWT fish accurately represent the aggregated stock group with may contain hatchery and natural components.
2. Chinook length at age is stock specific and constant from year to year to allow estimation of legal size in size-limit fisheries.
3. Stock distribution and migration is constant from year to year and estimated as the average distribution in the base period data. In the absence of information on annual variability, fishery-specific exploitation rates are computed relative to the entire cohort.
4. Chinook are assumed to be vulnerable to gear only once in each time area stratum as the catch equations are discrete and not instantaneous.

The FRAM base period is calibrated using the escapement, catch and CWT recovery data from 1974 to 1979 brood year CWT releases because fisheries were being conducted across an extensive geographic area and over an extended time period giving the best representation of CWT stock distribution. The Nooksack Early Management Unit is an out of base stock, one that had no indicator stock CWTs in the base period, and CWT data for these stocks are translated to the equivalent base period recovery and escapement data using known fishing effort and harvest relationships between recovery years. The base period data are used to estimate base period stock abundances and age-specific time-area fishery exploitation rates and maturation rates for modeled stocks derived from species-specific cohort analysis procedures to reconstruct a pre-fishing cohort size for each stock and age group using assumed natural mortality and incidental mortality rates.

5.2.4.1.2. FRAM Input values

1. Abundance estimates for each stock or stock aggregate are segregated by age class from age 2 to age 5.
2. Size limits where applicable
3. Catch mortality in either of five forms: quota, exploitation rate relative to the base period, a ceiling, selective harvest or for Puget Sound terminal fisheries, a harvest rate.
4. Release mortality based on studies of hook and line fisheries, or net fisheries. Mark selective fisheries also have mortality due to the inappropriate retention of un-clipped fish, or the mortality of a clipped fish subsequently released.
5. Mortality not otherwise associated with direct handling or landing, i.e. drop off of a hook and subsequently die, or drop out of a net and subsequently die.

5.2.4.1.3. FRAM Operations

Results of FRAM model runs are expressed in printed FRAM reports or Excel spreadsheets that are linked with FRAM reports. TAMM spreadsheets provide comprehensive summaries of fishery mortality, exploitation rate, run size and escapement for key stocks during the annual salmon season setting processes. For each time step and fishery, FRAM scales the predicted cohort size for the current year to the base period for the age 2 through age 5 cohorts. Each cohort is then processed through a time step loop where natural mortality is applied to the beginning cohort size, the projected catches for all fisheries in the time step are executed and totaled, and the remaining abundance of the stock is calculated. At the end of the time step loop, the program checks for the presence of a TAMM. If no TAMM has been specified, processing is complete and the terminal rune sizes are calculated. If a TAMM has been specified, FRAM will repeat processing through specified fisheries and time step loops.

After the pre-terminal catch has been calculated, the number of fish in each cohort maturation is calculated according to a time-area specific rate calculated from the base period data. The mature portion of the cohort is available to those fisheries that have been designated as harvesting only mature fish while the immature portion of the cohort is used to initiate the next time step. All fisheries are designated pre-terminal or terminal in the base period data. Escapement is defined any fish from the mature cohort that does not die from fishery related mortality. All maturation and escapement occurs within a single time step.

Fishery related mortality for chinook is expressed as a nominal value or adjusted for Adult Equivalents (AEQ) to account for the multiple ages that are available to fisheries. This allows all mortalities to be expressed as the number of fish that would have escaped to spawn in the absence of fishing adjusted for natural mortality. The AEQ s are calculated from the CWT base period calibration and consider age specific natural mortality and maturation rates calculated from CWT recoveries. The AEQ at maximum age is 1 and all other age-time step values are proportional to this value. The model stock proportion is the proportion of the total catch in a fishery that is accounted for by the modeled stocks as calculated during the model calibration process.

The FRAM interaction with the TAMM allows terminal area fisheries to be evaluated on a finer scale of resolution. The terminal areas are specified in the PSSMP and allow the development of unique regional management goals with the flexibility to analyze FRAM output according the their needs. Abundance levels of every Puget Sound stock are entered into the TAMM with the harvest impacts of all Puget Sound fisheries to allow fisheries specific impact analyses on stocks of interest. This allows TAMM to model fisheries at a finer time and area scale than FRAM. The TAMM fisheries impacts are summed into the terminal area impacts used by FRAM to calculated scalar inputs. TAMM allows the used of harvest rates (% of terminal area abundance) of the escapement of local stocks and the catch of all stocks (TAA) or the escapement and catch of local area stocks. (ETRS). The difference in fishery control mechanisms in TAMM creates problems in estimating FRAM fishery scalars because the run size in each terminal region is dependent upon the impacts from all other regions. An iterative process reruns terminal area time steps until the difference between TAMM specified expected fishery impacts and the FRAM estimates calculated from base period exploitation rates are within 0.1% of the expected value. On each iteration FRAM scalars are adjusted by the proportion of the expected value divided by the FRAM estimate for each terminal fishery.

5.2.4.2. Rebuilding Exploitation Rate

Several Management units have calculated a rebuilding exploitation rate (RER) is the highest allowable exploitation rate for a salmon population given normal or increased levels of return. Lower than usual returns generally require special restrictions in harvest, as outlined in the co-managers' Puget Sound Chinook Management Plan (PSIT and WDFW 2004). The rate is designed to both minimize the risk of natural origin (NOR) spawning escapement falling below some critical escapement threshold (CET) and insure, at a given level of probability, that the escapement would reach an rebuilding escapement threshold (RET) if the RER was maintained over 25 years. The RER is inclusive of all harvest mortalities on the population, direct and indirect.

A general method has been used is to forecast recruits 25 years into the future based on a derived spawner-recruit function for the population and assumed environmental survival conditions; test a range of exploitation rates (ER) on population abundance; and use risk assessment to determine the maximum ER value that satisfies the risk criteria, this maximum ER value becomes the RER. Escapement, age, harvest, and environmental covariate data for recent years are used to determine spawner-recruit function parameters. Environmental covariates include marine survival indices and freshwater discharge during the incubation period.

There are three analytical stages to developing an RER: first is the data collection and run reconstruction in the abundance and productivity (A&P) maintained in an Excel file, next is parameter estimation for the spawner recruit function in the Dynamic Model Excel spreadsheet, and finally the risk assessment analysis done with viability and risk assessment procedure (VRAP), a program in Visual Basic run from an Excel spreadsheet.

The NMFS has generated estimates of RERs for the Nooksack early chinook populations with this analytical method. For each combination of spawner-recruit relationship and exploitation rate they ran 1000 25-year projections. Estimated probabilities of exceeding the RET were based on the number of simulations for which the average of the spawning escapements in years 21-25 exceeded the RET. Estimated probabilities of falling below the CET were based on the number of years (out of the total of 25,000 individual years projected for each target exploitation rate for a particular spawner-recruit relationship) that the spawning escapement fell below the CET. The VRAP was run for exploitation rates of 0 to 0.51 in steps of 0.01. The percentage of the escapements that fall below the lower abundance threshold and the percentage of the escapements at the end of the 25 years (averaged over the last 5 years) that are above the rebuilding abundance threshold are calculated and presented in Table 5.4.

The RER is chosen as the lower of the exploitation rates that results in escapements 1) falling below the CET by 5 percentage points or less than with no fishing during the 25 year period and, 2a) above the RET at least 80% of the time at the end of 25 years OR 2b) above the RET no more than 10 percentage points different than with no fishing. For the Nooksack, it was the 5% rule that would determine the RER. Due to the variability in estimating the RER with multiple runs of VRAP, the model was run 25 times using the same parameters but a different starting seed that generates at random the parameters for marine and freshwater survival drawn from the 1984-1997 period.

Detailed results of these projections are summarized results are in Table _. For the Nooksack spring chinook management unit, the indicated target exploitation rates are 0.20 – Ricker, 0.13 – Beverton-Holt, and 0.17 – hockey stick. Since all three models performed similarly, we propose to use the average of these values as the target rebuilding exploitation rate (RER). This average is 0.17, rounding to the nearest whole percentage exploitation rate.

To make the RER compatible with the fishery model used in annual fishery planning (the FRAM model), the RER derived from data in the A&P tables were converted to a FRAM equivalent RER using the 1996-1999 average ratio of the post season exploitation rate estimates derived from FRAM divided by the exploitation rate estimates from the A&P table (Table 5.5). This period of years represents recent fishing patterns and exploitation rates more similar to that of the RER. Using this conversion, the FRAM RER to use for annual preseason fishery planning purposes is 10%.

0.17 (RER from VRAP) X 0.57 = 0.10 (RER in FRAM terms)

The co-managers have not yet agreed with the NMFS analysis because of inconsistencies between the results of the model and the information from EDT modeling and observed returns per spawner in the North/Middle Fork Population.

5.2.5. Guiding Principles for Managing Harvest Impacts on Nooksack Early Chinook

- Conserve the productivity, abundance and diversity of the Nooksack early chinook management unit.
- Manage risk through fishery mortality limits which incorporate a consideration of the uncertainty of estimates of current and future abundance and productivity,

and on-going monitoring, research and analysis to quantify risk factors and modify the plan as needed to minimize such risks

- Meet ESA Jeopardy standard that harvest does not appreciably reduce the likelihood of survival and recovery of the ESU.
- Provide an opportunity to harvest surplus production from other species and populations.
- Account for all sources of fishery related mortality
- Adhere to the principles of the Puget Sound Salmon Management Plan, and other legal mandates pursuant to US v. Washington to ensure equitable harvest sharing opportunity among tribes, and among treaty and non-treaty fishers.
- Achieve the guidelines on allocation of harvest benefits and conservation objectives that are defined in the 1999 Chinook Chapter to Annex IV to the Pacific Salmon Treaty.
- Ensure exercise of treaty reserved tribal fishing rights.
- Directed fisheries, fisheries in which more than 50% of the total fishery related mortality is made up of listed Puget Sound chinook, are precluded except for small tribal ceremonial and subsistence harvest, and restricted research related fisheries.

Harvest management alone cannot recover or rebuild WRIA 1 chinook stocks, but can help conserve the abundance, and diversity of populations while habitat capacity and productivity recover. Current harvest impacts only represent a small fraction of the historic production capacity of the populations. Restoration and protection of freshwater, estuarine, and nearshore marine habitat in WRIA 01 is essential to substantially improve productivity as is necessary for recovery.

While past harvest may have contributed to the reduced chinook abundances in WRIA 1, it doesn't follow that the absence of harvest will restore historic abundances due to impaired habitat capacity and productivity. For example, wild abundances of North/Middle Fork early chinook have not demonstrably increased despite a large increase in spawners from the large hatchery returns. This supports the hypothesis that habitat capacity and productivity are currently the primary factors limiting recovery.

Stewardship of chinook populations will come first in managing the resource, to ensure adequate annual wild spawning populations will be available for available habitat capacity and productivity. This will ensure harvest provides for recovery of healthy populations as habitat recovers to provide sustainable fishing opportunities over time. When faced with uncertainties, managers will err on the side of the resource.

- Where a mixed-stock fishery substantially impacts more than one stock unit simultaneously, harvest management should be geared to conserve and recover the weakest of the smaller stock units. This may mean reducing overall harvest rates, implementing selective fishing, or changing the location and timing of harvest activities to allow for stock differentiation (e.g. time or area closures; terminal fishing).

5.2.6. Escapement Goals

The Maximum Sustainable Harvest escapement goal was the initial objective of the PSSMP to achieve conservation and management objectives for each stock. Due to the lack of information relating spawning abundance to production during the early 20th century before major development in the watershed degraded the habitat, a MSH escapement goal can not be directly calculated. The co-managers adopted a goal of 2,000 spawners in each Nooksack early chinook population as a measure of when directed harvest could be considered.

Because the current management focuses on restricting exploitation rates based on the best available scientific information the management focus has changed from meeting escapement goals, which can only effectively managed for in the terminal area to meeting a variety of exploitation rates associated with different spawning escapement levels associated with actual or theoretical stock-recruit functions.

In the Nooksack early chinook management unit, there is insufficient data to compile a MSH escapement from spawner recruit functions under historic conditions and the co-managers are concerned that developing spawner recruit functions under existing degraded habitat conditions would jeopardize the recovery of the ESU and not support the treaty reserved fishing rights.

Where there is adequate spawner recruit information co-managers have chosen to identify an exploitation rate that represents an upper management threshold expected to provide the MSH escapement or a buffered surrogate. At levels above the upper management threshold there is harvestable surplus which would provide for a directed harvest or allow a higher level of incidental harvest. Demographic and genetic theory indicates that when the spawning abundance falls to a very low level, there is a significant risk of demographic instability, loss of genetic integrity and extinction. That level is not clearly identified in salmon populations, but the management plan provides for a low abundance threshold (LAT), a level of spawner abundance set well above the point of instability. In the Nooksack early chinook management unit, the co-managers have set that the LAT at 1,000 natural origin spawners in each population.

When the spawning escapement falls below the LAT, as it does regularly in the Nooksack early chinook management unit, the co-managers will implement extraordinary to increase the spawning escapement above the LAT or reduce the SUS exploitation rate to or below a critical exploitation rate ceiling (CERC). For the

Nooksack early chinook management unit, the CERC is an annual 7% Southern US (SUS) exploitation rate until April 30, 2010, with the possibility that the SUS exploitation rate will exceed 7% but not 9% in one year. Restrictions below this level would effectively limit treaty and non-treaty harvest opportunity on non-listed species and populations without ensuring recovery. If further resource protection is necessary, it must be found in mixed stock fisheries in Canada and Alaska, improving habitat conditions and/or providing supplementation where effective and appropriate. The Minimum Fisheries Regime (MFR) represents the lowest level of fishing mortality that is possible , while allowing a reasonable harvest of the surplus abundance of non-listed chinook, and sockeye, pink, coho and chum salmon. Reducing tribal fisheries to the levels specified in the MFR, while requiring a significant sacrifice of fishing opportunity for treaty reserved fishing rights, provides the minimum acceptable level of fishing that allows some exercise of those rights and their demonstrates their contribution to the recovery of the Chinook ESU to a point that would satisfy their treaty reserved fishing rights. The Co-managers established the CERC in consideration of the MFR and FRAM simulations of responses to the critical status for some management units. If there are significant changes in FRAM that alters the calculation of exploitation rates,

5.2.7. Harvest Management Actions and Strategies

The co-managers will take the following actions through April 30, 2010, consistent with, and in addition to commitments contained in the Harvest Management Component of the Comprehensive Management Plan for Puget Sound Chinook determined by NMFS to be in according to the Section 4d rule exempting fisheries covered by the plan from take prohibitions of Section 9a of the ESA:

- When escapement levels projected to be less than 1,000 NOR spawners, the LAT, in each of the Nooksack early chinook management unit populations:
- Fisheries in the Southern US will be planned using the best available information and tools during the PSSMP, PFMC, and PSC processes to limit the total mortality of all fisheries less than 7% of the returning adults, with the potential to exceed 7% but not 9% in one year under exceptional conditions according to the Minimum Fishing Regime.
- Total mortality will include only two limited directed harvest fishers
- A limited tribal ceremonial harvest of Nooksack early chinook in the Nooksack river, amounting to less than 10 natural origin spawners, and co-migrating cultured stock in excess of spawning requirements.
- A limited tribal subsistence fisheries targeted at less than 20 natural origin spawners and co-migrating cultured stock in excess of spawning requirement early July from Slater Road crossing to the river mouth in the lower Nooksack, and from the Mosquito Lake road crossing down to the SR 9 bridge in the lower North Fork to meet minimum tribal requirements.

- Fisheries in Bellingham Bay and the Nooksack River directed at fall chinook will not open prior to August 1. Subsequent fishing in the Nooksack River will occur in upstream zones on a weekly basis as early chinook clear these areas. Accordingly, the area extending two miles downstream of the confluence of the North and South Forks will not open prior to September 16.

- If escapement levels are projected to exceed 1,000 NOR spawners, the LAT, in each of the Nooksack early chinook management unit populations, remain at the MFR, unless that total mortality in all fisheries falls under an RER developed by jointly by the co-managers and NMFS, in which case Southern US harvest will be planned to equal or less than the agreed RER.

- Regulations will be promulgated to govern fisheries according plans developed and agreed in the PSSMP, PFMC and PSC processes.

- Enforcement actions necessary to verify that the regulations governing fisheries are observed and provide penalties for violations sufficient to deter violation of regulations promulgated to implement agreed fisheries will be implemented.

- Focus harvest management and monitoring of populations on ESA-listed or at-risk stocks. Both harvest management and hatchery production strategies should focus on the protection and recovery of at-risk wild salmon stocks (chinook, coho). Harvest monitoring should also include listed bull trout. Strategies should be designed to maintain the level and distribution of spawning escapements of naturally-produced salmonids that will protect the genetic diversity and resilience of populations within each ESU or genetic diversity area (GDU). Escapements in excess of targets will provide ecological benefits for chinook, bull trout and coho potentially increasing their abundance and productivity.

- Harvest management decisions are made at the management unit scale, and each management unit can contain more than one recognized population, within population diversity, and small groups of diverse groups of fish not yet recognized as stocks (upper North Fork coho, riverine sockeye etc.). When fisheries exist that may impact unique salmonids that appear to exist in small abundances, escapement and population data will be collected to help ensure genetic and ecological diversity are maintained.

- The State and Tribes will seek agreement on the total escapement rates, escapement levels, or escapement ranges that are most likely to maximize long-term surplus production (maximum sustainable yield or MSY) for wild populations or combinations of wild populations or management units. These rates, levels, or ranges will be based upon achieving MSH and will account for all relevant factors, including current abundance and survival rates, habitat capacity and quality, environmental variation, management imprecision, and uncertainty, and ecosystem interactions. MSH shall be calculated by using long-time series of accurate spawner and recruit statistics for each population where possible. When such statistics are not available, MSH may be calculated by using historical production, habitat availability, or the best available methods for calculation. Additionally, harvest management will consider the needs of smaller units or populations (upper North Fork coho, riverine sockeye, summer run steelhead, bull trout) to maintain viable population abundances and within population diversity and to maintain geographic distributions into less strong habitats (i.e. South Fork chum).

- Harvest management will be responsive to annual fluctuations in abundance of salmonids. Abundance of all WRIA 1 salmonid stocks that are likely to be harvested will need to be estimated yearly, both pre-season, in-season, and post-season. Survey effort will vary depending on stock priorities. Where direct measurement of spawner abundance are not possible, surrogate measures will need to be employed, such as abundance of index reaches.

- To accomplish the goal of maintaining or increasing genetic diversity within and among stocks, harvest should be managed to minimize differential selection for size, age, and return timing of wild populations, so as not to impede the goal of maintaining or increasing genetic diversity within and among stocks. Fishery selection within populations will be minimized to insure that population characteristics such as adult size, timing and distribution of population migration and spawning, and age at maturity are similar between the fished and unfished portions of the population. This means that the population will not be changing over time as the result of harvest influences except that a population may change back to its natural patterns as a result of this policy and other management actions. For the salmonids that have multiple spawning capabilities (bull trout, steelhead, cutthroat), the primary goal will be to prevent any significant harvest caused shift to sexual maturity at a smaller size and/or age.

- The fishery and hatchery management principles that are stated in the WDFW-Tribal Wild Salmonid Policy (WDFW and WWTT 1997) will be implemented by the Lummi Nation, Nooksack Tribe, and WDFW, who will cooperatively review and, where there is agreement, jointly amend management agreements and plans relating to affected fisheries. Such review and agreements shall utilize best available science and be made with appropriate consultation with affected stakeholders. Follow the principles of the Puget Sound Salmon Management Plan (PSSMP 1985), and other legal mandates pursuant to *U.S. v. Washington* (384 F. Supp. 312 (W.D. Wash. 1974), and *U.S. v Oregon*, in equitable sharing of harvest opportunity among tribes, and among treaty and non-treaty fishers.

    - Harvest Management Policy (WDFW and WWTT 1997): The fisheries will be managed to meet the spawning escapement policy as well as genetic conservation and ecological interaction policies.

- Spawner Escapement Policy (WDFW and WWTT 1997): The wild populations or management units to which this spawner escapement policy applies will be defined on a comprehensive, statewide, or regional basis. The parties will review existing court orders, joint agreements, and management plans to seek agreement on whether changes are necessary to be consistent with the goals of the wild salmonid policy. Within this context, sufficient escapement of appropriate naturally spawning fish will be provided to encourage local adaptation and maximize long-term surplus production that sustains harvest, and to provide for recreational opportunities and ecological benefits. Exceptions to this general policy may be developed on a regional basis through agreement of the Department and affected Tribes to provide for recovery and rebuilding of wild stocks or where natural productivity is low.
- Conserving Genetic Diversity Policy (WDFW and WWTT 1997): Genetic diversity within and among stocks will be maintained or increased to encourage local adaptation and sustain and maximize long-term productivity. Conditions will be created that allow natural patterns of genetic diversity and local adaptation to occur and evolve.
- Ecological Interactions Policy (WDFW and WWTT 1997): Wild salmonid stocks will be maintained at levels that naturally sustain ecosystem processes and diverse indigenous species and their habitats. Healthy populations of other indigenous species will be maintained within levels that sustain or promote abundant wild salmonid populations and their habitats
- Conserve the productivity, abundance, and diversity of the chinook populations that make up the Puget Sound ESU (PSIT and WDFW 2004).

- Manage risk. The development and implementation of the fishery mortality limits in the co-manager chinook harvest management plan (PSIT and WDFW 2004) incorporate measures to manage the risks, and compensate for the uncertainty associated with estimating current and future abundance and productivity of populations. In addition, the 'management error' associated with forecasting abundance and the impacts of a given harvest regime is built into simulating the long-term dynamics of individual populations. Furthermore, the plan commits the co-managers to ongoing monitoring, research, and analysis, to better quantify and determine the significance of risk factors, and to modify the plan as necessary to minimize such risks.
- Harvest plans must meet ESA or DPS jeopardy standards to not "appreciably reduce the likelihood of survival and recovery" of the ESU (50 CFR 223 vol 65(1):173).
- Harvest plans that assess total exploitation (harvest) rates will account for all sources of fishery-related mortality, whether landed or non-landed, incidental or

directed, commercial or recreational, and occurring in the U.S. (including Alaska) or Canada.

- To minimize conflict between recovery and other objectives, first priority in harvest management regimes should be to meet treaty fishing obligations. It is important to maintain fishing traditions and customs. Alternatives for fishers may be necessary (license buyback, alternate uses for fishermen's boats and gear), where harvest opportunities diminish.

5.2.8. Specific Harvest Actions

The low abundance management threshold is currently under review and under current conditions may be significantly less than 1000 spawners. After reviewing the best available information the co-managers in consultation with NMFS may establish more appropriate low abundance management thresholds.

With approximately 87% percent of the total annual harvest mortality occurring in Alaskan and Canadian fisheries (Table 4.10), the scope for total reducing fisheries impacts in Washington waters is limited. Net, troll, and recreational fisheries in Puget Sound have been shaped to minimize incidental chinook mortality to extent possible while maintaining fishing opportunity on other species such as sockeye and summer/fall chinook. The net fishery directed at Fraser River sockeye, in catch areas 7 and 7A in late July and August has caught very few Nooksack early chinook.

Total exploitation rates projected by the FRAM model for the 2001 – 2003 management years were 18%, 15%, and 20%, respectively. The analysis supporting derivation of a rebuilding exploitation rate (RER) for the Nooksack MU is in progress. It is recognized that tag data do not exist to support a direct analysis of the productivity of the South Fork stock, and given its status, there is ample reason to exert conservative caution in planning fishing regimes.

The co-managers are evaluating the productivity, abundance and diversity of the early chinook runs that could be expected from the Nooksack watershed under properly functioning habitat conditions, as well as those that might have been expected to exist under historical conditions at Treaty time. The calculation of a normal exploitation rate has not be made but at the current escapement goal of 2000 natural origin spawners in each population, and an exploitation rate of 60%, a AEQ recruit abundance of 5,000 in each population would be anticipated. An ambitious and long-term effort to restore and protect habitat, working in concert with appropriate hatchery production and harvest management regimes, is essential to recovery.

- The projected total harvest of early chinook by in-river tribal ceremonial and subsistence fisheries will be determined, during preseason planning, with reference to forecasted abundance of natural-origin and hatchery returns.

5.2.9. Data Gaps

Following are the highest priority needs for technical information necessary to understand stock productivity and refine harvest management objectives:

1) Improve estimates of population specific total escapement to the Nooksack basin, with emphasis on North/Middle and South Fork populations, including natural origin fish, and age data on these fish.
   a) Secure resources to read backlog of otoliths collected at the Kendall Creek hatchery to provide a complete evaluation of the contribution of the different release strategies.
   b) Improve the microsatellite DNA stock baselines of all chinook in the Nooksack Basin and conduct analyses to evaluate
      i) the NOR contribution of North/Middle Fork strays to the South Fork that can no longer be identified by otolith marks
      ii) the most appropriate break point to separate early and late chinook spawning in the South Fork
      iii) the relative success of chinook in the South Fork of the different populations as indicated by samples from the South Fork Smolt Trap
      iv) the relative success of North/Middle Fork spawners as indicated by samples collected at the Hovander smolt trap after eliminating the supplementation production identifiable by external mark (fin clip)
   c) Develop alternative spawning ground population estimates that will allow:

i) Update pre-spawning migration behavior through radio tags or DIDSON technology.

ii) Increase recovery of carcasses on the spawning ground to improve estimates of the NOR age structure, yearling/sub-yearling contributions, and population composition.

2) Investigate rearing conditions in the river and the estuary and near shore areas to assist in the development of habitat restoration and protection actions.
3) Improve estimates of stock specific natural early chinook smolt outmigration from the North/Middle and South Fork populations and late timed chinook.
4) Develop stock/recruit functions, or other estimates of freshwater survival data to monitor the productivity of the two populations and late timed chinook.
5) Collect information to determine whether the current SUS fishing regime, or the hatchery supplementation program, are exerting deleterious selective effects on the size, sex, or age structure of spawners.

Table 5.3. Optimum Values Calculated from the Beverton Holt Productivity Curves for the Nooksack Early Chinook Stocks Generated by EDT Model with Properly Functioning Conditions for Chinook Habitat

Stock	Spawners	Harvest	Return/Spawner	Population
North/Middle Fork	3,818	8,787	3.3	12,604
South Fork	1,960	5,161	3.6	7,121

Table 5.4. Results of VRAP runs for the Nooksack spring chinook management unit for each spawner-recruit function.

Note: The exploitation rate that results in escapements below the CET 5% or less, and above the RET 10% or more, than with no fishing are noted in the first two columns for each function. For each model run, the exploitation rate that results in a five percentage point or less difference than with no fishing is in the third column.

	Ricker			Bev-Holt			Hockey		
			0.20			**0.13**			**0.17**
	AT NO FISHING percentage of time		ER meeting 5% criteria	AT NO FISHING percentage of time		ER meeting 5% criteria	AT NO FISHING percentage of time		ER meeting 5% criteria
Run	**<LT**	**>UT**	**5%**	**<LT**	**>UT**	**5%**	**<LT**	**>UT**	**5%**
1	27.1	59.0	0.21	76.3	0.10	0.11	78.4	0.40	0.17
2	28.2	60.0	0.20	76.6	0.10	0.11	78.3	0.80	0.17
3	29.1	55.6	0.24	75.6	0.10	0.11	78.2	0.60	0.17
4	27.1	60.2	0.19	76.6	0.20	0.14	78.7	0.40	0.18
5	29.6	58.7	0.24	75.5	0.30	0.10	78.7	0.40	0.18
6	29.6	57.5	0.23	76.4	0.20	0.13	77.6	0.50	0.15
7	25.9	61.8	0.18	75.6	0.30	0.10	77.8	1.20	0.16
8	27	61.0	0.21	75.6	0.30	0.12	78.4	0.90	0.17
9	28	57.9	0.18	76.2	0.00	0.13	78.2	0.40	0.17
10	27.6	59.9	0.24	76	0.10	0.11	78.2	0.40	0.17
11	26.4	60.4	0.21	76.1	0.10	0.11	79.5	0.50	0.20
12	29.3	58.1	0.25	76.3	0.00	0.12	78.3	0.40	0.17
13	27.5	58.2	0.18	76.6	0.00	0.13	78.1	1.00	0.16
14	28	58.6	0.24	77	0.10	0.15	78.3	0.90	0.17
15	27.1	61.1	0.21	76.8	0.20	0.15	78.2	0.60	0.17
16	27.5	59.9	0.20	76	0.20	0.11	78.2	1.00	0.17
17	25.6	61.4	0.12	76	0.10	0.12	78.7	0.20	0.18
18	26.4	61.6	0.17	76.8	0.30	0.14	78	0.60	0.16
19	25.6	61.2	0.21	77.3	0.10	0.17	79.1	0.20	0.18
20	28.6	57.8	0.23	77.1	0.10	0.15	78.3	1.10	0.17
21	26.6	61.8	0.21	77.1	0.10	0.15	78.4	0.70	0.16
22	26.2	61.9	0.18	75.9	0.60	0.11	79	0.50	0.19
23	27.3	59.8	0.17	76.5	0.20	0.12	77.8	1.30	0.16
24	28	58.4	0.21	76.4	0.10	0.13	77.9	0.60	0.16
25	25.2	61.2	0.14	75.8	0.30	0.11	78.6	0.70	0.18

Table 5.5. Ratio of FRAM exploitation rates to A&P derived exploitation rates for the Nooksack spring chinook management unit.

Return Year	A&P	FRAM	FRAM/A&P
1984	97%	43%	0.44
1985	94%	42%	0.44
1986	86%	41%	0.48
1987	94%	40%	0.43
1988	96%	49%	0.51
1989	85%	36%	0.42
1990	66%	30%	0.46
1991	79%	34%	0.44
1992	70%	34%	0.48
1993	33%	30%	0.91
1994	72%	27%	0.38
1995	46%	23%	0.51
1996	31%	18%	0.57
1997	36%	21%	0.58
1998	26%	15%	0.57
1999	28%	16%	0.57
1996-99 avg			0.57

Table 5.6. Estimates of the Origin of the Early Chinook Stocks Entering the Nooksack River.

Return Year	North Fk NOR	Total NF w/ Stray to SF	South Fk NOR	Total River Entry	SF+NF NOR	% NOR
1995	171	224	290	514	461	90%
1996	209	537	203	740	412	56%
1997	74	574	180	754	254	34%
1998	37	370	157	527	194	37%
1999	85	3820	166	3986	251	6%
2000	160	3426	284	3710	444	12%
2001	264	8146	267	8413	531	6%
2002	224	9723	289	10012	513	5%
2003	210	8519	204	8723	414	5%

Figure 5.1. Display of Beverton Holt Curves Generated By the EDT Model for North/Middle Fork and South Fork Nooksack Chinook Populations.

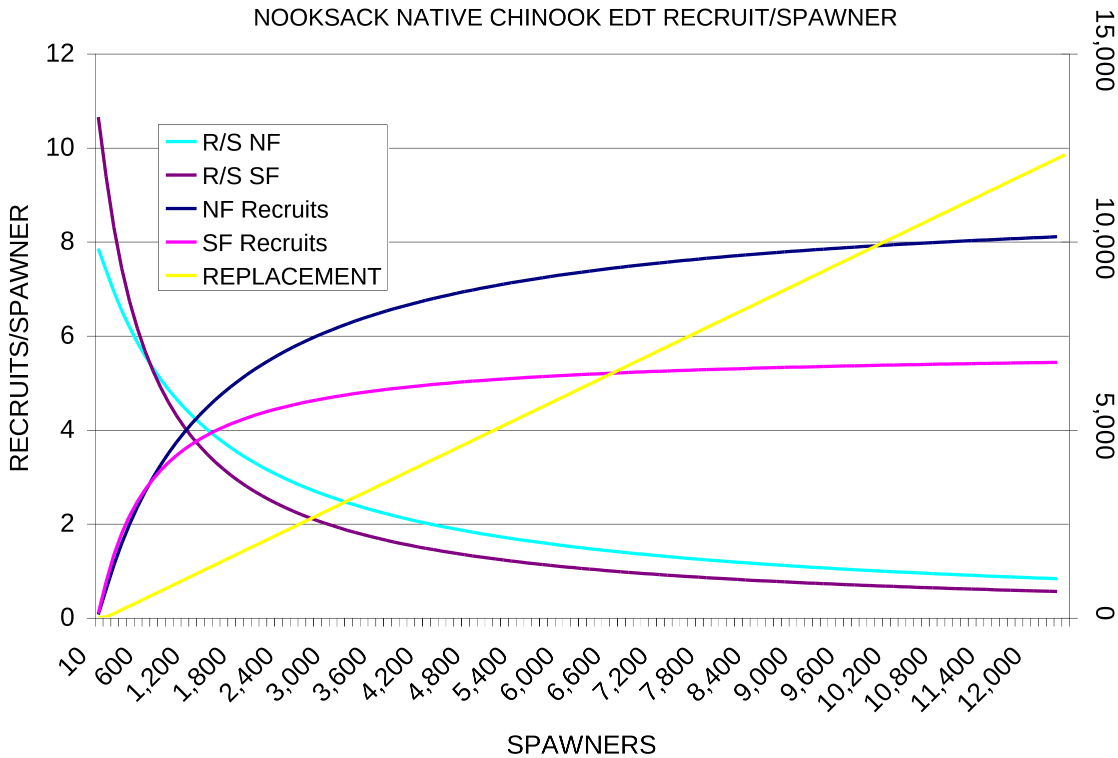
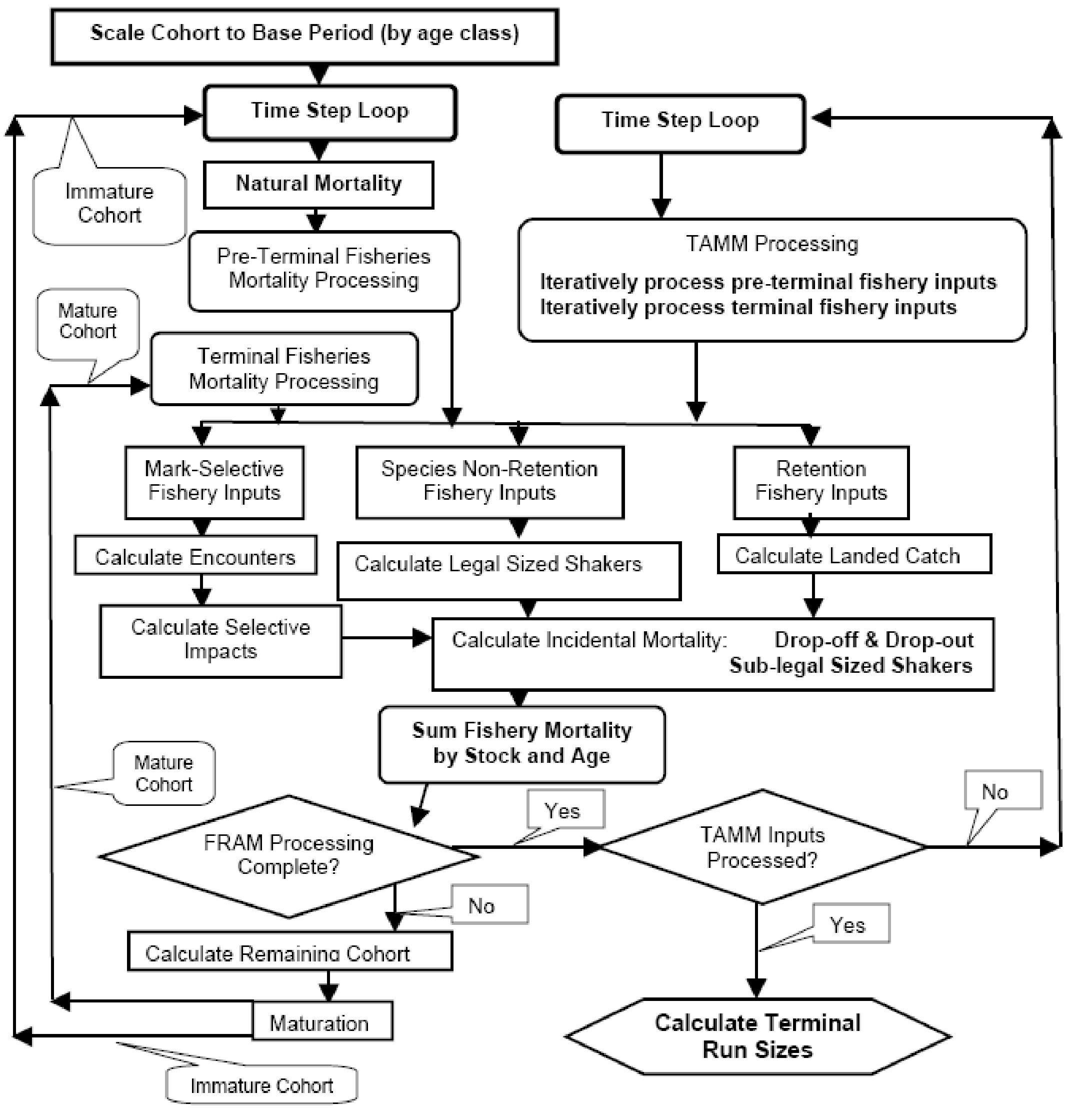


Figure 5.2. Flow Chart For the Chinook FRAM.



5.3. Hatchery

5.3.1. Recovery Objectives

- Use hatcheries to aid in the recovery of WRIA 1 wild salmonid populations using integrated principles of genetic conservation, ecology, fish culture, and fisheries management.

- Hatchery production of chinook and other salmon will neither cause further decline nor inhibit recovery of WRIA 1 naturally spawning early chinook populations. Genetic diversity within and among stocks will be maintained. Hatchery programs will be managed, and adaptively managed, to minimize adverse genetic and ecological interactions between hatchery origin (HOR) and natural origin (NOR) early chinook, which can include interbreeding among different stocks or populations, loss of genetic diversity within populations, domestication, competition, predation, and disease transmission between hatchery and wild fish.

5.3.2. Other Objectives

- Use hatcheries to sustain treaty-reserved fisheries and non-treaty fishing opportunities, in a manner consistent with salmon recovery.

- Use hatchery chinook coded-wire tag (cwt) and other marking programs (otoliths), and recovery programs in fisheries (cwt) and on spawning grounds (cwt, otoliths, adipose clip), to provide statistically reliable data for stock assessment and fishery evaluations.

- Use hatchery programs for education and outreach and to engage the community in salmon recovery, in a manner consistent with salmon recovery.

5.3.3. Guiding Principles

- Hatcheries cannot recover WRIA 1 early chinook populations, but can conserve genetic diversity for critically low abundance populations while habitat improvements occur. Hatcheries focused on recovery of at risk species can be considered an interim measure to conserve genetic diversity of native populations that are critically low in abundance while habitat recovers. They can also assist with restoring population spatial structure.

- Other hatchery programs will focus on maintaining genetic diversity within and among populations, minimizing risks from domestication, and potential ecological impacts to wild populations from competition and predation.

- As throughout Puget Sound, hatcheries currently provide the majority of the harvest for treaty and non-treaty fisheries as mitigation for past habitat degradation. Fishing opportunities and traditions need to be maintained through hatchery production, while the hatchery programs need to be managed to not degrade the genetic diversity, productivity, abundance and spatial structure of wild populations.

- While hatchery programs focused on recovery of at risk populations can maintain genetic diversity in the short term, hatcheries inherently can create a level of risk, however low, to wild populations (Busack and Currens 1995, Flagg et al. 2000). Over time these risks may increase, especially if wild population abundances are small. It is critical that restoration of habitat and habitat forming processes occur to increase wild population productivity, abundance, and spatial distribution. Healthy wild populations will support harvest, and reduce the need for artificial propagation. Healthy wild populations and reduced reliance on artificial propagation are important components of a comprehensive plan to minimize long-term risks of hatchery impacts to wild populations. Restoring habitat capacity and productivity are critical to reducing the risks from hatchery programs, even where overall population sizes are substantially increased from hatchery returns such as North/Middle Fork chinook.

- Hatchery management of chinook will ensure the maintenance of genetic diversity, productivity, abundance and spatial structure of wild populations, particularly native wild populations. Hatchery programs for listed and at risk species will have consistent, frequent evaluation, and adaptive management to avoid genetic or ecological impacts to wild chinook.

- Hatchery management will be integrated with harvest management to ensure natural origin (NOR) early chinook populations are protected through adequate escapements of NOR fish with minimal stray contributions from non-native or mixed origin hatchery fish.

- Habitat protection and recovery is critical to the survival of both wild and hatchery salmonids. For example hatchery propagation requires excellent water quality and sufficient quantity for efficient on-station incubation and rearing. After release, hatchery fish rely on the same habitats as wild fish. If habitat and water quantity and quality declines continue, most hatcheries and other fish rearing facilities will eventually fail. We cannot rely on increases in hatchery fish production to maintain harvest levels without addressing the habitat issues affecting wild and hatchery salmonids.

5.3.4. Management Strategies and Priorities

Hatchery reviews and operational commitments for anadromous salmonid hatcheries in WRIA 1 have recently been conducted under two processes. The first is the preparation of Hatchery Genetic Management Plans (HGMPs) for each facility program. Tribes submitted HGMPs for tribal programs and WDFW submitted them for WDFW programs and for third party operations including the Maritime Heritage Hatchery programs. The HGMPs are in a format developed by NOAA Fisheries to evaluate potential program risks to chinook, and include operational commitments for each program to ensure these risks are minimized. The NOAA Fisheries will consult with USFWS for potential impacts to other listed species such as bull trout that the USFWS is responsible for, as part of the NEPA review of NOAA Fisheries' Section 4d decision for HGMPs. These HGMPs include adaptive management and will be updated as needed by fisheries co-managers.

The second hatchery review process was by the Hatchery Scientific Review Group (HSRG 2003), which evaluated each hatchery program with respect to program and stock goals as described by fisheries managers. In addition to evaluating each program, the HSRG developed Statewide hatchery reform recommendations. The following principles include many of these recommendations.

- Operate hatchery programs as either genetically integrated or segregated relative to naturally spawning populations.

Hatchery programs may be classified and implemented either as *integrated* or *segregated* programs, depending on the genetic management goal for the broodstock.
Hatchery programs are integrated if a principal goal is to manage the broodstock as an artificially propagated component of a naturally spawning population. In contrast, hatchery programs are segregated if the management goal is to propagate the hatchery broodstock as a discrete or genetically segregated population, relative to naturally spawning populations.

A fundamental goal of an integrated program is to minimize genetic divergence between the hatchery broodstock and a naturally spawning population in areas where fish are released and/or collected for broodstock. The long-term goal is to maintain genetic characteristics of a local, natural population among the hatchery-origin fish, by minimizing genetic changes resulting from artificial propagation and potential domestication. In an idealized integrated program, natural-origin and hatchery-origin fish are genetically equal components of a common gene pool. A hatchery supporting an integrated program can be viewed conceptually as an artificial extension of the natural environment, where the population as a whole (hatchery plus wild) is sustained at a higher level of abundance than would occur without the hatchery. A properly managed integrated broodstock can potentially serve as a genetic repository, in the event of a major decline in the abundance of natural-origin fish.

An integrated program is not meant to imply that natural spawning of hatchery-origin fish is desired. Hatchery-origin fish spawning naturally does not make a hatchery broodstock genetically integrated. A program is considered integrated only if natural-origin fish are included in the broodstock. In this context, the management goal of an integrated program is to maintain the genetic characteristics of wild fish among hatchery-origin fish, not vice-versa.

Specific long-term recommendations for *integrated programs* include:

- Include natural-origin fish in the hatchery broodstock so that an annual average of 10–20% of the broodstock is composed of natural-origin adults from the watershed where adults are collected for broodstock. In some instances this is not currently possible due to very low numbers of wild spawners such as North/Middle Fork Chinook.
- Collect and spawn adults randomly with respect to time of return, time of spawning, size, and related characteristics.
- Impose hatchery management practices that minimize the potential domestication effects of the hatchery environment.
- Monitor and control natural spawning by hatchery-origin adults so that they constitute, at most, one-third of the natural spawners of a population within a stream.

The fundamental goal of a *segregated* program is to propagate the hatchery broodstock as a discrete population or gene pool that is segregated, genetically and reproductively, from naturally spawning populations. Once established, segregated broodstocks are composed almost entirely of hatchery origin adult returns. As a consequence, genetically segregated hatchery populations can, and will, change genetically, relative to naturally spawning populations. Such changes can be intentional to maximize the desired benefits of the program, while minimizing risks to naturally spawning populations.

Specific recommendations for *segregated programs* include:

- Release fish in areas where opportunities to capture non-harvested adults are maximized (for example from facilities that have an adult trap adults can return to) thus minimizing genetic risks to natural populations.
- Release fish in a manner and/or at a location that minimizes potential straying and opportunities for natural spawning.
- Ensure hatchery-origin adults constitute no more than one to five percent of natural spawners in a population.
- Mark all released hatchery-origin fish to maximize potential harvest, and to assess stray rates and genetic risks to naturally spawning populations.
- Avoid trapping natural-origin adults, and exclude them from the broodstock.

  - Operate hatcheries within the context of their ecosystems

The benefits and risks of hatcheries can only be properly evaluated in the context of their ecosystems, including the status of naturally spawning stocks and their habitats. This will determine the potential for success and the limitations needed for hatchery programs. Set releases (numbers) to the levels needed for harvest, ceremonial, conservation or educational needs, and no larger, for cost efficiencies and to minimize genetic and ecological risks to wild populations. Program release sizes should take into account the habitat carrying capacity of both freshwater and marine environments. Ocean conditions may have a very large influence of annual adult abundances. In addition to addressing carrying capacity concerns, this may also help reduce the proportion of hatchery strays into wild populations. Off-station releases (fry, fingerlings, smolts), including net pen releases, should be minimized to the smallest number needed to accomplish the intended goal (i.e. education, harvest) and eliminated if possible, to reduce genetic and ecological risks to wild populations.

Integrated harvest programs should be sized consistent with the productivity of the natural population and the capacity of the habitat to support that population. An integrated harvest program will be successful only if the habitat is capable of sustaining the naturally produced component of the population at a level consistent with guidelines for the proportions of natural and hatchery fish on the spawning grounds and in the hatchery broodstock. Conservation programs should be sized consistent with achieving rebuilding goals (including gene banking, reintroduction). This may require deviation from the hatchery/ wild proportional guidelines mentioned above (30% for integrated). Segregated harvest programs should be sized consistent with goals for potentially affected natural stocks and habitat. This requires limiting negative genetic and ecological interactions with other stocks. Determine the proportion of hatchery fish on the spawning grounds and adaptively manage hatchery programs (numbers released) to attempt to stay within segregated and integrated recommendations of hatchery origin fish spawning with wild fish.

More specific recommendations regarding acceptable proportions of hatchery origin fish are a maximum of 5% of any spawning population being comprised of spawners from another population (Withler 1997-NOAA Tech. Memo), and for hatchery contributions that are the same population as the wild population, guidance is only approximately 10% of a population should be comprised of hatchery spawners ((McElhany et al. 2000-VSP tech memo).

- Incorporate flexibility into hatchery design and operation

Facilities should be designed and operated in such a way that they are able to respond relatively easily to changes in harvest and conservation goals and priorities, ocean carrying capacity, stock status, freshwater habitat conditions, and the myriad other factors that will alter current policies and programs.

- Evaluate and adaptively manage hatchery programs regularly to ensure success

Commitments within HGMPs for the respective WRIA 1 anadromous salmon hatchery programs require a great deal of data collection, interpretation and continued adaptive management to ensure programs are successful, and are not further impacting natural populations, particularly for chinook. All chinook releases in and near the Nooksack River are now to enable samplers to determine release location (mostly through otoliths but also with coded wire tags). Evaluating survival, spawning escapements, and the relative contributions from various hatchery releases into wild populations requires adequate funding and dedicated commitment from fisheries co-managers to comprehensively conduct spawn surveys, evaluate carcasses, recovery scales, otoliths and coded wire tags, rapidly read these, then adjust programs as appropriate to protect wild populations.

- Locate and time releases of hatchery fish to minimize potential for interactions with naturally produced fish

Hatchery releases of yearling fish (steelhead, coho) into areas cohabited by chinook and other wild salmon will be released at sizes that increase their migratory tendency (i.e., reduce residualization) and to reduce potential predation on sub-yearling chinook and other small juveniles. Releases at sizes too small tend to residualize, and at sizes too large have a higher propensity to prey on sub-yearling chinook or other small juveniles. Additionally, releases will be timed to avoid ecological interactions with wild chinook to the extent possible, recognizing the need to maintain release timing within the normal smolt window for the species being propagated. Additionally, fisheries managers will minimize within species competition for chinook releases through timing releases to maximize downstream migration (minimizing the duration of potential competition).

- Take eggs throughout the natural period of adult return

One form of domestication is the shift in spawn timing resulting from not spawning fish over the entire natural period of adult return. Natural life history traits of the various hatchery stocks should be conserved or recovered to assure long-term sustainability.

- Develop spawning protocols to maximize effective population size

The mating of hatchery fish should strive to achieve two principal objectives: 1) maximize the genetic effective number of breeders; and 2) ensure that every selected adult has an equal opportunity to produce progeny. This is particularly critical in conservation programs, where populations are small. To achieve this, male and female hatchery fish can be mated following pairwise (one male to one female), nested (e.g., one male to three females), or factorial (e.g., three-by-three spawning matrix) designs. One common hatchery practice, the pooling of sperm, can reduce effective population size, since equal contributions of individual males are not assured. The approaches of single family mating and modified factorial mating have proven to be feasible and effective (up to 94% fertilization) even in some of the largest programs reviewed (up to five million eggs taken per year). Because these methods achieve the two principle objectives and can be implemented relatively easily, all programs should adopt one of these protocols. Additionally, including an initial rate of 10% jacks (young males) in spawning should occur, with adjustment after investigations are made to determine jacking rates among natural spawning populations. The inclusion of jacks to maintain year-to-year genetic variation among coho is especially important, because they mostly mature as three year olds.

- Establish goals for educational program releases and minimize numbers released

Fisheries managers will work with education and enhancement programs to develop clear goal statements for each program and make sure the participants understand these. These programs will be operated consistent with conservation principles (at numbers and with methods that minimize genetic and ecological risks to wild fish). Additional to developing the goals, methods will be developed and implemented by the programs for determining whether the goals are being met. In the process of establishing the appropriate sizes determine whether existing habitat capacity is adequately seeded with natural fish to minimize the potential for displacement of wild fish with hatchery fish. Also consider whether wild fish may differ genetically from the hatchery fish.

- Operate hatcheries in compliance with the Salmonid Disease Control Policy of the Fisheries Co-Managers of Washington State (NWIFC and WDFW 1998)

Fish will be regularly inspected by fish health professionals and appropriate treatments are prescribed as needed. Broodstock are screened for pathogens and treated to control fungus and pathogens. Potential for amplifying diseases in hatchery environments will be minimized by focusing on fish quality over quantity, and avoiding overcrowding which can increase stress and susceptibility to disease. Additional to the provisions of the disease control policy, funding will continue to be sought to distribute carcasses, except for pre-spawn mortalities from broodstocking and any adults surplus to broodstocking needs, to spawning grounds consistent with carcass distribution guidelines (WDFW 2002**b**). Prespawn mortalities have greater potential to amplify pathogens in the wild, and the risks of this may outweigh the benefits of distributing the carcasses to provide marine derived nutrients for wild anadromous salmonids.

- Use hatchery fish as indicators of wild salmon populations for fisheries management purposes for listed and at risk species

Hatchery managers will continue to mark and recover hatchery fish for listed or at risk species (chinook and coho) to enable fisheries managers to gain information on harvest rates, distributions, and timing, and for determining overall exploitation (harvest) rates, survival rates, age compositions and the proportion of the escapements that are hatchery origin. The North Fork Nooksack early chinook coded wire tag (CWT) program is one of eleven indicator stocks for Puget Sound chinook (WDFW and PSTT 2004). After tags are inserted into 400,000 fingerlings prior to release, the various fisheries are monitored to detect and recover these tags, then spawning ground recoveries are also conducted. These releases, and the data recovered from them, serve as indicators of harvest and survival rates for both Nooksack early chinook populations. Additionally, hatchery releases will be externally marked so as to be identifiable as hatchery origin fish at smolt traps to aid in the effort to estimate natural origin outmigration estimates (and ultimately productivity), and so as to be identifiable in juvenile studies in freshwater, estuarine or marine areas.

5.3.5 Specific Hatchery Actions

Existing Actions

- All hatchery production of anadromous fish follow the provisions of the HGMP's that are reviewed and agreed to by NOAA Fisheries, including adaptive management, and will also be consistent with the co-manager future brood document. These HGMPs reflect many program changes intended to protect the early chinook populations.

- Hatcheries also follow the provisions in the co-manager disease control policy.

- No brook trout hatchery releases will occur in WRIA 1.

- All Chinook released in or near WRIA 1 will be marked as to enable release locations to be determined through spawning ground sampling efforts

Additional Actions within 10 years

- Develop a HGMP, and implement a South Fork early-chinook integrated recovery rebuilding program at Skookum Creek Hatchery to maintain this population's genetic diversity by increasing abundances, while habitat recovery actions increase population productivity and abundances.

Additional to increasing abundances, the objective is also to increase the proportion of South Fork population chinook in this geographic area by 2015, with the long-term objective of increasing these each decade until <10% of spawners in the spring chinook period are from other populations. Relatively minor facility improvements are needed and will occur by 2006. Eventual program size is proposed to release 250,000 fingerlings (70-80 fish/lb) on station, although program will initially be smaller, and limited by the number of adults that are captured and determined to be suitable. Releases will occur in May or June. Improved DNA baselines are anticipated from WDFW by end of May 2005, and if funded, the program could begin in 2006. Juvenile releases will be marked with coded wire tags, and released with the initial objective of maximizing the likelihood of adults returning to Skookum Hatchery to provide broodstock.

Snorkel surveys conducted during the summer will help identify holding areas prior to capture, and collection will attempt to target the period of August or early September to reduce likelihood of including late-timed chinook or North/Middle Fork chinook. Once holding pools are identified, adults will be isolated from the rest of the river by using block nets. Broodstock will be collected from the wild using helicopter or other rapid transport options for transferring adults to the hatchery. Collection will be by seining if suitable, or by drift gill net, and will begin at first light when temperatures are cooler. If river temperatures rise above an established temperature threshold collection efforts will end. Chinook will be transferred to holding tubes immediately after capture and placed in areas with good river water velocity. Each day adults will be transferred to totes with at least 12 inches of fresh river water, then transported to the hatchery and held on creek water.

After delivery, adults will be injected with erythromycin, then again as recommended by NWIFC fisheries pathologists to control bacterial kidney disease. They will also be injected with oxytetracycline to control furunculosis, to minimize the potential for pre-spawn mortalities. Adult females will be screened for Renibacterium salmoninarum, and progeny segregated based on parental levels. Additionally all adults will have a floy tag inserted into their dorsal fin, and a fin clip taken and labeled with the floy tag number. Prior to spawning, rapid turn around microsatellite DNA will be run on each wild adult to verify that their genotypes match the South Fork Nooksack baseline. When returns from initial releases are possible, coded wire tags will be read at the facility after eggs and milt are taken, but prior to spawning.

The DNA tissue will be rapidly transported to the WDFW genetics laboratory, and stock of origin assignments will be made within 48 hours after arrival. Those that are deemed desirable after consultation with co-manager geneticists will be segregated when the adult pond is sorted. Undesirable stock will be removed from the South Fork population and not spawned. Remaining adults will be spawned in randomly determined pairings of single males with single females to maximize effective population size. Jack males will be included as thought to represent proportions in the wild population. Efforts will be taken to maximize productivity of collected broodstock without disrupting the scheme of single pair matings; for instance, in the event of a female-biased sex ratio, sperm will be frozen from any male pre-spawn mortalities that occur.

State and tribal geneticists will evaluate risks to the South Fork Nooksack population gene pool and adapt broodstock management protocols as needed to respond to changes in the population through time. Fertilized eggs will incubate in a half stack vertical incubator on well water. Initially fry will be reared in segregated raceways in a sheltered area. Segregation will assure different sizes are not mixed. The Integrated Hatchery Operations Team (IHOT) guidelines (IHOT 1995) will be reviewed and considered in refining the rearing strategy.

- By 2008 facility improvements will occur at the Lummi Bay facility to improve ability to capture returning fall chinook adults.

The objective is to reduce the potential for fall chinook straying to Nooksack early chinook spawning areas, particularly the South Fork. This will occur through improving the ability to entice and capture returning adults which appear to home back, but are reluctant to enter the facility. This will also lead to establishing a local broodstock, and improved homing may also occur by having juveniles incubate and rear entirely at the Lummi Bay facility.

- Maintain or reduce the size of the current hatchery release abundances for the fall chinook to the lower Nooksack River and by 2007 develop an alternate release strategy that is more likely to reducing potential for straying (such as having returning adults home to a location where adults can be captured upon return). Implement new strategy by 2008.

- Conduct another comprehensive evaluation of releases contributing to the South Fork by 2008. If Kendall Hatchery origin contributions to South Fork early chinook still exceed 10%, further reduce the program to best meet recovery objectives. Similarly, monitor fall chinook hatchery strays, particularly in the South Fork, and conduct a comprehensive evaluation of stray rates and sources by 2008. If hatchery fall chinook stray abundances exceed 10% of South Fork early chinook abundances, adjust fall release strategies to address highest contribution sources until less than 10% stray rate is attained.

- Collect tissue samples from natural origin late-timed chinook, as all hatchery releases are now mass marked. Conduct microsatellite DNA analysis of any groups that appear likely to be remnant genetic reserves.

5.3.5. Long-term Actions

- As habitat recovery occurs and productivity increases the abundance of natural origin (NORs) chinook within the two early chinook populations, incorporate NORs into broodstock.

When wild abundances increase appreciably, develop a strategy to begin to capture and incorporate NORs into the early chinook hatchery broodstocks annually. If wild populations rebuild sufficiently through increased productivity, decrease the percentage of hatchery origin (HORs) adults spawning naturally to limit potential domestication effects in the populations.

- As habitat recovery occurs and productivity increases the abundance of natural spawners, re-evaluate program sizes (potentially downward) to minimize competition with wild juvenile chinook.

Co-managers will evaluate the results from the Kendall and Skookum re-building programs every ten years and propose program adjustments through revised HGMPs and Future Brood Document changes as needed to maximize recovery effectiveness and minimize risks to the populations.

5.4. Hydropower

Existing small hydroelectric facilities located in salmonid streams should be evaluated and facility upgrades made and operations adjusted as necessary to avoid any impacts to salmon and trout. Specific areas to evaluate include ramping changes in flow, screening (if salmon or trout are present at the intake), minimum instream flows and how these are determined, and tailrace protection. Existing small hydroelectric facilities in salmonid streams need to have instream flows, ramping, screening, tailrace attraction and other operations revisited, with improvements and revisions made as appropriate to avoid impacting salmonids. New facilities need to address the same issues to avoid impacts to salmonids. Instream flow requirements need to be adhered to.

5.4.1. Recovery Objectives

- Ensure that hydropower projects have no net adverse impact on salmonids and salmonid habitat. Projects should ensure fish passage, maintain water quality, provide sufficient instream flows, provide tailrace protection, screen intake structures to prevent entrainment, and manage water releases using ramping, as well as mitigate fully for any habitat loss and degradation.

5.4.2. Other Objectives

- Provide inexpensive energy source.

5.4.3. FERC Authority

Nearly all non-federal dams must be licensed by the Federal Energy Regulatory Commission (FERC). FERC is an independent regulatory agency within the Department of Energy. It is designated by Congress to carry out the provisions of FPA and to oversee the construction and operation of hydroelectric projects. Modifying the operations at federally licensed hydroelectric projects is also done through FERC. FERC issues licenses for hydroelectric projects for a period of 30 to 50 years. A few non-federal projects are not licensed by FERC, either because FERC has determined that it does not have jurisdiction over the project, or the project is exempt (generates less than 5 Mega-watt, or it is located on a non-navigable water body), or it was constructed prior to the passage of the Federal Power Act and no modification was made to the project.

5.4.4. Management Strategies and Priorities

5.4.4.1. New Hydropower Projects

- Contest the siting of any new hydropower projects within known, presumed or potential/historic distribution of anadromous or resident salmonids, as depicted in the most current version of the WRIA 1 Salmonid Distribution maps.

- If a new project is sited within known salmonid-bearing waters, work with FERC, EPA, NOAA Fisheries, USFWS, WDOE, and WDFW to ensure adequate fish passage and intake screening, evaluate and set sufficient instream flows, and minimize and fully mitigate for any habitat loss.

5.4.4.2. Existing Hydropower Projects

- Ensure that ramping rates are established consistent with criteria set forth in:
  - Hunter, M.A. 1992. Hydropower Flow Fluctuations and Salmonids: A Review of the Biological Effects, Mechanical Causes, and Options for Mitigation. September 1992. State of Washington, Department of Fisheries, Habitat Management Division. Olympia, WA.
- Ensure that instream flow needs are met for all species and life stages likely to be affected.
- Ensure that structures do not interrupt routing of sediment, wood and other organic matter.
- Monitor impacts of water release fluctuations (e.g. redd dewatering, juvenile stranding), establish communication pathways between facility operators and local biologists, and develop mechanism for timely adaptive management of water releases.

5.5. Integrated

5.5.1. Recovery Objectives

- Achieve recovery goals outlined in *Goals* section of this plan.

5.5.2. Other Objectives

- Provide regulatory certainty for ongoing activities.
- Ensure fair and equitable distribution of costs and impacts for salmon recovery.

5.5.3. Guiding Principles

- Salmonid recovery will require an integrated approach to habitat, harvest, and hatchery management. Inherent in such an integrated approach is the need for analysis across multiple scales, jurisdictions, and activities and understanding of cumulative effects.
- Collaboration and cooperation from diverse interests, perspectives, and parties will be necessary to provide the funding, technical expertise, information, labor, land use permission needed for salmon recovery.
- Actions must be taken in the face of scientific uncertainty, but risk of negative impacts of actions should be minimized.
- Monitoring and adaptive management will be critical to successful salmon recovery. By incorporating flexibility into implementation of salmon recovery efforts, we can adapt to new information and to changes in the problems, conditions, technology, and sociopolitical context that affect salmon recovery.

5.5.4. Management Strategies and Priorities

- Establish governance and implementation structure that will oversee the implementation of the management strategies and actions outlined in this plan, as well as the overall monitoring and adaptive management framework.
- Develop coordinated monitoring approach and periodically assess progress toward recovery goals and review and revise action priorities
- Design decision-making processes to use best available science, (taking into consideration limited knowledge and inherent uncertainty of salmon recovery).
- Convene monthly meetings to review progress on recovery plan implementation.
- Generate annual progress reports on recovery plan implementation.

- Use and adapt existing programs and regulations to the extent possible, but develop new legislation and programs as the need arises.
- Coordinate salmon recovery efforts among governments, non-governmental organizations, stakeholders, and citizens to avoid duplication of effort and maximize efficient use of limited resources.
- Secure and expand state, federal, local and private funding to support salmon recovery efforts. Stable funding sources are necessary to provide time and predictability for planning, development, implementation and monitoring.

6. IMPLEMENTATION

6.1. Monitoring and Adaptive Management

While the recovery strategies and actions described in this summary rely on the best science available now, there is some uncertainty that proposed actions will have the desired effects. In order to evaluate the success of these actions and to adjust future projects accordingly, an adaptive management program must be included as part of salmon recovery efforts. The general structure of the adaptive management process is illustrated in Figure 6.1.

In general, successful adaptive management programs include the following six steps:

1. Acknowledgement of uncertainty about what policy or practice is "best" for the particular management issue.
2. Thoughtful selection of the policies or practices to be applied (the assessment and design stages of the cycle).
3. Careful implementation of a plan of action designed to reveal the critical knowledge that is currently lacking.
4. Monitoring of key response indicators.
5. Analysis of the management outcomes in consideration of the original objectives.
6. Incorporation of the results into future decisions.

The specific adaptive management component of the WRIA 1 Salmonid Recovery Plan will be developed as implementation gets underway. Adaptive management will entail the following components:

- Research to fill key data gaps.
- Monitoring to ensure compliance and effectiveness of salmon recovery actions.
- Decision-making structure that will use monitoring results to modify actions as necessary to ensure sufficient progress towards recovery goals.

6.1.1. Research

The research plan for WRIA 1 focuses on gaining a better understanding of habitat-forming processes, habitat conditions, biotic interactions and salmon population characteristics. Within each of these general areas of inquiry, specific data needs are: (1) identification and quantification of impairments to natural processes; (2) inventory and characterization of habitat conditions; (3) identification and characterization of biotic interactions; and (4) characterization of salmonid populations. Examples of key research questions are presented below. In some instances, data are being collected, or have been partially collected, to address the research question. A detailed research plan with timeline, costs, and commitments will be developed as a component of the broader Adaptive Management Plan.

6.1.1.1. Processes

- Sediment Supply, Transport, and Deposition
  - Freshwater
    - Distribution and nature of sediment sources in South Fork Nooksack.
    - Evaluation sediment transport and channel storage in mainstem channels
    - Evaluation of storage in tributaries and colluvial hollows
    - Evaluation of relationship between channel form and sediment dynamic
  - Estuarine/Nearshore
    - Nearshore sediment source characterization.
    - Longshore transport and drift cell characteristics.
    - Characterize sediment impacts on submerged aquatic vegetation.
- Hydrology
  - Freshwater
    - Relationship between forest practices, agriculture, land development and instream flow.
    - Expected changes in instream flow due to climate change.
  - Estuarine/Nearshore (circulation, tides/currents)
    - Characterization of Bellingham Bay freshwater and marine currents.
- Wood Inputs
  - Freshwater
    - Characterize wood recruitment mechanisms for the watershed.
  - Estuarine/ Nearshore
    - Characterize wood recruitment from the nearshore environment.
    - Characterize wood recruitment from tributaries, such as Dakota, California, Padden, and Chuckanut creeks to nearshore environment.
- Nutrient/Chemical Inputs
  - Freshwater
    - Characterize nutrient loading and impacts on Nooksack River and lowland tributaries
    - Impacts of nutrients on dissolved oxygen
  - Estuarine/Nearshore
    - Characterize saltwater/ freshwater interface in the Nooksack River Estuary.
    - Characterize saltwater/ freshwater interface in independent drainages including Dakota, California, Squalicum, Whatcom, Padden, and Chuckanut creeks.
    - Characterize nutrient and chemical impacts from land use on nearshore environment.
- Light/Heat Inputs
  - Freshwater
    - Develop model for stream heating for the South Fork Nooksack River.

- Identify processes that create and maintain thermal refuge areas.

6.1.1.2. Habitat Conditions

More detailed information is needed regarding access, the diversity and quantity of habitat types, riverbed stability and conditions, riparian conditions, floodplain conditions, the variation in flow levels through the seasons, and water quality.

- Access
    - Identify and characterize passage barriers
- Substrate
    - Characterize distribution and quality of spawning gravel
    - Identify reaches where fine sediment impacts spawning gravel quality
- Habitat Structure/Stability
    - Identify and characterize mechanisms for channel instability
    - Identify and characterize impacts of hydromodifications on habitat conditions
    - Describe habitat units and analyze changes through time in heavily used sections of the river
- Flow Regime
    - Identify high-flow and low-flow barriers to fish passage
    - Characterize low flow effects on habitat quantity
- Water Quality
    - Determine effects of stream temperature on habitat use and availability
    - Determine effects of fine sediment on juvenile rearing
    - Comprehensively measure turbidity throughout the year and in association with storm events in Forks and mainstem

6.1.1.3. Biotic Interactions

Research on the biotic interactions between listed species and other species is necessary to improve management in the Nooksack Watershed. Gaining a better understanding of competition and predation between different species of hatchery and native salmonids will inform decisions on habitat protection and restoration, hatchery, and harvest.

- Food Webs
    - Characterize prey and predator relationship of listed species
- Competition
    - Determine competition between listed species and hatchery species
    - Determine how brook trout distributions are changing over time, and whether bull trout continue to occupy habitats where both species exist
- Predation
    - Continue to evaluate yearling coho and steelhead predation on subyearling chinook
    - Characterize predation on listed species by other species

- Disease/parasitism
  - Characterize disease and parasitism impacts on listed species.
  - Determine if environmental conditions increase disease/ parasitism effects on listed species.
  - Monitor whether hatcheries are amplifying naturally occurring diseases in the basin.

6.1.2. Salmonid Populations

Research is needed to characterize the population dynamics of chinook and bull trout in the Nooksack watershed. Research will focus on the abundance, productivity, life-history diversity, and spatial structure of the populations.

- Abundance
  - Re-evaluate chinook escapement estimate methodologies, particularly for the North/Middle Fork population, especially in light of restored passage in Middle Fork
  - Develop bull trout spawn survey index areas to enable population abundance and trends (productivity) to be estimated
- Productivity
  - Estimate productivity of two early chinook populations by relating survival to outmigration using population escapement estimates, average fecundity of female spawners, and estimating the % of these that survive to outmigrate as subyearlings
  - Estimate productivity and survival associated with different life stages and habitats
- Diversity
  - Monitor genetic composition of South Fork early chinook, and changes in stock compositions over time
  - Determine whether Kendall hatchery's NF/MF chinook coded wire tag program actually represents harvest for the South Fork population, though peak spawn timing is 2-3 weeks different
  - Sample any potential genetic refugia for fall chinook that appear to consistently have high percentages of natural origin spawners
  - Identify life history patterns and characterize contribution to escapement
- Spatial Structure
  - Characterize distribution and habitat use by life history stage
  - Monitor recolonization by NF/MF chinook and anadromous bull trout above Middle Fork diversion dam
  - Monitoring areas with higher concentrations of wild chinook in North and Middle Forks through interpreting otolith data to determine key refugia areas and habitats with higher productivity
  - Confirm whether bull trout occupy Depot Creek on U.S. side of border

- Improve understanding of bull trout spawning and rearing areas, particularly in the more downstream portions of the Forks and their tributaries
- Monitor any changes in the relative distribution of South Fork early chinook spawners after Skookum Hatchery rebuilding program increases abundances
- Improve our understanding of the spatial structure of natural origin fall chinook in WRIA 1

6.1.3. Monitoring

Monitoring of salmon recovery in the Nooksack Basin will entail compliance, effectiveness, and validation monitoring of projects and programs that protect and restore salmon habitat. These data will then be used to monitor and evaluate salmon recovery in the watershed and contribute to monitoring programs across the Puget Sound. The general questions that will be addressed include:

- How well does a specific project work?
- Are the collective projects achieving the anticipated results? In the short-term, long-term?
- Are the hypotheses for what is limiting recovery valid and is our strategy appropriate?
- Are we achieving recovery of salmon in our watershed and across Puget Sound?

A monitoring and evaluation plan is currently under development for salmon recovery in WRIA 1 and is anticipated to be completed by December, 2005. The plan will identify what will be measured to assess actions relative to the goals presented in this plan, how the data will be collected and maintained, and how the information will be used to improve decision-making.

6.1.3.1. Compliance Monitoring

Compliance monitoring will be conducted by a variety of land management agencies and covers a wide array of topics relevant to salmon recovery. Monitoring will ensure compliance with regulations, agreements, permit conditions, and mitigation requirements. Compliance monitoring will be conducted from the project level to the program level and used to ensure that current regulations and activities are providing adequate protection to listed species and their habitats.

Regulatory compliance monitoring will focus on ensuring that current programs and projects are consistent with existing regulatory measures such as the Critical Areas Ordinance, State Hydraulic Code, Clean Water Act and Forest Practice Rules. Monitoring for these activities are conducted by a variety of management agencies, including both tribal Natural Resources Departments, Whatcom County Planning, WDFW, WDNR, WDOE, ACOE, USFWS, and NMFS. Collaboratively these agencies review projects and monitor compliance with existing regulations as a part of the environmental permitting process.

An example of regulatory compliance monitoring for a bank protection project is outlined below:

- *Goal:* The sustained presence of natural habitat-forming processes in a watershed (e.g. riparian community succession, bedload transport, precipitation runoff pattern, channel migration) that are necessary for the long-term survival of the species through the full range of environmental variation.
- *Monitoring Question:* Does the project maintain or restore habitat-forming processes?
- *Monitoring Metrics:* Channel migration width protected under County Shorelines, riparian wood recruitment area protected under County Shorelines and State Forest Practices.
- *Integration with Decision-making*: Assessment of monitoring metrics contributed to regulatory agencies as a part of the project permitting process.

6.1.3.2. Effectiveness Monitoring

Effectiveness monitoring will focus on the direct and cumulative effectiveness of projects and programs to meet their intended results. Monitoring will be conducted by a variety of agencies to determine how well specific conservation and production programs achieve their intended results.

Project effectiveness monitoring will focus on assessing to what extent an action, such as land use regulation, best management practice, or voluntary project, addresses the limiting factors that occur in the geographic area of the action. Specific monitoring plans will be developed for each project to determine

Project proponents would be expected to develop a reasonable monitoring plan to support their projects. Guidance from other agencies could be sought to determine which metrics would be most suitable for monitoring. An example of project effectiveness monitoring for a large woody debris placement project is outlined below:

Monitoring Goal:
The fundamental question that the monitoring and evaluation plan will seek to address is: are the conditions of the channel, fish habitat, and hydrology responding to the project as expected?

Project Objectives:
The objectives of the project include: (1) increase the amount and quality of pool habitat available at the site; (2) increase the channel roughness of the reach; (3) increase channel length through encouraging secondary channel development; (4) increase pre-spawning adult holding in the reach and (5) reduce fine sediment that passes through the reach.

Sample Hypotheses:
H_o: Total channel length at a given discharge before the project is equal to total channel length at a given discharge (i.e. bankfull stage) following the project.
H_a: Total length following the project is greater than total channel length prior to the project at a given discharge.

H_o: The main channel elevation has not increased downstream of the structure.
H_a: Bed elevation has increased in the main channel downstream of the logjams.

Sample Monitoring Parameters:
- Total Channel Length: A change in the total channel length through the reach will be reflected in more sinuosity in the main channel and more frequent flow in existing side-channels and the development of new side-channels. To monitor changes in channel length several parameters will be measured including discharge, channel geometry and habitat distribution across the floodplain. For channel geometry, cross-sections and longitudinal profiles will be surveyed through the main channel and floodplain channels. Annual cross-sections through the overflow channels and plan-view mapping of the floodplain channels will show secondary channel development. These surveys will be tied to stage measured at the site. Discharge measurements will be taken at several locations across the floodplain to monitor flow in floodplain channels relative to different stages in the main channel. Also, habitat mapping of all flowing areas was conducted and tied to river discharge to show plan-view habitat development.

6.1.3.3. Validation
Validation monitoring seeks to assess:
- How well does a specific project work?
- Are the collective projects achieving the anticipated results? In the short-term, long-term?
- Are the hypotheses for what is limiting recovery valid and is our strategy appropriate?
- Are we achieving recovery of salmon in our watershed and across Puget Sound?

6.1.4. Decision-making Structure

The decision-making structure should involve those responsible for implementation of salmon recovery actions, such as designated policy representatives from the cities and Whatcom County for land use regulations, and designated policy representatives from WDFW, Lummi Nation, and Nooksack Tribe for hatchery and harvest activities. The WRIA 1 Salmon Recovery Board, which also functions as the Lead Entity for WRIA 1, will be the forum used for adaptive management. Decisions will be made based upon information gathered in research and monitoring efforts. New information may come to light through research that may warrant revisions of the recovery strategies and actions. For the most part, however, it is expected that adaptive management will hinge on monitoring results.

- Tracking and guiding plan implementation
- Making technical assessments about effectiveness of hatchery, harvest and habitat actions
- Evaluating progress and making decisions about priorities within and across H's
- Communicating progress – County, City, nonprofits
- Managing data, describing plan effectiveness – co-managers
- Securing funds to support plan implementation – WRIA 1 SRB

In developing the adaptive management framework, thresholds will be established to measure progress towards recovery and to determine possible courses of action:

- No action—if target thresholds are met or exceeded.
- Continue or expand monitoring—if significant progress is made towards a threshold but it is not met.
- Modify strategy or action—if results fall far short of the target threshold or conditions worsen.

6.1.5. Timeline for Development of Adaptive Management Program

Development of the adaptive management program - including monitoring parameters and thresholds and timelines for action - is expected to be completed by December 2005. The follow steps are anticipated to occur over the next five years.

- 1st 2 years: develop detailed monitoring plan, initiate monitoring, reporting on implementation
- year 3+: effectiveness assessments and continue implementation reporting
- year 5+: use info to evaluate progress and priorities for continued funding of projects, engage discussion with broader policy committee for these decisions

6.2. Education and Outreach

Salmon recovery efforts will be most successful with broad community support. An effective education and outreach program will need to be developed. This should focus on increasing the understanding of recommendations in this Recovery Plan, engaging the broader community on actions that are needed, and make individuals aware of voluntary actions they can take that will aid in recovery. There are a variety of diverse organizations that, through increasing their understanding and awareness of the Plan, can provide additional education to the broader community.

The Whatcom County Comprehensive Plan visioning process, landowner participation in the purchase of development rights program for agricultural lands, the diverse membership and participation in organizations such as the Nooksack Salmon Enhancement Association, Nooksack Recovery Team, and Whatcom Land Trust, the Lake Whatcom watershed protection programs, volunteer participation in the Whatcom Conservation District's Stream Teams, and the creation of the Bertrand Creek Watershed Improvement District are all strong indicators of community support for watershed and salmon habitat protection and restoration.

Existing educational programs include the education and outreach provided by the NSEA through volunteer programs, elementary school programs, and the Stream Stewards. In addition, others such as Washington State University Extension - Whatcom County, Whatcom County Public Works, Whatcom County Parks, Whatcom Conservation District, Whatcom County Marine Resources Committee, and the City of Bellingham perform community education and outreach as part of their programs. The Nooksack Recovery Team hosts the annual Salmon Summit which is a significant event educating the community about salmon recovery plans, projects, and accomplishments. The NRT is also currently embarking on a pilot project to help organize salmon recovery implementation at the sub-basin level in a way that incorporates the restoration vision of the sub-basin residents.

Continued work to build community understanding, support, and resources for recovery projects will allow recovery partners to undertake more challenging, complex, or controversial projects in the future. Specific actions are likely to require outreach and educational support. General educational programs and topics should expand to include:

- The opportunities for mutual benefit and balance between flood hazard management and salmon habitat restoration
- Stormwater management and incorporation of best management practices into everyday behavior
- Estuarine/nearshore environment and their importance to the salmon lifecycle.
- The role of large woody debris in forming and maintaining salmon habitats.

6.3. Preliminary Funding Estimates

Table 6.1 is a compilation of all the preliminary estimates listed under the eight Actions described in the section *Actions in the Next Ten Years*. These estimates and timetables may be subject to change after the WRIA 1 Salmon Recovery Board begins formal discussion of these proposals.

Table 6.2 gives cost estimates for the actions listed in the 10-Year Implementation Scenario, as described in Habitat Action #2, with the exception of the Middle Fork Diversion Dam and Canyon Creek access projects. The costs of these two projects are already included in Table 6.1.

The preliminary cost estimates are not adjusted to account for inflation. The costs of on-going operations not related to these eight Actions have not yet been estimated.

6.4. Commitments

In order to implement the Near-Term Recovery Actions described in Appendix B, a variety of commitments, ranging from policy decisions to funding to private landowner support, must be secured. In particular, the projects listed under Habitat Action #2 are nearly all in the conceptual stage, and have not yet secured the commitments necessary for implementation. Table 6.3 presents the commitments and conditions for each of the *Actions*.

Figure 6.1. Diagram of Adaptive Management Process.

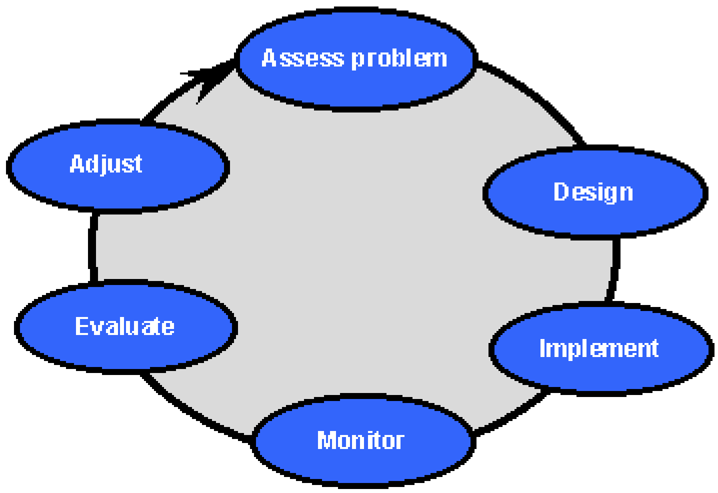


Table 6.1. Preliminary Cost Estimates for the Near-Term Actions.

	Name	Details	Estimate: Low end	Estimate: High end
ACTION #1 – Chinook Passage	**Middle Fork Diversion Dam**	Restore passage	$3,000,000	$6,600,000
		Annual spawning ground survey (beginning in 2006)	$750,000	$750,000
		Kokanee hatchery replacement: Start-up costs	$5,004,000	$5,004,000
		Kokanee hatchery replacement: Operating costs (beginning in 2010)	$1,164,000	$1,164,000
	Canyon Creek	Project design	$20,000	$75,000
		Interim passage measures (2004 and 2005)	$10,000	$30,000
		Implementation	$50,000	$75,000
		Development and implementation of restoration plan	$185,000	$1,635,000
		TOTAL for Action #1	**$10,183,000**	**$15,333,000**
ACTION #2 – Forks, Mainstem, Early Chinook Tributary Restoration	**Technical analysis of watershed conditions and processes**	Build on existing data, as well as develop relative sediment budgets, update and refine landslide inventory, quantify road network impacts, evaluate streamflow records and hydrologically degraded sub-basins, assess floodplain wetland function, evaluate relative importance of basin-scale vs. reach-scale processes in controlling South Fork stream temperatures	$500,000	$500,000
	Restoration planning	Reach-level assessment, plan development, solicit landowner and public support ($20,000/mile over 72 miles)	$1,400,000	$1,400,000
	Land acquisition	Estimated at $2 million/year for 10 years, based on average annual requests for funding of similar projects	$2,000,000	$2,000,000
	Restoration project implementation	See Table 6.2 for detailed breakdown	$ 59,702,500	$ 64,202,500
	CREP program implementation		TBD	TBD
	Forestland management	Implement FFR rules	TBD	TBD
		Monitor effectiveness of FFR rules	TBD	TBD
		Refine FFR rules	TBD	TBD
		TOTAL for Action #2	**$63,602,500**	**$68,102,500**

	Name	Details	Low end	High end

	Name	Details	Low end	High end
ACTION #5 – Instream Flows	**ISF recommendations in pilot watershed**		$300,000	$300,000
	ISF recommendations for remaining drainages		$2,000,000	$3,000,000
		TOTAL for Action #6	**$2,300,000**	**$3,300,000**
ACTION #6- Nearshore & Estuarine	**Develop restoration plan**		$500,000	$500,000
	Implement restoration projects		$5,000,000	$5,000,000
		TOTAL for Action #7	**$5,500,000**	**$5,500,000**
ACTION #7 – Lowland and Independent Tributaries	**Remove barriers to fish passage**	Supplemental inventory (if needed, $10,000/year for 5 years)	$50,000	$50,000
		Repair/replacement of priority barriers ($300,000/year for 10 years)	$3,000,000	$3,000,000
		Repair/replacement beyond normal M&O scope ($200,000/year for 10 years)	$2,000,000	$2,000,000
	Stormwater management to minimize negative effects on habitat		TBD	TBD
	Farm plan implementation	Implementation of farm plans for both commercial and hobby operations ($150,000/year for 10 years)	$1,500,000	$1,500,000
		TOTAL for Action #8	**$6,550,000**	**$6,550,000**
HATCHERY ACTION – SFK Hatchery	**Baseline DNA analyses**		$20,000	$30,000
	Hatchery modifications		$100,000	$100,000
	Program implementation	$120,000/year for 10 years	$1,200,000	$1,200,000
	Engineered log jams	To increase attraction flows	$250,000	$250,000
		TOTAL for Action #5	**$1,570,000**	**$1,580,000**

Table 6.2. Preliminary Cost Estimates for Habitat Action #2 10-Year Implementation Scenario.

Name	Description	Estimate: Low end	Estimate: High end
Estuary			
Marietta estuary/wetland restoration	Somewhat developed, purchase of 540 acres ($1,500,000), raising Slater Road ($3,000,000-$6,000,000), flood management in the town of Marietta ($1,000,000-$2,000,000), slough/riparian restoration ($500,000-$1,000,000), dike modification ($1,000,000)	$ 7,000,000	$11,500,000
Lower Nooksack			
Small Scale Wood Lower Nooksack mainstem	20 structures, each 60 feet long at $250 per lineal foot of structure. Large river, but structures require little excavation and fairly low-cost permitting and design.	$ 300,000	$ 300,000
BMP Lower Tributaries (Water Quality)	TBD	TBD	TBD
Whiskey-Schneider Creek Restoration	Passage improvement ($15,000 each), restoring 1 mile of each small tributary (50' riparian: $5000 per acre and wood placement: $10,000 per mile).	$ 160,000	$ 160,000
Kamm Creek Restoration	Restoring 2 miles small tributary (50' riparian: $5000 per acre and wood placement: $10,000 per mile).	$ 120,000	$ 120,000
Fishtrap Creek Restoration	Restoring 2 miles of small tributary (50' riparian: $5000 per acre and wood placement: $10,000 per mile).	$ 120,000	$ 120,000
Bertrand Creek Restoration	Restoring 1 mile small tributary (50' riparian: $5000 per acre and wood placement: $10,000 per mile).	$ 60,000	$ 60,000
Tenmile Creek Restoration	Restoring 0.5 mile small tributary (50' riparian: $5000 per acre and wood placement: $10,000 per mile).	$ 30,000	$ 30,000
Upper Nooksack			
Riparian/floodplain restoration (Upper Nooksack)	200' buffer 145 acres ($5000 per acre) agricultural land, easy access, simple planning and average maintenance	$ 725,000	$ 725,000
Large scale LWD placement (Upper Nooksack)	100 engineered logjams (10 logjams per mile in more confined areas, 30 logjams per mile in unconfined reaches) requiring large material, with fair access to the channel ($80,000 per logjam)	$ 8,000,000	$ 8,000,000
Anderson Creek Restoration	Restoring 2 miles small tributary (50' riparian: $5000 per acre and wood placement: $10,000 per mile).	$ 120,000	$ 120,000
Smith Creek Restoration	Restoring 2 miles small tributary (50' riparian: $5000 per acre and wood placement: $10,000 per mile).	$ 120,000	$ 120,000
Anderson Creek Fish Passage Mt Baker Highway	Major 2 lane highway passage project on moderate size stream.	$ 350,000	$ 350,000

Name	Description	Estimate: Low end	Estimate: High end
Riparian timber managed land (Low Nooksack Tribs)	TBD	TBD	TBD
North Fork Nooksack			
Large scale LWD placement (Mid NF Nooksack)	190 engineered logjams (10 logjams per mile in more confined areas, 30 logjams per mile in unconfined reaches) requiring large material, with fair access to the channel ($80,000 per logjam)	$15,200,000	$15,200,000
Large scale LWD placement (Upper NF Nooksack)	30 ballasted logjams (10 logjams per mile in more confined areas, 30 logjams per mile in unconfined reaches) requiring large material, with fair access to the channel ($20,000 per logjam)	$ 600,000	$ 600,000
Riparian restoration (NF Nooksack mainstem)	154 acres of farmland 200' riparian buffer establishment ($5000 per acre), 450 acres of riparian interplanting- 200' buffer ($2500 per acre)	$ 1,900,000	$ 1,900,000
Riparian restoration (NF Nooksack tributaries)	Completed/underway	$ -	$ -
Forest Rd management NF Nooksack Watershed	TBD	TBD	TBD
Riparian timber managed lands (NF Nooksack)	TBD	TBD	TBD
Re-route SR 542 (segments where confines river)	2.75 miles of major two-lane road relocation ($1.5 million per lane mile).	$ 8,300,000	$ 8,300,000
Middle Fork Nooksack			
MF Nooksack Diversion Flow Agreement		$ -	$ -
Riparian restoration (Lower MF Nooksack mainstem)	35 acres 200' buffer establishment ($5000 per acre), 215 acres of 200' buffer interplant ($2500 per acre)	$ 710,000	$ 710,000
Riparian timber managed lands (MF Nooksack)	TBD	TBD	TBD
Forest Rd management MF Nooksack Watershed	TBD	TBD	TBD
South Fork Nooksack			

Name	Description	Estimate: Low end	Estimate: High end
Large scale LWD placement (Lower SF Nooksack)	4.9 miles treated 49 logjams at 10 logjams per mile ($80,000 per logjam)	$ 3,900,000	$ 3,900,000
Large scale LWD placement (Acme-Saxon Reach)	2 miles treated 60 logjams at 30 logjams per mile ($80,000 per logjam)	$ 4,800,000	$ 4,800,000
Large scale LWD placement (Upper SF Nooksack)	5.25 miles treated 60 logjams at 30 logjams per mile in unconfined reaches and 10 logjams per mile in confined reaches ($80,000 per logjam)	$ 4,800,000	$ 4,800,000
Riparian restoration (Lower SF Nooksack)	100 acres 200' buffer riparian establishment ($5000 per acre)	$ 500,000	$ 500,000
Riparian restoration (Acme-Saxon Reach)	35 acres of 200' buffer riparian interplanting ($2500 per acre).	$ 87,500	$ 87,500
Riparian timber managed lands (Upper SF Nooksack)	TBD	TBD	TBD
Riparian timber managed lands (SF Nooksack tribs)	TBD	TBD	TBD
Forest Rd management SF Nooksack Watershed	TBD	TBD	TBD
Reduce landslide impacts to SF Nooksack mainstem	6 slope failures treated ($300,000 per retaining structure)	$ 1,800,000	$ 1,800,000
	TOTAL	**$59,702,500**	**$64,202,500**

Table 6.3. Commitments and Conditions for WRIA 1 Near-Term Salmon Recovery Actions.

	Action	Lead Implementing Entity(ies) & Partners	Types of commitments needed to implement actions	Conditions and resources needed to make commitments
ACTION #1 – Chinook Passage	Middle Fork Diversion Dam (passage)	**City of Bellingham**	Final design, permitting, construction	Acquisition of funding for final permitting and construction
	Middle Fork Diversion Dam (chinook release)	**WDFW**	Continue release of chinook fry upstream of diversion dam site	Continued funding for release and biological monitoring
	Middle Fork Diversion Dam (alternative kokanee program)	**WDFW**	Construct new brood facilities at multiple western Washington locations	Funding for engineering, construction, and operations
	Canyon Creek	Whatcom County, Whatcom Land Trust	Plan, design, and implement preferred fish passage alternative; develop restoration plan alternatives	Feasible alternatives are developed, funding to implement alternatives, landowner permission, funding for long-term evaluation and monitoring

	Action	Lead Implementing Entity(ies) & Partners	Types of commitments needed to implement actions	Conditions and resources needed to make commitments
ACTION #2- Forks, Mainstem, Early Chinook Tributary Restoration	Technical analysis of watershed conditions and processes	Nooksack Tribe, Lummi Nation, Whatcom County	Lead the assessment, coordinate with independent assessments	Funding for staff and contracted resources
	Restoration planning	Nooksack Tribe, Lummi Nation, WDFW, Whatcom County, cities	Conduct reach-level assessment and identify project feasibility and sequencing	Funding, adequate staffing
	Public Outreach	Nooksack Tribe, Lummi Nation, Whatcom County, WDFW/NSEA, Cities, WCD, NSEA	Engage community in developing restoration "vision", landowner and city agreements	Funding for outreach staff and contractors, communication materials
	Land acquisition	Whatcom Land Trust, Whatcom County, cities	Acquire lands to protect functional habitat and restoration opportunities	Identification of willing landowners, funding, Policy and community support for public acquisition as conservation tool
	Restoration project implementation	Nooksack Recovery Team partners	Implementation of various projects	Timely completion of restoration plans, landowner consent, community understanding, Whatcom County River & Flood approval for projects dealing with flood control infrastructure or that are expected to affect flood hazard
	CREP program implementation	Whatcom Conservation District	Continued administration of the program	Continued funding of the program, identification of willing landowners, mechanism to continue program or preserve conservation value beyond initial 15 year lease period

	Action	Lead Implementing Entity(ies) & Partners	Types of commitments needed to implement actions	Conditions and resources needed to make commitments
	Forestland management	DNR; Cooperative Monitoring, Evaluation, and Research Committee; FFR Policy, Forest Practices Board, USFS	Local monitoring efforts	Continued funding of tribal FFR programs, continued funding of state programs, formal engagement by USFS
ACTION #3- Integrate salmon recovery with flood hazard management	Coordination with Technical Advisory Committee	Whatcom County	Coordination with the TAC	Formation of an interdisciplinary Technical Advisory Committee for the Salmon Recovery Board; participation of the Army Corps of Engineers as a partner on the TAC and specific projects, participation of tribes and state agencies
	Channel migration zones	Whatcom County, cities, Lummi Nation, Nooksack Tribe	Utilize best available data to establish CMZ for use in flood planning, salmon recovery, and Shorelines Master Program administration	Public process regarding adoption of channel migration zones that engages community and small cities, Ecology adoption of CMZ's
	Hydraulic modeling of Nooksack River	Whatcom County	Complete flood hydraulic modeling for all reaches of Nooksack River	Continued funding to complete modeling, availability of and resources to run instream flow and habitat models and link to flood models where appropriate
	Public Outreach	Whatcom County, Cities, Lummi Nation, Nooksack Tribe, WDFW/NSEA	Engage community in developing restoration "vision", landowner and city agreements	Funding for outreach staff and contractors, communication materials

	Action	Lead Implementing Entity(ies) & Partners	Types of commitments needed to implement actions	Conditions and resources needed to make commitments
	Identify, design, and construct major capital/ infrastructure projects	Whatcom County, cities, Lummi Nation, Nooksack Tribe, WDFW	Work with landowners in long-term habitat restoration options for major capital projects in reaches limited by flood control infrastructure	Community awareness and support, landowner consent, support of affected cities, substantial state and federal funding
	Riparian function associated with flood control structures	Whatcom County	Re-establish functional riparian vegetation while retaining ability to maintain flood and drainage management infrastructure	Continued funding of CREP, local resources to support CREP, state and federal financial support, Army Corps of Engineers' willingness to participate in projects, increased funding for crews (e.g. jail, WCC, private) and materials
ACTION #4 – CAO and SMP Updates	Identify baseline conditions and recovery targets	Whatcom County, Nooksack Tribe	Complete salmonid recovery plan	Potentially additional staff and financial resources for small cities to identify in-city habitat needs and opportunities, consistency with city programs; focused public outreach program
	Coordinate Technical Advisory Group	Whatcom County	Coordinate Technical Advisory Group to provide recommendations re: CAO and SMP updates	N/A
	Public outreach program	Whatcom County, cities	Coordinate citizen involvement in update process, provide for meaningful opportunities for community input	Current update processes are funded. Cities will need resources for future updates.

	Action	Lead Implementing Entity(ies) & Partners	Types of commitments needed to implement actions	Conditions and resources needed to make commitments
	Revise WRIA 1 Salmonid Recovery Plan	Whatcom County	Integrate salmon recovery guidance and with the County CAO and SMP	Public review process and ability to revise plan in future based on public input and results from adaptive management
ACTION #5 – Instream Flows	ISF recommendations in pilot watershed	Intergovernmental Instream Flow Working Group	Develop flow recommendations for Bertrand Creek drainage	Funding – general; funding for small cities representative to participate
	ISF recommendations for remaining drainages	Intergovernmental Instream Flow Working Group	Develop flow recommendations for remaining drainages	Funding
	Public Education and outreach	Intergovernmental Instream Flow Working Group	Provide connections to community members in pilot and other drainages to ensure understanding and provide for participation in process	Funding
ACTION #6 – Nearshore and Estuary	Develop restoration plan	Lummi Nation, Nooksack Tribe, WDFW, Whatcom County, cities	Conduct and synthesize assessments	Funding
	Public Education and outreach	Lummi Nation, Nooksack Tribe, WDFW/NSEA, Whatcom County, cities	Provide connections to community members adjacent to nearshore, estuarine, and Shorelines of the State ensure understanding and provide for participation in reach or drainage level restoration vision and plans	Funding
	Implement restoration projects	NRT members, cities, community members or groups	Implement projects	Funding

	Action	Lead Implementing Entity(ies) & Partners	Types of commitments needed to implement actions	Conditions and resources needed to make commitments
ACTION #7- Lowland AND Independent Streams	Remove barriers to fish passage	Whatcom County, cities, WSDOT, WDFW/NSEA, WCD,	Complete inventory, begin replacement/repair of culverts	Available funding will determine rate of barrier removal. Funding to create private landowner assistance program housed at NSEA
	Stormwater management to minimize negative effects on habitat	Whatcom County, City of Bellingham, Whatcom Conservation District, Ecology	Prevent/minimize negative effects of stormwater on salmonid habitat	Issuance of state NPDES guidelines; funding
	Farm plan implementation	Whatcom Conservation District	Implement farm plans for both commercial and hobby operations	WCD Board acceptance of task; funding; landowner participation
HATCHERY ACTION – South Fork early chinook supplementation	Baseline DNA analyses	WDFW	Improve stock identification databases	Funding
	Hatchery modifications	Lummi Nation, Nooksack Tribe	Modify facilities as appropriate	Funding
	Program implementation	WDFW, Lummi Nation, Nooksack Tribe	Reduce North Fork early chinook and hatchery strays into South Fork, determine genetic benefit and risks associated with culturing SF chinook, develop HGMP, capture broodstock, spawn, incubate, rearing, acclimate progeny	Funding

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APPENDIX A. LIST OF ACRONYMS.

DPS: Distinct Population Segment

EDT: Ecosystem Diagnosis and Treatment

ESA: Endangered Species Act of 1973

ESU: Evolutionarily Significant Unit

NMFS: National Marine Fisheries Service, now referred to as NOAA Fisheries

NSEA: Nooksack Salmon Enhancement Association

NOAA Fisheries: The federal agency, a division of the National Oceanic and Atmospheric Administration, Department of Commerce, responsible for the stewardship of the nation's living marine resources and their habitat and for implementing the Endangered Species Act for Puget Sound chinook.

NWIFC: Northwest Indian Fisheries Commission

PFC+: (*EDT Scenario*) One of the habitat conditions scenarios modeled in EDT model for establishment of recovery goals for early chinook populations. Characterized by properly functioning conditions (after NMFS 1996) in freshwater environments, historical conditions in the estuarine environment.

PSRUT: Puget Sound Bull Trout Recovery Unit Team, appointed by USFWS to provide guidance and assist in drafting the Puget Sound Bull Trout Recovery Plan

SRFB: Salmon Recovery Funding Board

TRT: Puget Sound Technical Recovery Team, appointed by NOAA Fisheries to assist in development and evaluation of Puget Sound Chinook Recovery Plan

USFWS: United States Fish and Wildlife Service

VSP: Viable Salmonid Population

WDOE: Washington Department of Ecology

WDFW: Washington Department of Fish and Wildlife

WRIA 1: Water Resource Inventory Area 1 (Nooksack Basin)

APPENDIX B: NEAR-TERM (10-YEAR) SALMON RECOVERY ACTIONS.

APPENDIX C. TECHNICAL BACKGROUND.

APPENDIX D: WRIA 1 SALMONID PERIODICITY CHART.

APPENDIX E: WRIA 1 SALMONID HABITAT RESTORATION STRATEGY (VERSION 2.4; 2004).