SALMON AND STEELHEAD HABITAT LIMITING FACTORS IN WRIA 1, THE NOOKSACK BASIN

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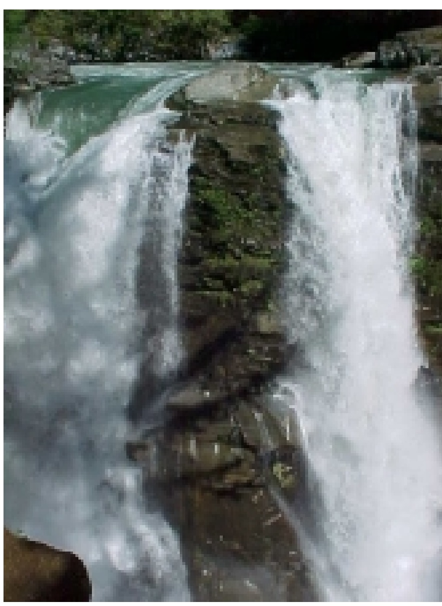

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EXECUTIVE SUMMARY

Introduction

In the last few decades, many salmonid populations in Washington State have declined, leading to the inclusion of bull trout and Puget Sound chinook salmon on the Endangered Species List. In response, the Washington State Legislature passed several bills to address the problem in a logical, concerted manner. Two key pieces of legislation (Engrossed Substitute House Bill 2496 and Second Engrossed Second Substitute Senate Bill 5596, now 77RCW) initiated the process towards the development of "Habitat Limiting Factors" reports.

This report is the habitat limiting factors project for WRIA 1, the Nooksack Basin. It provides a consolidation of existing habitat information in a Statewide consistent format, and rates various categories of habitat conditions. The habitat categories include fish habitat access, floodplain, sediment, streambed, riparian, water quality, flow, estuarine and nearshore conditions. Each of those conditions are rated as either "poor", "fair", "good", or "data gap", based upon a set of standards that are described in the Assessment Chapter. This Executive Summary presents only an overview of the worst habitat problems, but all the habitat ratings are provided in Tables 15 and 16 in the Assessment Chapter. More importantly, detailed discussions for each of these habitat conditions can be found within the Habitat Limiting Factors Chapter of this report. Maps of updated salmon and steelhead trout distribution and nearshore conditions are located in a separate electronic file on this disc.

The streams addressed in this report include all salmon- and steelhead-producing streams in the following basins: the Nooksack, Dakota, California, Terrell, Squalicum, Whatcom, Lake Whatcom, Padden, Chuckanut, Oyster, Colony, Sumas, Saar, Frost, Selesia, Domfino, Tomyhoi, and the Chilliwack Basins. The Fraser River tributaries include only those portions found in Washington State.

Major Habitat Problems in the Nooksack Basin

Of all the drainages in WRIA 1, the Nooksack is the largest and produces the greatest abundance of salmonids and the greatest number of salmonid stocks. As many as 19 different salmon, steelhead, bull trout, and cutthroat trout stocks are currently identified within the Nooksack Basin, including 4 possible stocks of chinook, 2 native chum stocks, coho, 3 pink stocks, 1 riverine sockeye stock, 4 steelhead stocks, 1 cutthroat stock, and 3 Dolly Varden/bull trout stocks.

Most of the salmonid spawning habitat in the Nooksack Basin is located in the three forks of the Nooksack River. However, much of this area has considerable sedimentation problems, most originating from landslides. In the South Fork Nooksack sub-basin, more than 1200 landslides have been identified with 37% associated with clearcuts and 32% related to roads. Road densities are generally high, especially in the Hutchinson, Skookum, Edfro, Cavanaugh, Deer, Roaring, Plumbago, and Howard Creek watersheds and along the middle reaches of the South Fork Nooksack River. The suspended sediment levels in the mainstem South Fork are sometimes higher than in the glacially fed Middle Fork Nooksack River. Sediment transport is further impaired by a lack of large woody debris (LWD), and the excess sedimentation has likely contributed to a lack of adequate pool habitat. In the past, streambed instability and poor gravel quality have been documented in the South Fork Nooksack River, but current conditions are unknown for these parameters.

The North and Middle Fork Nooksack Rivers have a naturally high sediment load due to glacial inputs. However, human-caused sedimentation is considerable. About 480 landslides have been recorded in the Middle Fork Nooksack River sub-basin with 36% linked to roads and 32% associated with clearcuts. Road densities are generally high; as much as 12.6 miles of road per square mile of watershed in Heislers Creek. Most roads are unpaved, which worsens the sedimentation impact. Very little data were found regarding gravel quality, LWD, pool habitat, streambed and channel stability conditions in the Middle Fork Basin.

An estimated 632 landslides have been documented in the North Fork Nooksack sub-basin. Roads have been associated with 36% and clearcuts with 28% of the landslides. Most landslides occurred within 10 years of intense timber harvest in a given area, and the landslide frequency correlates well to forest practice activity both temporally and spatially. Landslide densities are especially high in the Cornell, Racehorse, Gallop, Boulder, and Coal Creek watersheds with generally high road densities in most of the watersheds downstream of Nooksack Falls. Data were limited for substrate quality, LWD, pools, channel and streambed stability, but where data were available, channel and streambed instability and low levels of LWD were common.

Other habitat problems in the Forks include impacts to riparian, floodplain, water quality and flow conditions, and most of these problems occur in the lower reaches. The lower South Fork Nooksack River has dikes along 60% of its length, and its channel length has decreased by an estimated 37%, likely due to a loss of secondary channels. Riparian conditions are rated “poor” in this same area, as well as in some of the tributaries, such as Black Slough and Hutchinson Creek. Warm water temperatures are a critical problem in the South Fork Nooksack sub-basin with 52% of the samples warmer than 20^{o}C and a peak temperature of 23.9^{o}C in the lower South Fork Nooksack River in 1996. Warm water temperatures have also been documented in Hutchinson, Skookum, Cavanaugh, Roaring, Howard, and Wanlick Creeks, tributaries to the South Fork Nooksack River.

Warm water temperatures have also been recorded in the lower Middle Fork Nooksack River and in Canyon Lake Creek, but water temperatures are a data need in other Middle Fork Nooksack tributaries. Riparian conditions were rated “poor” along the lower Middle Fork Nooksack River and along Rankin Creek, but were “fair” to “good” elsewhere. There is naturally limited floodplain habitat in the Middle Fork Nooksack sub-basin.

While the lower North Fork Nooksack River has experienced some warm water temperatures, most of the water quality problems are in the tributaries. Warm water temperatures have been documented in lower Boulder, Gallop, lower Canyon, Cornell, Racehorse, Hedrick, and Kenney Creeks. Many of these areas also have degraded riparian and sedimentation conditions; both contribute to water quality problems. While there are some known floodplain impacts in the North Fork Nooksack sub-basin, quantification was lacking and is a data need.

The Nooksack River sub-basin (downstream of the Forks) has a heavily impacted floodplain and very poor riparian conditions throughout the mainstem and most tributaries. The lack of shade, loss of wetlands, and channel changes are probable causes for the warm water temperatures found in the Nooksack River and the Silver, Tenmile, Bertrand, Fishtrap, Kamm, and Anderson Creek watersheds. Also, compared to other rivers in the Puget Sound region, the Nooksack River near Ferndale has among the highest levels of nitrogen (including ammonia and nitrate), phosphorous, turbidity, and suspended solids. From 1979 to 1991, turbidity has increased between 1 to 2% per year in the lower mainstem Nooksack River.

Inadequate stream flows for salmonid habitat are a pervasive problem throughout WRIA 1, and can contribute to water quality problems. Many of the lowland streams and tributaries flow through land converted to agricultural or urban use, which has resulted in channelization, water withdrawals, a loss of wetlands, and altered land cover. More than thirty drainages and mainstem reaches are closed to further water allocations in WRIA 1, particularly targeting the South Fork Nooksack River and Hutchinson and Skookum Creeks, the North Fork Nooksack River and its major tributaries, and the tributaries to the Nooksack River downstream of the Forks. Land cover vegetation has been greatly altered in all of the Nooksack watersheds downstream of the Forks, as well as in watersheds draining to the lower North, South, and Middle Fork Nooksack Rivers. This can impact both high and low flow conditions.

Major Habitat Problems in the Dakota, California, Terrell, Squalicum, Whatcom, Padden, Chuckanut, Oyster, and Colony Creek Watersheds

The smaller, independent drainages provide habitat for coho, cutthroat, steelhead, chum, and to a lesser degree, chinook. Potentially low stream flows are also believed to be a problem in many of these streams. Dakota, California, Terrell, Squalicum, Whatcom, Padden, and Chuckanut Creeks all have closures for further water allocations, and existing water rights are numerous. The land cover vegetation has also been greatly altered, increasing the likelihood of water flow impacts. Impervious surfaces are rated “poor” in the Terrell and Colony Creeks, and are probably poor in Squalicum, Whatcom and Padden Creeks. Warm water temperatures have been documented in Dakota, Squalicum, Whatcom, Padden, and Chuckanut Creek watersheds, and have not been measured in California, Terrell, Oyster, and Colony Creeks. Other toxins, such as pentachlorophenol, and mercury, lead, zinc, and copper have been documented in Whatcom Creek with urban and industrial storm water runoff, the suspected source.

Based upon a broad-scale analysis, riparian conditions are tentatively rated "poor" in the watersheds of Dakota, California, Terrell, Squalicum, Whatcom, Padden, Chuckanut, Oyster, and Colony Creeks, but reach-specific data were lacking. Low levels of LWD were noted in Squalicum along with streambed instability. No other data on stability, LWD, pools, or sedimentation were found for any of the above-listed streams. Floodplain conditions are believed to be "poor" in Dakota, California, and Squalicum Creeks due to wetland loss or bank hardening. No other data on floodplain or fish access conditions were found for these streams.

The Lake Whatcom sub-basin supports native cutthroat and kokanee populations. Its tributaries are impacted by landslides in the upper reaches and floodplain degradations such as bank hardening in the lower reaches. Low levels of LWD exist throughout, and streambed stability has ranged from "fair" to "poor". Warm water temperatures and degraded riparian conditions are also common in these tributaries. Increased urbanization and residential development are thought to contribute to water quality problems in Lake Whatcom.

Major Habitat Problems in the Fraser River Tributaries

Habitat conditions in the Washington State portion of the Fraser River tributaries vary greatly with land ownership. The upper Chilliwack, Selesia, Domfino, and Tomyhoi watersheds are relatively pristine, located within either National Park Service or U.S. Forest Service boundaries. In contrast, the Sumas River, Saar Creek, and Frost Creek watersheds have extensive impacts to water quality, flow, and riparian vegetation. Levels of nitrogen (including ammonia) and phosphorous in the Sumas River are among the highest levels in the Puget Sound region, and low dissolved oxygen levels have been documented in several Sumas River tributaries. Numerous surface and ground water rights exist throughout the Sumas River watershed, and the Sumas River and Saar Creek are closed to further water allocations. Little information was found for fish access, floodplain, and sediment conditions in these streams. Chum, coho, and cutthroat are found throughout these streams with bull trout/Dolly Varden in the Chilliwack watershed and chinook salmon in the Sumas River.

Habitat Impacts in the WRIA 1 Estuarine and Nearshore Environments

The condition of the estuarine and nearshore habitat in WRIA 1 varies considerably according to location. Estuary habitat loss has been documented in Bellingham, Lummi, and Samish Bays, but no information was found for other estuaries in WRIA 1. Overall, Whatcom County ranked 8th out of 14 Puget Sound Counties for the percent of modified shoreline miles. Shoreline modifications (bulkheads, rip-rap, fills) were common along Point Roberts, the Peace Arch, Blaine, Birch Bay, Neptune Beach, Sandy Point Shores, Lummi Bay, Bellingham Bay, and Samish Bay. Most of the areas with high percentages of modified shorelines also had poor overhead riparian vegetation. Overwater structures, which can impact eelgrass beds and directly affect salmonid behavior are a concern in the following areas: Arco Pier, Intalco Pier, British Petroleum Pier, Gooseberry Point Ferry Terminal, Lummi Island Ferry Terminal, inner Bellingham Bay, Point Roberts Marina, Blaine Marina, Birch Bay Marina, Sandy Point Shores Marina, and Squalicum Marina.

Water quality (including sediment contamination) is a major problem in inner Bellingham Bay, where 9 of the 134 total Puget Sound contaminated sediment sites were located. Numerous toxins including mercury, arsenic, and PCBs have been found. Some of these are known to cause tumors and suppress immune systems in salmonids. They can also be lethal to benthic organisms, which serve as food for salmonids, resulting in a potential reduction of prey. Also, the toxins accumulate in benthic organisms, contaminating the food web. The locations and sources of these toxins have been located, and cleanup is in the initial planning and negotiation stages.

Other water quality issues in WRIA 1 include creosote treated materials and oil spills. This summer, the Department of Ecology plans to remove 350 tons of beached creosote-treated wood from the Whatcom County shoreline, but more will likely be deposited in the future.

Conclusion

This report consolidates and rates salmonid habitat conditions from the freshwater to nearshore environments and presents a list of data needs. It is one step in a coordinated effort towards salmonid recovery, providing the technical background that can aid in the development of restoration/protection projects, recovery strategy development, and project ranking. As conditions change over time, it is hoped that new information will be used to modify future versions of this analysis.

INTRODUCTION

Habitat Limiting Factors Background

The successful recovery of naturally spawning salmon populations depends upon directing actions simultaneously at harvest, hatcheries, habitat and hydro, the 4H's. The 1998 state legislative session produced a number of bills aimed at salmon recovery. Engrossed Substitute House Bill 2496 (now 77RCW) was a key piece of the 1998 Legislature's salmon recovery effort, with the focus directed at salmon habitat issues.

Engrossed Substitute House Bill (ESHB) 77RCW in part:

> directs the Conservation Commission in consultation with local government and the tribes to invite private, federal, state, tribal and local government personnel with appropriate expertise to act as a technical advisory group;
>
> directs the technical advisory group to identify limiting factors for salmonids to respond to the limiting factors relating to habitat pursuant to section 8 sub 2 of this act;
>
> defines limiting factors as "conditions that limit the ability of habitat to fully sustain populations of salmon."
>
> defines salmon as all members of the family salmonidae, which are capable of self-sustaining, natural production.

The overall goal of the Conservation Commission's limiting factors project is to identify habitat factors limiting production of salmon in the state. In waters shared by salmon, steelhead trout and bull trout we will include all three. Later, we will add bull trout only waters as well as cutthroat trout.

It is important to note that the responsibilities given to the Conservation Commission in 77RCW do not constitute a full limiting factors analysis. The hatchery, hydro and harvest segments of identifying limiting factors are being dealt with in other forums.

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

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

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

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

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

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

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

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

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

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

Except for bull trout and resident steelhead, juvenile parr convert to smolts as they migrate downstream towards the estuary. Again, flows are critical, and food and shelter are necessary. The natural flow regime in each river is unique, and has shaped the population's characteristics through adaptation over the last

10,000 years. Because of the close inter-relationship between a salmon stock and its stream, survival of the stock depends heavily on natural flow patterns.

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

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

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

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

In Washington, adult chum salmon (3-5 years old) have three major run types. Summer chum adults enter the rivers in August and September, and spawn in September and October. Fall chum adults enter the rivers in late October through November, and spawn in November and December. Winter chum adults enter from December through January and spawn from January through February. Chum salmon fry emerge from the nests in March and April, and quickly outmigrate to the estuary for rearing. In the estuary, juvenile chum follow prey availability. In Hood Canal, juveniles that arrive in the estuary in

February and March migrate rapidly offshore. This migration rate decreases in May and June as levels of zooplankton increase. Later as the food supply dwindles, chum move offshore and switch diets (Simenstad and Salo 1982). Both chum and pink salmon have similar habitat needs such as unimpeded access to spawning habitat, a stable incubation environment, favorable downstream migration conditions (adequate flows in the spring), and because they rely heavily on the estuary for growth, good estuary habitat is essential.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Introduction to Habitat Impacts

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

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

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

WATERSHED DESCRIPTION AND CONDITION FOR STREAMS IN WRIA 1

Introduction

This report describes habitat conditions and salmonid populations throughout WRIA 1 (Map 1; maps are in a separate file). The northern boundary of the WRIA is the U.S./Canadian border, and the southern border includes Colony Creek. The eastern boundary consists of these streams' glacial headwater sources in the Cascade Mountain Range, while the area extends west to the photosynthetic zone of the near shore environment. It also includes streams that are located within Whatcom County, but are tributaries to the Fraser River in Canada (e.g. Sumas, Chilliwack Rivers). The Washington State Department of Fish and Wildlife Stream Catalog lists 654 streams and 1325 linear miles of streams in WRIA 1 (Phinney and Williams 1975). The linear miles estimate does not include many of the small streams important to coho and cutthroat production and does not include streams that drain into Canada.

Most of the WRIA is located within Whatcom County, but parts of the South Fork Nooksack basin extend southwards into Skagit County. The WRIA includes two Indian reservations; the Lummi Nation on the Lummi Peninsula and Portage Island, and the Nooksack Indian Tribe, whose reservation is located along sections of the Nooksack River.

The region lies within a convergence zone with Arctic weather from the north and Pacific weather systems in the south (U.S. Forest Service 1995a). In the summer months, the Pacific systems dominate with mild, clear weather and low levels of precipitation. In the winter, Arctic systems move into the area bringing storms, high levels of precipitation, and occasionally very low temperatures. In the lowlands, annual average precipitation ranges from 30 to 50". In the higher elevations, precipitation averages 70 to 140" per year with much falling as snow on the Mount Baker slopes (U.S. Forest Service 1995a). Rain-on-snow events mostly occur from late October through January.

Euro-Americans began settling in the area in the 1850s, attracted by high quality timber coupled with an easy access to water transportation (Whatcom County Planning and Development Services Dept. 1997). Many changes in the land occurred from 1890 to 1925, due to increased logging, coal mining, and the clearing of 130,000 acres of lowlands for farms. By 1938, nearly all of the forests and the numerous wetlands in the delta and lower mainstem were converted to agricultural land, and more than 2,000 snags (woody debris) were cleared from the river by 1900 (Collins and Sheikh in prep.). Several meanders in the lower mainstem were cut-off (Collins and Sheikh in prep.), which began the straightening process that has continued to the present. Various industries (lumber mills, shake mills, and fish processing plants) were built in Bellingham and along Lake Whatcom. During this time period, logging companies sold logged-off lands to employees and immigrants for small farm development.

From 1950 to 1990, commercial activity greatly increased. Lands formerly used for agriculture became converted to residential, commercial, and industrial uses (Whatcom County Planning and Development Services Dept. 1997). Coal mining ceased, but sand and gravel mining activities grew to accommodate development. Human population growth in Whatcom County increased by nearly 100% in this 40-year period (Whatcom County Planning and Development Services Dept. 1997). From 1990 to 1995, the estimated annual human population growth rate ranged from 2.3 to 3.7% (Whatcom County Planning and Development Service Dept. 1997).

Currently, 82% of the Whatcom County lands are forest and rural lands, 9% consist of agricultural use, 3% are residential lands, 2% are urbanized, and the remainder consists of industrial, mining, and commercial development (Whatcom County Planning and Development Services Dept. 1997).

Watershed Description and Land Use in Dakota, California, and Terrell Creeks

Dakota and California Creeks are formed by springs and surface water run-off from the low hillslopes in the northwest portion of WRIA 1 (Phinney and Williams 1975). About 1% of the Dakota watershed lies in Canada (Nelson et al. 1991). Both watersheds drain into Drayton Harbor and are surrounded by rural lands in the upper and middle reaches with urban land use near the mouths (Phay 2000b). Specifically, 40% of the basin is forestland, 54% is rural or agricultural lands, and 2.5 % is urban land consisting of the City of Blaine (Nelson et al. 1991). This results in impacts typical to those land uses, such as channelization and loss of forested land cover. About 98% of the acreage in the Drayton WAU is under private ownership and 2% is State-owned (Lunetta et al. 1997). The Drayton WAU includes both Dakota and California Creek watersheds.

Much of the forestland lies in the North Fork Dakota Creek sub-watershed, and that area is relatively natural (Nelson et al. 1991). However, the South Fork and mainstem Dakota Creeks have experienced land conversions and associated impacts. 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). Draining, filling, excavating, grazing, hay production, and buildings and roads have reduced and impacted wetlands in this area. California Creek has many channelized sections and ditches. The ditches have been degraded by livestock access, which translates to water quality problems to the streams.

Terrell Creek is formed by Lake Terrell and the springs to Fingalson Creek (Phinney and Williams 1975). It drains to Birch Bay, and is also surrounded by low terrain currently characterized as a mix of rural and urban (Phay 2000b). About 90% of the land in the Birch Bay WAU is privately owned, 5% is under tribal ownership, and nearly 5% is State-owned (Lunetta et al. 1997). Terrell Creek is the largest watershed in the Birch Bay WAU. There is a small dam that controls water flow from Lake Terrell to Terrell Creek for the purpose of maintaining waterfowl habitat (Scott and McDowell 1994).

Watershed Description and Land Use in the Sumas River, Chilliwack River, and Damfino, Tomyhoi, Frost, and Silesia Creeks (Washington State Fraser River Tributaries)

The upper reaches of Sumas and Chilliwack Rivers, as well as Damfino, Tomyhoi, Frost, and Silesia Creeks originate in Washington State, but these streams ultimately drain into the Fraser River in British Columbia. The Sumas River, Damfino Creek, Frost Creek, and

Silesia Creek are tributaries to the Chilliwack River. The Chilliwack River crosses the Canadian border to flow into Chilliwack Lake, which drains into the Vedder River, a Fraser River tributary. Tomyhoi Creek is a tributary to Damfino Creek.

With the exception of the Sumas River and Saar Creek (a Sumas River tributary) watersheds, the Fraser River tributaries flow through forested lands in the United States. Nearly the entire Washington State portion of the Chilliwack River (99%) is protected in the North Cascades National Park and consists of mountainous, forested terrain. The upper reaches of Silesia Creek also lie in the Park, with lands further downstream contained in the Mount Baker Wilderness section of the Mount Baker Snoqualmie National Forest. The Washington State portion of Tomyhoi and Damfino Creeks flow through National Forest lands, with a forestry land use. Lands within the U.S. section of the Frost Creek watershed are privately owned and managed for timber production. Overall, the WAU that includes the Washington State reaches of Silesia, Damfino, and Tomyhoi Creeks consists of 81% U.S. Forest Service ownership, 1% private ownership, 18% Park ownership, and less than 1% State ownership (data from Lunetta et al. 1997).

The Sumas River and its eastern tributaries drain Sumas Mountain. Sumas Mountain is forestland, but the river and tributaries predominantly flow through agriculture and rural lands (Phay 2000b) that were historically wetland prairies (DOE 1995). The towns of Sumas and Nooksack have small levels of urbanization near Sumas River and Johnson Creek, respectively. About 92% of the Sumas WAU is privately owned, and 8% is State-owned (data from Lunetta et al. 1997).

Saar Creek is a tributary to the Sumas River and drains Vedder Mountain, flowing through forest and rural lands in its upper reaches and through agricultural land in the reaches south of the Canadian border (Phay 2000b). The Vedder WAU, which includes the entire Saar Creek watershed and the upper reaches of Frost Creek, consists of 84% privately owned lands and 16% State-owned lands (data from Lunetta et al. 1997).

Watershed Description and Land Use in the Nooksack Basin including the Lummi River

Three major forks form the Nooksack River: the North Fork, Middle Fork, and South Fork Nooksack Rivers. The North and Middle Forks originate from Mount Baker glaciers and snowfields (Dept. of Conservation 1960), and are typically turbid with moderate flows during the summer due to glacial melt. The Middle Fork enters the North Fork Nooksack River at rivermile (RM) 40.5 (Phinney and Williams 1975). The South Fork Nooksack River drains the slopes of the Twin Sisters Mountain and is usually low and clear in the summer. This results in very different flow patterns and water sources. While the North Fork has peak flows in June and low flows in March, the South Fork peaks in May and December, with low flows in August (Dept. of Conservation 1960). The different headwater sources also result in divergent water temperature patterns. The water temperature in the South Fork has been an average of 7.5^{o}C warmer than in the North Fork (Nooksack Spring Chinook Technical Team 1986). The North Fork produces 140,000 acre-feet more run-off in the summer compared to the South Fork for equal sized drainage areas (Dept. of Conservation 1960). The topography differs as well. In the North Fork, 42% of the basin is below 4000 feet, compared to 88% of the South Fork Nooksack Basin (Dept. of Conservation 1960). The South Fork enters the North Fork Nooksack River at RM 36.6 (Phinney and Williams 1975).

There is evidence that the North and South Forks differed even more in geological history. Easterbrook (1971) suggested that in the late Pleistocene, the Chilliwack River flowed southward into the present North Fork Nooksack drainage and the present day South Fork Nooksack River flowed southward into the upper Samish River. This time period coincides with the first indication of fossil salmonids from the genus *Oncorhynchus* (Miller 1965).

These geographical and geological differences between the North and Middle Forks and the South Fork manifests into divergent geomorphic environments with potentially different water chemistry that may explain why some of the native-origin salmonid stocks from the North Fork are genetically different from those in the South Fork (Marshall et al. 1995).

<u>The North Fork Nooksack Sub-Basin</u>

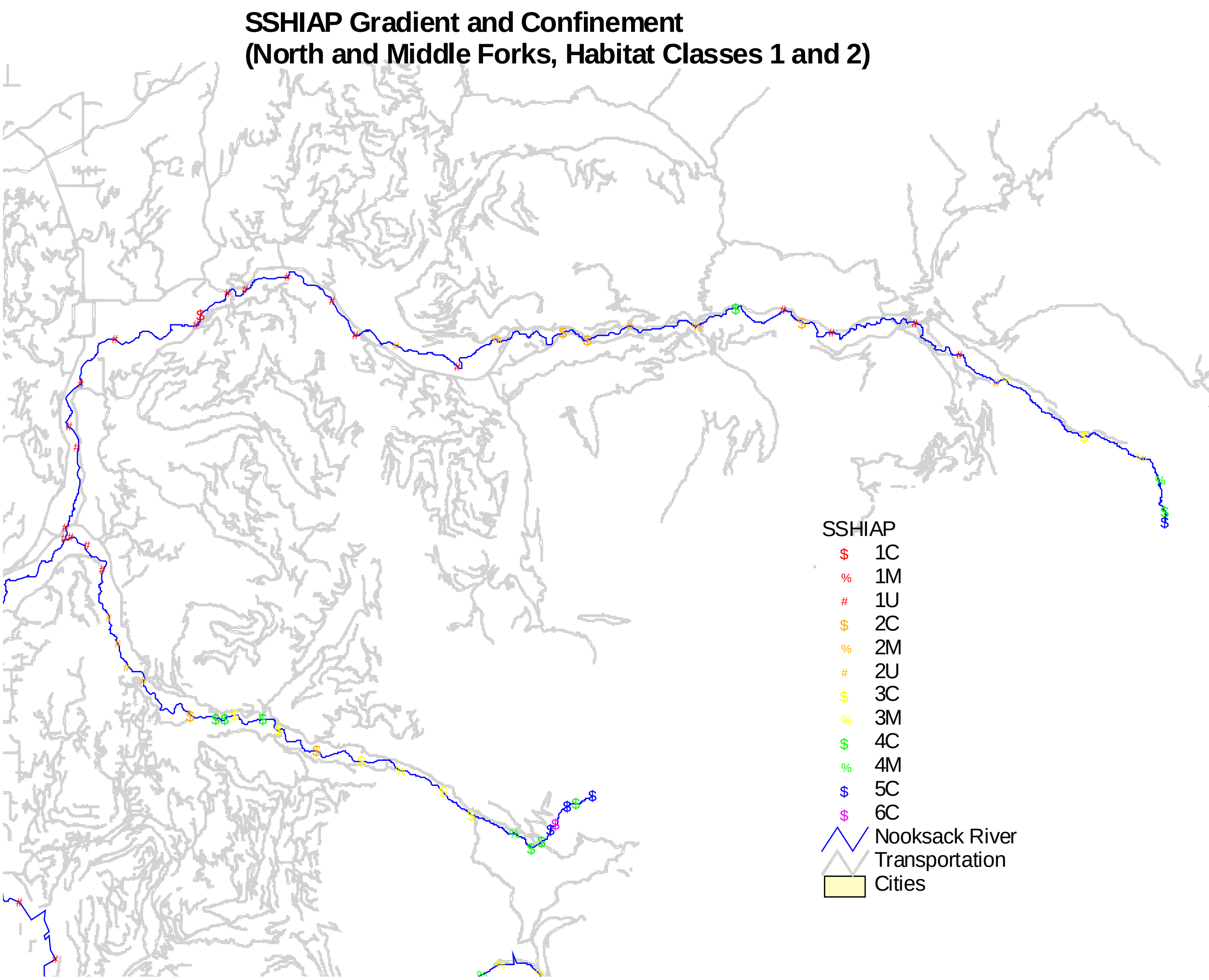
The North Fork Nooksack River originates from four large glaciers along with several small glaciers and snowfields (Phinney and Williams 1975). The surrounding terrain includes steep hillsides transitioning further upstream into steep mountain slopes. At RM 65, a 100-foot waterfall (Nooksack Falls) is the upstream limit for anadromous salmonid distribution. Upstream of the falls the gradients and channel confinements are highly variable (Figure 1) (SSHIAP 1995 to present).

The North Fork Nooksack River has a 1 to 2% gradient with moderate to confined channels from the falls to Glacier Creek (Figure 1) (SSHIAP 1995 to present). Downstream of the falls, important tributaries in the upper North Fork Nooksack drainage include Deadhorse (RM 63.4), Glacier (RM 57.6), Gallop (RM 57.4), Cornell (56.2), Canyon (RM 55), Boulder (RM 52.2), Maple (RM 49.7), and the Slide Mountain Creeks. The upper watershed lies within the Mount Baker Snoqualmie National Forest, and major land uses include forestry and recreation with limited residences and agriculture west of the National Forest boundary. Puget Sound Power and Light operates a small powerhouse shortly downstream of Nooksack Falls, which has not been operated since 1997, but may be in the future.

Glacier Creek starts in the Roosevelt Glacier with most of the watershed contained within the National Forest. The watershed is highly mountainous. A series of cascades and falls near the Forest Service Bridge results in a natural barrier for anadromous salmonids.

From Maple Falls to the confluence of the North and South Forks, the North Fork Nooksack River flows mostly through a broad valley that supports forestry with limited agriculture and rural residences (Phinney and Williams 1975). The lower four to five miles of the North Fork Nooksack River has a low gradient with numerous sites of channel braiding through an unconfined channel (Figure 1) (SSHIAP 1995 to present). Major tributaries in this area include Kendall (RM 45.9), Coal (RM 45.2), Racehorse (RM 45.1), Kenny (RM 41.3), and Bells (RM 40.8) Creeks and the Middle Fork Nooksack River (RM 40.5). The Kendall Creek Hatchery produces chinook and coho salmon.

Figure 1. Gradient and Channel Confinement Designations in the North and Middle Fork Nooksack Rivers (SSHIAP 1995 to present). Gradient definitions are as follows: red=<1%, orange=1-2%, yellow=2-4%, green=4-8%, blue=8-20%, and purple=>20%.



The Middle Fork Nooksack Sub-Basin

Like the North Fork Nooksack River, the Middle Fork also originates from glaciers on Mount Baker and consists of steep terrain in its upper reaches (Phinney and Williams 1975). The lower 2.5 miles of streambed has a low (<1%) gradient with an unconfined channel surrounded by rural residential land use (Figure 1) (SSHIAP 1995 to present). Logging activity has been extensive, and some gravel removal has occurred in the lower river. The diversion dam at RM 7.2 occasionally diverts surface water to Lake Whatcom for the City of Bellingham's water supply. This serves as the upstream barrier to anadromous salmonid distribution in the Middle Fork Nooksack sub-basin because it is not currently laddered. Upstream passage of anadromous salmonids has been hampered due to concerns that salmon will bring diseases, such as Infectious Hematopoietic Necrosis (IHN), into Lake Whatcom through the city's water intake pipe, which might spread to kokanee and cutthroat trout in the lake.

Upstream of the diversion dam, the gradients are variable ranging from 1 to 8%, and the channels are mostly confined (Figure 1) (SSHIAP 1995 to present). Upstream of Ridley Creek, the gradients increase to a range of 4 to greater than 20% with confined channels.

Major salmonid-producing tributaries to the Middle Fork Nooksack River include Canyon Lake (RM 0.9), Porter (RM 3.9), and Heislers (RM 5.1) Creeks in the lower watershed. Above the diversion, major non-anadromous salmonid spawning areas occur in Clearwater (RM 9.1), Warm (RM 12.9), and Green (RM 15.3) Creeks.

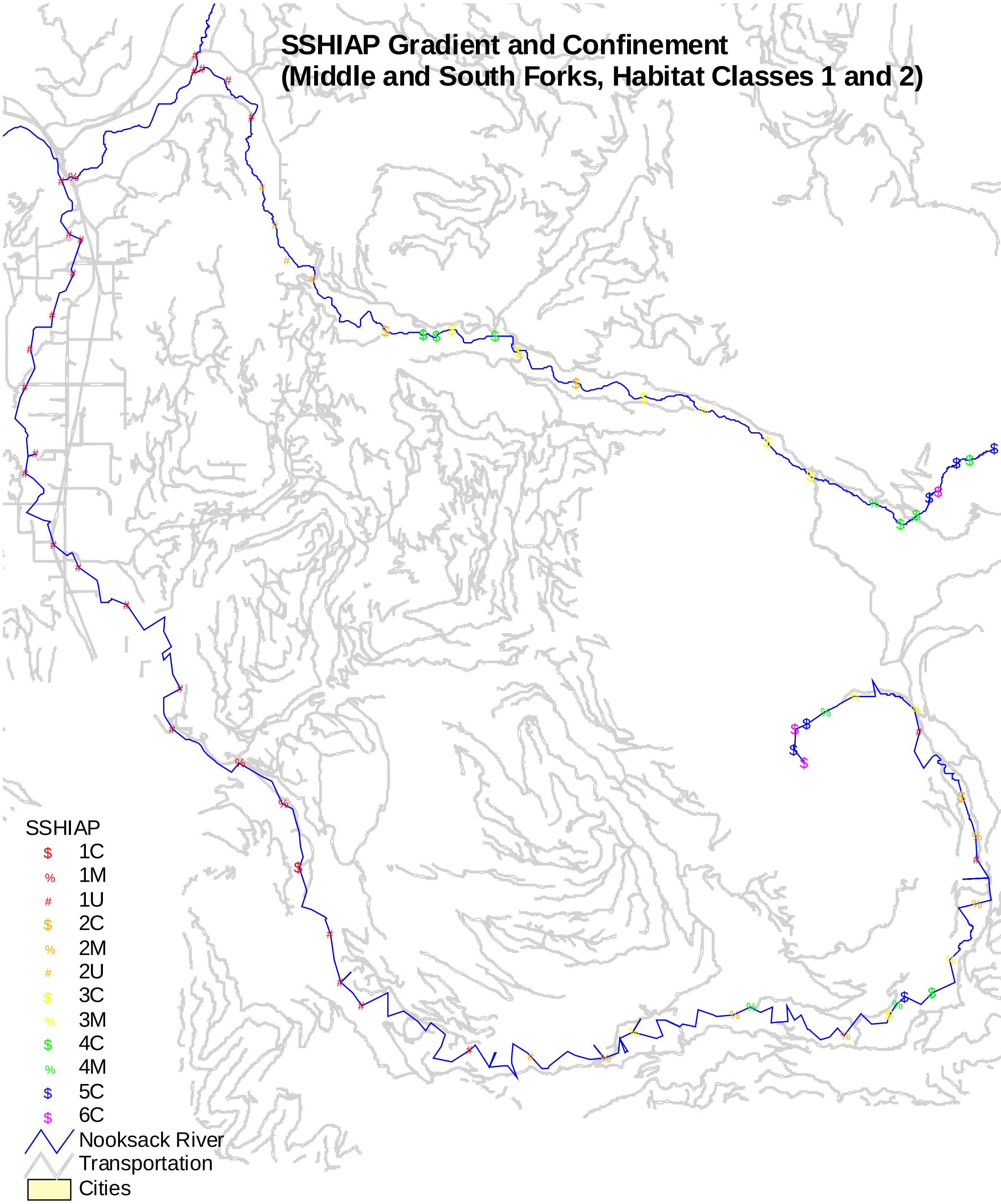
The South Fork Nooksack Sub-Basin

The South Fork Nooksack River joins the Nooksack River at RM 36.6. The lower thirteen miles are characterized by a low gradient, unconfined channel with major tributaries including Saxon (RM 11.8), Hutchinson (RM 10.1), Jones (RM 8.4), McCarty (RM 7.2), and Black Slough (RM 2.5) Creeks. Hutchinson Creek, a moderate-gradient stream, is the largest of the tributaries to the lower South Fork Nooksack River.

The lower South Fork Nooksack River flows through a valley floor that has been cleared for agriculture. Moderate and steep slopes with a forestry land use surround the valley (Phinney and Williams 1975). While agriculture has resulted in channel alterations and loss of riparian forest in the lower South Fork Nooksack drainage, timberlands and associated impacts predominate upstream of RM 13 (Phinney and Williams 1975).

From RM 16.5 to 34.1, the South Fork Nooksack River lies within Skagit County. The gradients range from 1 to 8% with moderately confined and confined channels (Figure 2) (SSHIAP 1995 to present). The U.S. Forest Service owns the watershed from approximately RM 33 upstream. The gradients are highly variable with some very steep reaches (Figure 2). Many of the smaller tributaries between RM 13 to 25 have limited access to anadromous salmonids because of cascades and falls due to the steeper terrain (Phinney and Williams 1975), but major tributaries, such as Skookum (RM 14.3), Cavanaugh (RM 16.5), and Edfro (RM 16.2) Creeks, among other streams, provide salmonid habitat.

Figure 2. Gradient and Channel Confinement Designations in the South Fork Nooksack River (SSHIAP 1995 to present). Gradient definitions are as follows: red=<1%, orange=1-2%, yellow=2-4%, green=4-8%, blue=8-20%, and purple=>20%.



The Mainstem Nooksack River Drainage and Lummi River

The mainstem Nooksack River has a low gradient just downstream of the forks and flows through a broad, flat valley with steep slopes to the sides. SSHIAP (1995 to present) has classified the reaches as low gradient (less than 1%) with unconfined channels (Figure 3). Logging occurs on the slopes with agriculture and rural residences in the valley. Smith (RM 29.3) and Anderson (RM 28.2) Creeks are the largest tributaries in this region, and both have low to moderate gradients (Phinney and Williams 1975). The conversion to agriculture and residences along the banks has resulted in channelization and loss of riparian forest.

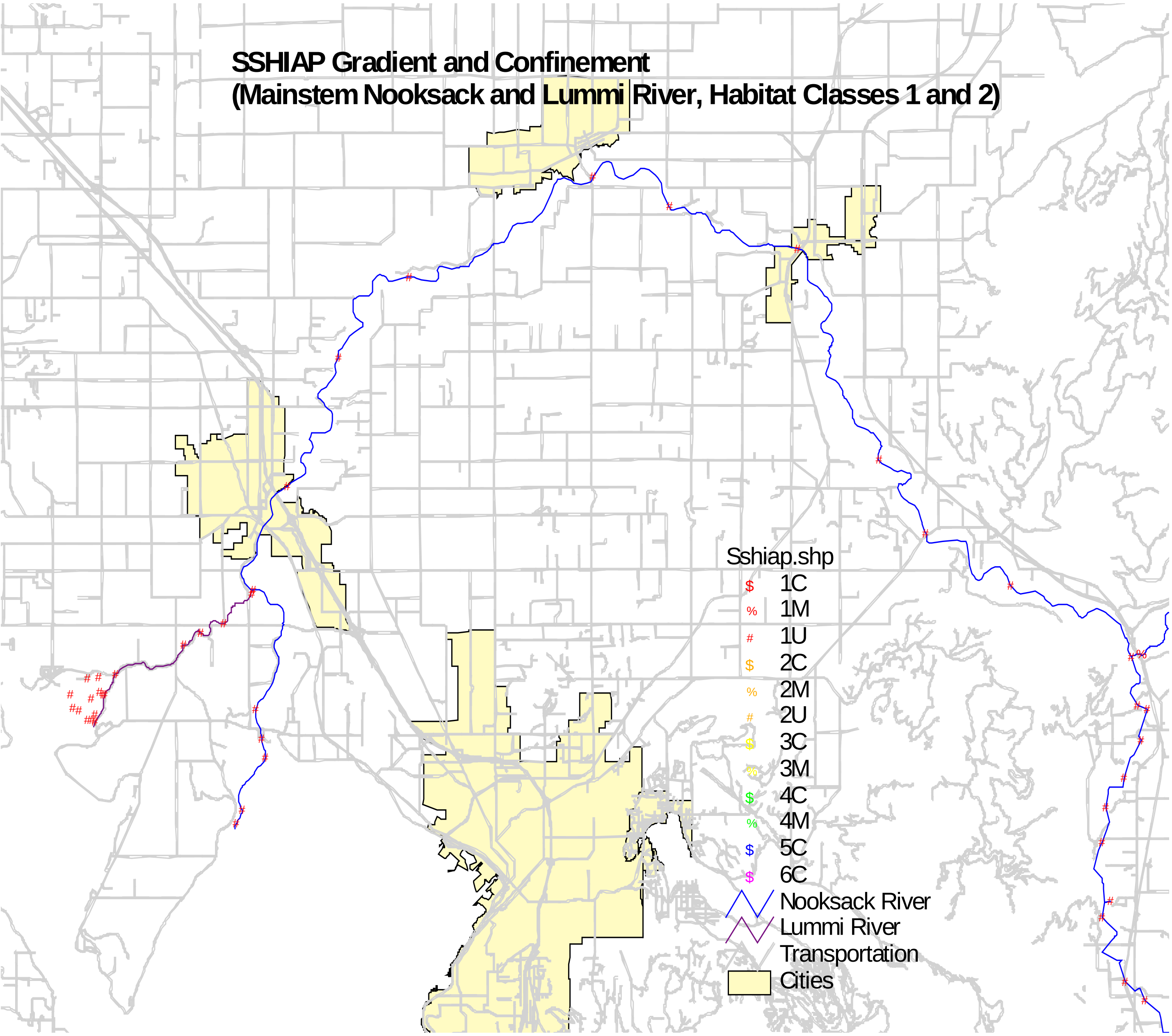
Downstream of Lynden, the mainstem flows through land used primarily for agriculture, dairy farms, and an increasing number of residences. Gravel mining, dredging, water withdrawals and loss of riparian forest have been noted in this area (Phinney and Williams 1975). These habitat conditions are discussed more fully in the Habitat Limiting Factors section of this report. Fishtrap (RM 13.2) and Bertrand (RM 12.6) Creeks are the larger tributaries in this reach, and slightly more than half of these two watersheds drain areas in Canada (Whatcom Conservation District 1988a). The Canadian region of Fishtrap and Bertrand Creeks consists of urban land use subjected to a high human population growth rate, and agriculture dominates the United States portion of these watersheds. However, the channels are more natural in the Canadian reaches, while ditching and draining has commonly occurred within the American reaches of these streams (Whatcom Conservation District 1988a).

The lower ten miles of the mainstem Nooksack River has a low gradient and flows through land used for agriculture, residences, and a small section of urbanization associated with the City of Ferndale. Channelization, dikes, and loss of forest vegetation are extensive in this area. Tenmile (RM 6.9) and Silver (RM 0.7) Creeks are the largest tributaries to the lower mainstem Nooksack River. Their channels are narrow and confined (Phinney and Williams 1975).

Historically, the lower Nooksack River and delta had extensive wetlands, with outlets to both Lummi and Bellingham Bay (Collins and Sheikh in prep.). In the late 1800s, a diversion was built to permanently divert most of the flow from the Nooksack River mouth into Bellingham Bay (People for Puget Sound 1997). Prior to the diversion and development, the lower Nooksack River was consisted of numerous channels and sloughs, and had a major outlet into Lummi Bay.

After the diversion dam was constructed to divert the Nooksack River into Bellingham Bay (People for Puget Sound 1997), the Lummi River became a high water overflow channel from the Nooksack River at RM 4.5 (Phinney and Williams 1975). During low flow conditions, the Lummi River acts as a slough, dominated by tidal influence. Diking has occurred along the banks. During periods of Nooksack River high flows, the Lummi River carries freshwater to Lummi Bay. The surrounding land use is agriculture (Phay 2000b).

Figure 3. Gradient and Channel Confinement Designations in the Nooksack and Lummi Rivers (SSHIAP 1995 to present). Gradient definitions are as follows: red=<1%, orange=1-2%, yellow=2-4%, green=4-8%, blue=8-20%, and purple=>20%.



Watershed Description and Land Use in Squalicum, Whatcom, Padden, and Lake Whatcom Watersheds

Squalicum, Whatcom, and Padden Creeks originate from lakes, with Lake Whatcom and Lake Padden used as domestic water supplies (Phinney and Williams 1975). These three streams flow through urbanized and industrial areas to drain into Bellingham Bay. The upper reaches of Squalicum Creek flow through rural lands (Phay 2000b) and have variable gradients with one reach having a gradient that is greater than 20% (Figure 4) (SSHIAP 1995 to present). From RM 6.3 downstream to Interstate 5, the gradient of Squalicum Creek is low and mostly unconfined. However, the reaches downstream of Interstate 5 are moderately confined to confined with a gradient of 1-2% (Figure 4) (SSHIAP 1995 to present).

Whatcom Creek is mostly comprised of a gradient that ranges from <1 to 2% with moderately confined to confined channels (Figure 4) (SSHIAP 1995 to present). Padden Creek is mostly a low gradient, unconfined channel below Interstate 5, but steepens to 2-20% confined channels upstream of Interstate 5.

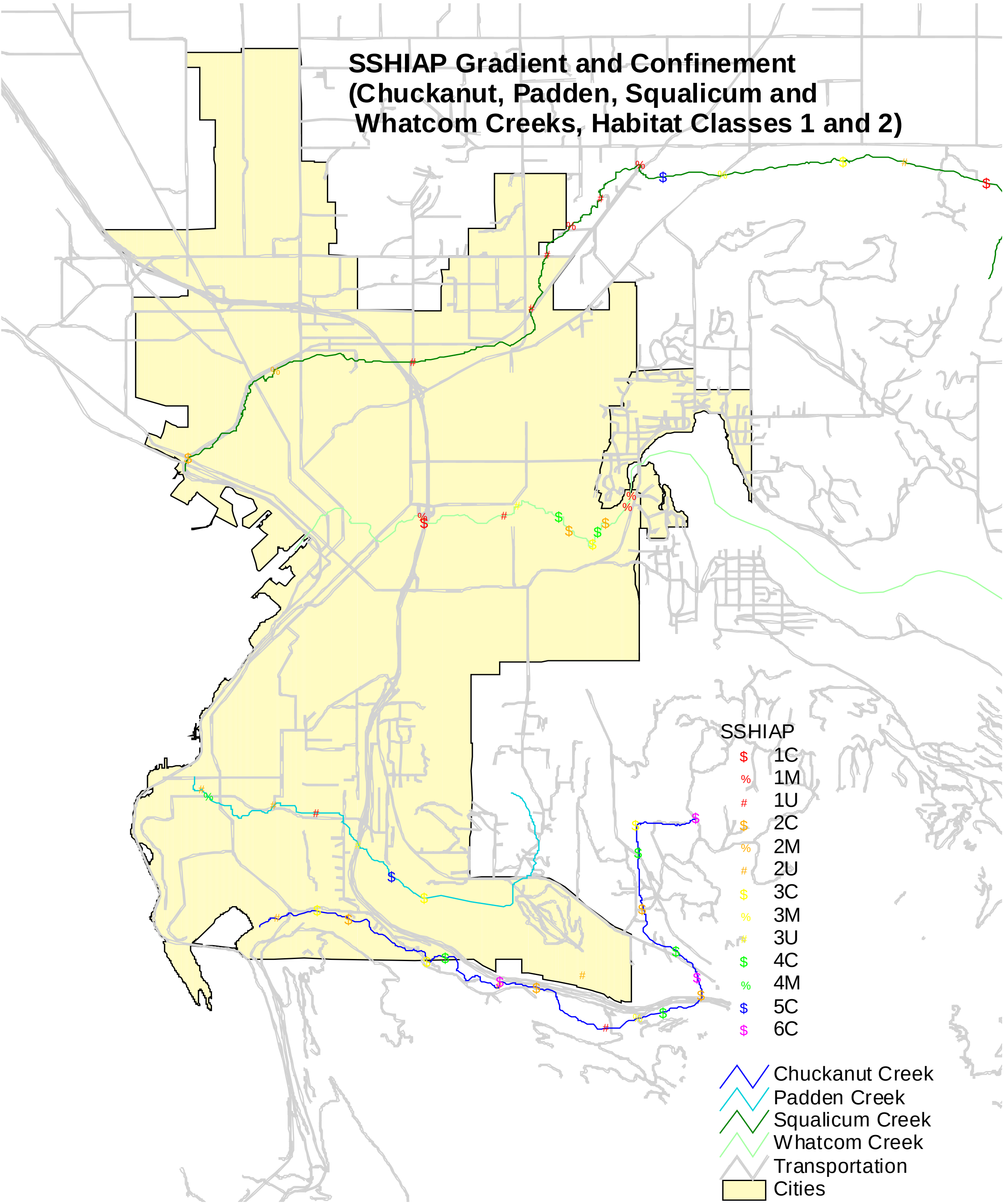
About 98% of the lands surrounding Silver Creek (a tributary to the lower Nooksack River) and Squalicum Creek are privately owned and 2% is State-owned (data from Lunetta et al. 1997). The WAU that includes Chuckanut Creek, Whatcom Creek, and Padden Creek is 96% privately owned and 4% State-owned. Whatcom Falls near RM 3 on Whatcom Creek prevents anadromous salmonid access to Lake Whatcom (DNR 1997).

Lake Whatcom is the largest lake in western Whatcom County, covering over 5000 acres and holding 746,000 acre-feet of water (Scott and McDowell 1994). It is bounded by Anderson Mountain to the south, Stewart Mountain to the east, and Lookout Mountain to the west (DNR 1997). Olson, Smith, Brannian, Fir, Carpenter, Anderson, and Austin Creeks drain into Lake Whatcom and are important streams for native trout production, especially for Lake Whatcom kokanee and cutthroat trout. The tributaries are short, ranging from 0.5 to 6 miles in length (DNR 1997), and most are surrounded by forestlands with some residential use. Kokanee are also reared at a hatchery facility in the Lake Whatcom Basin.

Lake Whatcom serves as the domestic water supply for half of the residents in Whatcom County including the City of Bellingham. Water in Lake Whatcom is occasionally supplemented with flow from the Middle Fork Nooksack River via a diversion dam. The water is channeled through Anderson Creek, which empties into Lake Whatcom.

Lake Whatcom consists of three basins. Two of the basins are shallow and impacted by urban development along the shores (Scott and McDowell 1994). The largest basin is very deep with areas that are 18 feet below sea level. The land use surrounding the largest basin is forestry. The City of Bellingham withdraws water from Basin II, one of the shallow basins, while Water District #10 withdraws water from the deepest basin.

Figure 4. Gradient and Channel Confinement Designations in Squalicum, Whatcom, Padden, and Chuckanut Creeks (SSHIAP 1995 to present). Gradient definitions are as follows: red=<1%, orange=1-2%, yellow=2-4%, green=4-8%, blue=8-20%, and purple=>20%.



Watershed Description and Land Use in Chuckanut, Oyster, and Colony Creeks

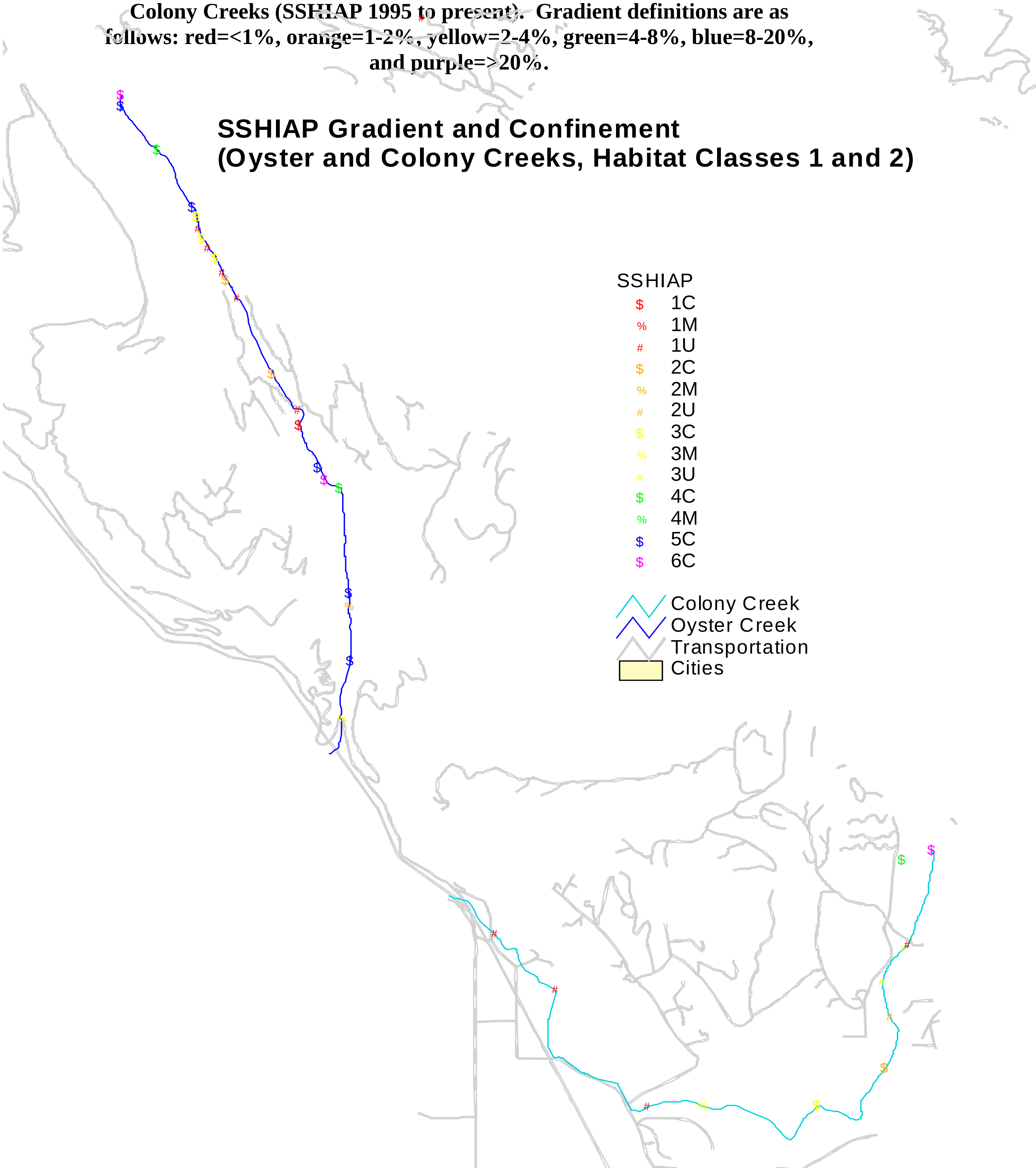
Chuckanut Creek flows just south of the City of Bellingham, formed by surface runoff (Phinney and Williams 1975). It has forested hills in the upper reaches and urbanization in the lower sections (Phay 2000b). The lower 1.8 miles are characterized by 1-4% gradients that are unconfined in the lowest reach, then become confined further upstream (Figure 4) (SSHIAP 1995 to present). Upstream of RM 1.8, the gradients are variable with some steep reaches that are greater than 20%. Most of the channels are confined upstream of RM 1.8.

Oyster Creek originates from Lost Lake on Chuckanut Mountain and drains into Samish Bay. The upper four miles flow through several small lakes and swamps then falls steeply with only about a quarter mile of the lowest reach having a moderate gradient (Phinney and Williams 1975). SSHIAP (1995 to present) has mapped the gradient and channel confinement designations, both of which are highly variable in this stream (Figure 5). Nearly the entire watershed is in timber production (Phay 2000b).

Colony Creek originates from the southern slopes of Chuckanut Mountain. The upper two-mile section has a moderate gradient and flows through beaver dams. The gradient steepens as it flows through a ravine between RM 2-3, and then flattens to a low to moderate gradient (Figure 5) (SSHIAP 1995 to present). Land use consists of rural lands upstream of RM 2 with agriculture in the lower two miles (Phay 2000b).

The WAU that includes the Oyster and Colony Creek watersheds is 64% privately owned and 35% State-owned (data from Lunetta et al. 1997). The WAU that includes Chuckanut Creek, Whatcom Creek, and Padden Creek is 96% privately owned and 4% State-owned.

Figure 5. Gradient and Channel Confinement Designations in Oyster and Colony Creeks (SSHIAP 1995 to present). Gradient definitions are as follows: red=<1%, orange=1-2%, yellow=2-4%, green=4-8%, blue=8-20%, and purple=>20%.



Watershed Description and Land Use along the Estuarine and Near Shore Environments of WRIA 1

WRIA 1 includes 134 miles of marine shoreline (Whatcom County Planning and Development Services Dept. 1997) with estuaries in Drayton Harbor, Birch Bay, Lummi Bay, Portage Bay, Bellingham Bay, Chuckanut Bay, and Samish Bay. Of these areas, Bellingham Bay has been the most developed and water quality problems, especially contaminated sediments, are numerous, including 303(d) listings for lead, arsenic, mercury, and many other toxins (DOE 2000). These are discussed in detail in the Estuarine/Nearshore section of the Habitat Limiting Factors chapter of this report. Dredging is another land use impact that has occurred in Bellingham Bay, the Whatcom Creek waterway, the I and J Street waterway, and the Squalicum Creek waterway (ACOE 2001).

The lower Nooksack River has been significantly altered. Prior to 1860, the Nooksack River emptied into both Lummi and Bellingham Bays with flows shifting between the two outlets over time depending on logjams (Collins and Sheikh in prep.). In the late 1800s, a dam was constructed to divert the Nooksack River to drain into Bellingham Bay (People for Puget Sound 1997). Because of this, the Nooksack delta is relatively young and is increasing in size into Bellingham Bay (People for Puget Sound 1997). The Nooksack delta has been less altered by human activities compared to other estuaries in Puget Sound. However, diking for farms and aquaculture has greatly impacted the Lummi delta (People for Puget Sound 1997). It is thought that reduced sediment input from the Nooksack River has led to regression of the Lummi Bay shoreline.

Drayton Harbor is a shallow bay that nearly empties at low tide (Scott and McDowell 1994). Its exposure to the marine habitat is limited by Semiahmoo Spit and the pier and marina owned by the City of Blaine. Drayton Harbor has been important for shellfish production and Pacific herring spawning habitat, but high fecal coliform levels have resulted in closures of shellfish harvest (Nelson et al 1991). Contamination is likely the result of agriculture and failing septic systems along Dakota and California Creeks and from urban run-off from the City of Blaine. Birch Bay is extremely shallow for up to one mile offshore, which results in warm water temperatures and increased recreational activities in the summer. It opens to the Strait of Georgia and provides habitat for Pacific herring (Scott and McDowell 1994).

The Samish Bay delta has been diked to support pastureland, and this land now also supports migratory birds (Determan 1995; Whatcom County Council of Governments 2000). Agricultural discharge is passed to Samish Bay via tidegates and pumps. Eelgrass beds in Samish Bay are routinely plowed to facilitate the commercial culture of Pacific oysters (West 1997).

Not only are the estuarine and nearshore habitats in this WRIA important for salmonids, but they also serve as vital spawning and rearing areas for herring, surf smelt, and anchovy, which are important food components of salmonids. All three species of forage fish have been noted in this area (Bargmann 1998; Pentilla 2001a). However, concerns regarding the Pacific herring population near Cherry Point have resulted in the listing of that stock as a Washington State Candidate Species of Concern (WDFW 2000). That stock historically comprised about half of the Pacific herring population in Washington State, but numbers have greatly declined since the early 1970s (Bargmann et al. 1999). Spawning distribution of Cherry Point herring has been reduced as well. In the past, spawning occurred throughout Birch Bay and along the nearshore down to Lummi Bay. Currently, the distribution is reduced to three linear miles of coastline near Cherry Point (WDFW 1998b).

Spawning habitat for Pacific herring is dependent on eelgrass beds, which can be impacted by development. Currently, the Cherry Point area has two oil refineries and an aluminum smelter nearby, and further development has been recently halted by the Washington DNR when they designated a 3,000-acre Cherry Point Reserve area. This extends from the southern boundary of Birch Bay State Park to the northern boundary of the Lummi Indian Reservation (WA DNR 2000). It includes either -70 feet from mean low water or ½ mile from shore, whichever is greater. Current leases and private tidelands are excluded from the reserve.

DISTRIBUTION AND CONDITION OF SALMONID STOCKS IN WRIA 1

Nooksack Basin Salmonid Stocks

A summary of salmonid stocks and SASSI stock status designations for the mainstem Nooksack, North Fork, Middle Fork, and South Fork Nooksack Rivers is presented in Table 1. Many of the similar-timed species that spawn in both the North Fork and Middle Fork Nooksack Rivers are classified as a single stock because the two forks have comparable environments and data are not available to support stock separation. Additionally, the Middle Fork is a tributary to the North Fork. Both forks originate from Mount Baker glaciers and have comparable flow patterns. However, the glacial nature of the North and Middle Forks makes stock assessment difficult with less reliable escapement estimates. In contrast, the South Fork Nooksack River provides a very different environment increasing the likelihood that fish adapted to these two dissimilar areas form biologically different populations. As more data are analyzed, the classifications listed below may change. A new version of SASSI is currently being developed.

There are two early-timed, native-origin chinook stocks in the Nooksack Basin (Map F1). One stock spawns in the North and Middle Forks and tributaries, while the other spawns in the South Fork Nooksack River. Both are described as “critical” and have wild production components, although the North Fork stock is supported by a hatchery supplementation program designed to rebuild the population. Marshall et al. (1995) classified each of these stocks as a separate Genetic Diversity Unit, but since then it was discovered that some samples in one of the baselines included fish from Okanogan. Because of this, the genetic information is under review, and no conclusions regarding the genetic baselines between these stocks can be made at this time. These stocks are also part of the Puget Sound Chinook ESU that is listed as threatened under the ESA (Meyers et al. 1998).

The North Fork Nooksack native chinook stock spawns in the mainstem North Fork Nooksack River to the falls at RM 65 in addition to North Fork tributaries such as Glacier, Canyon, lower Racehorse, Maple, and Boulder Creeks and the lower reaches of the Middle Fork Nooksack River (Map F1). The South Fork native chinook stock spawns in the mainstem to Sylvester’s Canyon (RM 25), and in some years are recorded upstream of the 11-12 foot waterfall in the reach to RM 30.4. Native early chinook also use the larger tributaries including Hutchinson, Skookum, Deer, and Plumbago Creeks (Ned Currence, Nooksack Indian Tribe, personal communication).

Fall chinook are known to spawn in the mainstem Nooksack River and tributaries (Bertrand, Fishtrap, Tenmile, Anderson, and Smith Creeks), and the North Fork, the Middle Fork, the South Fork Nooksack Rivers and numerous tributaries (Map F2). While late entering chinook historically existed in the basin, the origin of these more recent fall chinook is uncertain, and further data collection and analysis are underway to determine whether some of these areas support a distinct fall chinook population. A stock of non-native (primarily Green River origin) hatchery fall chinook has been released in large numbers throughout the North Fork, South Fork, and mainstem Nooksack Rivers for many years, as well as from the Lummi Sea Ponds in Lummi Bay. These fish might have served as the origin for the recent naturally spawning fall chinook in parts of the Nooksack Basin. It is also possible that there might be a native fall chinook population. Naturally spawning fall chinook have been documented for many decades in Hutchinson Creek, a tributary to the South Fork Nooksack River, and the origin of these fish warrants further investigation.

Data are also needed to determine the extent of natural fall chinook production and the potential interactions between non-native hatchery fall chinook and native chinook in the Nooksack Basin. Under NMFS policy, "attention should focus on natural fish, which are defined as the progeny of naturally spawning fish" (Waples 1991). The Endangered Species Act status review states that non-native hatchery production has likely decreased fitness and genetic diversity, and can have detrimental ecological effects (Meyers et al. 1998). It is not yet known to what extent the fall chinook spawners are from hatchery or natural production, and without that information, their stock status and inclusion in the ESA listed population is unclear.

The native adult chinook freshwater entry time and spawn time are generally earlier than for the fall chinook stock, but overlap in timing does exist (Marshall et al. 1995). Efforts have been made to release the hatchery fall chinook at downstream sites to reduce potential mixing on the spawning grounds, but this may have increased straying of fall chinook including to the South Fork Nooksack River, which has an early native chinook stock of concern, and which appears to have some overlap in spawn timing with fall chinook (Ned Currence, Nooksack Tribe, personal communication). This potentially negative interaction merits additional monitoring. In addition, some fish distribution data have unclear stock assignments, resulting in a need to have a chinook distribution map that does not separate by stock (Map F3). Additional fieldwork is needed to improve the database for chinook distribution by stock.

Two stocks of chum salmon have been identified within the Nooksack Basin. One stock spawns in the South Fork and mainstem Nooksack Rivers and tributaries (WDFW et al. 1994). It is described as native origin with wild production and an unknown status. Another stock of chum salmon spawns in the North Fork Nooksack River. This stock is described as native with wild production, but some hatchery releases of Hood Canal and Grays Harbor stocks have occurred in the past (WDFW et al. 1994), and limited hatchery production occurs from the Kendall Creek Hatchery (U.S. Forest Service 1995a). The stock is listed as "healthy" (Table 1), and spawns almost to the Nooksack Falls in the North Fork Nooksack River and to the diversion dam in the Middle Fork Nooksack River (Map F4). In the South Fork, chum salmon are far less abundant than in the North Fork.

The Nooksack Basin has one identified coho salmon stock, which is distributed in all accessible areas throughout the entire drainage, including all three forks of the Nooksack River (Map F5) (WDFW et al. 1994). For many decades, large quantities of hatchery coho salmon from various sources have been released at the Kendall Creek Hatchery on the North Fork Nooksack River and in the Nooksack River itself. In addition, coho salmon have been released at the Skookum Creek hatchery in the South Fork Nooksack Basin and from the Lummi Sea Ponds in Lummi Bay (WDFW et al. 1994). The Nooksack coho salmon stock is considered to be of mixed origin with composite production (both hatchery and natural spawning components) and has an unknown status. Genetic analysis is underway to develop a better understanding of the coho population (s) in the Nooksack Basin (Ned Currence, Nooksack Indian Tribe, personal communication). NMFS considers Puget Sound coho a candidate species, indicating that concern exists regarding population levels and other impacts but not enough concern to list the stock as threatened or endangered at this time (Weitkamp et al. 1995).

Two stocks of odd-year Nooksack pink salmon were identified in the SASSI report, and it is important to note that small numbers of even-year pink salmon spawn in the South Fork Nooksack sub-basin (Ned Currence, Nooksack Indian Tribe, personal communication). One of the odd-year stocks spawns in both the North and Middle Fork Nooksack Rivers (WDFW et al. 1994). It was described in SASSI as a mixed origin stock with wild production, and the status was listed as unknown on one page and healthy on another. However, more recent genetic analysis shows that the Nooksack pink salmon stocks are unique (Shaklee et al. 1995), even though outside stocks have been released in the area, including a stock from Hood Canal (Dungeness origin). Also, the North Fork Nooksack Watershed Analysis reported that the stock has the potential to have a depressed status (U.S. Forest Service 1995a). Adults enter freshwater from July through August and spawn from late August through late September. Their distribution extends to Nooksack Falls (RM 65) in the North Fork Nooksack River and to the diversion dam in the Middle Fork Nooksack River (Map F6). Upper North Fork tributaries including Thompson Creek, a Glacier Creek tributary, are also important pink salmon spawning sites. Pink salmon use Maple Creek to the falls and the lower reaches of other tributaries, many of which have flow dependent use (Map F6).

The second stock of odd-year pink salmon spawns in the South Fork Nooksack River up to RM 25 and in associated tributaries, including Hutchinson, Skookum, Cavanaugh, Deer, and Plumbago Creeks (Map F6). The overall contribution of South Fork pink salmon to the Nooksack total escapement is thought to be small (WDFW et al. 1994). Historically South Fork odd year pink salmon were apparently very abundant. Morse Monthly (1883) described the pink salmon abundance in 1881 as "completely filling the South Fork; literally there were millions of them." Overall, Nooksack River pink salmon have an earlier run timing and unique genetic baseline compared to other Puget Sound stocks (Shaklee et al. 1995). They are native in origin with wild production and an unknown stock status (WDFW et al. 1994). Adults enter freshwater from late June through August and spawn from late August to early October (WDFW et al. 1994). They are also smaller in size (Shaklee et al. 1995). While not included in the SASSI stock description, pink salmon also spawn in the mainstem Nooksack River (Ned Currence, Nooksack Tribe, personal communication).

For decades, small numbers of riverine sockeye salmon have been consistently documented in the North and South Fork Nooksack Rivers (Gustafson and Winans 1999), and have occasionally been recorded in the Middle Fork Nooksack River (Map F7) (Ned Currence, Nooksack Indian Tribe, personal communication). WDFW scale readings from adult sockeye indicate that these fish leave the river as yearlings. They are not described in the SASSI report. Gustafson and Winans (1999) state that the Nooksack (along with the Skagit) drainage has the most persistent evidence of river spawning populations in Washington, and recent analysis of allozyme frequencies show Nooksack sockeye are genetically unique and cluster with other river-sea type sockeye populations in the Skagit River, Canada and Alaska.

There are four separate steelhead trout stocks in this region. Three are winter steelhead, while one is a summer run steelhead stock. The three winter steelhead stocks are: 1) the Mainstem/North Fork stock, 2) the Middle Fork Nooksack stock, and 3) the South Fork Nooksack stock (WDFW et al. 1994). All are native origin with wild production and an unknown status, and their distribution is shown on Map F8. However, the SASSI report mentioned that these stocks may have a depressed status if the decline in index area redd densities are representative of the stocks. NMFS listed a declining trend in total escapement of –11.6 to –7.9, where trend is defined as percent annual change in total escapement or an index of total escapement (Busby et al. 1996). Summer steelhead spawn in the upper South Fork Nooksack River including upstream from RM 30.4, and are native with wild production and an unknown status, but the run has been historically small (WDFW 1998a). None of these stocks are currently listed under the ESA.

There is one stock of coastal cutthroat trout designated for the entire Nooksack Basin, and it is noted as mixed origin, supported by hatchery and natural production, and an unknown status (WDFW 2000). Anadromous cutthroat are native with wild production (WDFW 2000). Genetic analysis of cutthroat collected from a mainstem tributary (Double Ditch Creek) indicates they are significantly different from all other North Sound collections ($p<0.001$). All four life history forms (anadromous, resident, adfluvial, and fluvial) of the species are found in the Nooksack Basin. Most of the fluvial cutthroat are located upstream of Nooksack Falls on the North Fork and upstream of the diversion dam on the Middle Fork, while Maple Creek flowing from Silver Lake, supports adfluvial cutthroat (Map F9). Anadromous adult cutthroat enter freshwater early, from August through October, and spawn from January through April (WDFW 2000). The other life history forms spawn from January through July. The anadromous coastal cutthroat are native-origin, supported by wild production. However, hatchery produced resident cutthroat have been released in various lakes throughout Whatcom, Skagit, and Snohomish Counties in the past (U.S. Forest Service 1995a).

Three separate char stocks are listed for this area in the bull trout/Dolly Varden stock review: Lower Nooksack bull trout/Dolly Varden, Canyon Creek bull trout/Dolly Varden, and Upper Middle Fork Nooksack River bull trout/Dolly Varden (Map F10) (WDFW 1998a). These designations were based upon geographical distance because other types of stock data were lacking, and on reproductive isolation in the upper Middle Fork due to the diversion dam. All three stocks are listed as native origin with wild production and unknown status (WDFW 1998a), but are also part of the population that is listed as "threatened" under the Endangered Species Act. To-date, very limited sampling has occurred and indicates that upper Canyon Creek char are Dolly Varden, while the limited upper Middle Fork samples appear to be bull trout based on meristic analysis by Gordon Haas (Ned Currence, Nooksack Indian Tribe, personal communication). Limited samples from a tributary to the upper South Fork were Dolly Varden, and upper mainstem South Fork samples were bull trout (personal communication from Sewell Young to Ned Currence). Eastern brook trout (*Salvelinus fontinalis*) have also been identified in limited areas in the forks (Map F11). Eastern brook trout is also a char that can interbreed with bull trout. Bull trout populations typically decline in areas where eastern brook trout have been found (USFWS 1998).

In the North Fork Nooksack drainage, char have been noted up to Nooksack Falls at RM 65, as well as in Wells, Bar (presumed), Glacier, Thompson, Cornell, Canyon, Boulder, Racehorse, and Kenney Creeks (Map F10) (Ned Currence, Nooksack Tribe, personal communication). In the Middle Fork Nooksack River, bull trout are common upstream of the dam, and are also present or presumed to be present in Ridley, Rankin, Green, Warm, Sisters, and Clearwater Creeks; tributaries to the upper Middle Fork Nooksack River and in Canyon Lake Creek, a tributary to the lower Middle Fork Nooksack River (Map F10) (Currence 2001).

Bull trout/Dolly Varden are known to spawn in Bells, Wanlick, Howard and the mainstem South Fork Nooksack River (WDFW 1998a). Juveniles have been sampled in lower Hutchinson Creek, and one has been noted in the very lowest reaches of Black Slough (Ned Currence, Nooksack Tribe, personal communication).

Native rainbow trout are found in the North Fork Nooksack drainage, and non-native rainbow are cultured at the Whatcom Falls Hatchery for releases throughout North Puget Sound. The current understanding of their distribution is shown on Map F8, and their distribution is assumed to overlap with the steelhead trout distribution included on that map.

Table 1. Nooksack Basin Salmonid Stock Status.

Stock	Origin	Production	Status	Comments
North Fork Nooksack Chinook (early-timed)	Native	Composite	Critical in SASSI, ESA-Listed as Threatened	Hatchery production supplements wild component. Stock is genetically unique.
South Fork Nooksack Chinook (early-timed)	Native	Wild	Critical in SASSI and ESA-listed as Threatened	Somewhat later spawn timing than NF. Stock is genetically unique.
Fall Chinook	Non-Native	Composite	Unknown in SASSI	Hatchery stock released to support fisheries.
Fall Chinook	Unknown	Unknown	Unknown	Late spawning chinook in Hutchinson Creek and other streams. Not mentioned in SASSI.
North Fork/Middle Fork Nooksack Chum	Native	Wild	Healthy in SASSI	
South Fork/Mainstem Nooksack Chum	Native	Wild	Unknown in SASSI	Much lower abundance presently than in NF.
Nooksack Coho (includes all coho spawning in the entire Nooksack Basin)	Mixed	Composite	Unknown in SASSI	Large degree of hatchery influence.

Stock	Origin	Production	Status	Comments
North Fork/Middle Fork Nooksack Pink	Native	Wild	Healthy (page 92) or unknown (page 91) in SASSI. Might be depressed (USFS 1995a).	Listed as "Mixed" in SASSI, but recent information suggests "Native".
South Fork Nooksack Pink	Native	Wild	Unknown in SASSI	Much lower abundance presently in SF compared to NF.
Even-year Pinks	Unknown	Wild	Unknown	Small numbers spawn in the South Fork Nooksack. Not in SASSI.
Riverine Sockeye	Apparently Native	Wild	Unknown	Small numbers consistent over decades. Not in SASSI.
North Fork/Mainstem Winter Steelhead	Native	Wild	Unknown in SASSI	May be depressed based upon decline in index area redd densities.
Middle Fork Nooksack Winter Steelhead	Native	Wild	Unknown in SASSI	May be depressed based upon decline in index area redd densities.
South Fork Nooksack Winter Steelhead	Native	Wild	Unknown in SASSI	May be depressed based upon decline in index area redd densities.
South Fork Nooksack	Native	Wild	Unknown in SASSI	Historically small numbers.

Stock	Origin	Production	Status	Comments
Summer Steelhead			SASSI	small numbers.
Nooksack Coastal Cutthroat	Mixed	Composite	Unknown in WDFW 2000.	Anadromous cutthroat are native and wild.
Lower Nooksack River Bull Trout/Dolly Varden	Native	Wild	Unknown in WDFW 1998a.	ESA-Listed as Threatened (bull trout)
Canyon Creek Bull Trout/Dolly Varden	Native	Wild	Unknown in WDFW 1998a.	ESA-Listed as Threatened (bull trout)
Upper Middle Fork Nooksack River Bull Trout/Dolly Varden	Native	Wild	Unknown in WDFW 1998a.	ESA-Listed as Threatened (bull trout). Reproductively isolated by diversion dam.

Sources: WDFW et al. 1994; WDFW 1998a, 2000.

Salmonid Stock Status in the Smaller Independent Watersheds of WRIA 1

Two stocks of fall chum salmon spawn in various independent watersheds within WRIA 1. The Sumas/Chilliwack chum stock is described as native-origin with wild production and an unknown status with a note that the Chilliwack part of the stock appears to be at healthy levels (Table 3) (WDFW et al. 1994). Spawning occurs in the Chilliwack and Sumas Rivers and in Sumas tributaries such as Saar, Breckenridge, and North Fork Johnson Creeks (Map F4).

The other stock is the Samish/Independent chum stock, which is listed as a hybrid population mixed with Hood Canal, Samish, and other stocks (WDFW et al. 1994). In addition, hatchery-origin chum from Hood Canal and Quilcene were released in Oyster and Colony Creeks. The Samish portion of the population is not included in this report because it is located outside of WRIA 1, but this report does include the segments of this stock that spawn in WRIA 1 streams such as in Chuckanut, Padden, Whatcom, Squalicum, Oyster, and Colony Creeks and in the Lummi River (Map F4) (Phinney and Williams 1975; WDFW et al. 1994). Overall, the stock is described as a mixed-origin stock with composite (hatchery and natural) production and a healthy status (Table 3) (WDFW et al. 1994). The Samish/Independent chum stock is more genetically similar to

Hood Canal chum than to other North Puget Sound chum stocks (Phelps et al. 1995). The spawn timing of the Samish/Independent stock is also earlier than other North Puget Sound stocks, peaking in late November through early December compared to a peak in late December for Nooksack chum salmon stocks. Chum from Chuckanut Creek are bright skinned (Phelps et al. 1995).

Two coho salmon stocks also originate from this area. Sumas/Chilliwack coho salmon are native origin with wild production and unknown status, although the Chilliwack portion of the run appears to be healthy (WDFW et al. 1994). Some releases of Nooksack coho have occurred in these streams. The independent North Puget Sound tributary coho stock is described as mixed-origin with wild production and an unknown status, and includes spawning coho in all accessible areas of Dakota, California, Terrell, Squalicum, Whatcom, Padden, Chuckanut, lower Oyster, Colony, and Silver Creeks (Map F5) (WDFW et al. 1994; WDFW spawning ground database 2002).

Fall chinook salmon have been documented in Dakota Creek as far up as RM 3.4 in the North Fork of Dakota Creek and in Whatcom and Squalicum Creeks (Map F2) (WDFW spawning ground survey database 2002). The origin of these fish is not known. Phinney and Williams (1975) did not report chinook salmon as using these streams; however, WDF (1929/30 annual report) reported chinook in Dakota Creek. Chinook salmon are also noted in the Sumas River (Map F2).

Dakota Creek winter steelhead are native-origin with wild production and an unknown status (WDFW et al. 1994). Historically, this run was small. Steelhead distribution was mapped for Terrell, Squalicum, Whatcom, Padden, and Chuckanut Creek and in the Sumas River, but these populations were not mentioned in the SASSI report (Map F8) (WDFW et al. 1994).

Coastal cutthroat trout spawn in the Washington reaches of the Sumas River and tributaries (Map F9). Both anadromous and resident forms of cutthroat trout are present. The anadromous cutthroat adults enter freshwater from August through October and spawn from January through April (WDFW 2000). The North Puget Sound tributary coastal cutthroat stock spawns in Dakota, California, Terrell, Squalicum, Padden, Chuckanut, and Oyster Creeks, and adfluvial cutthroat are found in Lake Terrell (Map F9) (WDFW 2000). The adults of this stock enter freshwater at a later time, from November through March, while spawning is similar to other nearby stocks, from January through April. The adfluvial segment spawns from January through May, and the resident forms spawn from January through July.

Whatcom Creek coastal cutthroat consist of anadromous, resident, and adfluvial forms. Anadromous Whatcom Creek cutthroat are later-entry adults, returning from November through March. They spawn from January through April. Resident and adfluvial Whatcom Creek cutthroat spawn from January through mid-June (WDFW 2000). The native cutthroat population in Lake Whatcom has severely declined, decreasing 65% between 1987 and 1999 (Johnston 2000). The number of cutthroat spawners in Beaver Creek, a tributary to Lake Whatcom, dropped 92% in that time period. The primary spawning streams for the Lake Whatcom cutthroat population are Austin, Beaver, Carpenter, Olson, and Smith Creeks (Map F9) (DNR 1997). Some non-native (Toutle Creek) releases of cutthroat have occurred in the Lake Whatcom watershed in recent years (DNR 1997).

Bull trout/Dolly Varden spawn in the Chilliwack River and Selesia Creek, which is a tributary to the Chilliwack River (Map F10) (WDFW 1998). This stock has been described as native and wild, but with an unknown status.

A native population of kokanee reproduces in the Lake Whatcom watershed, and served as the broodstock for the Lake Whatcom Hatchery population, which is planted in area lakes and elsewhere (U.S. Forest Service 1995a). In 1974, the natural spawning population numbered 20,000, but in 1998, there were less than 100 spawners (Johnston 2000). Spawning areas include Brannian, Olson, Fir, Anderson, and to a lesser extent, Carpenter and Smith Creeks (Map F12) (DNR 1997). Hatchery-origin kokanee remain numerous, and are released in the watershed and throughout the State. The Lake Whatcom kokanee stock is the only WDFW source of kokanee eggs and fry in Washington State (DNR 1997).

Table 2. Salmonid Stock Status in the Smaller Independent Watersheds of WRIA 1.

Stock	Origin	Production	Status	Comments
Samish/Independent Streams Chum	Mixed	Composite	Healthy	
Sumas/Chilliwack Chum	Native	Wild	Unknown	
Sumas/Chilliwack Coho	Native	Wild	Unknown	
Independent North Puget Sound Trib. Coho	Mixed	Wild	Unknown	
Dakota Creek Winter Steelhead	Native	Wild	Unknown	Historically small numbers.
Chilliwack/Selesia Bull Trout/Dolly Varden	Native	Wild	Unknown	ESA-Listed as Threatened (bull trout)
Sumas Coastal Cutthroat Trout	Native	Wild	Unknown	
North Puget Sound Trib. Coastal Cutthroat	Native	Wild	Unknown	
Whatcom Creek Coastal Cutthroat	Native	Wild	Unknown	

(Sources: WDFW et al. 1993; WDFW 1998a, 2000).

WRIA 1 HABITAT LIMITING FACTORS BY SUB-BASIN

Categories of Habitat Limiting Factors used by the Washington State Conservation Commission

The following is a list and description of the major habitat limiting factor categories that are used to organize the Limiting Factors Reports. Although these categories overlap with each other, such that one habitat problem could impact more than one habitat limiting factor category, they provide a reasonable structure to assess habitat conditions within a basin or sub-basin. Within each category are one or more data types that provide a means to assess each category.

Loss of Access to Spawning and Rearing Habitat

This category includes culverts, tide gates, levees, dams, and other artificial structures that restrict access to spawning habitat for adult salmonids or rearing habitat for juveniles. Additional factors considered are low stream flow or temperature conditions that function as barriers during certain times of the year.

Floodplain Conditions

Floodplains are relatively flat areas adjacent to larger streams and rivers that are periodically inundated during high flows. In a natural state, they allow for the lateral movement of the main channel and provide storage for floodwaters, sediment, and large woody debris. Floodplains generally contain numerous sloughs, side-channels, and other features that provide important spawning habitat, rearing habitat, and refugia during high flows. Impacts in this category includes direct loss of aquatic habitat from human activities in floodplains (such as filling), disconnection of main channels from floodplains with dikes, levees, revetments, and riparian roads, and impeding the lateral movement of flood flows with dikes, riparian roads, levees, and revetments. Disconnection can also result from channel incision caused by changes in hydrology or sediment inputs.

Streambed Sediment Conditions

Changes in the inputs of fine and coarse sediment to stream channels can have a broad range of effects on salmonid habitat. Increases in coarse sediment can create channel instability and reduce the frequency and volume of pools, while decreases can limit the availability of spawning gravel. Decreased channel stability is often noted by analyzing aerial photographs for widespread channel changes or by measuring scour. Increases in fine sediment can fill in pools, decrease the survival rate of eggs deposited in the gravel (through suffocation), and lower the production of benthic invertebrates. As part of this analysis, increased sediment input from landslides, roads, agricultural practices, construction activities is examined as well as decreased gravel availability caused by dams and floodplain constrictions. This category also assesses instream habitat characteristics that are related to sedimentation and sediment transport, such as bank stability and erosion and large woody debris (LWD).

Riparian Conditions

Riparian areas include the land adjacent to streams, rivers, and nearshore environments that interacts with the aquatic environment. This category addresses factors that limit the ability of native riparian vegetation to provide shade, nutrients, bank stability, and large woody debris. Riparian impacts include timber harvest, clearing for agriculture or development, and direct access of livestock to stream channels. This section also examines future LWD recruitment, where data are available, and the abundance and depth of pool habitat. The data used to determine riparian conditions are temporal and subject to sometimes-rapid changes.

Water Quality

Water quality factors addressed by this category include stream temperature, dissolved oxygen, and toxics that directly affect salmonid production. Temperatures impact different species and life history stages of salmonids in various ways. Bull trout are the most sensitive to water temperatures, with egg survival dropping by at least 75% when water temperatures rise above 7^{o}C (Knowles and Gumtow 1996). Adult bull trout can withstand temperatures up to about 17^{o}C. Generally when water temperatures are 20^{o}C or more, metabolism in salmon increases to the point where juvenile growth ceases (Bell 1986). Water temperatures of 24^{o}C and greater can result in mortality of salmon. Turbidity is also included, although the sources of sediment problems are addressed in the streambed sediment category. In some cases, fecal coliform problems are identified because they may serve as indicators of other impacts in a watershed, such as direct animal access to streams.

Water Quantity

Changes in flow conditions can have a variety of effects on salmonid habitat. Decreased low flows can reduce the availability of summer rearing habitat and contribute to temperature and access problems, while increased peak flows can scour or bury spawning nests. Other alterations to seasonal hydrology can strand fish or limit the availability of habitat at various life stages. All types of hydrologic changes can alter channel and floodplain complexity. This category addresses changes in flow conditions brought about by water withdrawals, the presence of roads and impervious surfaces, the operation of dams and diversions, alteration of floodplains and wetlands, and changes in hydrological maturity (vegetation stand age).

Estuarine and Nearshore Habitat

This category addresses habitat impacts that are unique to estuarine and nearshore environments. Estuarine habitat includes areas in and around the mouths of streams extending throughout the area of tidal influence on fresh water. These areas provide especially important rearing habitat and an opportunity for transition between fresh and saltwater. Impacts include loss of habitat complexity due to filling, dikes, and channelization; and loss of tidal connectivity caused by tidegates. Nearshore habitat includes intertidal and shallow subtidal saltwater areas adjacent to land that provide transportation and rearing habitat for adult and juvenile fish. Important features of these areas include eelgrass, kelp beds, cover, large woody debris, and the availability of prey species. Impacts include bulkheads, overwater structures, filling, dredging, and alteration of sediment processes. Water quality issues of the estuarine or nearshore environment, such as sediment contamination, toxics, dissolved oxygen, and water temperatures are included in this section, as well as the presence of significant forage fish spawning sites. Also included are habitat changes that have promoted the increase in opportunistic predators on salmon, such as marine mammals and birds. The introduction of non-native species specific to the estuary, such as *Spartina*, is included in this section.

Rating Habitat Conditions

The major goal of this project is to identify the habitat conditions that should be restored or conserved for the best benefit to salmonid production. Often, numerous habitat degradations can be found within a watershed, and some have a greater impact on salmonids than others. To help identify the most significant habitat limiting factors, the Conservation Commission developed a system to rate the above-described habitat limiting factor categories as “good”, “fair”, or “poor”. This is useful to allow comparisons of limiting factors within a watershed, as well as provide the same general standards to rate conditions across the state for this project. These ratings are not intended to be used as thresholds for regulatory purposes. The details and data sources for the standards are described in the Assessment Chapter.

Habitat Limiting Factors in the Nooksack Basin including the Lummi River

Loss of Fish Access in the Nooksack Basin and the Lummi River

Surveys of habitat blockages have been conducted in various watersheds and jurisdictions within the Nooksack Basin, but many areas have not been surveyed comprehensively. The areas not yet completely surveyed are also those with generally high road densities (the Nooksack, lower North Fork, South Fork, and Middle Fork Nooksack sub-basins). This suggests that fish habitat blockages are likely and surveys for those should be a high priority data need. Also, a comprehensive effort to combine and prioritize existing data is greatly needed. Culvert surveys appear to have been conducted in the following regions.

In the lower Nooksack sub-basin, surveys have been conducted in the Kamm, Anderson, and Bertrand watersheds (Nooksack Salmon Enhancement Association Internship Program). Priority Indices (PI) have been estimated for these blockages, and they are listed in Table 3 as high priority (PI 20 or greater), medium priority (PI 10-20), or low priority (PI<10) (data from Gregg Dunphy, Lummi Indian Nation). Additional barriers throughout the lower Nooksack sub-basin have been identified by the City of Bellingham. These barriers have not been fully assessed and not all of these might be barriers to salmonids. They are listed in the unknown category in Table 3.

In the North Fork Nooksack sub-basin, anadromous fish habitat within the National Forest has been comprehensively surveyed for blockages (Nicole Luce, U.S. Forest Service, personal communication). This includes the North Fork Nooksack River and tributaries from RM 56.6 upstream, as well as mid-upper Canyon and upper Cornell Creeks. The U.S. Forest Service has prioritized these culverts according to priority species with 1 being the highest priority. However, this priority scheme differs greatly from the PI methodology. Because of this, U.S. Forest Service blockages are listed in the "unknown" priority section of Table 3. In addition, culverts in Kenney Creek have been identified and prioritized using the Priority Index system (data from Gregg Dunphy, Lummi Indian Nation).

In the Middle Fork, National Forest lands have been surveyed for fish blocking culverts. This area extends from RM 13.8 and includes upper Clearwater, Warm, and Sisters Creeks. The U.S. Forest Service has prioritized these culverts, but they are listed in the "unknown" priority section of Table 3 because of different prioritization methods.

In the South Fork Nooksack River, anadromous fish streams within the National Forest lands have been surveyed for fish habitat blockages. This includes the South Fork Nooksack River and tributaries from RM 33 upstream including some headwaters of tributaries that drain into the South Fork Nooksack River downstream of RM 33. In the lower South Fork Nooksack sub-basin, the Hutchinson Creek watershed has been extensively surveyed for blockages (DNR 1998). These have been prioritized into "high", "moderate", or "low" categories, based upon habitat quality and quantity, passability, and fish use. Also, Black Slough has been surveyed, and fish blocking culverts have been prioritized using the Priority Index system (data from Gregg Dunphy, Lummi Indian Nation).

Other culverts have been documented in the Tenmile, Fishtrap, and Skookum Creek watersheds, the Warnick WAU (except for Kenney Creek), the Middle Fork Nooksack sub-basin, and in the Lummi River and its tributary Schell Creek (DNR 1995; Whatcom Conservation District March 2000 data), but these blockages have not been prioritized. It is not known whether the surveys in these streams were comprehensive, documenting all fish habitat barriers. They are listed in the "unknown" prioritization section of Table 3.

The known and possible blockages to salmonid habitat are summarized in Table 3 and are grouped into "high", "medium", "low", and "unknown" priority salmonid blockages with most barriers in the "unknown" category. This stresses the need for a comprehensive database development and prioritization. Of the known barriers, the greatest fish passage problem in WRIA 1 is the diversion dam in the Middle Fork Nooksack River. It was built around 1960 to divert water into Lake Whatcom for human consumption. The dam blocks about 20% of the habitat for the North Fork early chinook stock (Currence 2000) amounting to 9 miles of mainstem habitat and 5.3 miles of tributary habitat. The loss of coho salmon habitat totals 15.9 miles (Currence 2000).

Within the Nooksack Basin, other significant fish habitat blockages have been documented in the Silver, Kamm, Black Slough, Kenney, Bertrand, and Hutchinson Creek watersheds (Table 3).   These include blockages that rated as "high" priority using the DNR methodology (DNR 1998) or had a Priority Index rating of 20 or greater.

Medium priority salmonid blockages have been found in the Hutchinson, Anderson (tributary to the mainstem Nooksack River), Black Slough, and Bertrand Creek watersheds (Table 3). These include culverts that were rated as "moderate" with the DNR priority rating or had a Priority Index of 10 to 20. The "low" and "unknown" priority culverts are also listed in Table 3. Deadhorse Creek (North Fork Nooksack tributary) is rated "good" for salmonid access conditions because no blockages were identified after a comprehensive survey by the U.S. Forest Service.

Fish habitat access conditions other than culverts were rated in the Warnick Watershed Analysis, resulting in "poor" ratings for Whalen and lower Hedrick Creeks due to dry channels, and "good" ratings for West Slide, lower Aldrich, Gallop and parts of Cornell Creeks (DNR 1995). The dry channels relate to aggradation from excess sedimentation. "Fair" to "good" ratings for access conditions were assigned to Big Slide Creek. The "fair" rating was due to a concern about low flows.

Table 3. Known and possible barriers to fish passage in WRIA 1. Arranged in priority order from "high", "medium", "low", then "unknown". Many of the unknown barriers identified by the City of Bellingham have not been assessed. Because of this, not all of them are likely passage problems for salmonids.

Stream	Tributary to:	Owner-ship	Road Name/Milepost	Sec	Town	Ran	Data Source	Original Priority	Notes
MF Nooksack R			Diversion Dam				Currence 2000	very high	
Squalicum	Squalicum Cr	city	Squalicum Pky, Pacific Concrete				NSEA	71.9	
Squalicum	Squalicum Cr	city	Squalicum Pky, Under N. W. Ave.				NSEA	70.89	
Squalicum	Squalicum Cr	private	18th E. Crestlane, 4493 Mt. Baker HWY.				NSEA	40.79	
Silver Cr.	Nooksack R	county	Rural Rd., at intersect with Marine Dr. and Country Lane				NSEA	40.62	
Black Slough	SF Nooksack R	private	3086 Standard Rd., Blue Gate				NSEA	39.43	
Kamm Cr.	Nooksack R	private	1778 E. Badger, S. 1/2 mile from E. Badger culvert				NSEA	39.38	
Black Slough	SF Nooksack R	private	3086 Standard Rd. S. end of property				NSEA	38.22	
Kamm Cr.	Nooksack R	private	1778 E. Badger				NSEA	35.26	
Kenny Cr.	NF Nooksack R	private	5348 Canyon Ck. Rd., triple culvert, lower culvert				NSEA	34.01	
Kenny Cr.	NF Nooksack R	private	5348 Canyon Ck. Rd., triple culvert, middle culvert				NSEA	34.01	
Kenny Cr.	NF Nooksack R	private	5348 Canyon Ck. Rd., triple culvert, top culvert				NSEA	34.01	
Kamm Cr.	Nooksack R	county	1778 E. Badger, W. 100yds, under W. Badger				NSEA	33.19	
Dakota	Dakota Cr	county	Under Sweet Rd., west of Harvey Rd.				NSEA	32.58	
Kamm Cr.	Nooksack R	private	1778 E. Badger				NSEA	32.33	
Squalicum	Squalicum Cr	private	120m w of Noon Rd in field				NSEA	31.8	
Toad Cr	Squalicum Cr	county	Dewey Rd.				NSEA	31.3	
Dakota	Dakota Cr	county	Under Pipeline Rd. near 4044 Pipeline Rd.				NSEA	30.4	
Squalicum	Squalicum Cr	private	300 yards w of Noon Rd in field				NSEA	29.85	
Squalicum	Squalicum Cr	county	4702 Noon Rd				NSEA	29.48	
Dakota	Dakota Cr	county	Under Haynie Rd., west of Valley View				NSEA	28.2	
Dakota	Dakota Cr	county	Haynie and Stien Rd. (under Stien)				NSEA	27.66	

Stream	Tributary to:	Owner-ship	Road Name/Milepost	Sec	Town	Ran	Data Source	Original Priority	Notes
Bertrand Cr.	Nooksack R	private	896 H St N				NSEA	26.17	
Squalicum	Squalicum Cr	private	Between Noon and Everson Goshen Rds				NSEA	25.84	
Wetland Trib.	Squalicum Cr	city	Squalicum Pkwy				NSEA	25.08	
Dakota	Dakota Cr	private	2206 H St., 200yds S. of H St.				NSEA	24.24	
Squalicum	Squalicum Cr	private	Behind 4817 Everson Goshen Rd.				NSEA	24.07	
Squalicum	Squalicum Cr	private	Upstream from 4634 Noon Rd. Seg 1 unit 14				NSEA	23.58	
Black Slough	SF Nooksack R	county	Under Clipper Rd., 300 ft. N. of mailbox for 3260				NSEA	23.54	
Squalicum	Squalicum Cr	private	4011 Britten Rd.				NSEA	23.2	
Dakota	Dakota Cr	county	Under Harvey Rd., south of 9943 Harvey Rd.				NSEA	23.13	
Wetland Trib.	Squalicum Cr	city	Guide Meridian				NSEA	23.03	
Dakota	Dakota Cr	county	9445 Sunrise Rd., 300' south of 9445 mailbox				NSEA	21.96	
Black Slough	SF Nooksack R	county	Under Clipper Rd., 100yds north of 2990 Clipper Rd				NSEA	21.75	
Dakota	Dakota Cr	private	2459 W Badger, Sunrise Church				NSEA	20.45	
Bertrand Cr.	Nooksack R	private	896 H St., 100 ft west of pump house				NSEA	20.37	
Unnamed	Hutchinson Cr		Mosquito Lake	4	37N	5E	DNR 98	High	
Unnamed	Hutchinson Cr		Mosquito Lake	3	37N	5E	DNR 98	High	
Unnamed	Hutchinson Cr		Mosquito Lake	2	37N	5E	DNR 98	High	
Unnamed	Hutchinson Cr		Blue Mtn. Spur	1	37N	5E	DNR 98	High	
Unnamed	Hutchinson Cr		Blue Mtn. Spur #3000	6	37N	6E	DNR 98	High	
Unnamed	Hutchinson Cr		Blue Mtn. Spur #4000	6	37N	6E	DNR 98	High	
Unnamed	Hutchinson Cr		Blue Mtn. Spur	36	38N	5E	DNR 98	High	
Unnamed	Hutchinson Cr		Blue Mtn. Spur #3000	36	38N	5E	DNR 98	High	
Unnamed	Hutchinson Cr		Blue Mtn. Spur #3000	36	38N	5E	DNR 98	High	
Unnamed	Hutchinson Cr		Blue Mtn. Spur #3000	36	38N	5E	DNR 98	High	
Unnamed	Musto Marsh		Blue Mtn. Spur	5	37N	5E	DNR 98	High	
Unnamed	Hutchinson Cr		Mosquito Lake	35	38N	5E	DNR 98	High	

Stream	Tributary to:	Owner-ship	Road Name/Milepost		Sec	Town	Ran	Data Source	Original Priority	Notes
Unnamed	Hutchinson Cr		Mosquito Lake		35	38N	5E	DNR 98	High	
Johnson Creek	Hutchinson Cr		Mosquito Lake		35	38N	5E	DNR 98	High	
Unnamed	Hutchinson Cr		Campground		3	37N	5E	DNR 98	High	
Unnamed	SF Nooksack R		Saxon		22	37N	5E	DNR 98	High	
Unnamed	Hutchinson Cr		Camp Spur Rd.		3	37N	5E	DNR 98	High	
Unnamed	Johnson Cr.		Spur Rd.		25	38N	5E	DNR 98	High	
Unnamed	Johnson Cr.		Spur Rd.		25	38N	5E	DNR 98	High	
Unnamed	Hutchinson Cr		Mosquito Lake		4	37N	5E	DNR 98	Mod/High	
Dakota	Dakota Cr	private	150m S. of end of Pipeline Rd., private rd. at Blaine city reservoir					NSEA	19.87	
Anderson Cr	Nooksack R		Hwy 542	MP 6.5500	6	38N	04E	WCD	PI=19.79	
Dakota	Dakota Cr	county	4389 Sweet Rd., 1/3 mile E. of Odell St.					NSEA	18.83	
Dakota	Dakota Cr	private	250 yards north of 4024 Pipleline Rd.					NSEA	18.67	
Dakota	Dakota Cr	county	2259 H St. (east 50 yards)					NSEA	18.46	
Black Slough	SF Nooksack R	county	150' north. of 3125 Clipper Rd.					NSEA	18.04	
Dakota	Dakota Cr	private	2206 H St.,150' upstream from culvert on H St. (0036.5-3)					NSEA	17.88	
Squalicum	Squalicum Cr	private	4973 Wahl Rd. (120' north of house)					NSEA	17.14	
Black Slough	SF Nooksack R	private?	Homesteader Rd. 400' E of pipeline, N. side of Rd.					NSEA	15.18	
Dakota	Dakota Cr	county	2206 H St. (west 25 yds)					NSEA	14.8	
Squalicum	Squalicum Cr	private	S. of private Rd.. On Wahl Rd., 1/4 mile N. of Kelly Rd.					NSEA	13.85	
Bertrand Cr.	Nooksack R	private	896 H St., 500 ft from house on Rd. to NSEA project					NSEA	12.94	
Squalicum	Squalicum Cr	private	Behind circle F Machine shop					NSEA	11.59	
EF Anderson Cr	Nooksack R							NSEA	PI=10.92	
Unnamed	Powers Cr		#4000		31	38N	5E	DNR 98	Mod	
Unnamed	Powers Cr		Blue Mtn.?		36	38N	5E	DNR 98	Mod	
Nessit's Creek	Hutchinson Cr		Spur Rd.		15	37N	5E	DNR 98	Mod?	
Unnamed	Johnson Cr.		Spur Rd.		25	38N	5E	DNR 98	Mod?	

Stream	Tributary to:	Owner-ship	Road Name/Milepost	Sec	Town	Ran	Data Source	Original Priority	Notes
Unnamed	Johnson Cr.		Spur Rd.	25	38N	5E	DNR 98	Low	
Unnamed	Hutchinson Cr		Spur Rd.	4	37N	5E	DNR 98	Low	
Unnamed	Johnson Cr.		Spur Rd.	25	38N	5E	DNR 98	Low	
Nessit's Creek	Hutchinson Cr		Spur Rd.	21	37N	5E	DNR 98	Low	
Unnamed	Hutchinson Cr		Campground	3	37N	5E	DNR 98	Low	
Unnamed	Hutchinson Cr		Blue Mtn. Spur #3000	36	38N	5E	DNR 98	Low	
Unnamed	Hutchinson Cr		Blue Mtn. Spur #3000	36	38N	5E	DNR 98	Low	
Unnamed	Musto Marsh		Blue Mtn. Spur	1	37N	5E	DNR 98	Low?	
Unnamed	Hutchinson Cr		Blue Mtn.	35	38N	5E	DNR 98	Low	
Hutchinson Cr	SF Nooksack R		Blue Mtn.	1	37N	5E	DNR 98	Low	
Unnamed	Hutchinson Cr		Mosquito Lake	3	37N	5E	DNR 98	Low	
Unnamed	Hutchinson Cr		Blue Mtn. Spur	31	38N	6E	DNR 98	Low	
Dakota	Dakota Cr	private	3573 Haynie Rd (250' upstream from driveway culvert)				NSEA	8.48	
Dakota	Dakota Cr	private	3469 Haynie Rd. (downstream from Haynie Rd. about 1/4 mile)				NSEA	8.09	
Dakota	Dakota Cr	county	Under Sweet Rd., west of Valley View				NSEA	4.98	
Black Slough	SF Nooksack R	private	100yds up logging Rd. S. of 2990 Clipper Rd.				NSEA	3.54	
Dakota	Dakota Cr	county	Under H St., 800 ft W. of 3906 H St.				NSEA	3.44	
Anderson Trib	EF Anderson Cr						NSEA	low	<200 m habitat
Anderson Trib	EF Anderson Cr						NSEA	low	<200 m habitat
Anderson Trib	RB Trib at RM 1.2						NSEA	low	<200 m habitat
Anderson Trib	RB Trib at RM 1.2						NSEA	low	<200 m habitat
Anderson Trib	LB Trib at RM 2.5						NSEA	low	<200 m habitat
Lummi R	Lummi Bay			33	39N	02E	WCD	Unknown	
Schell Ditch	Lummi R		Imhoff Road	30	39N	01E	WCD	Unknown	

Stream	Tributary to:	Owner-ship	Road Name/Milepost		Sec	Town	Ran	Data Source	Original Priority	Notes
Schell Ditch	Lummi R		Private					WCD	Unknown	
Schell Ditch	Lummi R		Field View Rd					WCD	Unknown	
Schell Ditch	Lummi R		Heather Dr					WCD	Unknown	
Unnamed	Silver Cr	City	0.608	Aldrich Rd	12	38N	2E	Bellingham	unknown	
Unnamed	Silver Cr	City	1.277	Aldrich Rd	1	38N	2E	Bellingham	unknown	blockage
Silver Cr	Nooksack R	City	1.334	Aldrich Rd	1	38N	2E	Bellingham	unknown	blockage
Silver Cr	Nooksack R	City	1.333	Aldrich Rd	1	38N	2E	Bellingham	unknown	blockage
Andreasen Ditch	Silver Cr	City	2.577	Aldrich Rd	35	39N	2E	Bellingham	unknown	Level B req
Andreasen Ditch	Silver Cr	City	2.578	Aldrich Rd	35	39N	2E	Bellingham	unknown	Level B req
Unnamed	Silver Cr	City	0.358	Aldrich Rd	12	38N	2E	Bellingham	unknown	
Unnamed	Silver Cr	City	0.499	Aldrich Rd	12	38N	2E	Bellingham	unknown	
Unnamed	Andreason Ditch	City	3.281	Aldrich Rd	35	39N	2E	Bellingham	unknown	
Deer Cr	Tenmile Cr	City	4.020	Aldrich Rd	26	39N	2E	Bellingham	unknown	Level B req
Unnamed	Silver Cr	City	1.700	Northwest Dr	2	38N	2E	Bellingham	unknown	blockage
Silver Cr	Nooksack R	City	2.750	Northwest Dr	34	39N	2E	Bellingham	unknown	blockage
Unnamed	Silver Cr	City	3.010	Northwest Dr	34	39N	2E	Bellingham	unknown	Level B reqd
Unnamed	Silver Cr	City	3.110	Northwest Dr	34	39N	2E	Bellingham	unknown	blockage
Unnamed	NA	City	5.473	Noon Rd	10	39N	3E	Bellingham	unknown	Unassessed
Unnamed	NA	City	6.721	Noon Rd	3	39N	3E	Bellingham	unknown	Unassessed
Unnamed	Fourmile	City	7.257	Noon Rd	3	39N	3E	Bellingham	unknown	Level B reqd
Scott Ditch	Nooksack R	City	8.071	Noon Rd	34	40N	3E	Bellingham	unknown	Level B reqd
Unnamed	Fourmile	City	1.806	Mission Rd	19	39N	4E	Bellingham	unknown	
Unnamed	Fourmile	City	1.881	Mission Rd	19	39N	4E	Bellingham	unknown	
Unnamed	Fourmile	City	4.272	Everson Goshen Rd	13	39N	3E	Bellingham	unknown	blockage
Unnamed	Fourmile	City	4.363	Everson Goshen Rd	13	39N	3E	Bellingham	unknown	
Unnamed	Fourmile	City	5.323	Everson Goshen Rd	12	39N	3E	Bellingham	unknown	

Stream	Tributary to:	Owner-ship	Road Name/Milepost		Sec	Town	Ran	Data Source	Original Priority	Notes
Unnamed	Fourmile	City	5.699	Everson Goshen Rd	12	39N	3E	Bellingham	unknown	Level B req'd
Unnamed	Fourmile	City	0.448	Fazon Rd	19	39N	4E	Bellingham	unknown	
Unnamed	Fourmile	City	4.974	E Hemmi Rd	14	39N	3E	Bellingham	unknown	Unassessed
Unnamed	Fourmile	City	5.357	E Hemmi Rd	13	39N	3E	Bellingham	unknown	Unassessed
Unnamed	Fourmile	City	5.675	E Hemmi Rd	13	39N	3E	Bellingham	unknown	Unassessed
Unnamed	Fourmile	City	5.848	E Hemmi Rd	13	39N	3E	Bellingham	unknown	Unassessed
Unnamed	Fourmile	City	0.086	Beard Rd	8	39N	3E	Bellingham	unknown	Level B req'd
Unnamed	Fourmile	City	2.993	Central Rd	11	39N	3E	Bellingham	unknown	
Deer Cr	Nooksack R		539	4.3000	30	39N	02E	WCD	Unknown	
Unnamed	Deer Cr				28	39N	03E	WCD	Unknown	
Unnamed Ditch	Nooksack R		539	11.1000		38N	02E	WCD	Unknown	
Unnamed Ditch	Nooksack R		539	11.1000		38N	02E	WCD	Unknown	
Fourmile Cr	Tenmile Cr		Noon Rd					WCD	Unknown	
Unnamed	Tenmile Cr							WCD	Unknown	
Unnamed	Tenmile Cr		Everson-Goshen Rd		26	39N	03E	WCD	Unknown	
Unnamed	NA	City	5.656	Aldrich Rd	14	39N	2E	Bellingham	unknown	
Unnamed	NA	City	6.466	Aldrich Rd	11	39N	2E	Bellingham	unknown	
Unnamed	NA	City	6.943	Aldrich Rd	11	39N	2E	Bellingham	unknown	
Deer Cr	Barret Lk	City	4.226	Aldrich Rd	26	39N	2E	Bellingham	unknown	blockage
Unnamed	Tenmile Cr	City	5.192	Aldrich Rd	26	39N	2E	Bellingham	unknown	blockage
Unnamed	Deer Cr	City	0.052	Boyer Rd	28	39N	3E	Bellingham	unknown	Level B req'd
Unnamed	NA	City	2.826	Central Rd	11	39N	3E	Bellingham	unknown	Level B req'd
Deer Cr	Tenmile Cr	City	2.650	E Axton Rd	28	39N	3E	Bellingham	unknown	blockage
Unnamed	Tenmile Cr	City	0.206	Chasteen Rd	17	39N	3E	Bellingham	unknown	Level B reqd
Unnamed	Tenmile Cr	City	0.499	Chasteen Rd	17	39N	3E	Bellingham	unknown	blockage
Unnamed	NA	City	1.100	E Laurel Rd	20	39N	3E	Bellingham	unknown	

Stream	Tributary to:	Owner-ship	Road Name/Milepost		Sec	Town	Ran	Data Source	Original Priority	Notes
Unnamed	NA	City	1.200	E Laurel Rd	20	39N	3E	Bellingham	unknown	
Unnamed	NA	City	1.600	E Laurel Rd	20	39N	3E	Bellingham	unknown	
Unnamed	NA	City	1.850	E Laurel Rd	20	39N	3E	Bellingham	unknown	
Unnamed	NA	City	2.010	E Laurel Rd	21	39N	3E	Bellingham	unknown	
Silver Springs	Tenmile Cr	City	0.031	E Hemmi Rd	18	39N	3E	Bellingham	unknown	blockage
Unnamed	Tenmile Cr	City	1.206	E Hemmi Rd	17	39N	3E	Bellingham	unknown	Level B reqd
Unnamed	Tenmile Cr	City	1.245	E Hemmi Rd	17	39N	3E	Bellingham	unknown	blockage
Unnamed	Tenmile Cr	City	2.149	E Hemmi Rd	16	39N	3E	Bellingham	unknown	Level B reqd
Tenmile Cr	Nooksack R	City	2.551	E Hemmi Rd	16	39N	3E	Bellingham	unknown	Unassessed
Unnamed	Tenmile Cr	City	3.023	E Hemmi Rd	15	39N	3E	Bellingham	unknown	Unassessed
Unnamed	NA	City	3.411	E Hemmi Rd	15	39N	3E	Bellingham	unknown	Unassessed
Unnamed	NA	City	3.623	E Hemmi Rd	15	39N	3E	Bellingham	unknown	Unassessed
Unnamed	NA	City	3.797	E Hemmi Rd	15	39N	3E	Bellingham	unknown	Unassessed
Unnamed	NA	City	3.871	E Hemmi Rd	15	39N	3E	Bellingham	unknown	Unassessed
Unnamed	NA	City	3.991	E Hemmi Rd	15	39N	3E	Bellingham	unknown	Unassessed
Unnamed	Shuksan Cr	City	4.292	E Hemmi Rd	14	39N	3E	Bellingham	unknown	blockage
Unnamed	Shuksan Cr	City	4.690	E Hemmi Rd	14	39N	3E	Bellingham	unknown	Unassessed
Unknown	Tenmile Cr	City	0.400	E Laurel Rd	19	39N	3E	Bellingham	unknown	blockage
Unnamed	NA	City	0.470	E Laurel Rd	19	39N	3E	Bellingham	unknown	
Unnamed	NA	City	0.860	E Laurel Rd	19	39N	3E	Bellingham	unknown	
Unnamed	NA	City	2.120	E Laurel Rd	21	39N	3E	Bellingham	unknown	
Unnamed	NA	City	2.650	E Laurel Rd	21	39N	3E	Bellingham	unknown	
Unnamed	NA	City	0.014	W King Tut Rd	11	39N	2E	Bellingham	unknown	
Unnamed	Tenmile Cr	City	0.770	W King Tut Rd	12	39N	2E	Bellingham	unknown	blockage
Unnamed	NA	City	0.254	Old Guide Rd	24	39N	2E	Bellingham	unknown	
Unnamed	Nooksack R	City	0.200	Neevel Rd	22	39N	2E	Bellingham	unknown	Level B req'd

Stream	Tributary to:	Owner-ship	Road Name/Milepost		Sec	Town	Ran	Data Source	Original Priority	Notes
Unnamed	NA	City	0.005	Market Rd	27	39N	3E	Bellingham	unknown	
Unnamed	NA	City	0.396	Market Rd	27	39N	3E	Bellingham	unknown	
Unnamed	NA	City	0.007	Market Rd	27	39N	3E	Bellingham	unknown	
Unnamed	Shuksan Cr	City	1.208	Mission Rd	19	38N	4E	Bellingham	unknown	blockage
Unnamed	NA	City	1.475	Mission Rd	19	39N	4E	Bellingham	unknown	
Unnamed	NA	City	1.624	Mission Rd	19	39N	4E	Bellingham	unknown	
Unnamed	NA	City	0.003	Mertz Rd	22	39N	3E	Bellingham	unknown	
Unnamed	Starry Cr	City	2.537	Noon Rd	27	39N	3E	Bellingham	unknown	Level B reqd
Deer Cr	Tenmile Cr	City	4.430	Northwest Dr	27	39N	2E	Bellingham	unknown	Level B reqd
Unnamed	Tenmile Cr	City	5.010	Northwest Dr	22	39N	2E	Bellingham	unknown	Unassessed
Unnamed	Nooksack R	City	5.680	Northwest Dr	15	39N	2E	Bellingham	unknown	Level B reqd
Unnamed	Nooksack R	City	6.690	Northwest Dr	10	39N	2E	Bellingham	unknown	Unassessed
Unnamed	Nooksack R	City	6.900	Northwest Dr	10	39N	2E	Bellingham	unknown	Unassessed
Unnamed	Swamp Cr	City	2.000	Twin Lakes Rd	31	40N	8E	Bellingham	unknown	
Unnamed	Starry Cr	City	0.195	Starry Rd	27	39N	3E	Bellingham	unknown	Level B req'd
Unknown	Tenmile Cr	City	0.621	Starry Rd	27	39N	3E	Bellingham	unknown	blockage
Unknown	Tenmile Cr	City	0.715	Starry Rd	27	39N	3E	Bellingham	unknown	blockage
Unnamed	Tenmile Cr	City	0.768	Starry Rd	27	39N	3E	Bellingham	unknown	
Unnamed	NA	City	0.386	Tenmile Rd	15	39N	3E	Bellingham	unknown	
Unnamed	NA	City	0.922	Tenmile Rd	15	39N	3E	Bellingham	unknown	
Unnamed	NA	City	1.267	Tenmile Rd	15	39N	3E	Bellingham	unknown	
Unnamed	Tenmile Cr	City	3.020	Tenmile Rd	18	39N	3E	Bellingham	unknown	Level B req'd
Unknown	NA	City	3.629	Central Rd	12	39N	3E	Bellingham	unknown	Level B req'd
Unknown	NA	City	3.630	Central Rd	12	39N	3E	Bellingham	unknown	Level B req'd
Deer Cr	Barret Lk	City	0.136	East Rd	29	39N	3E	Bellingham	unknown	Level B req
Unnamed	NA	City	2.064	Everson Goshen Rd	25	39N	3E	Bellingham	unknown	

Stream	Tributary to:	Owner-ship	Road Name/Milepost		Sec	Town	Ran	Data Source	Original Priority	Notes
Unknown	Tenmile Cr	City	2.463	Everson Goshen Rd	25	39N	3E	Bellingham	unknown	blockage
Tenmile Cr	Deer Cr	City	2.620	Everson Goshen Rd	25	39N	3E	Bellingham	unknown	blockage
Tenmile Cr	Deer Cr	City	2.621	Everson Goshen Rd	25	39N	3E	Bellingham	unknown	blockage
Unnamed	NA	City	1.475	Mission Rd	19	39N	4E	Bellingham	unknown	
Unnamed	NA	City	1.624	Mission Rd	19	39N	4E	Bellingham	unknown	
Unnamed	NA	City	0.030	Glendale Rd	15	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	City	0.376	Glendale Rd	15	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	City	2.217	Jackman Rd	1	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	City	0.454	Weidkamp Rd	14	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	City	1.276	Weidkamp Rd	11	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	City	1.517	Weidkamp Rd	11	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	City	1.643	Weidkamp Rd	11	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	City	1.928	Weidkamp Rd	11	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	City	2.054	Weidkamp Rd	2	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	City	2.370	Weidkamp Rd	2	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	City	2.613	Weidkamp Rd	2	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	City	0.501	Glendale Rd	15	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	City	1.003	Glendale Rd	15	40N	2E	Bellingham	unknown	Unassessed
Unnamed	Bertrand Cr	City	0.005	Jackman Rd	12	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	City	0.814	Jackman Rd	12	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	City	1.000	Jackman Rd	12	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	City	1.030	Jackman Rd	1	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	City	0.191	Axlund Rd	2	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	City	0.356	Axlund Rd	2	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	City	0.416	Axlund Rd	2	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	City	0.703	Axlund Rd	2	40N	2E	Bellingham	unknown	Unassessed

Stream	Tributary to:	Owner-ship	Road Name/Milepost		Sec	Town	Ran	Data Source	Original Priority	Notes
Unnamed	NA	City	0.117	Barnhart Rd	3	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	City	0.324	Barnhart Rd	3	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	City	0.662	Barnhart Rd	3	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	City	0.759	Barnhart Rd	3	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	City	0.990	Barnhart Rd	3	40N	2E	Bellingham	unknown	Unassessed
Unknown	McClelland Cr	City	1.269	Barnhart Rd	2	40N	2E	Bellingham	unknown	blockage
Unnamed	NA	City	1.396	Barnhart Rd	2	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	City	1.593	Barnhart Rd	2	40N	2E	Bellingham	unknown	Unassessed
Duffner Ditch	Bertrand Cr		Tromp Rd		24	40N	02E	WCD	Unknown	
Unnamed	Duffner Ditch							WCD	Unknown	
Unnamed	Bertrand Cr		Loomis Trail Rd		15	40N	02E	WCD	Unknown	
Bender Ditch	Fishtrap Cr							WCD	Unknown	
Bender Ditch	Fishtrap Cr							WCD	Unknown	
Unnamed	NA	City	0.002	Markworth Rd	10	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	City	1.010	Markworth Rd	3	40N	2E	Bellingham	unknown	Level B reqd
Unnamed	NA	City	2.450	Markworth Rd	34	41N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	City	2.451	Markworth Rd	34	41N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	City	0.836	Marshall Hill Rd	32	39N	5E	Bellingham	unknown	Unassessed
Unnamed	NA	City	0.437	Marshall Hill Rd	31	39N	5E	Bellingham	unknown	Unassessed
Unnamed	Nooksack R		542	19.6000		39N	04E	WCD	Unknown	
Elder Ditch	Nooksack R Trib		Van Dyk Rd		33	40N	03E	WCD	Unknown	
Unnamed	Nooksack R		Marshall Hill Rd		32	39N	05E	WCD	Unknown	
Unnamed	Anderson Cr	City	0.826	Sand Rd	1	39N	4E	Bellingham	unknown	blockage
Unnamed	Anderson Cr	City	1.763	Sand Rd	31	39N	4E	Bellingham	unknown	Unassessed
Unnamed	McCauley Cr	City	1.265	Deming Rd	26	39N	4E	Bellingham	unknown	Unassessed
Unnamed	McCauley Cr	City	0.060	Hillard Rd	26	39N	4E	Bellingham	unknown	Unassessed

Stream	Tributary to:	Owner-ship	Road Name/Milepost		Sec	Town	Ran	Data Source	Original Priority	Notes
Unnamed	Anderson Cr	City	2.584	Sand Rd	30	39N	4E	Bellingham	unknown	Unassessed
Unnamed	Anderson Cr	City	2.588	Sand Rd	30	39N	4E	Bellingham	unknown	Unassessed
Unnamed	Anderson Cr	City	3.115	Sand Rd	19	39N	4E	Bellingham	unknown	Unassessed
Unnamed	Anderson Cr	City	4.339	Y Rd	7	38N	4E	Bellingham	unknown	Unassessed
Unnamed	Anderson Cr	City	3.522	Y Rd	7	38N	4E	Bellingham	unknown	Unassessed
Unknown	Anderson Cr	City	3.863	Y Rd	7	38N	4E	Bellingham	unknown	blockage
Unnamed	Anderson Cr	City	0.001	Eberly Rd	32	39N	4E	Bellingham	unknown	blockage
Unnamed	Anderson Cr	City	0.818	Sand Rd	1	39N	4E	Bellingham	unknown	blockage
Unnamed	Smith Cr	City	0.300	Deming Rd	27	39N	4E	Bellingham	unknown	Unassessed
Unnamed	McCauley Cr	City	0.738	Williams Rd	26	39N	4E	Bellingham	unknown	Level B reqd
Anderson Creek	Nooksack R	City	0.608	Henderson Rd	8	38N	4E	Bellingham	unknown	blockage
Unnamed	Anderson Cr	City	0.810	Henderson Rd	17	38N	4E	Bellingham	unknown	blockage
Unnamed	NA	City	5.100	E Smith Rd	25	39N	3E	Bellingham	unknown	
Unnamed	NA	City	5.220	E Smith Rd	25	39N	3E	Bellingham	unknown	Level B req'd
Unnamed	Anderson Cr	City	6.002	E Smith Rd	25	39N	3E	Bellingham	unknown	
Unnamed	Anderson Cr	City	6.131	E Smith Rd	30	39N	4E	Bellingham	unknown	Level B req'd
Unnamed	Anderson Cr	City	6.264	E Smith Rd	30	39N	4E	Bellingham	unknown	blockage
Unnamed	Anderson Cr	City	6.420	E Smith Rd	30	39N	4E	Bellingham	unknown	blockage
Unnamed	Anderson Cr	City	6.471	E Smith Rd	30	39N	4E	Bellingham	unknown	
Unnamed	Anderson Cr	City	6.711	E Smith Rd	30	39N	4E	Bellingham	unknown	
Unnamed	Anderson Cr	City	7.085	E Smith Rd	29	39N	4E	Bellingham	unknown	
Unnamed	Anderson Cr	City	7.411	E Smith Rd	29	39N	4E	Bellingham	unknown	
Unnamed	Anderson Cr	City	7.698	E Smith Rd	29	39N	4E	Bellingham	unknown	blockage
Unnamed	Anderson Cr	City	7.861	E Smith Rd	29	39N	4E	Bellingham	unknown	blockage
Unnamed	Anderson Cr	City	7.846	E Smith Rd	29	39N	4E	Bellingham	unknown	
Unnamed	Anderson Cr	City	0.033	Fazon Rd	19	39N	4E	Bellingham	unknown	Level B reqd

Stream	Tributary to:	Owner-ship	Road Name/Milepost		Sec	Town	Ran	Data Source	Original Priority	Notes
Unnamed	Anderson Cr	City	0.544	Goshen Rd	19	39N	4E	Bellingham	unknown	Level B req'd
Unnamed	Anderson Cr	City	5.166	Kelly Rd	31	39N	4E	Bellingham	unknown	blockage
Unnamed	Anderson Cr	City	6.033	Kelly Rd	31	39N	4E	Bellingham	unknown	
Unnamed	Maple Cr	City	2.950	Silver Lk Rd	19	40N	6E	Bellingham	unknown	Unassessed
Unnamed	Maple Cr	City	3.840	Silver Lk Rd	18	40N	6E	Bellingham	unknown	Unassessed
Unnamed	NA	City	6.080	Silver Lk Rd	6	40N	6E	Bellingham	unknown	Level B reqd
Unnamed	NA	City	6.240	Silver Lk Rd	31	41N	6E	Bellingham	unknown	Unassessed
Unnamed	NA	City	6.460	Silver Lk Rd	31	41N	6E	Bellingham	unknown	Unassessed
Unnamed	Maple Cr	City	3.070	Silver Lk Rd	18	40N	6E	Bellingham	unknown	blockage
Unnamed	NA	City	6.680	Silver Lk Rd	31	41N	6E	Bellingham	unknown	Unassessed
Unnamed	NA	City	13.507	South Pass Rd	31	41N	6E	Bellingham	unknown	Unassessed
Unnamed	Hendrick Cr	City	1.200	Cornell Cr Rd	1	39N	6E	Bellingham	unknown	Unassessed
Unnamed	Hendrick Cr	City	1.070	Cornell Cr Rd	1	39N	6E	Bellingham	unknown	Unassessed
Unnamed	Maple Cr	City	2.070	Silver Lk Rd	19	40N	6E	Bellingham	unknown	Unassessed
Doaks Cr	Maple Cr	City	2.640	Silver Lk Rd	19	40N	6E	Bellingham	unknown	blockage
Unnamed	Hendrick Cr	City	0.360	Cornell Cr Rd	1	39N	6E	Bellingham	unknown	blockage
Unnamed	NA	City	1.700	North Fork Rd	15	39N	5E	Bellingham	unknown	Unassessed
Unnamed	NF Nooksack R	City	2.198	North Fork Rd	15	39N	5E	Bellingham	unknown	blockage
Unnamed	NA	City	0.100	Marshall Hill Rd	31	39N	5E	Bellingham	unknown	Unassessed
Kenny Cr	NF Nooksack R		Canyon Lk Rd		26	39N	05E	WCD	Unknown	
Kenny Cr	NF Nooksack R		Canyon Lk Rd		26	39N	05E	WCD	Unknown	
Whalen Cr	NF Nooksack R							Warnick WA	Unknown	
Unnamed	NF Nooksack R		North Fork Rd		15	39N	05E	WCD	Unknown	
Unnamed	Silver Lake				6	40N	06E	WCD	Unknown	
Baptist Camp Cr	NF Nooksack R		Hwy 542	MP 28.72		39N	05E	WCD	Unknown	
Aldrich Cr	NF Nooksack R							Warnick	Unknown	log bridge/jam

Stream	Tributary to:	Owner-ship	Road Name/Milepost		Sec	Town	Ran	Data Source	Original Priority	Notes
								WA		
Hedrick Cr	NF Nooksack R		Hwy 542	MP 32	1	39N	06E	WCD	Unknown	
Unnamed	NF Nooksack R		Hwy 542	MP 29	34	40N	06E	WCD	Unknown	
Unnamed	NF Nooksack R		Hwy 542	MP 14.1	31	39N	05E	WCD	Unknown	
Unnamed	NF Nooksack R		Hwy 542	MP 15.05	32	39N	05E	WCD	Unknown	
Unnamed	NF Nooksack R		Hwy 542	MP 15.05	32	39N	05E	WCD	Unknown	
Unnamed	NF Nooksack R		Hwy 542	MP 17.85	16	39N	05E	WCD	Unknown	
Unnamed	NF Nooksack R		Hwy 542	MP 29.62	34	40N	06E	WCD	Unknown	
Unnamed	NF Nooksack R		Hwy 542	MP 29.7	34	40N	06E	WCD	Unknown	
Unnamed	NF Nooksack R		Hwy 542	MP 29.8	34	40N	06E	WCD	Unknown	
Unnamed	NF Nooksack R		Hwy 542	MP 29.9	34	40N	06E	WCD	Unknown	
Unnamed	NF Nooksack R		Hwy 542	MP 31.4	2	39N	06E	WCD	Unknown	
Unnamed	NF Nooksack R		Hwy 542	MP 36.6	34	40N	07E	WCD	Unknown	
Unnamed	NF Nooksack R		Hwy 542	MP 38.9	31	40N	08E	WCD	Unknown	
Unnamed	NF Nooksack R		Hwy 542	MP 16.1		39N	05E	WCD	Unknown	
Unnamed	Unknown		Hwy 9					WCD	Unknown	
Unnamed	NF Nooksack R		Hwy 542	MP 16.3		38N	04E	WCD	Unknown	
Unnamed	Kendall Cr		Hwy 542	MP 24.9		39N	05E	WCD	Unknown	
Unnamed	NF Nooksack R		Hwy 542	MP 27.18		40N	05E	WCD	Unknown	
NF Nooksack R Trib	NF Nooksack R	USDA-FS		0.2	4	39N	7E	U.S.F.S.	1	Coho
Boyd Creek	NF Nooksack R	USDA-FS		3.2	2	39N	7E	U.S.F.S.	3	Pink, Chum
Anderson Creek	NF Nooksack R	USDA-FS		0.99	1	39N	8E	U.S.F.S.	2	Brook Tr
Canyon Creek trib5	NF Nooksack R	USDA-FS		5.8	30	40N	7E	U.S.F.S.	1	Cutthroat
Grouse Creek trib		USDA-FS		8.3	9	38N	7E	U.S.F.S.	2	Bull Trout
Anderson Creek	NF Nooksack R	USDA-FS		0.99	1	39N	8E	U.S.F.S.	1	Cutthroat
Thompson Creek	NF Nooksack R	USDA-FS		2	3	39N	7E	U.S.F.S.	2	Bull Trout

Stream	Tributary to:	Owner-ship	Road Name/Milepost		Sec	Town	Ran	Data Source	Original Priority	Notes
Boyd Creek	NF Nooksack R	USDA-FS		3.2	2	39N	7E	U.S.F.S.	1	Coho
Bald Lake creek	Canyon Cr (NF)	USDA-FS		4.9	7	40N	7E	U.S.F.S.	2	Rainbow
Whistler Creek	Canyon Cr (NF)	USDA-FS		1.45	15	40N	7E	U.S.F.S.	2	Bull Trout
Canyon Creek trib2	Canyon Cr (NF)	USDA-FS		1.6	18	40N	8E	U.S.F.S.	1	Bull Trout
Canyon Creek trib	Canyon Cr (NF)	USDA-FS		0.2	10	40N	7E	U.S.F.S.	2	Bull Trout
Anderson Creek	NF Nooksack R	USDA-FS		0.98	1	39N	8E	U.S.F.S.	2	Brook Tr
Anderson Creek	NF Nooksack R	USDA-FS		3.9	1	39N	8E	U.S.F.S.	1	Cutthroat
Thompson Creek	Glacier Cr	USDA-FS		2	3	39N	7E	U.S.F.S.	3	pink chum
Chain-Up Creek	NF Nooksack R	USDA-FS		0.68	36	40N	7E	U.S.F.S.	1	Cutthroat
Canyon Creek trib6	Canyon Cr (NF)	USDA-FS		8	17	40N	7E	U.S.F.S.	1	Cutthroat
Anderson Creek	NF Nooksack R	USDA-FS		0.98	1	39N	8E	U.S.F.S.	1	Cutthroat
Kidney Creek	Canyon Cr (NF)	USDA-FS		1.6	20	40N	7E	U.S.F.S.	1	Cutthroat
Canyon Creek trib3	Canyon Cr (NF)	USDA-FS		0.69	18	40N	8E	U.S.F.S.	1	Bull Trout
Twin Lakes	NF Nooksack R	USDA-FS		6.9	16	40N	9E	U.S.F.S.	2	Brook Tr
Anderson Creek	NF Nooksack R	USDA-FS		0.98	1	39N	8E	U.S.F.S.	3	Bull Trout
Thompson Creek	Glacier Cr	USDA-FS		2	3	39N	7E	U.S.F.S.	4	Cutthroat
Canyon Creek trib6	Canyon Cr (NF)	USDA-FS		8	17	40N	7E	U.S.F.S.	2	Bull Trout
Canyon Creek trib2	Canyon Cr (NF)	USDA-FS		1.6	18	40N	8E	U.S.F.S.	2	Cutthroat
Canyon Creek trib4	Canyon Cr (NF)	USDA-FS		2.4	13	40N	7E	U.S.F.S.	1	Bull Trout
Thompson Creek	Glacier Cr	USDA-FS		2	3	39N	7E	U.S.F.S.	1	Coho
Anderson Creek	NF Nooksack R	USDA-FS		0.99	1	39N	8E	U.S.F.S.	3	Bull Trout
Canyon Creek trib5	Canyon Cr (NF)	USDA-FS		5.8	30	40N	7E	U.S.F.S.	2	Bull Trout
Twin Lakes	NF Nooksack R	USDA-FS		6.9	16	40N	9E	U.S.F.S.	1	Cutthroat
Kidney Creek	Canyon Cr (NF)	USDA-FS		1.6	20	40N	7E	U.S.F.S.	2	Bull Trout
NF Nooksack Trib	NF Nooksack R	USDA-FS		0.2	4	39N	7E	U.S.F.S.	2	Cutthroat
Swamp Creek trib	NF Nooksack R	USDA-FS		0.1	31	40N	9E	U.S.F.S.	1	Cutthroat

Stream	Tributary to:	Owner-ship	Road Name/Milepost		Sec	Town	Ran	Data Source	Original Priority	Notes
Anderson Creek	NF Nooksack R	USDA-FS		3.9	1	39N	8E	U.S.F.S.	2	Bull Trout
Bald Lake creek	Canyon Cr (NF)	USDA-FS		4.9	7	40N	7E	U.S.F.S.	1	Cutthroat
Whistler Creek	Canyon Cr (NF)	USDA-FS		1.45	15	40N	7E	U.S.F.S.	1	Cutthroat
Jim Creek	Canyon Cr (NF)	USDA-FS		5.69	30	40N	7E	U.S.F.S.	1	Cutthroat
Boyd Creek	NF Nooksack R	USDA-FS		3.2	2	39N	7E	U.S.F.S.	2	Cutthroat
Canyon Creek trib3	Canyon Cr (NF)	USDA-FS		0.69	18	40N	8E	U.S.F.S.	2	Cutthroat
Dippy Creek	NF Nooksack R	USDA-FS		1.79	5	39N	7E	U.S.F.S.	1	Cutthroat
Unnamed	NA	city	14.037	Mosquito Lk Rd	28	39N	5E	Bellingham	unknown	Unassessed
Unnamed	NA	city	0.130	Truck Rd	32	39N	5E	Bellingham	unknown	Unassessed
Unnamed	NA	city	5.924	Mosquito Lk Rd	26	39N	5E	Bellingham	unknown	Unassessed
Unnamed	NA	city	6.067	Mosquito Lk Rd	26	38N	5E	Bellingham	unknown	Unassessed
Unnamed	Jorgenson Lk	city	6.177	Mosquito Lk Rd	26	38N	5E	Bellingham	unknown	Level B reqd
Unnamed	NA	city	6.338	Mosquito Lk Rd	26	38N	5E	Bellingham	unknown	Unassessed
Unnamed	Jorgenson Lk	city	6.724	Mosquito Lk Rd	26	38N	5E	Bellingham	unknown	Yes
Unnamed	NA	city	7.638	Mosquito Lk Rd	23	38N	5E	Bellingham	unknown	Unassessed
Unnamed	NA	city	8.262	Mosquito Lk Rd	13	38N	5E	Bellingham	unknown	Unassessed
Unnamed	NA	city	9.135	Mosquito Lk Rd	11	38N	5E	Bellingham	unknown	Unassessed
Unnamed	NA	city	9.759	Mosquito Lk Rd	11	38N	5E	Bellingham	unknown	Unassessed
Unnamed	NA	city	9.844	Mosquito Lk Rd	11	38N	5E	Bellingham	unknown	Unassessed
Unnamed	NA	city	9.984	Mosquito Lk Rd	11	38N	5E	Bellingham	unknown	Unassessed
MF Nook Trib	MF Nooksack R	State		6.1	22	38N	6E	U.S.F.S.	1	Cutthroat
MF Nook Trib	MF Nooksack R	State		7.59	26	38N	6E	U.S.F.S.	1	Bull Trout
MF Nook Trib	MF Nooksack R	State		6.5	32	38N	6E	U.S.F.S.	1	Bull Trout
MF Nook Trib	MF Nooksack R	State		6.1	22	38N	6E	U.S.F.S.	2	Bull Trout
Unnamed	MF Nooksack R				35	39N	05E	WCD	Unknown	
Unnamed	MF Nooksack R				35	39N	05E	WCD	Unknown	

Stream	Tributary to:	Owner-ship	Road Name/Milepost		Sec	Town	Ran	Data Source	Original Priority	Notes
Bear Cr	MF Nooksack R				14	38N	05E	WCD	Unknown	
Unnamed	MF Nooksack R	city	1.422	Marshall Hill Rd	32	39N	5E	Bellingham	unknown	blockage
Unnamed	MF Nooksack R	city	0.024	Truck Rd	32	39N	5E	Bellingham	unknown	Level B reqd
Unnamed	MF Nooksack R	city	1.012	Truck Rd	33	39N	5E	Bellingham	unknown	blockage
Unnamed	MF Nooksack R	city	10.965	Mosquito Lk Rd	2	38N	5E	Bellingham	unknown	blockage
Unnamed	MF Nooksack R	city	10.970	Mosquito Lk Rd	2	38N	5E	Bellingham	unknown	blockage
Unnamed	MF Nooksack R	city	10.970	Mosquito Lk Rd	2	38N	5E	Bellingham	unknown	blockage
Unnamed	NA	city	11.088	Mosquito Lk Rd	2	38N	5E	Bellingham	unknown	Unassessed
Unnamed	NA	city	11.417	Mosquito Lk Rd	2	38N	5E	Bellingham	unknown	Unassessed
Heiser Cr	MF Nooksack R	city	12.155	Mosquito Lk Rd	35	39N	5E	Bellingham	unknown	Level B reqd
Unnamed	NA	city	12.340	Mosquito Lk Rd	35	39N	5E	Bellingham	unknown	Unassessed
Unnamed	Canyon Cr	city	12.545	Mosquito Lk Rd	27	39N	5E	Bellingham	unknown	blockage
Unnamed	NA	city		Mosquito Lk Rd	4	37N	5E	Bellingham	Unknown	
Unnamed	NA	city	Mosquito Lk Rd		4	37N	5E	Bellingham	Unknown	
Unnamed	NA	city	Mosquito Lk Rd		4	37N	5E	Bellingham	Unknown	
Unnamed	Hutchinson Cr	city	Mosquito Lk Rd		4	37N	5E	Bellingham	Unknown	fish use
Unnamed	Hutchinson Cr	city	Mosquito Lk Rd		4	37N	5E	Bellingham	Unknown	
Unnamed	NA	city	Mosquito Lk Rd		4	37N	5E	Bellingham	Unknown	
Unnamed	Hutchinson Cr	city	Mosquito Lk Rd		3	37N	5E	Bellingham	Unknown	susp.fish use
Unnamed	NA	city	Mosquito Lk Rd		3	37N	5E	Bellingham	Unknown	susp.fish use
Unnamed	Hutchinson Cr	city	Mosquito Lk Rd		3	37N	5E	Bellingham	Unknown	fish use
Unnamed	Hutchinson Cr	city	Mosquito Lk Rd		35	38N	5E	Bellingham	Unknown	susp.fish use
Unnamed	NA	city	Mosquito Lk Rd		35	38N	5E	Bellingham	Unknown	
Unnamed	Hutchinson Cr	city	Mosquito Lk Rd		35	38N	5E	Bellingham	Unknown	susp.fish use
Unnamed	NA	city	Mosquito Lk Rd		35	38N	5E	Bellingham	Unknown	
Unnamed	NA	city	Mosquito Lk Rd		35	38N	5E	Bellingham	Unknown	

Stream	Tributary to:	Owner-ship	Road Name/Milepost	Sec	Town	Ran	Data Source	Original Priority	Notes
Unnamed	Black Slough	city	Nelson Rd	20	38N	5E	Bellingham	Unknown	
Unnamed	Black Slough	city	Nelson Rd	17	38N	5E	Bellingham	Unknown	fish use
Unnamed	SF Nooksack R	city	Potter Rd	18	38N	5E	Bellingham	Unknown	
Unnamed	NA	city	Potter Rd	8	38N	5E	Bellingham	Unknown	
Unnamed	NA	city	Potter Rd	8	38N	5E	Bellingham	Unknown	
Unnamed	SF Nooksack R	city	Potter Rd	8	38N	5E	Bellingham	Unknown	fish use
Unnamed	NA	city	Saxon Rd	27	37N	5E	Bellingham	Unknown	fish use
Unnamed	SF Nooksack R	city	Schornbush Rd	9	38N	5E	Bellingham	Unknown	fish use
Unnamed	NA	city	Standard Rd	28	38N	5E	Bellingham	Unknown	
Unnamed	NA	city	Standard Rd	28	38N	5E	Bellingham	Unknown	susp.fish use
Unnamed	NA	city	Standard Rd	28	38N	5E	Bellingham	Unknown	
Unnamed	NA	city	Standard Rd	28	38N	5E	Bellingham	Unknown	
Unnamed	Black Slough	city	Strand Rd	20	38N	5E	Bellingham	Unknown	fish use
Unnamed	Jones Cr	city	Turkington Rd	6	37N	5E	Bellingham	Unknown	fish use
Unnamed	McCarty Cr	city	Turkington Rd	6	37N	5E	Bellingham	Unknown	fish use
Unnamed	Hutchinson Cr	city	Mosquito Lk Rd	35	38N	5E	Bellingham	Unknown	fish use
Johnson Cr	Hutchinson Cr	city	Mosquito Lk Rd	35	38N	5E	Bellingham	Unknown	fish use
Unnamed	Johnson Cr	city	Mosquito Lk Rd	26	38N	5E	Bellingham	Unknown	fish use
Unnamed	NA	city	Mosquito Lk Rd	26	38N	5E	Bellingham	Unknown	
Unnamed	SF Nooksack R	city	Caron Rd	7	38N	5E	Bellingham	Unknown	fish use
Unnamed	Black Slough	city	Clipper Rd	29	38N	5E	Bellingham	Unknown	fish use
Unnamed	Black Slough	city	Clipper Rd	29	38N	5E	Bellingham	Unknown	fish use
Tinling Cr	Black Slough	city	Clipper Rd	29	38N	5E	Bellingham	Unknown	fish use
Unnamed	SF Nooksack R	city	Mosquito Lk Rd	5	37N	5E	Bellingham	Unknown	fish use
Unnamed	SF Nooksack R	city	Mosquito Lk Rd	8	37N	5E	Bellingham	Unknown	susp.fish use
Unnamed	NA	city	Hillside Rd	19	38N	5E	Bellingham	Unknown	

Stream	Tributary to:	Owner-ship	Road Name/Milepost		Sec	Town	Ran	Data Source	Original Priority	Notes
Unnamed	Todd Cr	city	Hillside Rd		18	38N	5E	Bellingham	Unknown	fish use
Unnamed	NA	city	Hillside Rd		18	38N	5E	Bellingham	Unknown	
Jones Cr	SF Nooksack R	city	Hudson Rd		6	37N	5E	Bellingham	Unknown	fish use
Unnamed	NA	city	Linnel Rd		9	38N	5E	Bellingham	Unknown	susp.fish use
Unnamed	SF Nooksack R	city	Linnel Rd		9	38N	5E	Bellingham	Unknown	fish use
Unnamed	SF Nooksack R	city	Hillside Rd		19	38N	5E	Bellingham	Unknown	
Unnamed	NA	city	Hillside Rd		19	38N	5E	Bellingham	Unknown	
Unnamed	NA	city	Mosquito Lk Rd		4	37N	5E	Bellingham	Unknown	
Black Slough	SF Nooksack R	city	Homesteader Rd		29	38N	5E	Bellingham	Unknown	fish use
Unnamed	Black Slough	city	Homesteader Rd		29	38N	5E	Bellingham	Unknown	susp.fish use
Hutchinson		NW	3	37N	5E	RND	PCC	Bellingham	Unknown	
Black Slough	SF Nooksack R	private	River Farm, end Hillside Rd. 200yds on left Rd.					NSEA	Unknown	Grad. Barrier
Black Slough	SF Nooksack R	private	4202 Caron Rd.					NSEA	Unknown	Grad. Barrier
Loomis Cr	Wanlick (SF)	USDA-FS		8.	30	37N	8E	U.S.F.S.	1	Cutthroat
Unnamed	SF Nooksack R		9	70.6000		37N	04E	WCD	Unknown	
Skookum Creek	SF Nooksack R		upstream of Musto Marsh					Skookum WA	Unknown	
Bell Creek	SF Nooksack R	USDA-FS		15	15	37N	7E	U.S.F.S.	1	Cutthroat
Unnamed	Musto Marsh		Blue Mtn. Spur		1	37N	5E	DNR 98	Unknown	
Edfro Creek	Skookum Creek							Skookum WA	Unknown	
California Cr	Drayton Harbor		Portal Way		7	39N	02E	WCD	Unknown	
Unnamed	California Cr		Bay Rd		35	39N	01E	WCD	Unknown	
Dakota	Dakota Cr	private	2459 W. Badger, behind Sunrise Baptist Church,					NSEA	Unknown	Grad. Barrier
Dakota	Dakota Cr	county	2315 Burk Rd., under Burk Rd.					NSEA	Unknown	Grad. Barrier
Unnamed	Dakota Cr	city	2.151	Northside Rd	21	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	city	0.918	Pipeline Rd	5	40N	1E	Bellingham	unknown	Unassessed

Stream	Tributary to:	Owner-ship	Road Name/Milepost		Sec	Town	Ran	Data Source	Original Priority	Notes
Spooner Cr	Dakota Cr	city	1.080	Pipeline Rd	4	40N	1E	Bellingham	unknown	blockage
Unnamed	NA	city	0.326	Stadsvold Rd	9	40N	1E	Bellingham	unknown	Unassessed
Unnamed	NA	city	0.379	Stadsvold Rd	9	40N	1E	Bellingham	unknown	blockage
Unnamed	NA	city	0.820	Stein Rd	24	40N	1E	Bellingham	unknown	Unassessed
Unnamed	NA	city	1.170	Stein Rd	24	40N	1E	Bellingham	unknown	Unassessed
Unnamed	NA	city	1.400	Stein Rd	24	40N	1E	Bellingham	unknown	Unassessed
Unnamed	NA	city	1.680	Stein Rd	13	40N	1E	Bellingham	unknown	Unassessed
Unnamed	NA	city	1.681	Stein Rd	13	40N	1E	Bellingham	unknown	Unassessed
Unnamed	NA	city	3.110	Stein Rd	12	40N	1E	Bellingham	unknown	
Unnamed	NA	city	3.170	Stein Rd	12	40N	1E	Bellingham	unknown	blockage
Unnamed	NA	city	3.200	Stein Rd	12	40N	1E	Bellingham	unknown	Level B reqd
Unnamed	NA	city	1.840	W Badger Rd	8	40N	2E	Bellingham	unknown	Unassessed
Unnamed	Dakota Cr	city	2.285	W Badger Rd	9	40N	2E	Bellingham	unknown	Level B reqd
Unnamed	NA	city	0.220	Behme Rd	14	41N	1E	Bellingham	unknown	Unassessed
Unnamed	NA	city	0.695	Behme Rd	14	41N	1E	Bellingham	unknown	Unassessed
Unnamed	NA	city	5.680	Birch Bay Lynden Rd	24	40N	1E	Bellingham	unknown	Unassessed
Unnamed	NA	city	5.900	Birch Bay Lynden Rd	24	40N	1E	Bellingham	unknown	Unassessed
Unnamed	NA	city	6.310	Birch Bay Lynden Rd	19	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	city	6.450	Birch Bay Lynden Rd	19	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	city	7.260	Birch Bay Lynden Rd	20	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	city	8.010	Birch Bay Lynden Rd	21	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	city	8.050	Birch Bay Lynden Rd	21	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	city	8.200	Birch Bay Lynden Rd	21	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	city	8.290	Birch Bay Lynden Rd	21	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	city	1.015	Burk Rd	5	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	city	1.520	Burk Rd	5	40N	2E	Bellingham	unknown	Unassessed

Stream	Tributary to:	Owner-ship	Road Name/Milepost		Sec	Town	Ran	Data Source	Original Priority	Notes
Unnamed	NA	city	1.693	Burk Rd	5	40N	2E	Bellingham	unknown	Unassessed
Unnamed	NA	city	1.852	Burk Rd	5	40N	2E	Bellingham	unknown	Unassessed
Unnamed	Dakota Cr	city	2.270	Custer School Rd	23	40N	1E	Bellingham	unknown	Level B reqd
Unnamed	NA	city	0.223	Delta Line Rd	24	40N	1E	Bellingham	unknown	Unassessed
Unknown	NA	city	0.874	Delta Line Rd	24	40N	1E	Bellingham	unknown	blockage
Spring Branch Cr	Dakota Cr	city	2.091	Delta Line Rd	12	40N	1E	Bellingham	unknown	Level B reqd
Unnamed	NF Dakota	city	2.500	Delta Line Rd	12	40N	1E	Bellingham	unknown	Unassessed
Unnamed	NF Dakota	city	2.932	Delta Line Rd	12	40N	1E	Bellingham	unknown	Level B reqd
Unnamed	Dakota Cr	city	0.030	Giles Rd	10	40N	1E	Bellingham	unknown	Level B reqd
Unnamed	Dakota Cr	city	0.104	Giles Rd	10	40N	1E	Bellingham	unknown	Unassessed
Unnamed	NA	city	4.816	H St Rd	33	41N	2E	Bellingham	unknown	blockage
Unnamed	Dakota Cr	city	5.011	H St Rd	31	41N	2E	Bellingham	unknown	Unassessed
Unnamed	Dakota Cr	city	5.231	H St Rd	31	41N	2E	Bellingham	unknown	blockage
Unnamed	Dakota Cr	city	5.276	H St Rd	31	41N	2E	Bellingham	unknown	Unassessed
Unnamed	Dakota Cr	city	5.387	H St Rd	31	41N	2E	Bellingham	unknown	blockage
Haynie	Dakota Cr	city	7.380	H St Rd	35	41N	1E	Bellingham	unknown	Level B reqd
Unknown	Spooner	city	0.620	Harvey Rd	4	40N	1E	Bellingham	unknown	blockage
Spooner	Dakota Cr	city	0.074	Harvey Rd	4	40N	1E	Bellingham	unknown	Level B reqd
Unnamed	NA	city	0.003	Haynie Rd	9	40N	1E	Bellingham	unknown	Unassessed
Unnamed	NA	city	0.350	Haynie Rd	10	40N	1E	Bellingham	unknown	Unassessed
Unnamed	NA	city	0.554	Haynie Rd	10	40N	1E	Bellingham	unknown	Level B reqd
Unnamed	Dakota Cr	city	0.872	Haynie Rd	10	40N	1E	Bellingham	unknown	blockage
Unnamed	NA	city	0.956	Haynie Rd	10	40N	1E	Bellingham	unknown	Unassessed
Unnamed	NA	city	1.452	Haynie Rd	11	40N	1E	Bellingham	unknown	Unassessed
Unnamed	NA	city	1.677	Haynie Rd	11	40N	1E	Bellingham	unknown	Unassessed
Unnamed	NA	city	2.030	Haynie Rd	11	40N	1E	Bellingham	unknown	Unassessed

Stream	Tributary to:	Owner-ship	Road Name/Milepost		Sec	Town	Ran	Data Source	Original Priority	Notes
Unnamed	NA	city	2.494	Haynie Rd	12	40N	1E	Bellingham	unknown	Unassessed
Unnamed	NA	city	2.639	Haynie Rd	11	40N	1E	Bellingham	unknown	Unassessed
Unnamed	NA	city	2.639	Haynie Rd	12	40N	1E	Bellingham	unknown	Unassessed
Unknown	Dakota Cr	city	2.304	Haynie Rd	12	40N	1E	Bellingham	unknown	Level B reqd
Unnamed	Dakota Cr	city	0.146	Hoier Rd	9	40N	1E	Bellingham	unknown	Level B reqd
Unnamed	Dakota Cr	city	0.625	Hoier Rd	9	40N	1E	Bellingham	unknown	Unassessed
Unnamed	NA	city	2.602	Loomis Trail Rd	15	40N	1E	Bellingham	unknown	Unassessed
Unnamed	NA	city	2.794	Loomis Trail Rd	15	40N	1E	Bellingham	unknown	Unassessed
Unnamed	NA	city	3.409	Loomis Trail Rd	14	40N	1E	Bellingham	unknown	Unassessed
Unnamed	Dakota Cr	city	3.600	Loomis Trail Rd	14	40N	1E	Bellingham	unknown	blockage
Unnamed	McCormick Cr	city	0.328	Noon Rd	3	38N	3E	Bellingham	unknown	blockage
Unnamed	McCormick Cr	city	0.557	Noon Rd	3	38N	3E	Bellingham	unknown	Unassessed
McCormick Cr	Squalicum Cr	city	0.610	Noon Rd	3	38N	3E	Bellingham	unknown	Level B reqd
Unnamed	McCormick Cr	city	0.961	Noon Rd	3	38N	3E	Bellingham	unknown	Unassessed
Unnamed	McCormick Cr	city	1.744	Noon Rd	3	38N	3E	Bellingham	unknown	Unassessed
Unnamed	McCormick Cr	city	1.703	Noon Rd	3	38N	3E	Bellingham	unknown	Unassessed
Unnamed	McCormick Cr	city	1.979	Noon Rd	3	38N	3E	Bellingham	unknown	Unassessed
Unnamed	McCormick Cr	city	0.413	Mission Rd	6	38N	4E	Bellingham	unknown	blockage
Unnamed	McCormick Cr	city	0.737	Mission Rd	6	38N	4E	Bellingham	unknown	Level B reqd
Unnamed	McCormick Cr	city	0.837	Mission Rd	6	38N	4E	Bellingham	unknown	
Unnamed	McCormick Cr	city	1.050	Mission Rd	31	39N	4E	Bellingham	unknown	
Unnamed	McCormick Cr	city	1.182	Mission Rd	31	39N	4E	Bellingham	unknown	
Unnamed	McCormick Cr	city	1.380	Mission Rd	31	39N	4E	Bellingham	unknown	
Unnamed	McCormick Cr	city	1.400	Mission Rd	31	39N	4E	Bellingham	unknown	
Unnamed	McCormick Cr	city	5.516	Kelly Rd	36	39N	3E	Bellingham	unknown	Level B req'd
Unnamed	Squalicum Lk	city	2.739	Y Rd	18	38N	4E	Bellingham	unknown	blockage

Stream	Tributary to:	Owner-ship	Road Name/Milepost		Sec	Town	Ran	Data Source	Original Priority	Notes
Unnamed	Carpenter Cr	city	2.249	Y Rd	18	38N	4E	Bellingham	unknown	blockage
McCormick Cr	Squalicum Cr	county	Van Wyck Rd.(west of Noon Rd.)					NSEA	Unknown	
Toad Lk Cr	Squalicum Cr		542	2.4000	10	38N	03E	WCD	Unknown	
Squalicum Cr	Bellingham Bay		SR542	3.5000	10	38N	03E	WCD	Unknown	
Baker Cr	Squalicum Cr		5	256.2800	18	38N	03E	WCD	Unknown	
Little Squalicum	Bellingham Bay				23	38N	02E	WCD	Unknown	
Squalicum Cr	Bellingham Bay				23	38N	02E	WCD	Unknown	
Unnamed	Baker Cr		parking lot		18	38N	03E	WCD	Unknown	
Unnamed	Baker Cr		Telegraph Rd		18	38N	03E	WCD	Unknown	
L Squalicum Cr	Squalicum Cr		Guide Meridian		18	38N	03E	WCD	Unknown	
Toad Lk Cr	Squalicum Cr		Dewey Rd		9	38N	03E	WCD	Unknown	
Toad Lk Cr	Squalicum Cr		private driveway		15	38N	03E	WCD	Unknown	
Toad Lk Cr	Squalicum Cr		County Road Crossing		15	38N	03E	WCD	Unknown	
Toad Lk Cr	Bellingham Bay		Dupont St		30	38N	03E	WCD	Unknown	
Lake Whatcom Tribs	Lake Whatcom		not specified					DNR 97	Unknown	
Padden Cr	Bellingham Bay		Fairhaven Pkwy		12	37N	02E	WCD	Unknown	
Unnamed	Chuckanut Cr		11	18.6200	13	37N	02E	WCD	Unknown	
Chuckanut Cr	Bellingham Bay		11	18.0000	13	37N	02E	WCD	Unknown	
Saar Cr	Sumas R		Frost Rd.		8	40N	05E	WCD	Unknown	
Unnamed	Goodwin Ditch (Sumas)		private driveway		4	39N	04E	WCD	Unknown	
Dale Cr	Sumas R		Goodwin Rd		9	39N	04E	WCD	Unknown	
Unnamed	Saar Cr	city	7.842	South Pass Rd	17	40N	5E	Bellingham	unknown	blockage

Floodplain Conditions in the Nooksack Basin including the Lummi River

Floodplain Conditions in the Mainstem Nooksack River and Tributaries

Historically, the lower reaches of the mainstem Nooksack River flowed through a broad, gentle sloping valley; channel patterns were relatively straight from RM 5 to 11 and meandering from RM 5 to 24. Upstream of Everson, the valley narrowed and steepened and the channel pattern shifted to anastomosing (branching) channels with stable, forested (Fox and Greenberg 1994; Collins and Sheikh in prep.) (Figure 6a). Instream levels of large woody debris (LWD) were likely more numerous than current levels, as concentrated snagging operations occurred in the late 1880s to remove LWD (Collins and Sheikh in prep.). Wetlands were common, especially along the lower mainstem.

By 1910, the lower mainstem had been shortened through meander cutoffs while the upper mainstem had shifted to a braided pattern with increases in channel area (Collins and Sheikh in prep.). The increased gravel bar area (braiding) is suggested to be the result of cleared riparian forests, which might have led to increased bank erosion (sedimentation) and channel width (Collins and Sheikh in prep.). Dikes and levees have converted the nearly all of the mainstem Nooksack River to a single channel, resulting in a major loss of slough, side-channel, and off-channel habitat (Figure 6b). In addition to channel confinement, wetlands have been filled, compounding the loss. Overall, floodplain impacts are believed to be one of the greatest salmonid habitat problems downstream of the Forks. A reach-by-reach description of current bank conditions was provided by the Whatcom Dept. Public Works (1999), and is used to detail the impacts and develop the specific floodplain ratings.

Reach 1 of the mainstem Nooksack River extends from the mouth to RM 6.0 (Ferndale). Diking occurs along both sides of this reach, and the banks are heavily rip-rapped (Figure 6b) (Whatcom Dept. Public Works 1999). The largest wetland complex outside of estuarine wetlands is Tennant Lake, and estimated current wetlands comprise 33% of the area (Figure 7) (Cascades Environmental Systems, Inc. 1995 in Whatcom Dept. Public Works 1999). Hydric soils (soils formed during saturation or flooding with anaerobic upper layers, one of three conditions for wetland identification) cover 62% of this section, suggesting that changes in hydrology, such as draining, have greatly reduced wetland habitat from pre-disturbance times (Figure 8). Sections of lower Silver Creek, a tributary to this reach of the Nooksack River, have been ditched and straightened (Whatcom Dept. Public Works 1999). The Lummi River has levees along its banks and has experienced a considerable loss of estuarine wetland habitat, which is discussed in the Estuarine/Nearshore chapter.

Reach 2 is located from RM 6.0 to 15.3 (Guide Meridian). Historically, the channel displayed local lateral migration with small meanders (Collins and Sheikh in prep.). Currently, this section is described as a reach with looped meanders and small gravel bars (Whatcom County Dept. Public Works 1999).

Levees and riprap are common throughout this reach of the mainstem Nooksack River (Figure 6b). Some of the levees have been constructed, but others consist of sediment deposited from flood events, and although they are not human-built, they are at least partially the result of excess sedimentation from upstream human-caused sources (see Sediment Chapter). Sixty percent of the area has hydric soils, yet current wetlands comprise an estimated 16% of the area (Figures 7 and 8) (Cascades Environmental Systems, Inc. 1995 in Whatcom Dept. Public Works 1999). Drained hydric soils can be an indication of historic wetlands, as well as areas suitable for restoration (U.S. Geological Society 1998). Collins and Sheikh (in prep.) estimated that palustrine wetlands from RM 6 to 24 decreased from approximately 1,800 hectares to 100 hectares from the years 1880 to 1938.

Several of the tributaries to Reach 2 of the Nooksack River also have impacted floodplains. Tenmile, Fishtrap, and lower Bertrand Creeks have been straightened, re-routed, and dredged (Whatcom County Dept. Public Works 1999), and the tributaries to Fishtrap Creek are a series of parallel ditches (Whatcom Conservation District 1988). Levees exist along parts of Fishtrap and Bertrand Creeks (Figure 6b) (Whatcom County Dept. Public Works 1999a). A tributary that once drained into the South Fork Dakota Creek has been diverted into Bertrand Creek (Doug Huddle, WDFW, personal communication). The extent of overall floodplain impact appears to be considerable, although quantification was not found. Most of Fishtrap Creek is channelized and diked, and most of Tenmile Creek is channelized (Whatcom County Dept. Public Works 1999). In the Fishtrap and Bertrand watersheds, 118 acres of wetlands have been documented with the largest complex (80 acres) located near the center of the Fishtrap Creek drainage (Whatcom Conservation District 1988a).

Reach 3 of the Nooksack River extends from RM 15.3 to 23.6 (Everson), and has limited channel braiding, exposed gravel bars, and numerous levees (Figure 6b) (Whatcom County Dept. Public Works 1999). Three drainage ditches: Kamm Creek, Mormon Ditch, and Scott Ditch, provide fish habitat and are associated with wetlands, but also have floodplain impacts. Mormon Ditch is channelized, and Kamm Creek is channelized, bounded by levees, and impacted by drainage ditches through its wetlands. However, riprap is uncommon along Mormon and Scott Ditches (Whatcom County Dept. Public Works 1999).

The Nooksack River reaches 1-3 have similar extensive floodplain impacts such as levees, dikes, and riprap. In addition, side-channel habitat has been filled for agricultural purposes (Whatcom County Dept. Public Works 1999). Floodplain habitat is rated “poor” in these reaches of the mainstem Nooksack River, including lower Silver, Bertrand, Fishtrap, Tenmile, and Kamm Creeks, and Mormon and Scott Ditches. The Lummi River is also rated “poor” for floodplain conditions, due to channelization and the re-routing of the Nooksack River outlet from the Lummi River to Bellingham Bay. These floodplain impacts are believed to be one of the greatest salmonid habitat problems downstream of the Forks.

Reach 4 of the mainstem Nooksack River extends from RM 23.6 to the confluence with the South Fork Nooksack River. This reach is the only section of the mainstem Nooksack River that has some considerable natural floodplain habitat. Well-developed braiding spans throughout much of the reach, but historically, the channel was anastomosing with stable, forested islands; the braiding is likely the result of excess sedimentation (Collins and Sheikh in prep.). This reach has only short sections of levees near Everson and Deming. However, bank protection is common, and wetlands are limited to the active channel (Whatcom County Dept. Public Works 1999). Although floodplain conditions are better in this reach compared to reaches 1-3, the extensive bank protection and loss of wetland habitat results in a "poor" floodplain rating.

Another section of floodplain habitat has been defined between the Nooksack River at Everson and the Sumas River watershed (Whatcom County Dept. Public Works 1999). A low divide separates these two basins, but in high flow conditions, floodwaters from the Nooksack River flow over the divide and into Johnson Creek, a tributary to the Sumas River.

<u>Floodplain Conditions in the North Fork Nooksack Sub-Basin</u>

A comprehensive study of the North Fork Nooksack River floodplain is needed. Currently, impacts have been documented or are known in limited sites with little to no quantification. These impacts include the area near Maple Falls, which has been dredged, straightened, and bank-armored (Schuett-Hames and Schuett-Hames 1987) and along several sections of the North Fork Nooksack River that are bounded by the Mount Baker Highway. The highway lies close to the Nooksack River at many sites, preventing channel migration and side-channel/off-channel habitat development. It also reduces the quality of riparian habitat.

Floodplain impacts within the tributaries to the North Fork Nooksack River have also been noted, but quantification was not done. Dredging has occurred in Boulder, Cornell, and Glacier Creeks to protect Mount Baker Highway bridges (Schuett-Hames and Schuett-Hames 1987), and the lower reaches of the Glacier Creek floodplain have been logged and developed with roads and houses (Roger Nichols, U.S. Forest Service, personal communication). Also, channelization has occurred in Cascade and Excelsior Creeks (U.S. Forest Service 1995a). Off-channel habitat was rated in the Warnick Watershed Analysis, resulting in several "poor" rated areas such as lower Gallop, lower Whalen, lower Big Slide, West Slide, Aldrich, and parts of Cornell and Hedrick Creeks (DNR 1995). Only one sampled reach (one section of Big Slide Creek) rated "good" for off-channel habitat.

Intact known wetland habitat is located along the mainstem North Fork Nooksack River and along Wells, Thompson, Deadhorse, Gallop, Ruth, Swamp, and Cornell Creeks (U.S. Forest Service 1995a). To a lesser extent, wetlands can be found along Glacier Creek and the area between Hedrick, Cornell, and Gallop Creeks. These areas provide important fish habitat and ecosystem functions, and should be conserved.

Floodplain Conditions in the Middle Fork Nooksack Sub-Basin

Information regarding floodplain conditions in the Middle Fork Nooksack sub-basin is very sparse, and because of this, cannot be rated. Current known wetlands are mapped (Figure 7) and appear to be limited along the lower mainstem Middle Fork Nooksack River and Mosquito Lake Creek. Soils are predominantly not hydric in this sub-basin, suggesting that historically, wetland habitat was not abundant (Figure 8) (Map from Andrew Phay, Whatcom Conservation District, 2001).

Floodplain Conditions in the South Fork Nooksack Sub-Basin

Historically, the lower South Fork Nooksack River was a sinuous braided set of channels with numerous sloughs and abundant river-spanning logjams (Trillium Corporation 1996 draft). By 1938, much of the mainstem South Fork Nooksack River had been straightened, and many of the side-channels had been lost. The largest logjams had been cleared away, and approximately half of the swamps identified in the 1885 survey were gone. Since 1938, the South Fork Nooksack River has been straightened to an even greater extent, and dikes have been constructed along most of its length. An aerial survey in 1994 estimated that 60% of the length of the South Fork Nooksack River in the Acme WAU is diked, and river-spanning logjams no longer exist (Trillium Corporation 1996 draft). In addition, the channel length of the South Fork Nooksack River has decreased by an estimated 37%, likely due to a loss of secondary channels. Diking and riprap have also been documented along the banks of the South Fork Nooksack River near Hutchinson Creek (DNR 1998).

Historically, wetlands were abundant throughout the lower and middle South Fork Nooksack sub-basin. Black Slough was once an 80-acre swamp, but much of the wetland habitat has been filled or drained (Trillium Corporation 1996 draft). Slough habitat has been greatly reduced not only in Black Slough, but also throughout the lower South Fork Nooksack sub-basin. An estimated 86% of slough habitat length has been lost mostly due to filling with the purpose of increasing agricultural lands (Trillium Corporation 1996 draft). The loss of sloughs and wetlands not only is a direct impact on salmonids due to reduced rearing and over-wintering habitat, but may also decrease the water table. Many of the tributaries in the lower South Fork Nooksack sub-basin have dry reaches in the summer.

The loss of slough habitat results in a “poor” floodplain rating for Black Slough and the South Fork Nooksack River. The extensive diking along the South Fork Nooksack River also results in a “poor” floodplain rating. The floodplain impacts are major losses because this habitat probably served as the primary over-wintering refuge habitat for most of the salmonid production in the sub-basin including juveniles that would migrate downstream in high flow conditions (Trillium

Corporation 1996 draft). Also, these types of impacts result in serious disruptions to watershed processes such as decreased sediment storage, increased water velocity, and decreased water storage capacity. Opportunities to increase and restore floodplain habitat should be a high priority in the lower South Fork Nooksack drainage.

Wetland habitat is still a prominent feature in many of the tributaries to the South Fork Nooksack River, even though it is significantly reduced from historical quantities. This results in an increased importance of the remaining over-wintering habitat and the need for continued habitat protection. Black Slough and Toss Creek have been identified as having excellent over-wintering habitat (Trillium Corporation 1996 draft). Also in the Skookum Creek watershed, tributary wetland habitat provides excellent over-wintering habitat, but concerns exist regarding impacts from the county road (DNR 1994). The floodplain habitat in Skookum Creek was not rated due to insufficient information.

While numerous wetlands exist in upper Hutchinson Creek, off-channel habitat was rated "poor" in five out of seven sampled segments, "fair" in one segment, and "good" in only one segment (DNR 1998). For this reason, floodplain habitat in Hutchinson Creek is rated "poor". In addition to off-channel habitat impacts, channel incision is a problem in four out of 12 sampled segments in Hutchinson Creek (DNR 1998). Channel incision dissociates a stream from its floodplain, and is considered to be a floodplain impact. This contributes to its "poor" floodplain rating. The likely causes of channel incision are increased sedimentation from landslides and a loss of instream LWD.

Figure 6a (top). 1895 map of the mainstem Nooksack River by David B. Ogden. Figure 6b (bottom). Current map of the mainstem Nooksack River with levees highlighted in red (data from Whatcom Dept. Public Works 1999).

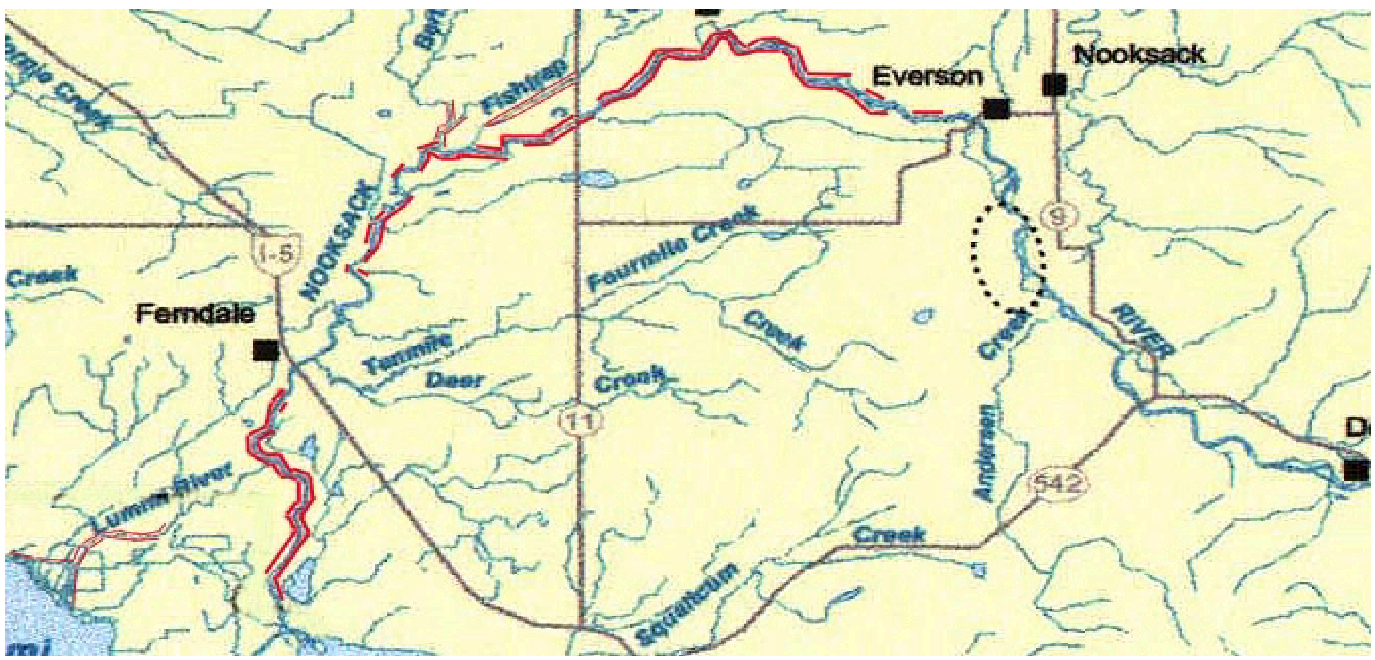


Figure 7. Known wetland habitat in WRIA 1. Wetlands are colored green (NWI Wetland data, mapped by Andrew Phay, Whatcom Conservation District March 2000).

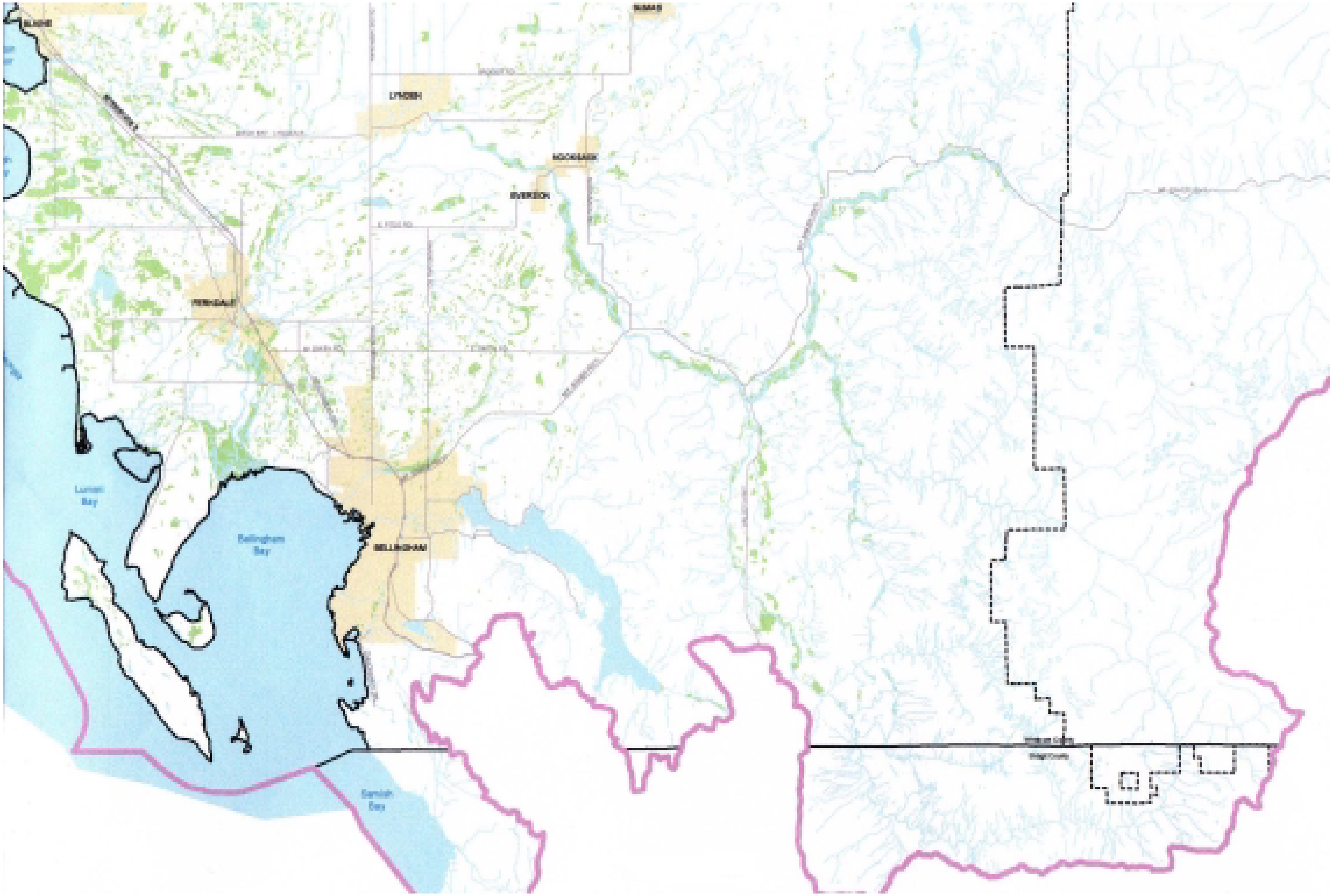
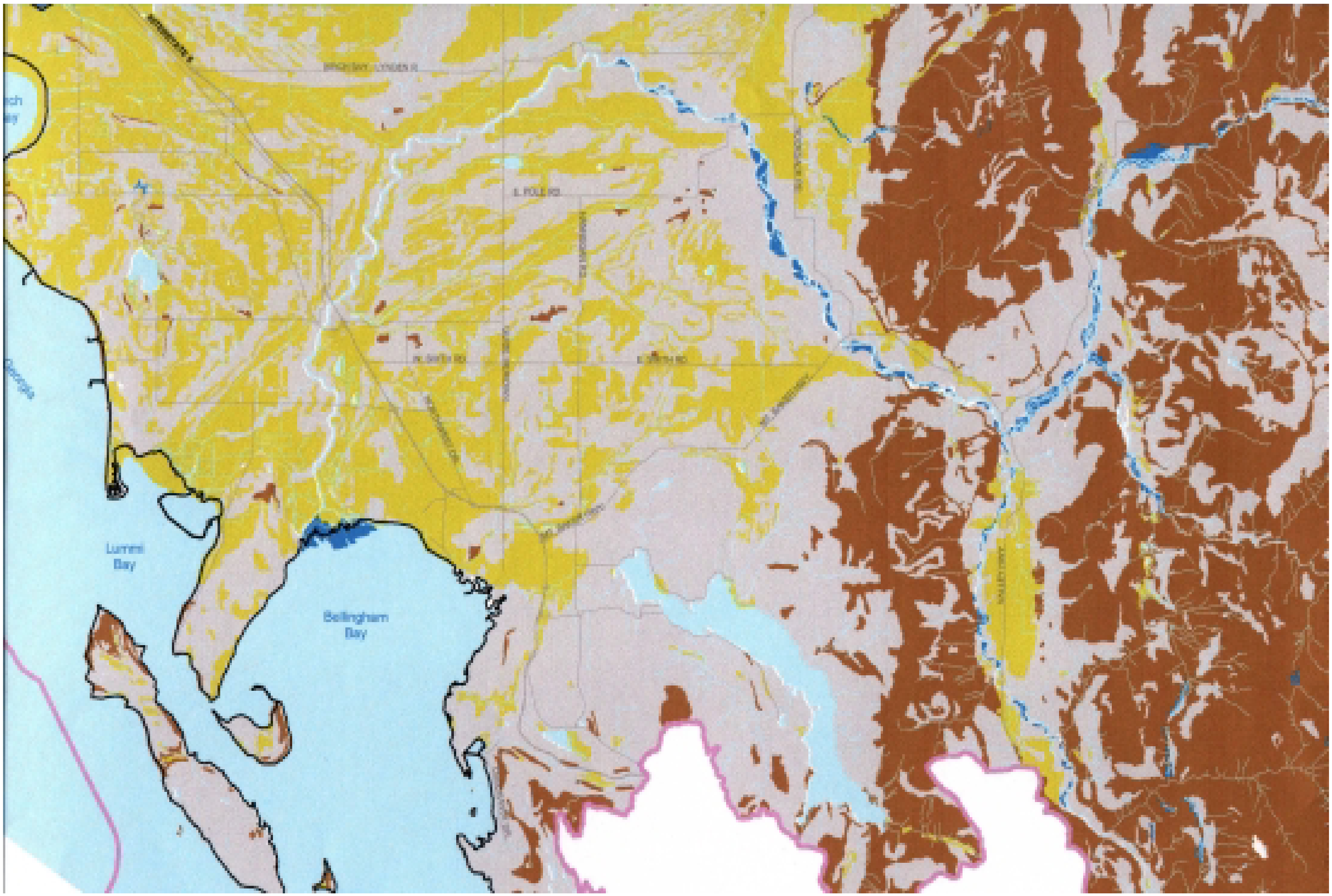


Figure 8. Hydric soils in WRIA 1. Fully hydric soils are blue. Partially hydric soils are gold. Unknown areas are grey, and not hydric soils are brown (data from NRCS, mapped by Andrew Phay, Whatcom Conservation District June 2001).



Streambed and Sediment Conditions In the Nooksack Basin and the Lummi River

Introduction

This section of the report summarizes and rates habitat conditions relating to sedimentation, including sediment quantity (landslides, road density, erosion, etc. caused by human impact), sediment quality (fine sediments and embeddedness as a result of human impacts), instream large woody debris (LWD) levels, pool habitat, and stream channel impacts, including channel stability. Impacts to the stream channel encompass a variety of problems such as channel incision, a widened, aggraded channel, and unstable streambed bottom material. An incised channel is a deeply cut channel that is disconnected from the surrounding floodplain (discussed in the Floodplain chapter). It has lost side-channel habitat and is lacking diverse habitat features. A widened, aggraded channel is characterized by an unstable, shallow channel with an elevated streambed that can cut laterally into adjacent slopes to trigger more sedimentation. Aggraded channels also flood more easily (reduced capacity), and are more likely to experience elevated water temperatures due to a lack of depth. Unstable streambed bottom material reduces salmonid incubation survival due to deposition and scour. Channel stability impacts are usually the result of excess sedimentation, a lack of LWD, a degraded riparian, an altered hydrologic regime, altered floodplain, or a combination of these conditions.

It is important to distinguish that these channel condition impacts differ from the natural stream channel changes that occur during high flow events. Channel changes that result from natural processes in an unaltered channel are not considered to be a habitat degradation in this report. Most of the stream channel stability information summarized in this report is older data from Schuett-Hames and Schuett-Hames (1984a), who used the Rickert et al. (1978) rating methodology. This scores 15 different factors using two different observers who visually rated each factor. The factors include mass wasting, vegetative bank protection, channel capacity, cutting, deposition, debris jam potential, landform slope, bank rock content, obstruction flow deflector sediment traps, rock angularity, brightness, packing, percent stable bottom material, and clinging aquatic vegetation (Schuett-Hames and Schuett-Hames 1984a). Because of the age of these data, the channel condition ratings are provisional. More recent data on channel conditions are greatly needed.

In addition to the Schuett-Hames reports, other types of streambed and sediment conditions have been analyzed. The recent inventories of landslides and roads in all three Forks of the Nooksack Basin provide comprehensive information regarding the sources and extent of sedimentation, enabling confident sediment quantity ratings except in the mainstem Nooksack River and tributaries (see

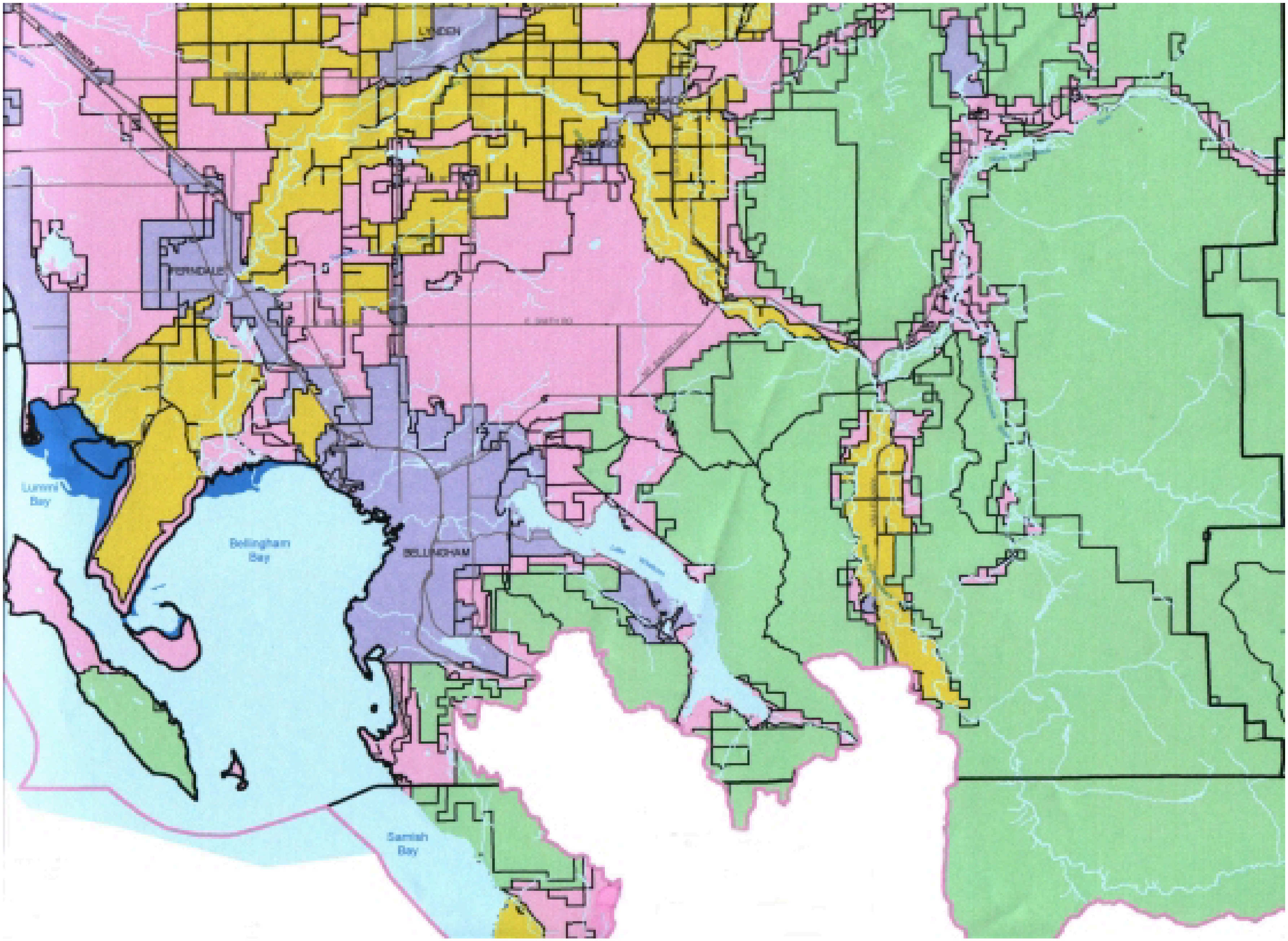
Watts 1996, 1997, 1998; Zander 1996, 1997, 1998). Additional landslide data are in other reports.

Two sources of road density data are used in this report. A detailed set of estimates was provided by Treva Coe (Nooksack Indian Tribe) combining road data from the Zander (1997) dataset with the GIS watershed delineations from the WRIA 1 Watershed Management Process. The watershed delineation map is in Appendix 2. The other road density estimates are directly from the Zander (1996, 1997, 1998) reports. In some instances the two estimates differed considerably, and in those cases, the results from both are presented. Most of the differences between the two estimates are likely due to different definitions of the watershed boundaries (basin size).

Sediment quality data are limited to either the Warnick Watershed Analysis (DNR 1995) or to older studies (Schuett-Hames and Schuett-Hames 1984a). The results of the 1980s work lead to a lower certainty for these ratings because of the age of the data. Even more scarce are data regarding instream levels of LWD and pool habitat, and these conditions are not rated for many of the streams.

Land use and landform play an important role in sediment and streambed conditions. The lowland valleys such as most of the mainstem Nooksack River and tributaries, the lower South Fork Nooksack River valley, and the lower North and Middle Fork River valleys, are surrounded by land used for agriculture, rural, or urban purposes (Figure 9) (Phay 2000). Because these land uses are generally associated with valleys, they have a lower risk of mass wasting compared to hillslopes used by forestry (Watts 1997). Landslides are the predominant source of sediment to streams in the Nooksack River Basin, and most of the landslides are a result of forestry activities on slopes, although many of the slides are due to past forest practices that have since improved (see specifics below for each sub-basin). However, even though most of the landslides are associated with timber harvest, the other land uses contribute to streambed impacts in other ways, such as altering bank erosion, removing LWD and riparian vegetation, and altering hydrology. These types of impacts relate to sedimentation, but many of them are discussed in other chapters.

Figure 9. Land use in the Nooksack Basin. Forestry is represented by green, agriculture by yellow, rural by pink, and urban as lavender (map by Andrew Phay, Whatcom Conservation District 2000).



Streambed and Sediment Conditions in the North Fork Nooksack River Basin

Basin Overview of Sedimentation Impacts

Sedimentation and streambed conditions have been analyzed in many of the major sub-basins within the North Fork Nooksack Basin. In general, landform stability in unmanaged areas within the North Fork Nooksack Basin is high relative to other unmanaged areas in the Pacific Northwest, indicating that when undisturbed, conditions are relatively stable (Peak Northwest, Inc. 1986). However, the terrain is very sensitive to disturbance because of the steep topography, glaciation, soil types, and high annual precipitation levels. Results from the Department of Natural Resources SHALSTAB model illustrate differences in proportion of highly unstable areas with higher percentages of instability located in the upper portions of the Forks (Figure 10) (map from Victor Johnson, Lummi Indian Nation). The moderate to high percentages of unstable slopes should be of great concern, particularly where road densities are high. These areas are discussed in greater detail below.

Timber harvest has been the dominant land use in the basin, and its level of disturbance varies, depending on land ownership and the amount of time since harvest. In areas intensively harvested within the last 30 years, there are serious impacts to stream channels and sedimentation processes. Routing of landslide-supplied sediment, leading to both lateral migration and channel bottom instability, ie. scour and deposition, are the greatest streambed/sedimentation problems in the basin, and forest practice activities (timber harvest and road building/maintenance) have accelerated the frequency and rate of all landslide types posing considerable impact to salmonid streams.

A recent inventory of landslides within the North Fork Nooksack Basin estimates 632 mass wasting sites from 1940 through 1995, and most of them (512) are shallow rapid (including debris flows) (Watts 1997). These types of slides along with small sporadic, deep-seated (slumps or rotational) landslides are more prone to deliver sediments to streams (Watts 1997). They are also the types of landslides that can be treated and for these reasons, are emphasized in this report. Seventy-four percent of shallow, rapid and small, deep-seated landslides delivered sediment to streams. The highest densities of these sediment-delivering landslides are located in the Cornell (11 events per square mile), Racehorse (11), Gallop (8), Boulder (6), Coal (5), Canyon (3), and Glacier (2) Creek Watersheds (Figure 11) (data from Watts 1997). Roads and clearcuts are associated with 36% and 28% of these types of landslides, respectively.

The number of landslides in the North Fork Nooksack Basin increased considerably in the mid-1960s with similar increases in the 1970s and 1980s, then increased to a greater extent in 1991. In general, most landslides occurred within 10 years of intense timber harvest in a given area (Watts 1997), and the landslide frequency correlates well to forest practice activity both temporally and spatially. However, significant climatic events also occurred during this time and were key triggers of both natural and management-related slope instability, sediment delivery to the channel network, and sediment transport.

Road density for the entire North Fork Nooksack basin is estimated at 3.1 miles of road per square mile of watershed, and this level is considered to be high (data from Zander 1997). A detailed road inventory was conducted for the basin, and resulted in prioritized areas for road improvement work, such as road abandonment, drainage, upgrades, and studies (Zander 1997). These areas are highlighted in Figure 12, and include Canyon, Boulder, Cornell, Gallop, Hedrick, upper Racehorse, Coal, and Bell Creeks, among others (map from Phay 2000; data from Zander 1996, 1997, 1998). Specific sediment and streambed conditions for individual sub-basins are discussed below, beginning with the upper North Fork Nooksack sub-basin and continuing downstream.

Figure 10. Slope stability in the Nooksack Basin (map from Victor Johnson, Lummi Indian Nation using DNR SHALSTAB model). The watersheds are numbered and names and data for each can be found in Appendix 2.

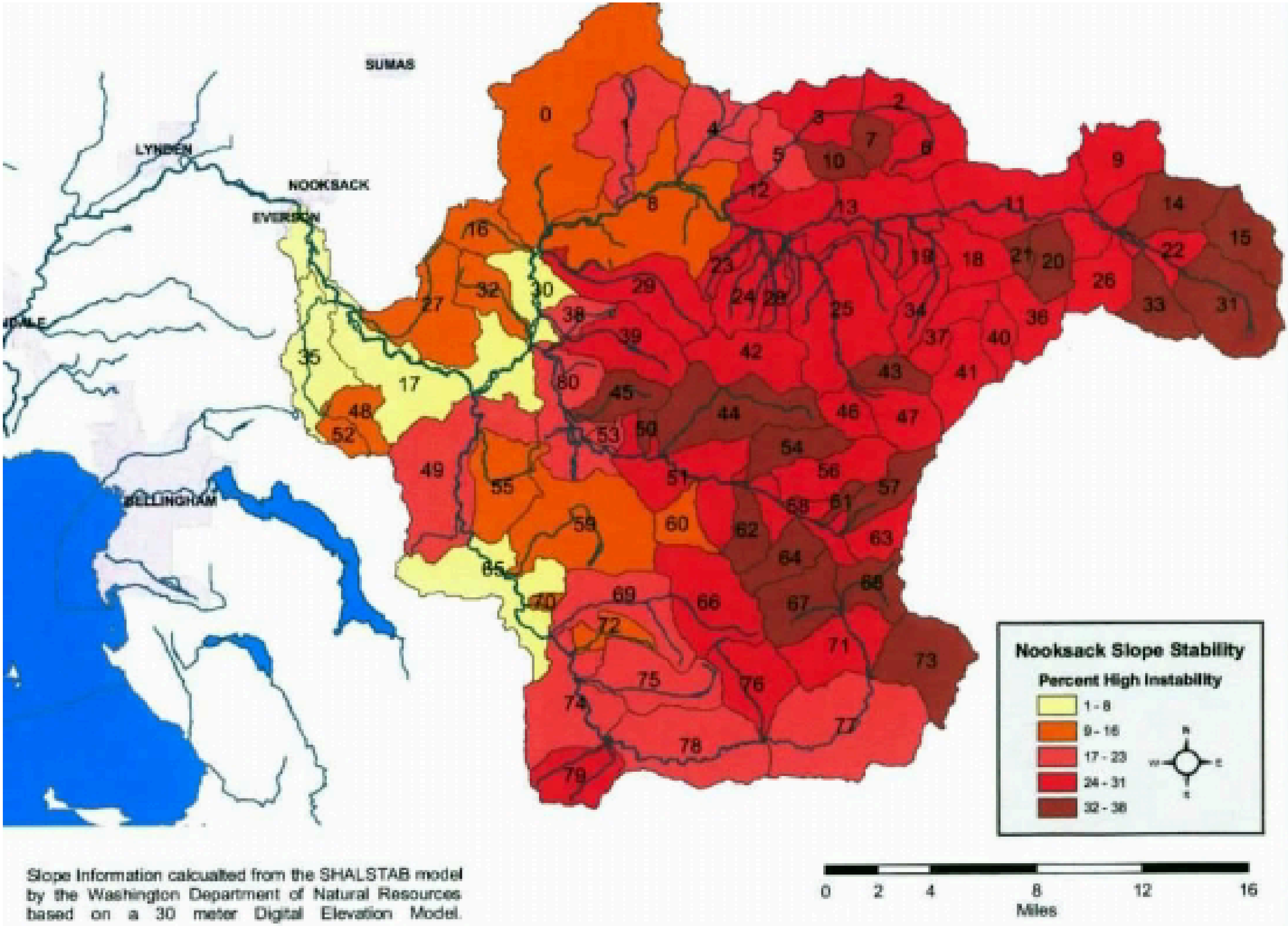


Figure 11. Landslide density (number of events per square mile) in the North Fork Nooksack Basin (data from Watts 1997).

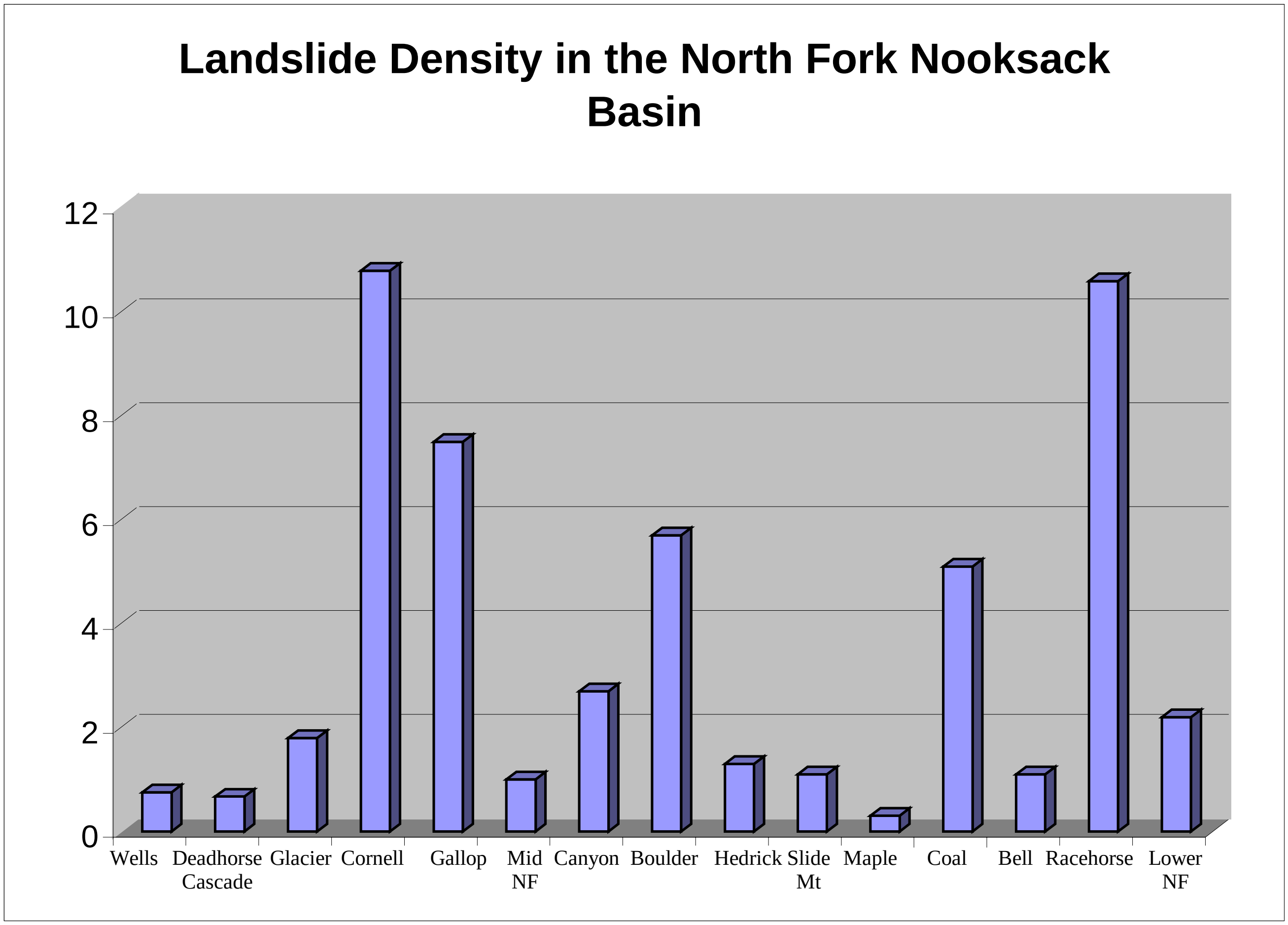
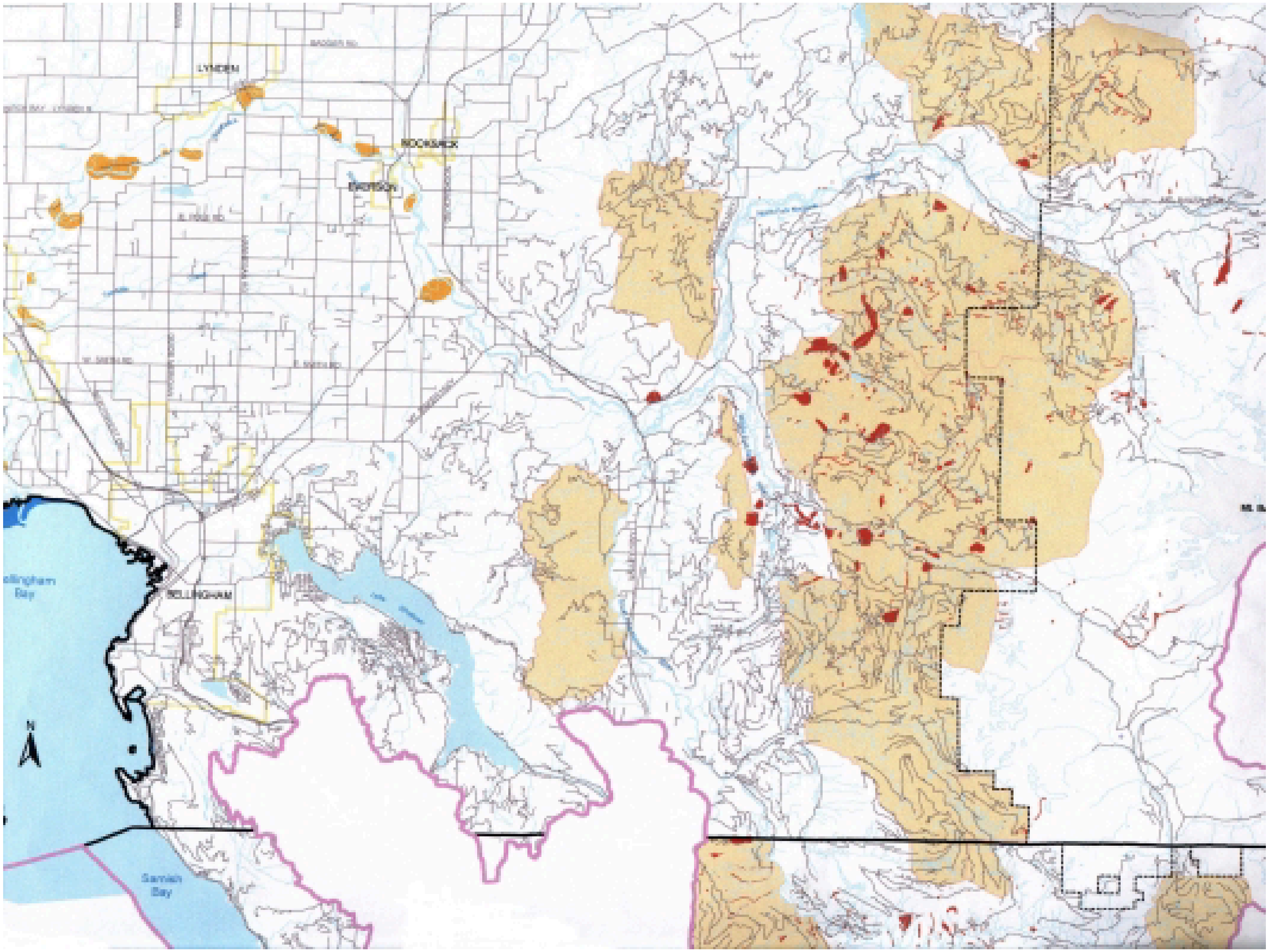


Figure 12. Areas of the Nooksack Basin at high risk of mass wasting due to roads. The light tan areas are road priority regions, where there is a high priority need for road improvements. The darker tan areas along the mainstem Nooksack River are lowland areas that have a high need for protection. The red areas are mass wasting priority areas (map from Andrew Phay, Whatcom Conservation District 2000, data from Zander 1996, 1997, 1998).

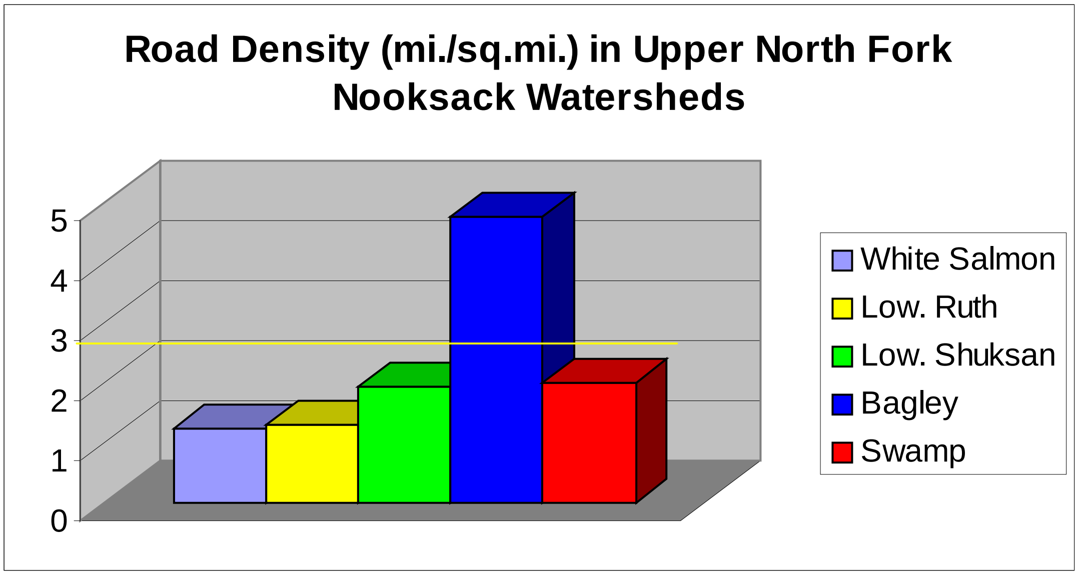


Streambed and Sediment Conditions in the Upper North Fork Nooksack Sub-Basin

The upper North Fork Nooksack sub-basin (Cornell Creek and all waters upstream of Cornell) has an annual sediment yield of approximately 600,200 tons, and most of the sediment is natural from glacially-derived bedload (U.S. Forest Service 1995a). The uppermost sub-basins (upstream of White Salmon Creek) are designated as “wilderness”, and are unmanaged with “good” streambed/sediment conditions. The White Salmon, Ruth, and Shuksan watersheds have very high (32 to 38%) percentages of natural slope instability (Figure 10), and their reaches are predominantly sediment source and transport type (Appendix 1). Further downstream, the Bagley Creek watershed has a high road density (“poor”) at 4.8 miles per square mile of watershed, and the Swamp Creek watershed has a “fair” road density at 2 miles per square mile of watershed (Figure 13). Road densities in other watersheds in this region are rated “good” (Figure 13) including the upper North Fork Nooksack River upstream of Wells Creek (Figure 14) (data from T. Coe, Nooksack Indian Nation using data from Zander 1997 and the WRIA 1 Watershed Management Process).

Natural flood events have triggered landslides or have re-distributed the large sediment deposits to cause channel changes such as widening in the upper mainstem North Fork Nooksack River (from White Salmon Creek to Swamp Creek) (U.S. Forest Service 1995a). The storm events and natural landslides can have positive effects on fish habitat by introducing LWD into streams, flushing coarse sediment, and developing side-channels.

Figure 13. Road density in the upper North Fork Nooksack watersheds (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). Densities above the yellow line are considered to be "poor".



Further downstream, habitat degradations begin to increase and continue to increase in a downstream direction. The reach of the North Fork Nooksack River from Nooksack Falls to Glacier Creek is a mix of steep gradient bedrock-confined canyons (transport reaches) and broader, low gradient areas (response reaches) with numerous side-channels (Schuett-Hames and Schuett-Hames 1987). The road density along the North Fork Nooksack River (from Wells Creek downstream to Canyon Creek) is rated "poor" at 4.8 miles of road per square mile of watershed (data from T. Coe, Nooksack Indian Nation using data from Zander 1997 and the WRIA 1 Watershed Management Process). In addition, the surrounding watersheds are areas with a high percentage (24 to 31%) of slope instability (Figure 10) (Victor Johnson, Lummi Indian Nation, using the DNR SHALSTAB model).

Logging activity in the last 15 to 20 years has resulted in an estimated additional 45,550 tons of sediment per year, which is a low amount relative to the estimated 546,000 tons of glacially-derived sediment per year (U.S. Forest Service 1995a). The primary human impacts in the area from Glacier Creek to Nooksack Falls include disturbed slopes, road drainage and fill failure, and to a lesser extent, mining activities. Road activities are believed to have increased landslide activity including the routing of debris flows and landslide dam-break floods in Cascade, Boyd, and Deadhorse Creeks, which are thought to have contributed to sediment pulses and localized aggradation in the mainstem North Fork Nooksack River (U.S. Forest Service 1995a). And although overall road density is "good" in Wells Creek (1.1 miles road per square mile watershed), lower Wells Creek has a much higher road density of 3.5 miles per square mile watershed; a “poor” rating (Figure 14) (data from T. Coe, Nooksack Indian Nation using data from Zander 1997 and the WRIA 1 Watershed Management Process).

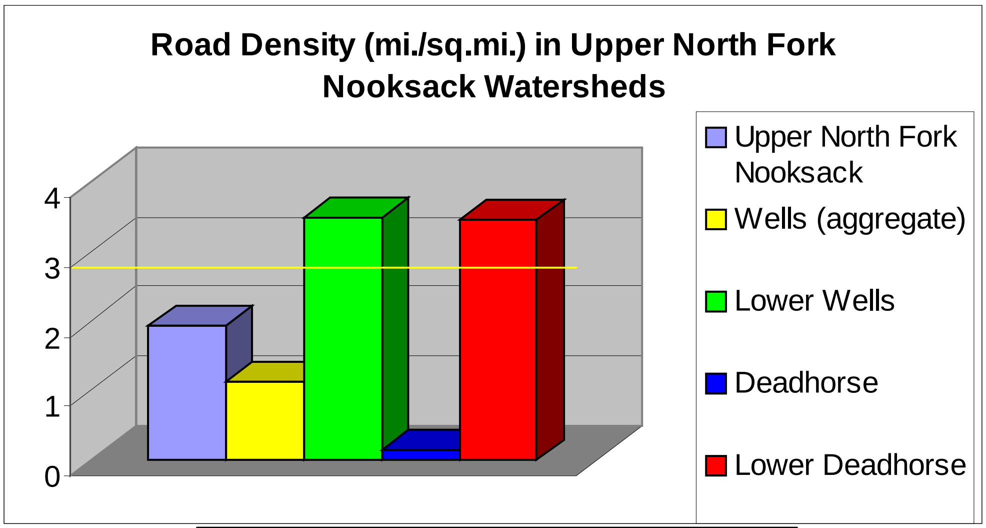
Also, lower Deadhorse Creek has a high road density of 3.5 miles per square mile watershed, but the remainder of the watershed is rated “good” for road density (Figure 14) (data from T. Coe, Nooksack Indian Nation using data from Zander 1997 and the WRIA 1 Watershed Management Process). However, landslide density (shallow rapid and small, persistent deep-seated events/square miles) is low in both the Wells Creek watershed (0.75) and in the combined watersheds of Cascade, Thompson, and Deadhorse Creeks (0.67), and no sediment delivering landslides were identified in the Cascade and Deadhorse Creek watersheds (Watts 1997). Also, Westbrook (1988) states that the predominate source of sediment into Wells Creek is from glacial processes with a note of numerous failures on the east side due to a 1951 forest fire that has failed to revegetate.

Most of the Mazama WAU is rated “good” for sedimentation because although impacts have occurred, they are low relative to other areas and to our habitat standards (see the Assessment Chapter for details on habitat standards). The exceptions are the “poor” ratings for road density in lower Wells and lower Deadhorse Creeks. Recent habitat improvement projects such as storm proofing and road abandonment have occurred in Deadhorse and Excelsior Creeks, and sedimentation processes in Boyd Creek appear to have recovered to “good” habitat conditions (Roger Nichols, U.S. Forest Service, personal communication). Of the 151.9 miles of roads on National Forest Service lands in Glacier Creek and the upper North Fork Nooksack River, 34.6 miles (23%) have been upgraded (U.S. Forest Service 1998).

In the early to mid-1980s, fine sediment levels were measured in many of these upper North Fork Nooksack tributaries. In Deadhorse Creek, the percent of fine sediment averaged 11.2% (“fair”), while Boyd Creek fine sediment levels were “good” (averages ranged from 4.5 to 8.1%) (data from Schuett-Hames and Schuett-Hames 1984a; Schuett-Hames et al. 1988a). Both of these measurements occurred in the lower reaches of these streams where fine sediment deposition would be expected to be higher than in upstream reaches. Stream stability was variable in Deadhorse and Boyd Creeks ranging from stable to unstable depending on the year sampled, and the largest causes of the moderately unstable ratings were deposition and scour. One reach of Boyd Creek was aggraded above the surrounding land elevation (Schuett-Hames and Schuett-Hames 1984a), but this sediment was subsequently transported during high flow events, and the bed has since lowered (John Thompson, Whatcom County, personal communication).

Salvage removal of instream LWD was a problem in lower Cascade Creek (U.S. Forest Service 1995a), but specific data regarding instream LWD levels were not found for the upper North Fork Nooksack River, Deadhorse Creek, Boyd Creek, and Cascade Creek. Pool data were also lacking. These habitat conditions are not rated, due to the lack of data. Updated surveys are needed for each of these streams.

Figure 14. Road density in the upper North Fork Nooksack watersheds (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). Density values above the yellow line are considered to be "poor".



Streambed and Sediment Conditions in the Glacier Creek Sub-Basin

Glacier Creek is a major sediment producer in the North Fork Nooksack Basin, containing 10% of the most common sediment-delivering landslides in the entire North Fork Basin (Watts 1997). An estimated 76% of its reaches are sediment source reaches (data from Mike Maudlin, Lummi Indian Nation using the DNR SHALSTAB model). In the Glacier Creek mainstem, Cary Van Siclen (1994), citing Hosey and Associates, indicates that glacially-derived sediment is by far the largest source of coarse and fine sediment. These natural sources of sediment and the effects that climatic trends may have on basin sediment yield are factors that must be considered when evaluating the relative streambed and habitat conditions in Glacier Creek. Also, numerous projects to storm-proof or abandon roads have occurred in the Glacier Creek WAU (Nooksack Recovery Team 2001), and these are expected to contribute to improved future conditions. Tributary watersheds draining into the west side of Glacier Creek are among the prioritized areas for future roadwork (Figure 12) (data from Zander 1997).

Specific conditions within the Glacier Creek watershed are variable. The overall landslide density is moderate at 1.8 events/square mile with shallow, rapid events comprising 75% of the landslides (Figure 11) (data from Watts 1997).

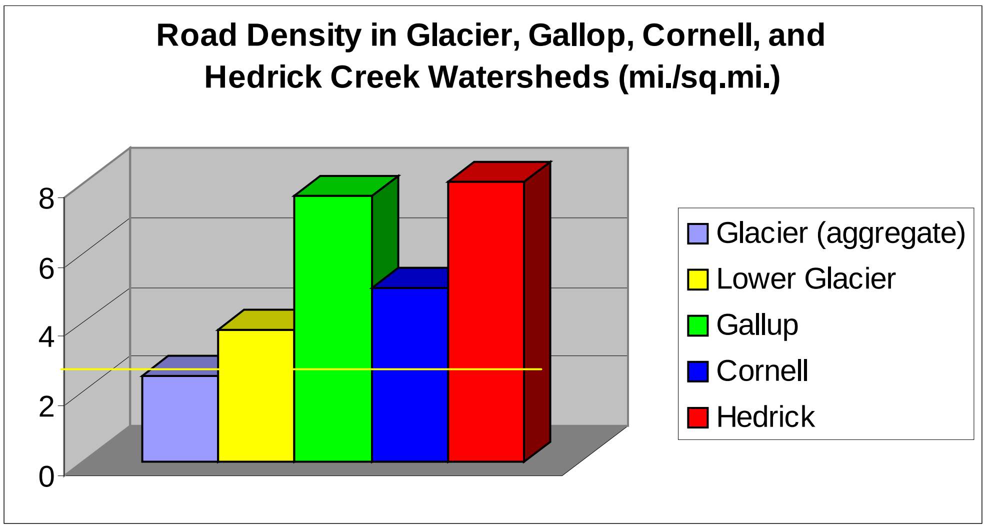
Both roads and clearcuts are associated with many of the identified shallow, rapid and small, persistent deep-seated landslides, accounting for 30% and 36% of those types of landslides, respectively (Watts 1997). Many of those slides contribute sediment to the tributaries, likely posing an impact to native char habitat (Roger Nichols, U.S. Forest Service, personal communication). The sediment quantity ratings in the Glacier Creek watershed are 'fair" for the tributaries to Glacier Creek and "good" for the mainstem Glacier Creek, based upon the moderate landslide density and large number of sediment-delivering landslides, mostly located in the tributaries. Road density is "good" in the uppermost reaches of the Glacier Creek watershed with a higher ("poor") road density of 3.8 in the region below Smith Creek (Figure 15) (data from T. Coe, Nooksack Indian Nation using data from Zander 1997 and the WRIA 1 Watershed Management Process).

Increased channel instability was observed in the middle and lower reaches of Glacier Creek due to floods, sedimentation, and a lack of LWD. This has thought to result in possible aggradation and channel widening (U.S. Forest Service 1995a). In the lower reaches, the floodplain has been logged and developed with roads and houses (Roger Nichols, U.S. Forest Service, personal communication). The floodplain disturbance and lack of LWD has likely contributed to unstable conditions in the alluvial fan area, resulting in a provisional "poor" rating for channel stability in the lower reaches. The reaches upstream of the alluvial fan are believed to be "fair", but more specific analysis of channel stability is needed throughout the Glacier Creek watershed.

Quantitative information regarding pool habitat was not found for Glacier Creek, but pool habitat is believed to be impacted by fill from excess sediment (U.S. Forest Service 1995a). Another possible cause might be a lack of local scour or low levels of LWD. Instream LWD levels are less than 10 pieces per mile and are rated "poor" in Glacier Creek (data from U.S. Forest Service 1995a). Recruitment potential for LWD is also "poor" due to the condition of the riparian vegetation and the broad terraces separating the riparian from the stream channel (U.S. Forest Service 1995a). High flows and steep gradients result in a quick transport of LWD. Updated habitat data are greatly needed in this WAU.

Thompson Creek, a tributary to Glacier Creek, provides important spawning habitat for pink salmon, chinook salmon, and char (Roger Nichols, U.S. Forest Service, personal communication), and should be a high priority for protective actions. It is fed by groundwater with a few terrace tributaries, such as Beaver Creek (John Thompson, Whatcom County, personal communication). Fine sediment levels were "good" (5.5 to 10.9%), and channel stability was rated stable ("good") over five years in the 1980s (data from Schuett-Hames et al. 1988a). Removal of LWD was a problem in lower Thompson Creek (U.S. Forest Service 1995a), although recent LWD placement projects in the lower to middle reaches of Thompson Creek have increased the quantity of wood (Roger Nichols, U.S. Forest Service, personal communication).

Figure 15. Road density in North Fork Nooksack watersheds (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). Densities above the yellow line are considered to be "poor".



Streambed and Sediment Conditions in the Gallop Creek Sub-Basin

Sediment quantity and channel stability are rated "poor" in Gallop Creek. The Gallop Creek watershed has a very high landslide density at 7.5 events per square mile, and contains 5% of the Nooksack Basin's landslides that deliver sediment to streams with 67% shallow, rapid and 29% small, deep-seated slides (Figure 11) (Watts 1997). Roads are associated with 35% of the sediment delivering landslides (Watts 1997), and the Gallop Creek watershed has a very high road density of 7.6 miles of road per square mile of watershed (Figure 15) (data from T. Coe, Nooksack Indian Nation using data from Zander 1997 and the WRIA 1 Watershed Management Process) or 5.3 miles per square mile watershed in Zander (1997). This excessive road density is in a sub-basin that has an elevated percentage (24 to 31%) of high slope instability (Figure 10) (Victor Johnson, Lummi Indian Nation, using the DNR SHALSTAB model). The mid to upper reaches of the watershed are a prioritized area for future road improvements (Figure 11) (Zander 1997). No landslides were associated with clearcuts in Watts (1997).

The Gallop Creek watershed is rated "poor" for channel or streambed stability. In the 1980s, half of the Gallop Creek sampled reaches rated stable and half rated moderately unstable (Schuett-Hames et al. 1988a). In the 1990s, scour and deposition potential was rated "poor" for Gallop Creek based upon survey observations of channel, bank, and LWD conditions. Also noted in the 1990s, Gallop Creek widened from aggradation (DNR 1995). The timing and magnitude of widening corresponds the timing of landslides and timber harvest in the upper watersheds, developing sediment waves that are being transported downstream (DNR 1995). Channel changes have been evident in Gallop Creek, and the aggradation has reduced flood capacity. It is estimated that 94% of overbank flooding in Gallop Creeks is due to sediment impacts (loss of capacity) compared to 6% due to loss of land cover vegetation (DNR 1995) (see Water Quantity section for land cover conditions). The unstable channel conditions have also impacted riparian vegetation (DNR 1995).

Fine sediment levels (sediment quality) were “fair” (14.9%) in the streambed of Gallop Creek with high levels (22.6%) of fines in the aggraded terraces (“poor”) (data from DNR 1995). Gallop Creek has only “fair” to “poor” quantities of spawning habitat with “poor” levels of instream LWD (data from U.S. Forest Service 1995a). Salvage removal of LWD in the lower reaches has contributed to the problem. Both pool frequency and percent pool habitat is rated “fair” to “poor” in Gallop Creek (data from DNR 1995).

Streambed and Sediment Conditions in the Cornell Creek Sub-Basin

The Cornell Creek watershed contains 12% of the Nooksack Basin’s landslides that deliver sediment to streams, and has a very high landslide density of 10.8 events (shallow rapid and small, persistent deep-seated landslides) per square mile (Figure 11) (data from Watts 1997). Most (91%) of the landslides in this sub-basin are shallow, rapid slides (Watts 1997). However, from a sediment volume perspective, most (62%) of the sediment delivered to streams within the Cornell Creek watershed comes from translational/rotational landslides, which account for only 6% of the total landslides. Debris slides and flows (shallow, rapid) comprised 85% of the number of landslides in the 1980s and 21% of delivered sediment (Peak Northwest, Inc. 1986).

Even though most of the excess sediment comes from translational/rotational landslides, debris flows and dam-break floods have altered stream morphology by transporting large volumes of sediment to response reaches and creating a more heavily armored streambed than would result from normal fluvial processes alone. Accelerated bank erosion/sloughing from the toes of the large translational/rotational slides (Peak Northwest, Inc. 1986) and inner gorge areas has resulted in channel widening as waves of upstream-derived sediment are transported to the response reaches and as the stream migrates laterally into less resistant stream bank deposits preferentially over the coarse bed armor. An estimated 71% of the stream reaches are source type with 25% transport reaches (Appendix 1) (data from Mike Maudlin, Lummi Indian Nation, 2002).

Nearly half of the Cornell Creek watershed was logged by 1955 with very little timber harvest since, but past timber harvest and associated roads have greatly increased the extent of landslides (Peak Northwest, Inc. 1986). The failure rate in unmanaged areas of Cornell Creek ranges from 0 to 3.6, while the rate in harvested areas ranged from 7.6 to 208 landslides/(acre X year) X 10,000 from 1979-1983 (Peak Northwest, Inc. 1986). Roads have increased the failure rate as well, resulting in a range from 0 to 66.7 events/(acre X year) X 10,000. The highest rate of landslides for both roads and timber harvest impacts is in the most recent year class analyzed (1979-1983).

Although timber harvest in Cornell Creek was greatly reduced after 1955, landslides still increased. Road fills, stream crossings, and inadequate road drainage systems are major problems that initiated some of these landslides (Watts 1997). In a recent analysis, roads were associated with 32% and clearcuts were related to 38% of the sediment delivering landslides (Watts 1997). Road density levels are high at 5.0 miles of road per square mile of watershed (Figure 15) (data from T. Coe, Nooksack Indian Nation using data from Zander 1997 and the WRIA 1 Watershed Management Process) or 3.2 miles per square mile in Zander (1997). The mid to upper reaches are in a high priority area for future road improvements (Figure 12) (Zander 1997).

Inner gorge landslide failures are also a concern, and reflect the origin of these landforms through stream incision and repeated slope failure. Land management actions that reduce rooting strength of the native vegetation (e.g. timber harvest) or that alter the slope hydrology (e.g. road drainage concentration) need to be designed to prevent management related inner gorge landslide failures. Road abandonment actions were taken as recommended in the Warnick Watershed Analysis to reduce the landslide potential from several road systems in upper Cornell. Overall, sediment quantity is rated "poor" for the Cornell Creek watershed, due to a very high landslide density, a high road density, and a large quantity of sediment-delivering landslides.

In the early 1980s, West Cornell Creek was rated unstable, while eight out of eleven segments in Cornell Creek were rated as unstable (Schuett-Hames et al. 1988a). In addition, 80% or more of the channel bottom (substrate) of Cornell Creek shifted at high flows, with numerous channel shifts after deposits from debris torrents (Schuett-Hames and Schuett-Hames 1984a). Only one segment in the Cornell watershed was rated as stable. In the 1980s, the aggradation in Cornell Creek resulted in a higher stream elevation compared to the surrounding land, and a reach in lower Cornell Creek would dry up due to sediment deposits (Schuett-Hames and Schuett-Hames 1984a).

In the 1990s, scour and deposition potential was rated "poor" to "fair" for Cornell Creek based upon survey observations of channel, bank, and LWD conditions. Also noted in the 1990s, upper West Cornell Creek widened from the deposit of debris flow sediments along with aggradation in Cornell Creek (DNR 1995). The timing and magnitude of widening corresponds with the timing of landslides and timber harvest in the upper watersheds, developing sediment waves that are being transported downstream (DNR 1995). Channel changes have been evident, and the aggradation has reduced flood capacity. It was estimated that 94% of overbank flooding in Cornell Creek is due to sediment impacts (loss of capacity) compared to 6% due to loss of land cover vegetation (DNR 1995) (see Water Quantity section for land cover conditions). The unstable channel conditions have also impacted riparian vegetation (DNR 1995).

Sediment quality is rated "good" in Cornell Creek. Fine sediment levels were in the "good" range (9.9%) in the streambed, although fines in the aggraded terraces were in the "poor" range (21.6%) (data from DNR 1995). Cornell Creek was rated "good" for spawning habitat type and frequency in the Warnick Watershed Analysis (DNR 1995). Levels of instream LWD were noted as low ("poor") with salvage removal of LWD in the lower reaches contributing to the problem (data from U.S. Forest Service 1995a). While percent pool habitat is "fair" in Cornell Creek, pool frequency is "fair" to "poor" (data from DNR 1995).

Streambed and Sediment Conditions in the Middle Reaches of the North Fork Nooksack River

The middle reaches of the North Fork Nooksack River from Glacier to Canyon Creeks provide important habitat for chinook salmon, and this importance may have increased due to impacts in the nearby tributaries (Roger Nichols, U.S. Forest Service, personal communication). The landslide density in this area is one event per square mile with 9% of the entire Nooksack Basin's sediment delivering landslides located near and in unnamed tributary watersheds along the mainstem (Watts 1997). Most (72%) of the landslides are shallow, rapid slides. Of the landslides near the mainstem North Fork Nooksack River, 45% were associated with roads and 19% were observed from clearcuts (Watts 1997). In addition, road density is high at 3.8 miles of road per square mile of watershed (Zander 1997). However, these data include the smaller tributaries near the mainstem. Without specific sediment data for the mainstem North Fork Nooksack River, sediment conditions cannot be rated.

Further downstream, the gradient of the North Fork Nooksack River lessens, and braided channels typical of glacial systems provide ample spawning gravel. Sedimentation processes in this reach of the North Fork Nooksack River have been impacted by contributions from tributaries, especially from Canyon, Boulder, Racehorse and Coal Creeks, but without quantification, the impacts within the mainstem cannot be rated. However, it should be noted that nearby tributaries to this reach generally rate "poor" for sediment quantity. In addition, fine sediment averaged 14% in the North Fork Nooksack River (Schuett-Hames and Schuett-Hames 1984a), resulting in a "fair" rating for sediment quality, although more recent data are needed. No data on levels of LWD and pool habitat were found.

Future conditions will likely improve due to changes in land management. The Northwest Forest Plan (U.S. Forest Service and USDI Bureau of Land Management 1994) assigned 40,886 acres of Late Successional Reserve within the North Fork Nooksack River upstream of Cornell Creek (U.S. Forest Service 1998). Combined with 41,545 acres of Mt. Baker Wilderness, this results in 89% of the watershed above Canyon Creek in land allocations that allow little land disturbing activities (U.S. Forest Service 1998). The Plan also established the Aquatic Conservation Strategy, which develops objectives for managing lands to protect the aquatic resources including Riparian Reserves along all streams, lakes and wetlands (U.S. Forest Service 1998).

Streambed and Sediment Conditions in the Canyon Creek Sub-Basin

The percentage of high slope instability varies from 17 to 38% (moderate to high) in the Canyon Creek sub-basin with the highest percentages of instability in the Kidney and Whistler watersheds (Figure 10) (Victor Johnson, Lummi Indian Nation using the DNR SHALSTAB model). The landslide density in Canyon Creek was estimated at 2.7 shallow rapid and small, persistent deep-seated events/square mile (Figure 11), with most (81%) categorized as shallow, rapid slides (Watts 1997). Of slides delivering sediment to streams, 11% of the Nooksack basin's total are located in the Canyon Creek watershed (Watts 1997). The moderate landslide density results in a "fair" rating for sediment quantity.

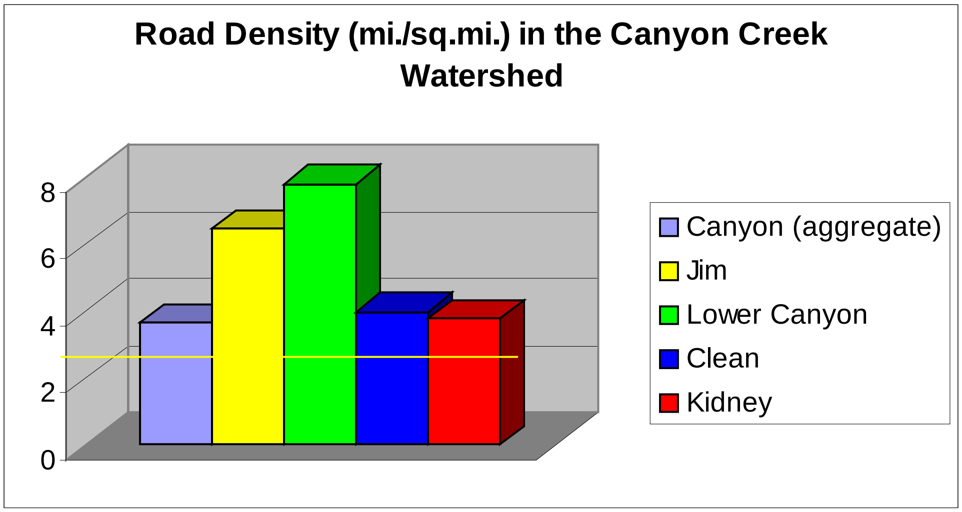
There have been numerous clear-cut and road-induced landslides in the western half of the Canyon Creek watershed (Peak Northwest, Inc. 1986), and these have contributed high levels of sediment to streams compared to lower levels from surface erosion (U.S. Forest Service 1995b). Of 111 total landslides in the Canyon Creek sub-basin, 85 were debris slides or debris flows, and these have been estimated to deliver 80% of the sediment to streams. Earth flows were estimated to deliver 19% of sediment to streams. The failure rate in unmanaged areas ranged from 0 to 1.6 landslides/(acre X year), while the range for timber harvested areas was 4.1 to 74.3. The greatest landslide problem was road fill, with a failure rate for roads as high as 700 landslides/(acre X year). Most of the previously failed roads were mid-slope roads built in the 1950s and 1960s. Road density levels have been high throughout the Canyon Creek sub-basin, especially in lower Canyon Creek and Jim Creek (Figure 16). Extensive storm proofing and decommissioning have recently occurred, which has greatly reduced sediment inputs in the Canyon Creek watershed. Harr and Nichols (1993) demonstrated that after treating all of the roads in the mid-Canyon Creek sub-basin, only one landslide occurred after 50-year recurrence interval storms in 1989 and 1990. Prior to road treatments, two to five-year interval storms resulted in 17 road-related landslides.

One major landslide exists in the Jim Creek watershed, a tributary to Canyon Creek. This slide encompasses 67 million cubic yards and is dormant, but a secondary, shallow slide has developed within the dormant slide. The secondary slide is a major sediment contributor to the lower mainstem Canyon Creek (U.S. Forest Service 1995b). Sediment from this slide has increased from 9100 cubic yards from 1940 to 1983 to 84,300 cubic yards during 1983 to 1991. The slide has also increased its rate of movement from 0.004 ft/year during 1956 to 1972 to 3.6 ft/year during 1985 to 1991 (Ballerini 1993).

The excess sedimentation from landslides has resulted in channel changes within Canyon Creek. In the 1980s, six out of ten stream reaches were rated as unstable and three additional reaches were rated moderately unstable (Schuett-Hames et al. 1988a). Channel stability decreased from 1989 to 1992 (U.S. Forest Service 1995b) and the mainstem Canyon Creek has shown an increased gradient and channel incision (Ballerini 1993). The lower mainstem of Canyon Creek is variable. It widened from 1940 to 1956 and remained stable until 1991, when it widened considerably (4.5 fold) (U.S. Forest Service 1995b). Channel widths also increased in Canyon Creek near Jim Creek and Whistler Creek, which doubled in width by 1991, but the areas near Kidney Creek and the Forest Service Road 31 upper bridge remained stable. These channel conditions result in a "poor" rating for channel stability in lower Canyon Creek. However, it is noted that the improved road conditions should ultimately improve streambed and channel conditions in the future, and updated habitat survey data are greatly needed.

Coincident with the sedimentation and channel changes in Canyon Creek is a reduction in habitat diversity. From 1989 to 1992, the percent of riffles increased from 43 to 87%, while glides decreased from 37 to 0% and pools decreased from 18 to 12% (U.S. Forest Service 1995b). All sampled areas within Canyon Creek rated "poor" for percent pool habitat (all values were less than 30%). Instream levels of LWD have decreased from 53 pieces/mi. in 1989 to 23 pieces in 1990 and 20 pieces/mi. in 1992. Target levels are 80 pieces/mi. (U.S. Forest Service and U.S. Bureau of Land Management 1994). This results in a "poor" rating for LWD in Canyon Creek. In addition, side-channel habitat has been nearly non-existent since 1989. Fine sediment levels were measured in the 1980s and ranged from 5.6 to 10.4%, which would result in a "good" rating for sediment quality (data from Schuett-Hames et al. 1988a). However, more recent measurements are needed.

Figure 16. Road density in the Canyon Creek (NF Nooksack) watersheds (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). Densities above the yellow line are considered to be "poor".

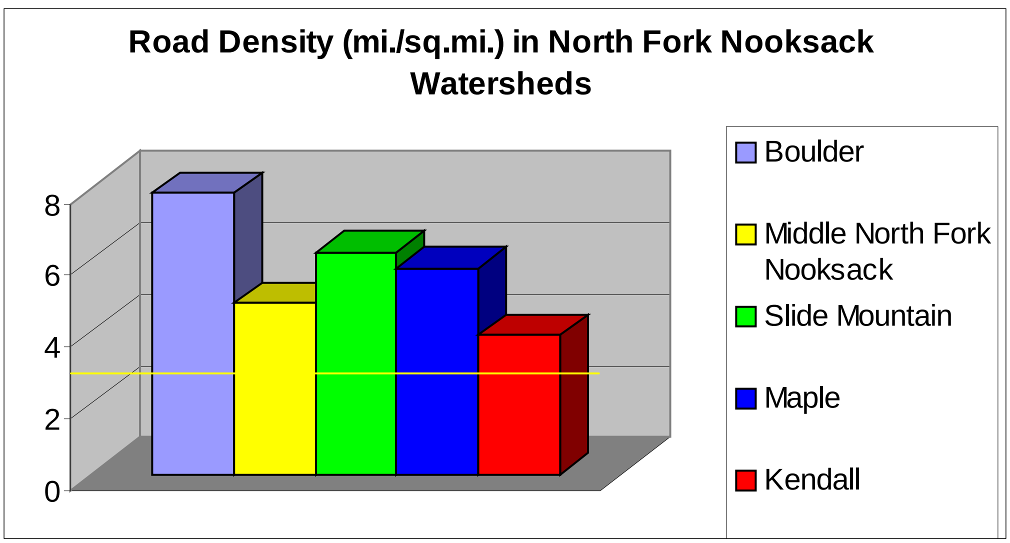


Streambed and Sediment Conditions in the Boulder Creek Sub-Basin

The Boulder Creek watershed contributes a major source of sediment to the basin, containing 13% of the Nooksack Basin's landslides that deliver sediment to streams (Watts 1997). The majority (59%) of the stream reaches are source type with 40% classified as transport reaches (Appendix 1). Even though Boulder Creek has a moderate percentage of slope instability (Figure 10) (data from Victor Johnson, Lummi Indian Nation), it has a high landslide density at 5.7 events per square mile. Most of the slides (89%) are shallow, rapid slides (Figure 11) (Watts 1997) with most (58%) of the stream-delivered sediment from sites of stream bank instability, specifically, the toes of older debris flows (Peak Northwest, Inc. 1986). The failure rate (number of landslides/acre X year) X 10,000 ranged from 0 to 6.8 in unmanaged areas, and increased to a range of 3.5 to 66.7 in timber-harvested areas. The failure rate from roads ranged from 0 to 7.4 (Peak Northwest, Inc. 1986). The highest rates are in the most recent year class (1979-1983). In a more recent analysis, 39% of the sediment delivering landslides was associated with roads while 13% was related to clearcuts (Watts 1997). Boulder Creek has one of the highest road densities in the North Fork Nooksack Basin at 7.9 miles of roads per square mile of watershed (Figure 17) (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). These data result in a "poor" rating for sediment quantity.

Timber harvest has greatly increased landslides in the Boulder Creek watershed. The increased sedimentation has resulted in aggradation, widening, and channel shifts (Peak Northwest, Inc. 1986), resulting in a "poor" rating for stability. In addition, Schuett-Hames and Schuett-Hames (1984a) reported that 80% or more of the channel bottom (substrate) shifts during high flow events, although those observations occurred near the alluvial fan area, which is expected to be unstable. Fine sediment levels were "fair" (11.9 to 12.6%) in the early 1980s, but the debris flows resulted in compacted coarse sediment greater than 9" diameter (data from Schuett-Hames and Schuett-Hames 1987; Schuett-Hames et al. 1988a). Recent data are lacking. No data on pool or LWD conditions were found.

Figure 17. Road density in North Fork Nooksack watersheds (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). Densities above the yellow line are considered to be "poor".



Streambed and Sediment Conditions in the Hedrick Creek Sub-Basin

Landslide density was estimated at 1.3 events per square mile in the Hedrick Creek watershed with five identified shallow, rapid slides (Watts 1997), a "fair" rating. However, only one of these slides was associated with a human impact (a road), even though road density levels are very high at 5.7 miles of road per square mile of watershed (data from Watts 1997; Zander 1997). In a separate road density estimate, values were even greater at 8 miles per square (Figure 15) (T. Coe, Nooksack Indian Tribe using data from Zander 1997 and the WRIA 1 Watershed Management Process). DNR (1995) noted that debris flow deposits have widened Hedrick Creek, but no direct linkage to a human cause was provided. In the early 1980s, Hedrick Creek rated unstable (Schuett-Hames et al. 1988a) mostly due to serious bank cutting, although only the lowest reach was analyzed (Schuett-Hames and Schuett-Hames 1984a). The Hedrick Creek watershed has a high (24 to 31%) percentage of slope instability (Figure 10) (Victor Johnson, Lummi Indian Nation using the DNR SHALSTAB model). More data are needed before a rating can be assigned for channel or streambed stability. Because of the high percentage of slope instability and the extremely high road density, this area should be prioritized for more analysis to determine current sediment quantity conditions.

Sediment quality varies greatly with levels of fine sediments ranging from "poor" to "good" in Hedrick Creeks (data from DNR 1995). Levels of LWD are rated "poor" for all sampled areas in Hedrick Creek (data from DNR 1995). Pool frequency is "poor" and percent pool habitat ranges from "fair" to "poor" (data from DNR 1995).

Streambed and Sediment Conditions in the Slide Mountain Streams

The landslide density for the Slide Mountain streams was estimated at 1.1 events per square mile based upon 1940 to 1995 photographs (Figure 11) (Watts 1997), which is a "fair" rating. However, road density is high at 4.9 miles of road per square mile of watershed in Zander (1997) and even greater (6.2) in the Coe analysis (Figure 17) (T. Coe, Nooksack Indian Tribe using data from Zander 1997 and the WRIA 1 Watershed Management Process). Aggradation and an associated loss of riparian vegetation have been observed in Whalen, upper West Slide, and Big Slide Creeks (DNR 1995). Debris flow deposits have widened Whalen, West Slide, upper Big Slide, and Wildcat Creeks, while aggradation has increased channel width in Aldrich and Whalen Creeks (DNR 1995). All sampled areas within Aldrich Creek have shown evidence of recent channel changes due to sedimentation, but quantitative data are lacking. While it is likely that channel stability has been impacted, no ratings for channel or streambed stability are provided due to a lack of specific data.

In general, the Slide Mountain area has moderately low percentages (9-16%) of slope instability (Figure 10) (Victor Johnson, Lummi Indian Nation using the DNR SHALSTAB model). While most of the reaches are classified as source reaches (56%), 29% of the reaches are response type and likely include reaches of the North Fork Nooksack River (Appendix 1, data from Mike Maudlin, Lummi Indian Nation).

Sediment quality varies greatly with levels of fine sediments ranging from "fair" to "good" in Whalen Creek, "good" in Aldrich Creek, "fair" in West Slide Creek", and "poor" to "good" in Big Slide Creeks (data from DNR 1995). West Slide and Aldrich Creeks also rate "poor" for the type and frequency of spawning habitat. However, habitat diversity is lacking. Levels of LWD are rated "poor" for all sampled areas in Whalen, West Slide, Aldrich, and Big Slide Creeks (data from DNR 1995). Pool frequency is "poor" in all of these streams as well, while percent pool habitat is "poor" in Whalen, West Slide, and Aldrich

Creeks. Percent pool habitat ranges from "poor" to "good" in Big Slide Creek (data from DNR 1995).

Streambed and Sediment Conditions in the Maple Creek Sub-Basin

Landslide density in the Maple Creek watershed was estimated at 0.3 events per square mile, a relatively low level (Figure 11) (data from Watts 1997). Only four landslides (two shallow, rapid and two large, deep-seated) were recorded in the watershed, and those did not appear to deliver sediment to streams (Watts 1997). This results in a "good" rating for sediment quantity. There is concern though, that residential development and logging may be impacting sediment conditions, and additional data are needed to investigate this concern. Also, road density is "poor" at 5.8 miles per square mile (Figure 17) (T. Coe, Nooksack Indian Tribe using data from Zander 1997 and the WRIA 1 Watershed Management Process).

Fine sediment levels were "good" in 1982 and "fair" in 1983 and 1984 (data from Schuett-Hames et al. 1988a). Also, bedload movement was noted, and Maple Creek was rated "moderately unstable" (Schuett-Hames and Schuett-Hames 1984a). However, pool habitat, LWD, and streambed stability are not rated due to a lack of recent data.

Streambed and Sediment Conditions in the Kendall Creek Sub-Basin

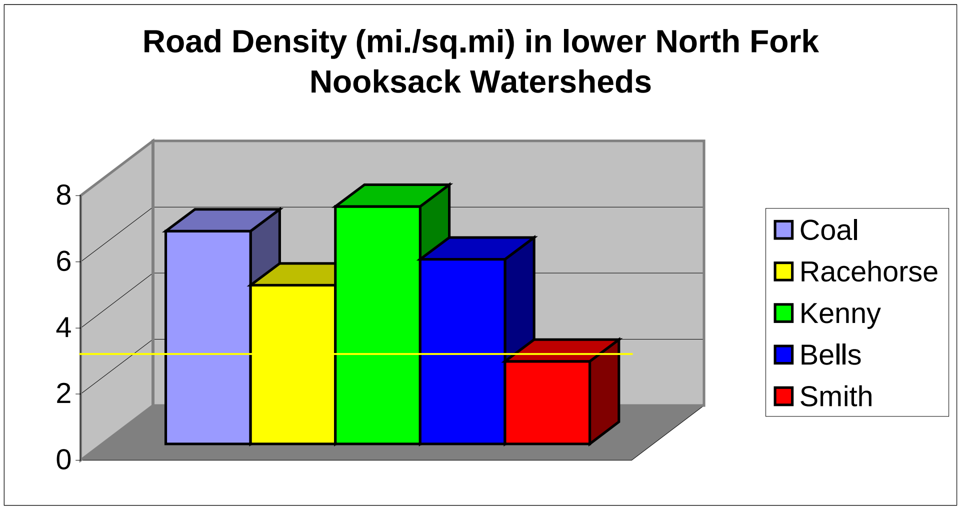
A total of six landslides were recorded in the watershed, and five were shallow, rapid slides that deliver sediment to streams (data from Watts 1997). Four of these slides were associated with roads (data from Watts 1997), and Kendall Creek has a very high road density at 7.2 miles of road per square mile of watershed (data from Zander 1997). The road density estimated by T. Coe (Nooksack Indian Tribe) is lower (3.9 mi./sq.mi.) (Figure 17), but this estimate includes a much larger basin size that encompasses land located far from salmonid streams. Both estimates are in the "poor" rating category for road density. The overall landslide density is low at 0.6 events per square mile of watershed, and is rated "good". However, sediment quantity is rated "fair" because of the known sediment-delivering landslides as a result of roads. No data were found for stream stability, sediment quality, LWD, and pool habitat, and these are not rated. The percentage of high slope instability is moderately low at 9 to 16% (Figure 10) (Victor Johnson, Lummi Indian Nation, using data from the DNR SHALSTAB model). While 43% of the reaches are classified as sediment source reaches, 37% are identified as response reaches (Appendix 1, data from Mike Maudlin, Lummi Indian Nation).

Streambed and Sediment Conditions in the Racehorse Creek Sub-Basin

Racehorse Creek is a significant sediment contributor to the Nooksack Basin, and 76% of its reaches are classified as sediment source reaches (Appendix 1) (data from Mike Maudlin, Lummi Indian Nation). Racehorse Creek also has a high percentage (24 to 31%) of slope instability (Figure 10) (Victor Johnson, Lummi Indian Nation using data from the DNR SHALSTAB model). More (26%) of the most common sediment-delivering landslides in the North Fork Nooksack Basin are located in the Racehorse Creek watershed compared to any other area, and the landslide density is very high at 10.6 events per year, resulting in a "poor" rating for sediment quantity (Figure 11) (data from Watts 1997). This watershed has a low background failure rate of 0 to 5.5 landslides/(acre X year) X 10,000, but areas exposed to timber harvest show an increased failure rate of 4.8 to 42.6, while landslides associated with roaded areas ranged from 3.6 to 60 landslide events/(acre X year) X 10,000. Road fill failures and inner gorge failures are major landslide problems, and the road density is high at 4.8 miles of road per square mile of watershed watersheds (Figure 18) (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). In Watts (1997), 45% of the sediment-delivering landslides were found to be associated with roads, while 30% were observed from clearcuts, and 87% of the slides are categorized as shallow, rapid events. Many recent habitat recovery projects, such as storm-proofing, have occurred in the Racehorse watershed (Nooksack Recovery Team 2001), and sedimentation conditions are expected to improve with time and additional recovery efforts.

In the early 1980s, fine sediment levels in Racehorse Creek were high (17.8 to 19.8%) in three out of four years (Schuett-Hames et al. 1988a) and believed to have been deposited by debris torrents (Schuett-Hames and Schuett-Hames 1984a). Debris torrents have also changed the streambed conditions into alternating stretches of scour and aggradation (Peak Northwest, Inc. 1986). Serious bank cutting, channel shifts, and channel bottom (substrate) shifts of 80% or more at high flows were observed (Schuett-Hames and Schuett-Hames 1984a). Aggradation has resulted in a higher streambed than the surrounding land and in 1984, sediment from debris torrents blocked passage to salmon at RM 0.4, which later led to a channel shift around the sediment deposition (Schuett-Hames and Schuett-Hames 1987). These problems result in "poor" ratings for sediment quantity, sediment quality, and channel stability in Racehorse Creek. The ratings are tentative until more recent data are acquired, with the exception of sediment quantity where new estimates still support a "poor" rating. No data were found for LWD or pool habitat conditions.

Figure 18. Road density in lower North Fork Nooksack watersheds and Smith Creek (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). Densities above the yellow line are considered to be "poor".



Streambed and Sediment Conditions in the Coal and Bell Creek Sub-Basins

Information was scant regarding Coal Creek, although it has a high landslide density at 5.1 shallow rapid or small, deep-seated landslides per square mile (Figure 11), and 96% of the events were categorized as shallow, rapid slides (data from Watts 1997). For its size, Coal Creek is a significant contributor of sediment to the Nooksack Basin with 5% of sediment-delivering landslides in the entire North Fork Nooksack Basin, and 71% of the landslides were associated with clearcuts (data from Watts 1997). Even though most of the landslides were associated with clearcuts, Coal Creek has one of the highest road densities in the basin; 6.4 miles of road per square mile of watershed (Figure 18) watersheds (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). Because of this, it is one of the priority watersheds for future road improvements (Figure 12) (data from Zander 1997). The high landslide and road densities result in a "poor" rating for sediment quantity.

Coal Creek was rated as "moderately unstable in the 1980s (Schuett-Hames et al. 1988a), but recent data are needed before a rating can be provided. The percentage of high slope instability is moderately low (9 to 16%) in the Coal Creek sub-basin (Figure 10), and its reaches are classified as source (52%) and transport (48%) reaches (Appendix 1) (data from Victor Johnson and Mike Maudlin, Lummi Indian Nation, using data from the DNR SHALSTAB model).

Bells Creek has a landslide density of 1.1 events per square mile with seven shallow, rapid, sediment-delivering landslides (Watts 1997). This density results in a "fair" rating. Three of the landslides are associated with roads, while the others are thought to be "natural" slides associated with mature vegetation. However, road density is high at 5.6 miles of road per square mile of watershed (Figure 18) (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). The Bells Creek watershed has a moderately low (9 to 16%) percentage of high slope instability (Figure 10), and most of its reaches are classified as either sediment source (52%) or transport (48%) reaches (Appendix 1) (data from Victor Johnson and Mike Maudlin, Lummi Indian Nation using data from the DNR SHALSTAB model). More analysis is needed to determine the overall sediment quality impacts to salmonids. No additional data were found for channel, LWD, sediment quality, and pool conditions.

Streambed and Sediment Conditions in the Kenney Creek Sub-Basin

Landslide density is low (0.73 events per square mile) in the Kenney Creek watershed, and no further information was found regarding the type of landslides and sediment production (data from Watts 1997). Road density is 7.2 miles of road per square mile of watershed ("poor"), and this density is among the highest in the North Fork sub-basin (Figure 18) (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process).

In the early 1980s, Kenney Creek was rated unstable (Schuett-Hames et al. 1988a) with 80% or more channel bottom (substrate) shifts (Schuett-Hames and Schuett-Hames 1984a). All of these impacts result in tentatively "poor" ratings for channel stability in these streams, but more recent and extensive analyses are greatly needed. Kenney Creek has a moderate percentage (17 to 23%) of slope instability (Figure 10) with 41% of its reaches classified as sediment source reaches and 43% as transport reaches (Appendix 1) (data from Victor Johnson and Mike Maudlin, Lummi Indian Nation using data from the DNR SHALSTAB model). No information was found for LWD and pool habitat conditions.

Streambed and Sediment Conditions in the Lower North Fork Nooksack Mainstem

Road density was estimated for the lower North Fork Nooksack River from Coal to Bell Creeks, and is very high at 7.3 miles of road per square mile of watershed (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). The only other sediment and streambed data found for this area is a moderate landslide density of 2.2 events per square mile surrounding the reach between Coal Creek to Bell Creek (Watts 1997). While ratings can be provided for the road and landslide densities, more information is greatly needed to understand the sediment conditions and potential impacts to salmonids in this important reach. No information was found for sediment quality, LWD, and pool habitat conditions.

Streambed and Sediment Conditions in the Middle Fork Nooksack River Basin

Introduction

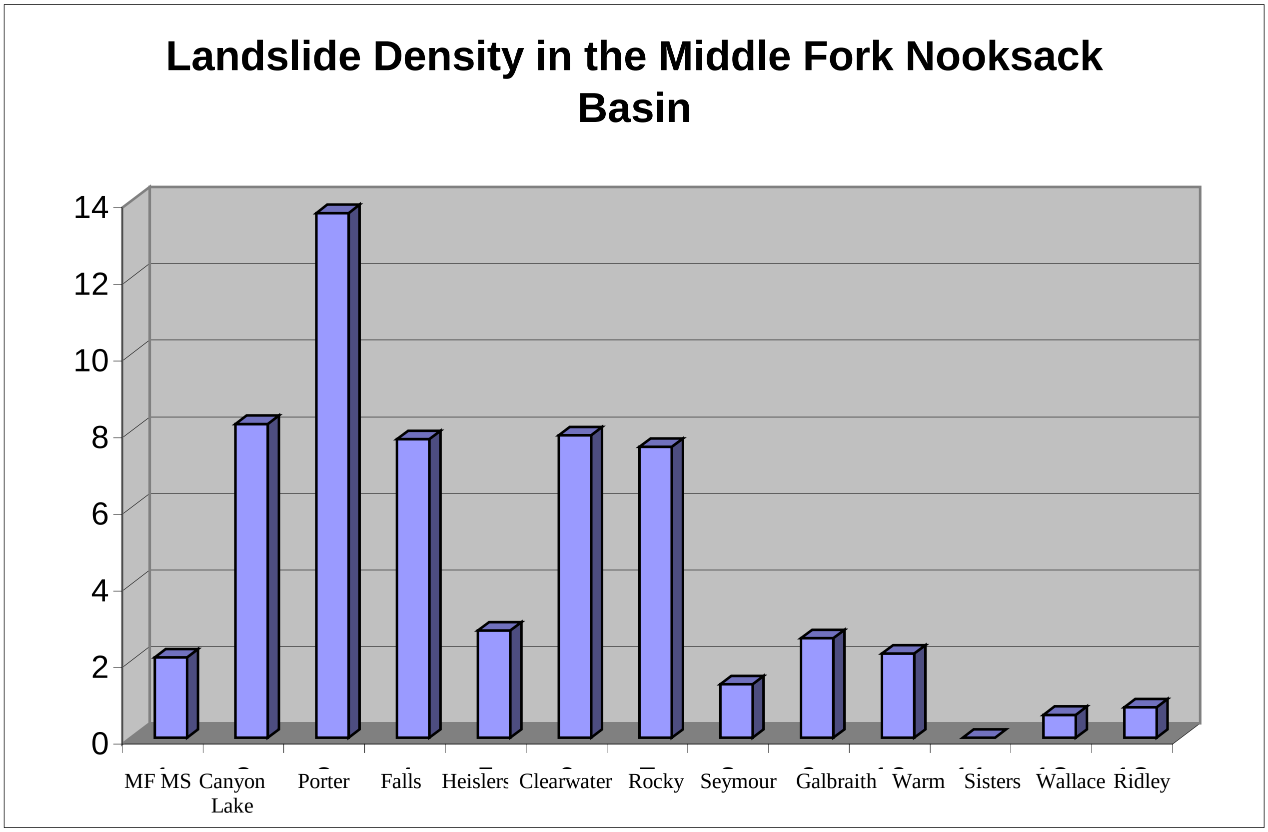
The Middle Fork Nooksack River has a naturally high sediment yield from the Deming Glacier, but past timber harvest activities have greatly increased sediment delivery to streams (Zander 1998). In 1909, railroad logging began in the lower valley, expanding upstream within the next few decades. By the late 1930s, the transport of timber shifted to trucks, and the railroad grades were reconstructed and extended as roads into steeper terrain especially into the Porter, Clearwater, and Falls Creek watersheds. Road construction peaked in the mid-1950s, but continued at high levels to the early 1980s (Zander 1998). Numerous road failures occurred from the 1940s through the 1980s due to side-cast technology, which is no longer used in forest practices (Zander 1998). Currently, more road miles consist of inactive or abandoned roads instead of active roads, and although maintenance of these roads is specified in the new Forests and Fish Agreement, many of the inactive roads are not maintained (Zander 1998).

The Middle Fork Nooksack Basin includes the first land that was set aside due to concerns regarding timber harvest activities in sensitive ecological areas (the west side of the Clearwater River), but this land is presently being reconsidered for harvest activities (Roger Nichols, U.S. Forest Service, personal communication). Currently, road construction is increasing again as second growth harvest escalates, and road density in the basin is already high at 3.0 miles of roads per square mile of watershed (Zander 1998).

Potential sources of sedimentation have been documented in the Middle Fork Nooksack Basin, but specific information regarding the quantity of sediment has not been estimated. Overall, 480 landslides have been identified in the Middle Fork Nooksack Basin, and sub-basin road densities are generally high with most roads unpaved (Watts 1998). The majority of the landslides are shallow, rapid landslides (82%), and these 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). The numbers of mass wasting sites that delivered sediment to streams are highest along Clearwater Creek (77 landslides), Rocky Creek (54), Porter Creek (52), the mainstem Middle Fork Nooksack River (48 events), and Canyon Lake Creek (37), and landslide density (number of events per square mile watershed) is shown in Figure 19 (Watts 1998). It is noteworthy that the Middle Fork Nooksack sub-basin has the most watersheds with the highest percentages of slope instability in the entire Nooksack Basin (Figure 10) (map from Victor Johnson, Lummi Indian Nation).

While data regarding sediment quantity are readily available, very few areas of the Middle Fork Nooksack Basin have data for sediment quality, streambed or channel stability, levels of LWD, and pool habitat. Data for each sub-basin in the Middle Fork Nooksack Basin are discussed below beginning downstream and working upstream, and data needs are also highlighted.

Figure 19. Landslide density (number of events per square mile) in the Middle Fork Nooksack Basin (Watts 1998).



Sedimentation in the Mainstem Middle Fork Nooksack River

The mainstem Middle Fork Nooksack River and smaller tributaries have a moderate landslide density of 2.1 events per square mile (Figure 19), resulting in a "fair" rating for sediment quantity (data from Watts 1998). However, this region is a major sediment contributor to streams, containing 17% of the sediment-delivering shallow, rapid or small, deep-seated slides in the entire Middle Fork Nooksack sub-basin. Thirty-two percent are associated with roads and 34% with clearcuts (Watts 1998). Shallow-rapid slides account for 63% of the landslides near the mainstem Middle Fork Nooksack River and unnamed tributaries, while 34% are large, persistent deep-seated slides (Watts 1998). Road density is very high at 5.8 miles per square mile in the lower Middle Fork Nooksack sub-basin downstream of the diversion (Figure 20) (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). The area from the diversion to Sisters Creek also has a “poor” road density of 5.2 miles per square mile of watershed (Figure 21).

Channel changes have been documented for the mainstem Middle Fork Nooksack River. In recent decades, the channel width of the mainstem from the mouth of Ridley Creek to the diversion has greatly changed. From the diversion to just upstream of the Mosquito Lake Road Bridge, the channel is constrained. However from the Mosquito Lake Road Bridge to the confluence with the North Fork Nooksack River, the Middle Fork mainstem is braided and has shown extensive lateral migration in response to the delivered sediment (Watts 1998). Historically, logging and LWD removal has occurred in the floodplain, but it is not known to what extent this movement is related to human-caused impacts versus climatic change and natural sedimentation. Tentatively, channel stability from Mosquito Lake Road Bridge to the Forks is rated as “poor” with a note that more analysis is needed.

No data were found regarding levels of instream LWD, sediment quality, and pool habitat in the Middle Fork Nooksack Basin. These habitat conditions are not rated and remain a data need.

Sedimentation in the Canyon Lake Creek Sub-Basin

The lower Middle Fork Nooksack sub-basin has a very high road density of 5.3 miles of road per square mile of watershed (data from Zander 1998). The nearby Canyon Lake Creek watershed also has a “poor” road density level at 5.7 miles of road per square mile of watershed (Figure 20) (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). Seventy-four landslides have been documented in the Canyon Lake Creek watershed, resulting in a high landslide density of 8.2 events per square mile (Figure 19) (Zander 1998). Eighty-three percent of the landslides in the Canyon Lake Creek watershed are shallow, rapid slides (Watts 1998). The Canyon Lake Creek watershed contains 13% of the sediment-delivering landslides in the entire Middle Fork Nooksack Basin (Watts 1998). Of these landslides, 38% are associated with roads and 33% with clearcuts (Watts 1998). Both the lower Middle Fork Nooksack River and nearby tributaries and Canyon Lake Creek are rated “poor” for sediment quantity due to the high landslide densities and numerous landslides that deliver sediment to streams.

Canyon Lake Creek was described as unstable in the 1980s (Schuett-Hames et al. 1988a), and is tentatively rated as “poor”, pending more recent studies. The watershed has a high percentage (24 to 31%) of slope instability and most (81%) of its reaches are classified as sediment source reaches (Appendix 1) (data from Victor Johnson and Mike Maudlin, Lummi Indian Nation using the DNR SHALSTAB model). No data were found regarding sediment quality, instream levels of LWD, and pool habitat in the Canyon Lake Creek watershed. These habitat conditions are not rated, and remain a data need.

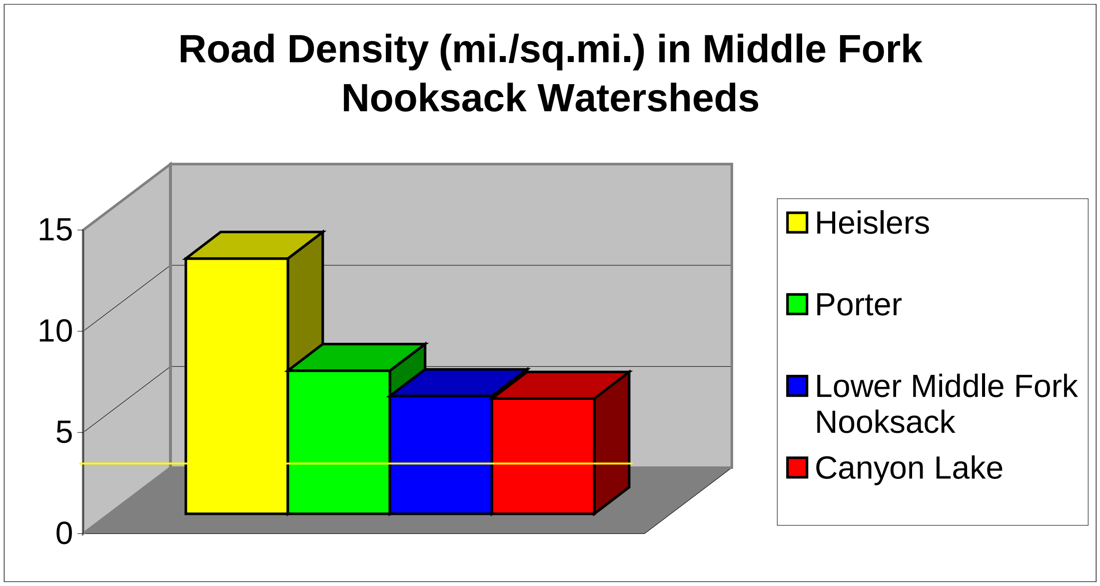
Sedimentation in the Porter Creek Sub-Basin

The Porter Creek watershed has the greatest landslide density in the Middle Fork Nooksack Basin at 15.7 events per square mile (Figure 19) coupled with a very high road density of 7.1 miles per square mile of watershed (Figure 20) (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). This watershed also contains 18% of the entire Middle Fork Nooksack Basin's sediment-delivering landslides (Watts 1998). Nearly all of the identified landslides in the Porter Creek watershed are shallow, rapid slides (95%), and 42% are associated with roads and 9% with clearcuts (Watts 1998). The high landslide and road densities result in a "poor" rating for sediment quantity.

In the 1980s, it was noted that channel shifts were common, and aggradation elevated the streambed higher than the surrounding land (Schuett-Hames and Schuett-Hames 1984a). Overall, Porter Creek was rated as unstable in one year of sampling and as moderately unstable in another sample with fine sediments in the "fair" range (11.1%) (data from Schuett-Hames et al. 1988a). Based on these older studies, sediment quality is tentatively rated as "fair", while channel stability is not rated because the stability estimates were taken near the mouth where alluvial fan instability is expected. New analyses are greatly needed. The Porter Creek watershed has a very high percentage (32 to 38%) of slope instability (Figure 10), and most (86%) of its reaches are classified as sediment source reaches (Appendix 1) (data from Victor Johnson and Mike Maudlin, Lummi Indian Nation using data from the DNR SHALSTAB model). Given the high landslide and road densities, channel and streambed stability analysis should be a priority data need.

No information regarding instream levels of LWD or pool habitat was found for the Porter Creek watershed, and these are an additional data need.

Figure 20. Road density in lower Middle Fork Nooksack watersheds (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). Densities above the yellow line are considered to be "poor".



Sedimentation in the Heislers and Falls Creeks Sub-Basins

In the smaller watersheds of Heislers and Falls Creeks, road densities were extremely "poor" at 8.9 miles per square mile of watershed for Falls Creek and 12.6 for Heislers Creek, and the Heislers road density value is the highest in the three Nooksack Forks (Figures 20 and 21) (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). Landslide density is rated as "poor" in Falls Creek at 7.8 events per square mile and "fair" in Heislers Creek at 2.8 events per square mile (Figure 19) (data from Zander 1998). In Falls Creek, four landslides that deliver sediment to streams were identified, and two of those were associated with roads while the other two were associated with immature second growth, and all were shallow, rapid slides (Watts 1998). Heislers Creek had one sediment-delivering landslide, and this shallow, rapid slide was associated with immature second growth (Watts 1998).

While Heislers Creek is predominantly an area with moderate (17 to 23%) slope instability, Falls Creek has a very high percentage (32 to 38%) of instability (Figure 10) (Victor Johnson, Lummi Indian Nation using the DNR SHALSTAB model). All of the Falls Creek reaches have been classified as sediment source reaches while 70% of the reaches in Heislers Creek are transport reaches (Appendix 1, data from Mike Maudlin, Lummi Indian Nation). No data were found for channel or streambed stability, as well as for sediment quality, instream levels of LWD, and pool habitat conditions. These habitat elements are not rated, and are a data need.

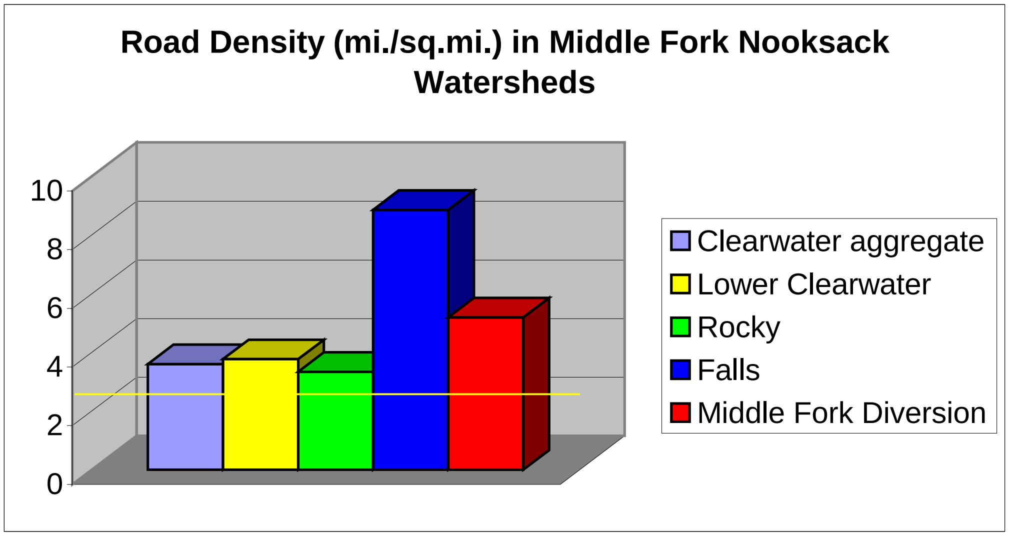
Sedimentation in the Clearwater Creek Sub-Basin

The Clearwater Creek sub-basin has a high landslide density at 7.9 events per square mile (Figure 19) coupled with a high road density of 3.6 miles of road per square mile watershed (Figure 21) (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). Most of the landslides in the Clearwater Creek watershed are shallow, rapid slides (89%) (Watts 1998). Clearwater Creek contains 27% of the Middle Fork Nooksack Basin's sediment-delivering landslides, and 44% of these are associated with roads while 28% are associated with clearcuts (Watts 1998).

A high landslide density (7.6 events per square mile) also exists in the Rocky Creek watershed, a tributary to Clearwater Creek (data from Zander 1998), and 91% of these slides are shallow, rapid landslides (Watts 1998). The Rocky Creek watershed contains 19% of the Middle Fork Nooksack Basin's sediment-delivering landslides with 26% associated with roads and 53% with clearcuts (Watts 1998). The entire Clearwater Creek sub-basin is rated "poor" for sediment quantity due to the high road and landslide densities. It is also noteworthy that together, Rocky and Clearwater Creeks contain 45% of all the shallow-rapid and small, deep-seated sediment-delivering landslides in the entire Middle Fork Nooksack Basin (data from Watts 1998).

The Clearwater Creek watershed has a very high percentage (32 to 38%) of slope instability, while Rocky Creek has a high percentage (24-31%) (Figure 10) (Victor Johnson, Lummi Indian Nation using the DNR SHALSTAB model). Most of the reaches are classified as sediment source reaches (69% in Clearwater and 61% in Rocky) (Appendix 1, data from Mike Maudlin, Lummi Indian Nation). No data were found regarding streambed or channel stability, sediment quality, instream levels of LWD, or pool habitat conditions in the Clearwater Creek watershed, and these are a data need.

Figure 21. Road density in the Middle Fork Nooksack watersheds (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). Densities above the yellow line are considered to be "poor".

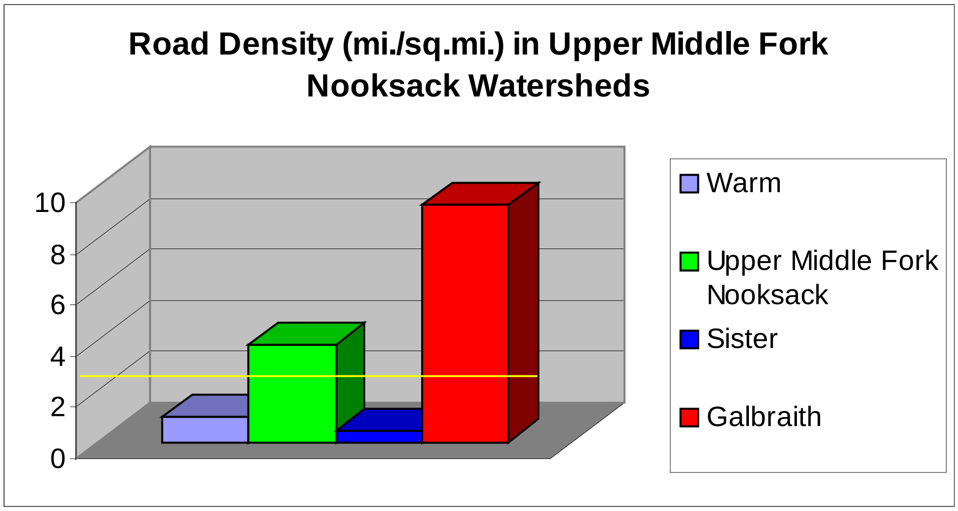


Sedimentation in the Seymour and Galbraith Creek Watersheds

Seymour and Galbraith Creeks have a very high combined road density of 5 miles of roads per square mile of watershed, but when the data for Galbraith Creek is separated, it has an extremely high road density of 9.3 (Figure 22) (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). Separate data for Seymour Creek were not available. Both have moderate landslide densities of 1.4 and 2.6 events per square mile, respectively (Figure 19) (data from Zander 1998). Only one of the shallow, rapid landslides in Seymour Creek has been identified as delivering sediment to streams, but eight such landslides in the Galbraith watershed deliver sediment (Watts 1998). Most of those landslides (88%) are associated with clearcuts while the remaining slide is associated with roads (Watts 1998). Seymour Creek is rated "fair" for sediment quantity, based upon its landslide density while Galbraith Creek is rated "poor" because of numerous sediment-delivering slides.

Galbraith Creek has a moderately low percentage (9 to 16%) of slope instability (Figure 10) and consists of mostly (65%) sediment source reaches (Appendix 1) (data from Victor Johnson and Mike Maudlin, Lummi Indian Nation using the DNR SHALSTAB model). Sediment quality, channel stability, LWD, and pool habitat were not rated due to a lack of data.

Figure 22. Road density in the upper Middle Fork Nooksack watersheds (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). Densities above the yellow line are considered to be "poor".



Sedimentation in the Warm Creek Watershed

The Warm Creek watershed has a "good" road density at 0.9 miles of road per square mile of watershed (Figure 22) (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). The landslide density is "fair" at 2.2 events per square mile (data from Zander 1998). Eight shallow, rapid landslides have been identified in the Warm Creek watershed, and two of these deliver sediment to streams (Watts 1998). Six are associated with clearcuts and two with roads (Watts 1998).

Warm Creek has a very high percentage (32 to 38%) of slope instability (Figure 10), and most of its reaches are sediment source reaches (Appendix 1) (data from Victor Johnson and Mike Maudlin, Lummi Indian Nation using the DNR SHALSTAB model). No data were found for sediment quality, channel or streambed stability, instream level of LWD, or pool habitat conditions, and these remain a data need.

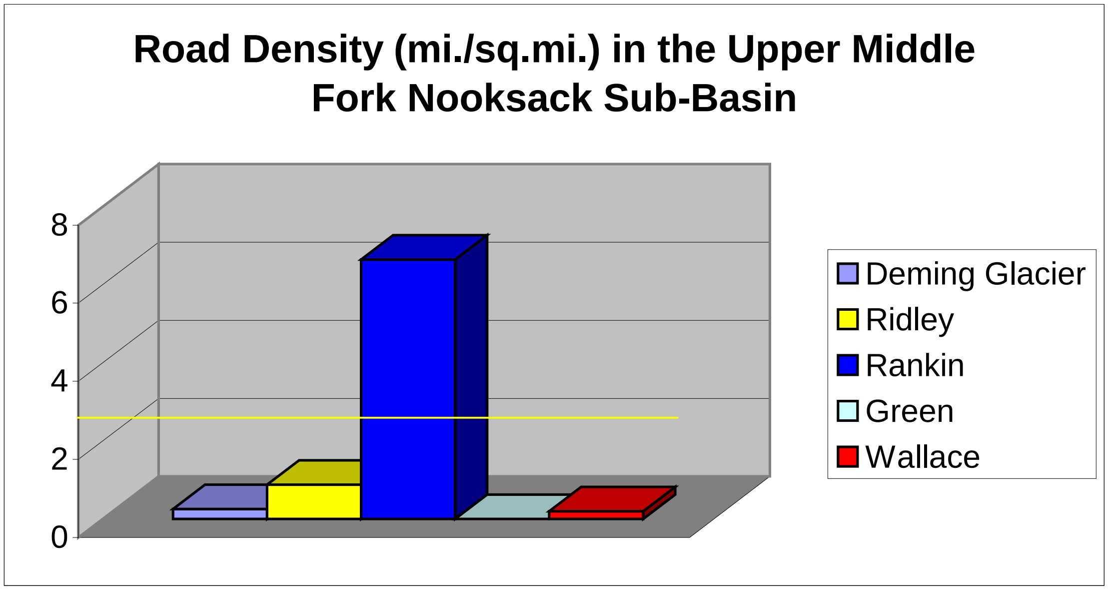
Sedimentation in the Upper Middle Fork Nooksack River

Sedimentation conditions continue to improve upstream of the Warm Creek confluence. While the upper Middle Fork River has a "poor" road density of 3.8 miles per square mile of watershed, "good" road densities exist in the Sisters Creek area (0.4 miles of road per square mile of watershed) (Figure 22) (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). No shallow, rapid or small, deep-seated landslides (the types that tend to deliver sediment) were noted in the Sisters Creek watershed (data from Zander 1998; Watts 1998). Low landslide densities are also found in Wallace Creek (0.6 events per square mile of watershed), and all of those slides are believed to be natural slides associated with old growth forest (Figure 19) (data from Zander 1998; Watts 1998). In addition, Wallace Creek has a very low road density (0.2) (Figure 23) (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process).

In the Ridley Creek watershed, landslide density is low (0.8 events per square mile) with one shallow-rapid slide recorded and associated with old growth forest (Figure 19) (data from Zander 1998; Watts 1998). All of these watersheds are rated "good" for sediment quantity, and all are in the upper Middle Fork Nooksack Basin on National Forest lands. Several storm-proofing and road abandonment projects have occurred in this area (Nooksack Recovery Team 2001). Road density is "good" in Ridley and Green Creeks and in the uppermost region of the Middle Fork Nooksack sub-basin (Figure 23) (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). However, Rankin Creek has a "poor" road density of 6.6 miles per square mile of watershed (Figure 23).

All of these watersheds have either a high or very high level of slope instability (Figure 10). No ratings were given to any of these streams for sediment quality, streambed or channel stability, levels of LWD, or pool habitat conditions due to a lack of data.

Figure 23. Road density in the upper Middle Fork Nooksack watersheds (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). Densities above the yellow line are considered to be "poor".



Streambed and Sediment Conditions in the South Fork Nooksack River Basin

Introduction

In the South Fork Nooksack Basin, the conversion from railroad logging to trucks began around 1940 (Zander 1996). At this time, railroad grades became reconstructed into logging roads and were extended into steeper areas of the basin. Extensive road building spanned from the mid-1950s to the early 1980s, and many of the roads used side-cast technology, which is prone to trigger landslides. Road-related failures may be initiated by a number of mechanisms. Failures may happen where the road crosses and destabilizes, or side-cast material is placed on an unstable landform, such as a colluvial hollow or inner slope above a stream. A lack of drainage structure maintenance or concentrated intercepted drainage can result in failure of the structure or a side-cast fill or in the hydraulic loading of a slope feature with a resulting landslide.

Failures from these aging side-cast roads are still contributing sediment to the streams today. Areas identified at a high risk of failure due to roads are: 1) the region bounded by the South Fork Nooksack River on the west and drainage divide and Goat Mountain on the east; 2) Deer, Plumbago, and Roaring Creek Watersheds, 3) Jones, McCarty, and Sygitowicz Watersheds; 4) the upper reaches of Howard, Cavanaugh, Hutchinson, and Skookum Creek Watersheds; and 5) the east facing hillside above Howard Creek (Zander 1996) (Figure 12).

These areas have been targeted for road drainage improvement and abandonment/inactivation projects to reduce the potential for road failure and sediment delivery to the stream network (Nooksack Recovery Team 2001).

Various landslide inventories have been conducted in the South Fork Nooksack Basin encompassing the entire drainage (Table 4). When totaled, there is a conservative estimate of 1216 landslides in the South Fork Basin even though the percent of slope instability appears to be lower than for the Middle and North Fork Basins (Figure 10). The landslides include 346 in the Skookum Creek watershed, 191 in the Acme WAU (lower South Fork), 171 in the South Fork valley from Skookum to Howard Creeks, 444 in the upper South Fork, 55 in the Hutchinson Creek watershed, and 9 additional slides not previously inventoried in the Howard Creek watershed (sources listed in Table 4). The landslides listed in the report by Hale (1992) are not included in this total because the same events should also be compiled in Kirtland (1995) whose geographical area was greater and included the region summarized in Hale (1992).

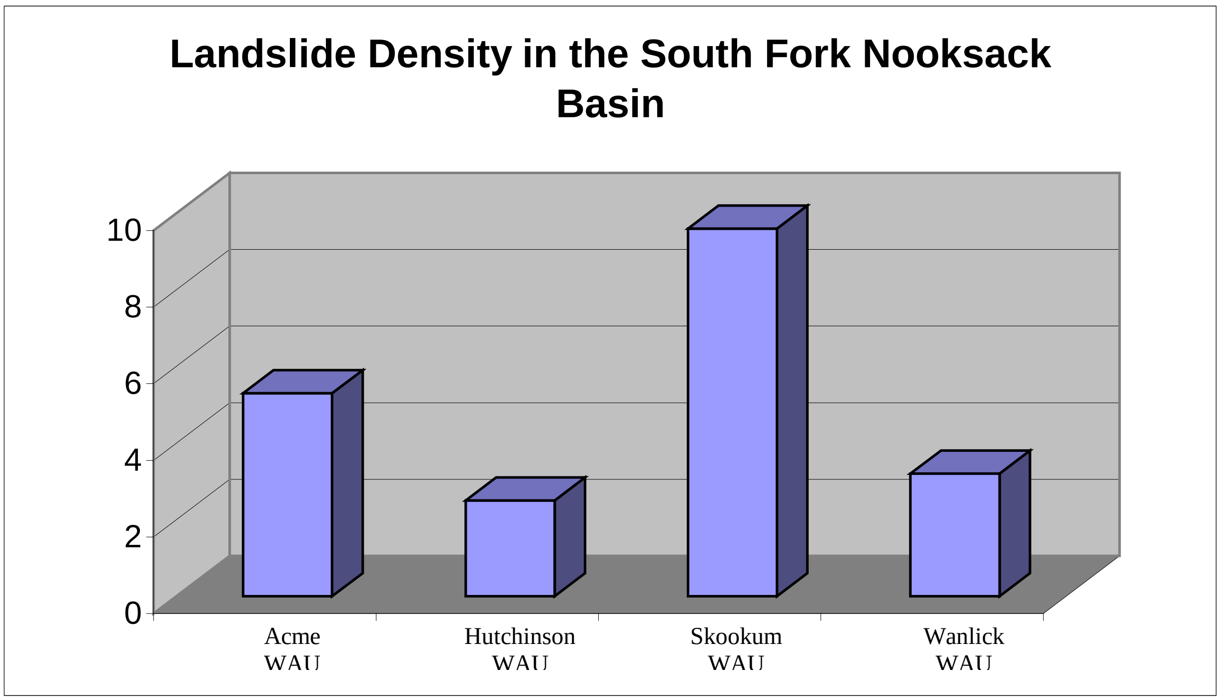
Landslide density is very high in the Skookum, Acme, and Wanlick WAUs (Figure 24) (data from Hale 1992, DNR 1994; Lunetta et al. 1997, Benda and Coho 1999 draft). A moderate landslide density has been estimated in the Hutchinson WAU (data from DNR 1998). However, densities weren't estimated for Howard Creek and along the South Fork Nooksack River due to a lack of readily available data. The Acme WAU includes the mainstem South Fork Nooksack River from RM 0 to 13 and all tributaries downstream of RM 10, such as Jones, McCarty, Standard, Hardscrabble, Sygitowicz, Caron, Toss, Tinling, and Black Slough (Trillium 1996). The Wanlick WAU includes all waters upstream of the confluence Wanlick Creek and the South Fork Nooksack River.

Table 4. Landslide estimates in various regions of the South Fork Nooksack Basin.

Region	Number of Landslides	Number of Shallow, Rapid Slides	Number that Deliver Sediment to Streams	Data Source
Skookum Creek watershed	346	291	263	DNR 1994
Acme WAU (lower 13 miles of SF and tributaries)	191	108	140	Benda and Coho 1999 draft
SF Valley (between Skookum and Howard Creeks)	171	150	115	Watts 1996
Upper SF from Howard upstream (not including Howard)	444 in 1991		72% of total events from 1940-1991	Kirtland 1995
Upper SF at Wanlick confluence (including Loomis, Bell, Wanlick). This overlaps in area with Kirtland inventory.	96	96	Data Not Available	Hale 1992
Hutchinson Creek watershed	55	50	43	DNR 1998
Howard Creek Watershed (these are new slides since Peak Northwest 1996)	9	9	9	Watts 1996

The majority of landslides (81%, excluding the Kirtland (1995) report due to insufficient data) in the South Fork Nooksack Basin are shallow, rapid events, which tend to deliver sediment to streams (Table 4). Most of the landslides are associated with human-caused impacts with 37% related to clearcuts and 32% associated with roads (DNR 1994, 1998; Kirtland 1995; Watts 1996, Benda and Coho 1999 draft). Most slides appeared within ten years of timber harvest or road building with heavily logged inner gorge or gully areas showing a nearly immediate impact while high elevation roads failing after several years (Watts 1996). Streambed and sediment conditions are discussed in greater detail below for each major watershed within the South Fork Nooksack Basin.

Figure 24. Landslide density (total number of slides per square mile) in the South Fork Nooksack Basin (data from Hale 1992; DNR 1994; Lunetta et al. 1997; DNR 1998; Benda and Coho 1999 draft).



Streambed and Sediment Conditions in the Lower South Fork Nooksack River Basin and Black Slough

Landslides contribute the largest volume of sediment to the South Fork Nooksack River, and the high sediment volume can lead to unstable channels and streambeds. The South Fork Nooksack River has experienced considerable bedload movement in the past, and was rated as unstable in seven sampled sites and as moderately unstable in four other sites (Schuett-Hames et al. 1988a). No sites were rated as stable, but more recent data are greatly needed. The unstable sediment disturbs redds (salmon nests), potentially resulting in a major source of mortality. Redd scour is suspected in the South Fork Nooksack River (Schuett-

Hames et al. 1988b), and additional data is being collected by the Nooksack Indian Tribe.

Schuett-Hames et al. (1988b) attributed the causes of channel instability to excess sedimentation; specifically, inadequate channel capacity (6/7 sites), bank cutting (4 sites), scour/deposition, bottom material instability, and mass wasting (2 sites). However, disruption of watershed processes such as loss of land cover vegetation, riparian vegetation, wetlands, floodplain habitat, LWD, and increased bank hardening and channelization and disrupted hydrology are also likely contributors. Also, many of these habitat conditions interact. For example, unstable channels impact riparian vegetation, and the removal of riparian vegetation contributes to further instability.

In the Acme WAU (the most downstream portion of the South Fork Nooksack Basin), 191 landslides have been estimated with 45% related to roads and 32% associated with clearcuts (Benda and Coho 1999 draft). Most (73%) of the events deliver sediment to streams. In a recent inventory of mass wasting in the South Fork Nooksack valley between the confluences of Skookum and Howard Creeks, 171 landslides were recorded, and 88% of these were shallow, rapid events (Watts 1996). Clearcuts were related to 41% of the slides while roads were associated with 36% of the shallow, rapid slides (Watts 1996). Of the 150 shallow, rapid slides, 77% delivered sediment to streams. The high number of slides coupled with the associated to human causes and high sediment delivery, result in a “poor” rating for sediment quantity in both of these regions.

In the South Fork Nooksack River upstream of RM 20, 82% of the landslides consisted of 50% or more sand, silt, or clay, which can greatly increase the level of fine sediments, particularly at high flows (Schuett-Hames et al. 1988b). Similar volumes of fine sediment are believed to come from both mass wasting sites and surface erosion, and the channel banks upstream of Cavanaugh Creek are thought to contribute high levels of fines due to erosion and slumping (Zander 1996). However, direct measurements indicate that fine sediment estimates have been variable ranging from “good” (9.7-10.4%) to “fair” (13.1-13.3%) (Schuett-Hames et al. 1988a and b), and these levels suggest that fine sediments have not been a major problem in the mainstem South Fork Nooksack River. The risk of increased fine sediments remains, and should warrant additional studies. In contrast, the quality of spawning habitat is reduced by embeddedness (Schuett-Hames et al. 1988 a and b). Thirty-seven percent of the spawning habitat is moderately embedded, and 4% is unusable due to embeddedness, resulting in a “poor” rating for sediment quality in the mainstem South Fork Nooksack River.

Road density in the lower South Fork sub-basin, which includes the South Fork River and western tributaries from the Forks to the mouth of Jones Creek (Appendix 2), is rated “fair” at 2.6 miles per square mile of watershed (Figure 25) (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). This area also has a moderate percentage of slope instability (Figure 10) (Victor Johnson, Lummi Indian Nation using the DNR SHALSTAB model). Both of these values indicate that this area should be considered for future sediment abatement/road improvement work.

The Black Slough watershed is also rated “fair” for road density, but is slightly less than the “poor” level at 2.9 miles per square mile of watershed (Figure 25). This watershed is in the moderately low range (9 to 16%) for percent of slope instability (Figure 10) and consists mostly (52%) of sediment response reaches (Mike Maudlin, Lummi Indian Nation using data from the DNR SHALSTAB model).

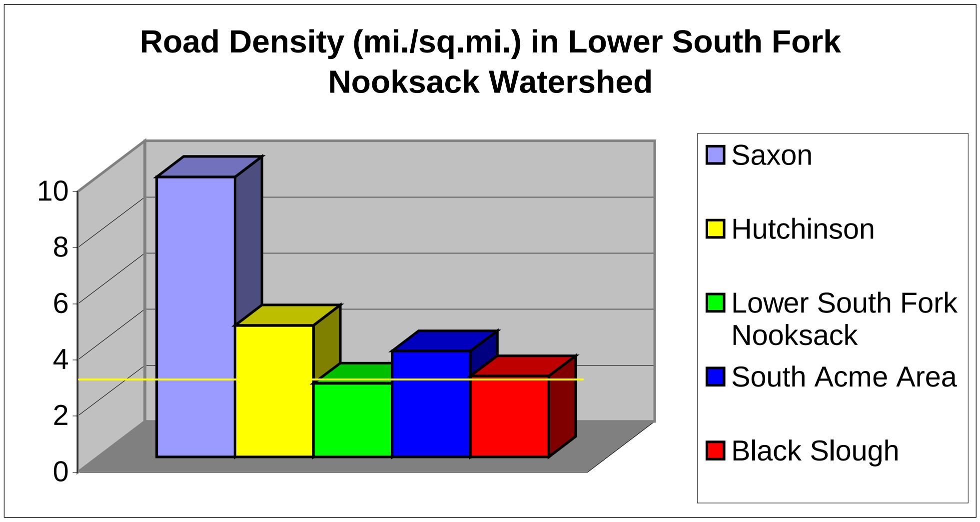
Further upstream, the road densities increase. The south Acme area has a “poor” road density of 3.8 miles per square mile of watershed (Figure 25), and includes the watersheds from Jones Creek to Skookum Creek excepting Hutchinson Creek (Appendix 2). However, this area has a low percentage (1 to 8%) of slope instability (Figure 10) (Victor Johnson, Lummi Indian Nation using the DNR SHALSTAB model).

Historically, the lower South Fork Nooksack River was “full of log jams that reached the full width of the river” (Leo Sygitowicz in Dept. Natural Resources 1992 draft). In the past, log drives occurred in the South Fork Nooksack River, decreasing habitat complexity. Currently, LWD is low in the mainstem South Fork Nooksack River with less than 1 piece per channel width documented in the stretch near Hutchinson Creek (DNR 1998). In this same reach, floods deposited wood on the upper banks, unavailable to serve as salmonid habitat. Levels of LWD in other sections of the mainstem South Fork are thought to be numerous, but there has been a loss of stable accumulations, which are important for wider channels (Mike Maudlin, Lummi Indian Nation, personal communication).

Pool habitat has been greatly impaired throughout the South Fork Nooksack River due to filling from excess sediment and loss of pool-forming features such as logjams. Holding habitat is of poor quality with little LWD (Schuett-Hames and Schuett-Hames 1984a; Schuett-Hames et al. 1988a and b). Pool habitat is especially limiting from RM 1 to 10 and RM 20 to 25, and the average pool depth was five feet (Schuett-Hames et al. 1988b). The lack of pools from RM 0 to 10 is particularly problematic because this reach has abundant spawning gravels and very warm water temperatures. This results in a “poor” rating for pool habitat, but these data are older and need to be updated. There has been an increase in both the number and depth of pools from the Saxon Bridge to the Acme Reach observed since the 1980s surveys, but many of these pools are associated with bank armoring and are probably not providing ideal holding habitat (Mike Maudlin, Lummi Indian Nation, personal communication).

In addition to direct sediment impacts, the South Fork Nooksack River receives additional sediment from tributaries. Howard, Cavanaugh, Deer/Roaring, Plumbago, stream 01-0318, and tributaries draining the east flank of the Twin Sisters are the greatest contributors (Schuett-Hames et al. 1988b). The tributary impacts are discussed below, proceeding in an upstream direction.

Figure 25. Road density in the lower South Fork Nooksack watersheds (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). Densities above the yellow line are considered to be "poor".



Streambed and Sediment Conditions in the Hutchinson Creek Watershed

In the Hutchinson Creek WAU, shallow, rapid landslides are common and related to land use. Of 50 shallow, rapid slides, 18 were associated with recent clearcuts, 14 associated with older clearcuts (20-50 years), 15 were associated with roads, and 3 were related to other forest practices such as yarding (DNR 1998). Eighty-six percent of these landslides deliver sediment to streams. In addition to the 50 shallow, rapid landslides, 5 large deep-seated slides were identified in mature forest and one small deep-seated slide was noted in a 20-50 year old clearcut.

Road densities are very high throughout the Hutchinson Creek WAU, and most roads are unpaved, worsening the sedimentation problems associated with roads (DNR 1998). Road densities range from 6.4 miles of road per square mile of watershed in the Peterson Watershed, 5.6 in lower Hutchinson Creek, 5.3 in upper Hutchinson Creek, 5.4 in the Johnson Creek watershed, to 4.2 in the Pond Creek watershed (DNR 1998). All of these densities are in the "poor" range established by the NMFS (see Assessment Chapter). In a different assessment, an aggregate road density of 4.7 miles per square mile of watershed was estimated for the Hutchinson Creek watershed (Figure 25); a level that is also in the "poor" range (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process).

Hutchinson Creek was rated as moderately unstable in three years of sampling during the 1980s (Schuett-Hames et al. 1988a), and in the 1998 Watershed Analysis, channel changes were noted in the lowest reach of Hutchinson Creek, but much of the remainder of the watershed appeared stable due to the buffer effect of numerous wetlands on basin hydrology (DNR 1998). For this reason, the lower reach is rated "poor" for channel stability while the other reaches are rated "good". The percentage of slope instability is moderately low (9 to 15%) for the Hutchinson Creek watershed (Figure 10) (Victor Johnson, Lummi Indian Nation using the DNR SHALSTAB model).

In the 1980s, fine sediment levels were in the "fair" range, but more extensive sampling in the mid-1990s indicates that most of the sampled sites have very high level of fine sediments. In the later study, 8 out of 12 segments had fine sediment levels of 20% or more and are rated "poor" (data from DNR 1998). Two additional segments were in the 15-20% range ("fair" to "poor"), and two segments were in the 10-15% range. High levels of fine sediments were especially prominent in the lower 0.7 miles of Hutchinson Creek and the nearby segment of the mainstem South Fork Nooksack River, but this area has a very low gradient and the Hutchinson Creek reach is occupying a remnant South Fork channel and is likely reworking South Fork alluvium (Mike Maudlin, Lummi Indian Nation, personal communication). Sediment quality was further reduced by embeddedness, which averaged 25-50% (34% is a threshold) (in DNR 1998).

Pieces of LWD per channel width were low (in the "poor" range) for 11 out of 28 samples, in the "fair" range for 12/28 samples, and in the "good' range for 5 out of 28 samples (data from DNR 1998). In Hutchinson Creek, much of the LWD is unavailable because floods have deposited pieces (although small pieces) on the upper banks, and stream cleaning was common in Hutchinson Creek until the mid-1980s (DNR 1998). Another likely cause is the lack of LWD recruitment (see riparian conditions). The percent pool habitat is mixed. "Good" percent pool habitat existed in 13/34 samples. "Fair" habitat was noted in 9/34 samples, and "poor" pool habitat in 12/34 samples (data from DNR 1998).

Streambed and Sediment Conditions in the Skookum, Edfro, and Cavanaugh Creek Watersheds

Numerous landslides associated with logging and roads exist throughout the Skookum Creek watershed, along with considerable bedload movement and pool-filling (Schuett-Hames and Schuett-Hames 1984a). Of 346 landslides, 263 delivered sediment to streams from 1952 to 1992 (DNR 1994), and most of these have been classified as shallow, rapid slides (84%). Most (50%) were associated with timber harvest (clearcuts on steep slopes were a common initiator) while 25% were associated with roads and landings and 19% associated with mature forest. Most (70%) of the road-generated sediment is from 50 miles of seldom-used roads (DNR 1994), and in the last few years, many storm-proofing projects have occurred in the Skookum Creek watershed (Nooksack Recovery Team 2001). Surface erosion sediment is minimal compared to the impact from landslides.

Landslide densities are very high in the upper Skookum Creek (13.2 events per square mile), Orsino Creek (11.3 events per square mile), Cavanaugh Creek (10.8 events per square mile), lower Skookum Creek (10.4 events per square mile), and North tributary (9.3 events per square mile) (Figure 27) (data from DNR 1994). This compares to “fair” landslide densities in the Edfro (1.6 events per square mile) and Cavanaugh tributary (2.7 events per square mile), and to the “good” density value in South tributary (0 events) (Figure 27) (data from DNR 1994). Overall, the excess sedimentation from human-caused sources results in a “poor” rating for sediment quantity in the Skookum and Cavanaugh Creek watersheds. The percentage of slope instability is high (24 to 31%) in the upper Skookum Creek watershed, while it is moderate (17 to 23%) in lower Skookum and Cavanaugh Creeks and moderately low (9 to 16%) in the Edfro Creek watershed (Figure 10) (Victor Johnson, Lummi Indian Nation using the DNR SHALSTAB model).

Although the density of landslides is still at a high level, the extent of landslides (acres) has been declining. From 1943 to 1968, there were six landslide acres per year. From 1968 to 1983, there were seven landslide acres per year and from 1983 to 1993, the landslide rate had decreased to three acres per year (DNR 1994). The rate of timber harvest has remained about the same during those time periods (207-298 acres per year), although timber harvest and road construction and maintenance methods have changed.

Road densities are rated “poor” for the Skookum and Edfro Creek watersheds with densities of 4.8 and 4.6, respectively (Figure 26) (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). Cavanaugh Creek has a very high road density of 5.5 miles per square mile of watershed (Figure 26), which combined with the high landslide density, suggests that this watershed (as well as Skookum Creek) should be considered for road improvements and sediment abatement projects.

Figure 26. Road density in South Fork Nooksack watersheds (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). All of these road densities are considered to be "poor" (>3).

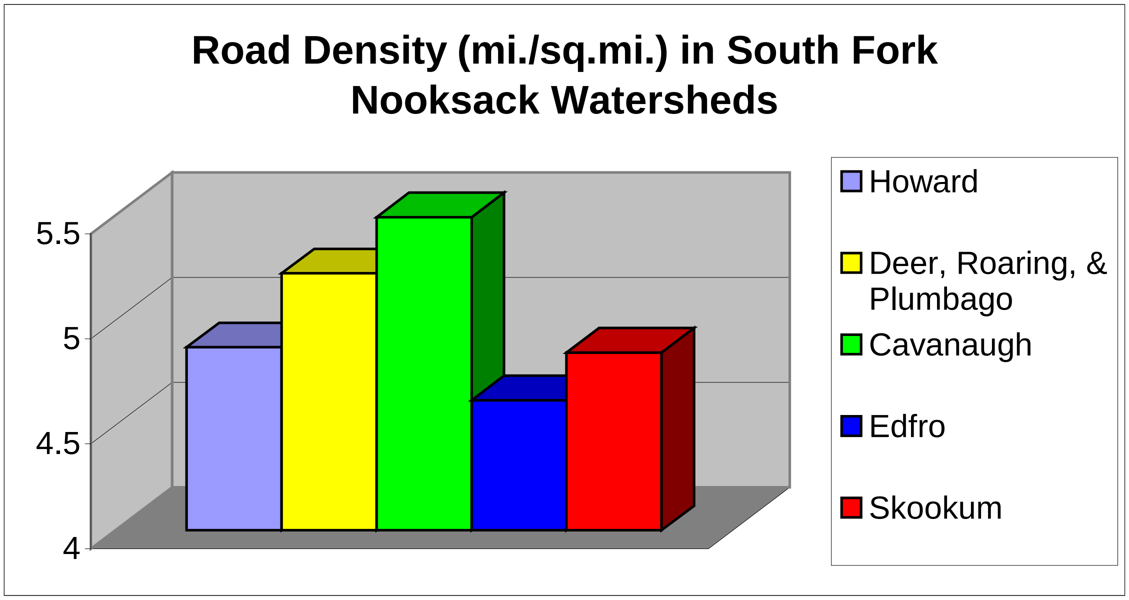
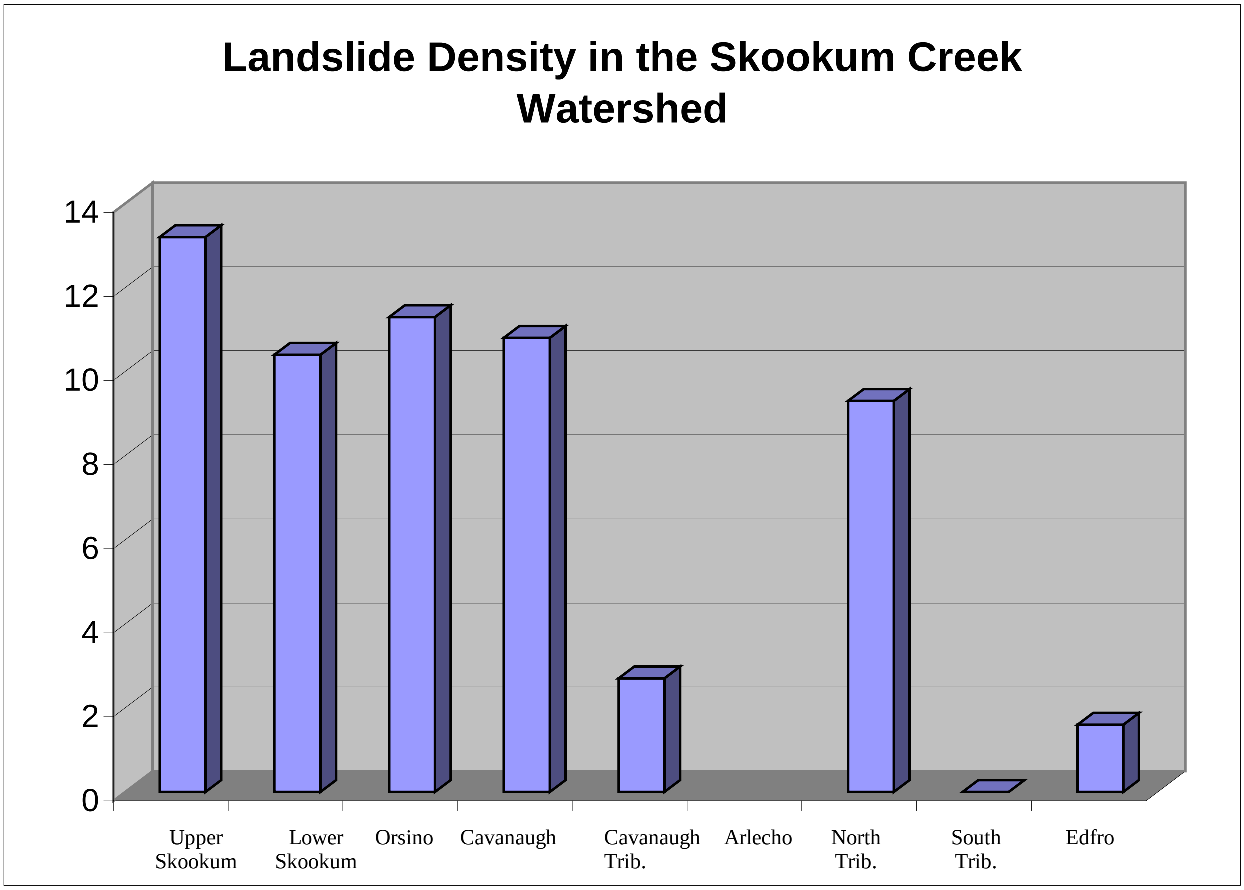


Figure 27. Landslide density (number of landslides per square mile) in the Skookum and Edfro Watersheds (data from DNR 1994).



Channel stability in Skookum Creek has been described as moderately unstable in four years of sampling during the 1980s (Schuett-Hames et al. 1988a), and several debris flows widened the stream in the middle reaches of the basin as the result of the precipitation events and floods in 1989 and 1990 (DNR 1994). Current data regarding channel stability were not found and are greatly needed. Skookum Creek is tentatively rated "poor" for channel stability based upon past studies and very high landslide densities. Fine sediment levels have ranged from "good" to "fair" levels (7.0-12.3%) in the 1980s (data from Schuett-Hames et al. 1988a), probably due to the high energy, transport-type streams. However, DNR (1994) noted that spawning gravels were limited and armored (DNR 1994). More extensive and current data are needed to provide a rating for sediment quality in the Skookum Creek watershed.

LWD is lacking in the wider streams of the Skookum Creek watershed due to riparian harvest and dam break floods (DNR 1994). Areas with low counts of LWD include Skookum and Cavanaugh Creeks, and these are rated "poor" for instream levels of LWD. A few streams still have adequate levels of LWD including Hayden, Arlecho (now in a protected status by the Lummi Nation), upper Cavanaugh, and upper Orsino Creeks. Pool habitat has been filled in Skookum and Cavanaugh Creeks (DNR 1994). However, a wetland associated with North Tributary provides excellent overwintering habitat.

Edfro Creek has been rated as stable in four samples and as moderately unstable in one sample (Schuett-Hames et al. 1988a), resulting in a “good” rating for channel stability. However, fine sediment levels have been in the “fair” to “poor” range (data from Schuett-Hames et al. 1988a), and pool habitat has been filled with sediments (DNR 1994). Levels of LWD are low in Edfro Creek, and are rated “poor”. Landslide density is moderate at 1.6 events per year, leading to a “fair” rating for sediment quantity (Figure 27) (data from DNR 1994).

Streambed and Sediment Conditions in the Deer, Roaring, and Plumbago Creek Watersheds

Few streambed or sediment data were found for the Deer, Roaring, and Plumbago Creek watersheds. Road density is very high at 5.2 miles per square mile of watershed (Figure 26) (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). Also, these watersheds have a high percentage (24 to 31%) of slope instability (Figure 10) (Victor Johnson, Lummi Indian Nation using the DNR SHALSTAB model). This suggests that sediment impacts are highly likely. Identification and quantification of sediment impacts should be a priority for these streams.

Streambed and Sediment Conditions in the Howard Creek Watershed

Between 1940 and 1955, 69% of the Howard Creek watershed had been logged (Peak Northwest, Inc. 1986). In the next two decades the rate of failures greatly increased, stream bank debris slides enlarged, and there was an increase in stream bank instability and streambed aggradation. In unmanaged areas of Howard Creek, the failure rate ranged from 2.27 to 200 events/(acre X year) X 10,000; a high level that likely relates to its high percentage of slope instability (Figure 10). In timber-harvested areas, the rate ranged from 2.1 to 545 while roads accounted for a failure rate range of 2.1 to 400 landslides/(acre X year) X 10,000 (Peak Northwest, Inc. 1986). In the 1980s, most (48%) of the sediment delivered to streams came from translational/rotational slides. Debris flows and slides accounted for 57% of the landslides, but contributed 34% of the sediment to streams. Another 18% of delivered sediment came from sites of stream bank instability.

In a more recent inventory, nine additional shallow, rapid landslides have been recorded in the Howard Creek watershed, and all are shallow, rapid slides that deliver sediment to streams (Watts 1996). Eight of these have occurred since the 1986 Peak Northwest study. For these new slides, 67% of the slides are "natural" (associated with either mature vegetation or undisturbed land) with 33% associated with roads, and none associated with clearcuts. The increased sediment delivery from human-caused landslides results in a "poor" rating for sediment quantity in Howard Creek. Road density is also rated "poor" at 4.9 miles per square mile of watershed (Figure 26) (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process).

Howard Creek was rated as unstable in the 1980s (data from Schuett-Hames et al. 1988a). Excess sedimentation resulted in deposition near the mouth of Howard Creek raising the mouth 20 feet above the South Fork Nooksack River (Schuett-Hames et al. 1988b). These observations result in a tentative rating of "poor" for channel stability, although recent data are needed. Fine sediment levels are "fair" (15.2%) range (data from Schuett-Hames et al. 1988a), and these data should also be updated. It is important to note that many of the inner gorge slides have revegetated since these data were collected (John Thompson, Whatcom County, personal communication). In recent years, several slope stability, riparian revegetation, and road storm-proofing projects have occurred in the Howard Creek watershed, which should lead to improved habitat conditions in the future (Nooksack Recovery Team 2001).

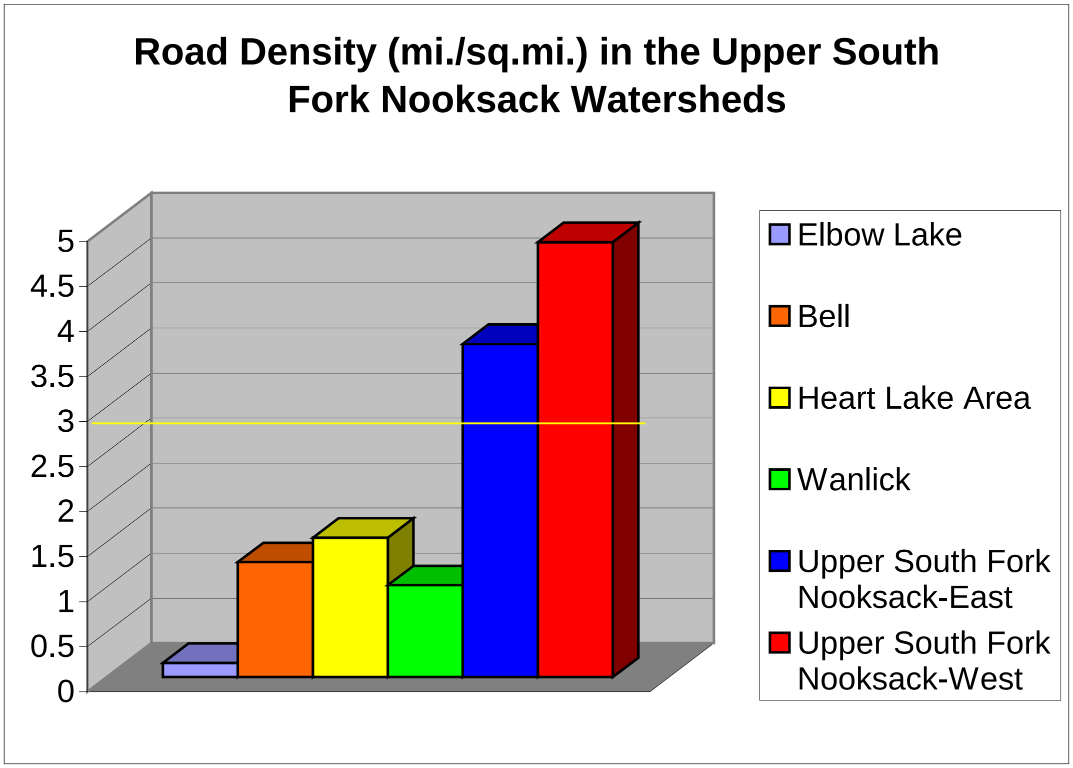
Streambed and Sediment Conditions in the Upper South Fork Nooksack Sub-Basin

Landslides account for an estimated 72% of the sediment delivered to streams in the upper South Fork Nooksack drainage with another 20% of delivered sediment from streambank erosion (Kirtland 1995). In the upper South Fork Nooksack Basin, 96 landslides have been documented in the Wanlick, Loomis, and Bell Creek watersheds, and the upper South Fork Nooksack River from the Wanlick confluence to the headwaters (Hale 1992). Many (42) of these landslides have natural causes due to soil type with 33 caused by human impacts, and 21 multi-causal sites. In another inventory, 444 landslides were identified from 1991 photographs in a larger area of the South Fork Nooksack drainage, including all streams from Howard Creek upstream, but not including Howard Creek (Kirtland 1995). While clearcuts were associated with 28% of these landslides, roads were related to 32% of the events (data from Kirtland 1995).

Initial road building and logging occurred in the 1940s, but substantial logging began in this area in 1964, increasing the number of slides and number of slide acres (Hale 1992). Kirtland (1995) also stated that both the number of landslides and the volume of produced sediment increased in the upper South Fork Nooksack drainage from 1940 through 1991. Debris block slides produced the largest volume of landslide-delivered sediment, but comprised less than 10% of events (Kirtland 1995). Debris avalanches accounted for 90% of the events, but only 25% of delivered sediment. Road densities are “poor” in the upper South Fork east and west areas (Figure 28) (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). The upper South Fork east area includes the watersheds between but not including, Howard and Wanlick Creeks, and the west area includes watersheds from but not including, Howard and Deer Creeks (Appendix 2). The other upper South Fork regions have “good” road density levels (Figure 28).

The extent of mass wasting volume in Bell Creek increased from 282,800 cubic yards in 1947 to 26 million cubic yards in 1991 with a total of 50 landslides (Hale 1992). The Wanlick watershed had 43 landslides, with a volume increase from 22,500 cubic yards in 1947 to 38 million cubic yards in 1991. The volume of mass wasting in the Loomis Creek watershed increased from zero in 1947 to 2.6 million cubic yards in 1991, while the upper South Fork (upstream of Wanlick confluence) increased in mass wasting volume from 15,000 in 1947 to 64,000 in 1991 (Hale 1992). The mass wasting acres increased from 3.7 in 1947 to 767.5 in 1991 for the entire upper South Fork region (Hale 1992). Because of the human-caused landslides, sediment quantity is rated “poor” in this region, but several habitat improvement projects such as road abandonment and storm-proofing have occurred, and these data should be updated. No other data regarding sedimentation and streambed issues, such as sediment quality, channel stability, LWD, and pools were found.

Figure 28. Road density in the upper South Fork Nooksack watersheds (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). Densities above the yellow line are considered to be "poor".



<u>Streambed and Sediment Conditions in the Mainstem Nooksack River Basin</u>

Streambed and Sediment Conditions in the Mainstem Nooksack River

Historically, much of the mainstem Nooksack River from the Forks downstream to the mouth was anastomosing (multiple channels separated by vegetated islands) and slow moving, with numerous side-channels and accumulations of LWD (Whatcom Dept. Public Works 1999; Collins and Sheikh in prep.). Wetlands were abundant in the Nooksack floodplain especially in the floodplain downstream of RM 24 (Collins and Sheikh in prep.). Presently, the reach between Deming and Everson is braided while the remainder of the mainstem is a single channel due to dikes, wetland and side-channel filling for agricultural development, and removal of LWD. The braiding is thought to be a response to increased sediment, perhaps from bank erosion caused by the loss of riparian vegetation (Collins and Sheikh in prep.). The reach between Everson and the confluence with the South Fork Nooksack River is unstable and has moved thousands of feet in a few decades (Whatcom Dept. Public Works 1999). It is not known to what extent this instability might be natural of a result of human influence. Because of this, no rating for streambed or channel stability is provided.

Several landslides are known along the mainstem Nooksack River from Deming to Nuggent's Corner (Roger Nichols, U.S. Forest Service, personal communication). At least one of these has appeared to contribute large quantities of fine silts and sands to the river, and this needs further quantification. No other sediment or stream channel data were found for this reach of the Nooksack River.

It is important to note that the mainstem Nooksack River is probably more impacted by floodplain loss, impervious surfaces, riparian loss, and impaired water quality, rather than sedimentation conditions, and these conditions are discussed in other chapters. However, sediment impacts are important in some of the tributaries to the Nooksack River, which are discussed below.

Streambed and Sediment Conditions in the Anderson and Smith Creek Watersheds

Major sediment and channel problems have been documented in Anderson Creek. Fine sediment levels have averaged 29.1%, 14.8%, and 18.6%, which are very high levels that can greatly reduce the survival of salmon eggs (Schuett-Hames and Schuett-Hames 1984a). In addition, Anderson Creek is rated "poor" for streambed stability due to 80% or more of the channel bottom (substrate) shifting during high flow events and a rating of unstable (data from Schuett-Hames and Schuett-Hames 1984a). Debris flows have been common in the watershed, resulting in a "poor" rating for sediment quantity. No ratings are given for pool and LWD conditions in Anderson Creek due to a lack of data.

Debris flows are common in Smith and MaCauley Creeks and deposit material on the creeks respective alluvial fans (Whatcom Dept. Public Works 1999). Road density is rated "fair" at 2.5 miles per square mile of watershed (Figure 18) (data from T. Coe, Nooksack Indian Tribe combining Zander 1997 road data with the GIS watersheds from the WRIA 1 Watershed Management Process). Deep (> 1 meter) pools were infrequently found in McCormick Creek, a tributary to Smith Creek, and pool habitat is rated "poor" for McCormick Creek (Table 5) (data from Nooksack Salmon Enhancement Association Intern monitoring program). However, LWD levels were adequate and are rated "good" for McCormick Creek. No other streambed or sediment data were found for the Smith Creek watershed.

Streambed and Sediment Conditions in the Kamm and Fishtrap Creek Watersheds

In Kamm Creek, infrequent gravel patches are found from the Northwood Road to Badger Road while downstream, the streambed consists of sand, silt, and muck (Whatcom Conservation District 1986), but these are likely natural conditions and the sediment load appears to be low (Steve Seymour, WDFW, personal communication). However, bank erosion and dredging have been common problems, and Kamm Creek has also been described as unstable (Schuett-Hames et al. 1988a), resulting in a "poor" rating for channel stability, pending more recent data. Fine sediments averaged 25.3% in Kamm Creek (Schuett-Hames et al. 1988a), resulting in a "poor" rating for sediment quality. Very few deep pools (>1 meter) were documented in Kamm Creek and two of its tributaries (01.0226 and 01.0222a) with only 2 deep pools in 8887 sampled meters channel length (data from Nooksack Salmon Enhancement Association Intern monitoring program). This results in a "poor" rating for pool habitat. The quantity of large wood (>50 cm diameter) was extremely low with only 6 pieces in the sampled 8887-meter channel length (data from Nooksack Salmon Enhancement Association Intern monitoring program).

Fishtrap Creek averaged 16.4% fine sediments in the 1980s (Schuett-Hames et al. 1988a), and was described as "moderately unstable" (Schuett-Hames and Schuett-Hames 1984a). These data result in a "fair" rating for sediment quality and channel stability, but the ratings are provisional until the data are updated. Data regarding sediment quantity, LWD levels, and pool habitat in Fishtrap Creek have not been found.

Streambed and Sediment Conditions in the Bertrand Creek Watershed

Serious bank cutting was documented in Bertrand Creek, and the stream averaged 19.1% fine sediment levels in the 1980s (Schuett-Hames and Schuett-Hames 1984a; Schuett-Hames et al. 1988a) leading to a "poor" rating for sediment quality. The streambed was rated as unstable ("poor") with 80% or more of the channel bottom (substrate) shifting during high flow events (Schuett-Hames and Schuett-Hames 1984a). These ratings are tentative until more recent data are available. No data were found for sediment quantity conditions.

The lowest reach and the upper reaches (above RM 6.5) of Bertrand Creek are rated "poor" for instream levels of LWD and quantity of deep pools (Table 5) (data from Nooksack Salmon Enhancement Association Intern monitoring program). However, the middle reaches have "fair" to "good" levels of LWD and "fair" deep pool habitat. In tributary 01.0208, no deep pools and few pieces of LWD were documented.

Table 5. Pool habitat and LWD in Bertrand, Kamm, and McCormick Creeks (data from Nooksack Salmon Enhancement Association Intern monitoring program).

Stream	# Pools as deep or deeper than 1 meter	Pooh Habitat Rating	# Pieces LWD/bank full width	LWD Rating
Bertrand Reach 1	2	Poor	0.26	Poor
Bertrand Reach 2	19	Fair	1.36	Fair
Bertrand Reach 3	21	Fair	1.28	Fair
Bertrand Reach 4	16	Fair	2.19	Good
Bertrand Reach 5	5	Poor	0.82	Poor
Bertrand Reach 6	4	Poor	0.25	Poor
Bertrand Reach 7	6	Poor	0.08	Poor
Bertrand Trib. (01.0208)	0	Poor	0.02	Poor
Bertrand Trib. (01.0208.5)	0	Poor	0.00	Poor
Kamm Reach 1	1	Poor	0.03	Poor
Kamm Reach 2	0	Poor	0.06	Poor
Kamm Reach 3	0	Poor	0.01	Poor
Kamm Reach 4	1	Poor	0.01	Poor
Kamm Reach 5	0	Poor	0.01	Poor
Kamm Trib. (01.0222.5)	0	Poor	0.07	Poor

Streambed and Sediment Conditions in the Tenmile Creek Watershed

In Tenmile Creek, dredging, agriculture, and to a lesser extent, road construction have contributed to erosion problems in the past (U.S.D.A. Soil Conservation Service 1993). However, no specific data were found to indicate that sediment quantity has been impaired. In the 1980s, fine sediment levels were exceptionally high at 24.7% (Schuett-Hames et al. 1988), and the quality of sediment was further impaired due to embeddedness (USDA Soil Conservation Service 1993), leading to a “poor” rating for sediment quality with a note that more recent data are needed.

Deer Creek, a tributary to Tenmile Creek, is also rated “poor” for sediment quality with average fine sediment percentages of 19.3% and 25.2% (Schuett-Hames et al. 1988a). In addition, Deer Creek was described as unstable (Schuett-Hames et al. 1988a) leading to a tentative rating of “poor” for channel stability until more recent data are provided. The preliminary data regarding instream levels of LWD in Tenmile and Deer Creeks suggest very low levels (7-13 pieces LWD per segment, with pieces per bank full width likely less than 1) (data from Nooksack Salmon Enhancement Association Intern monitoring program). A provisional “poor” rating for LWD is assigned to these two creeks based upon the initial data review.

Streambed and Sediment Conditions in the Silver Creek and Lummi River Watersheds

Not much information was found for the streams in the lower Nooksack sub-basin. The level of fine sediments was extremely high (21.6 to 31.8%) in Silver Creek as measured in 1987 at two sites (Schuett-Hames et al. 1988a). This results in a “poor” rating for sediment quality, but the rating is provisional until more recent data become available. The Lummi River is channelized (Whatcom Dept. Public Works 1999), and the late 1800s diversion of the Nooksack River from a primary exit into Lummi Bay to Bellingham Bay is a serious degradation to the Lummi River and Lummi Bay. The reduced flow through the Lummi River results in a loss of access for salmonid smolts to Lummi Bay, and greatly reduces sediment inputs to the Lummi River estuary (see estuarine chapter).

Riparian Conditions in the Nooksack Basin including the Lummi River

General Riparian Conditions Basin-Wide

A recent riparian assessment has been conducted for the Nooksack Basin focusing on shade and near-term LWD recruitment potential as they relate to land use classifications in riparian areas[1] (Coe 2001). In general, 50% of the entire Nooksack Basin riparian areas rated low for near-term LWD recruitment potential with the worst conditions in the mainstem Nooksack sub-basin. Moderate recruitment potential comprised 19% of the riparian areas while high recruitment potential accounted for 31% of the riparian areas. Most (76%) of the high rated (good) areas are in the North Fork and South Fork Nooksack sub-basins (Coe 2001).

Low near-term LWD recruitment potential was the most common classification in all land use categories except for U.S. Forest Service lands and National Park lands, which generally rated high (Coe 2001). The worst land use categories were agriculture and urban. In agricultural lands, 85% of the riparian areas were rated low for near-term LWD recruitment potential while riparian buffers in urban lands consisted of 77% low recruitment potential. Rural, rural forest, and commercial forestland use categories had 60%, 41%, and 37% low near-term LWD recruitment potential (Coe 2001). Shade hazard was highest (worst) in urban, agricultural, and rural lands. Specific ratings by location are discussed below.

Riparian Conditions along the Mainstem Nooksack River, Tributaries, and Lummi River

Riparian Conditions along the Nooksack and Lummi Rivers

Historic conditions have been described for the greater Nooksack River delta, which includes the Lummi River. Historically, the most common streamside tree was red alder followed by willow and Pacific crabapple, while Sitka spruce covered the greatest basal area (Collins and Sheikh in prep.). The lower Nooksack River riparian (RM 6 to 24) was dominated in basal area by Sitka spruce and black cottonwood, but red alder was the most frequently found tree (Collins and Sheikh in prep.). From river mile 24 to 37, the historic Nooksack River riparian forest consisted mostly of western redcedar by basal area and red alder by frequency (Collins and Sheikh in prep.).

[1] Near-term LWD recruitment potential and stream shading were estimated using 1:12,000 scale aerial photos from 1991 (federal ownership) and 1995 (state and private ownership). Riparian condition was classified in 100-foot-wide units beyond apparent channel migration zones along both right and left banks of salmonid-bearing and contiguous type 4 streams less than 20% gradient.

Extensive amounts of riparian lands have been converted to non-forest uses along the mainstem Nooksack River and tributaries. The Ferndale WAU includes the Lummi River and the mainstem Nooksack River from RM 12.5 to the mouth, and its riparian buffers are comprised of 81% non-forestland (Figure 29) (data from Lunetta et al. 1997, using classified Landsat Thematic Mapper imagery). The remaining riparian zones are either hardwoods or cleared forestland. The Lynden WAU consists of the mainstem Nooksack River from RM 12.5 to RM 29 and also includes Bertrand, Fishtrap, and Kamm Creeks. This WAU has also experienced a large conversion to non-forest riparian (90%) with the remaining buffers classified as hardwood or cleared forestland (Figure 29) (data from Lunetta et al. 1997).

The mainstem Nooksack sub-basin had the worst riparian conditions for both LWD recruitment potential and shade compared to the North, Middle, and South Fork Nooksack Rivers. Nearly all of the Nooksack River segments downstream of Everson were classified as low ("poor") for near-term LWD recruitment potential with a mix of moderate to low LWD recruitment potential between Everson and the Forks (Coe 2001). The only high rated ("good") riparian sections for near-term LWD recruitment potential in the lower Nooksack sub-basin were found in tributaries. Overall, the sub-basin was classified as low ("poor") in near-term recruitment potential for 76% of the riparian segments (Coe 2001). Shade levels were remarkably poor; 77% of tributary riparian areas fell short of target shade levels by over 40%, and most mainstem reaches had percent canopy cover in the 0 to 20% range (Coe 2001).

The extensive conversion of riparian land to non-forest land coupled with very low canopy cover and low LWD recruitment potential result in a "poor" rating for riparian conditions along the Nooksack and Lummi Rivers. These reaches provide important connectivity corridors for anadromous salmonids, and the riparian impacts along with the degradations to floodplain habitat (see Floodplain chapter) are considerable.

Silver, Schneider, and Tenmile Creek Riparian Conditions

The near-term LWD recruitment potential along the Silver Creek streams was a mix of classifications that were predominantly low ("poor") with a few segments of high and moderate (Coe 2001). The canopy cover (shade) is "poor" with mostly 0 to 20% canopy cover and 77% of riparian areas below target shade levels by over 40% (data from Coe 2001). The Silver Creek watershed is rated "poor" for overall riparian conditions.

Almost all of the analyzed segments along Schneider Creek were classified as having a low near-term LWD recruitment potential and shade conditions over 40% below target ("poor") with most segments in the 0 to 20% canopy cover range (Coe 2001). This watershed is rated "poor" for riparian conditions.

About 81% of the riparian response reaches along Tenmile Creek have been converted to non-forestlands, and 18% are hardwood or cleared forestland (Figure 29) (data from Lunetta et al. 1997). Nearly all of the analyzed reaches along Tenmile and Fourmile Creeks had "poor" canopy cover with most in the 0 to 20% range and well below target shade levels (data from Coe 2001). Deer Creek had "poor" stream shading all reaches below target shade levels by at least 10% and most below target by at least 40% (Coe 2001). These results match the sporadic estimates of canopy cover ranging from 0 to 36% along Tenmile Creek and 0 to 18% along Shuskan Creek with better canopy cover reported in Deer and Starry Creek, tributaries in the Tenmile Creek watershed (data from Nooksack Salmon Enhancement Association Intern Monitoring Program). Much of the original riparian vegetation along Tenmile Creek has been replaced with Reed canarygrass, which has contributed to flow problems (U.S. Dept. Agriculture Soil Conservation Service 1993).

Parts of Tenmile Creek had moderate LWD recruitment potential reaches mixed in with low rated sections while most of Fourmile Creek was dominated by low LWD recruitment potential (data from Coe 2001). Deer Creek was predominantly low in LWD recruitment potential, but with substantial reaches with moderate (25%) and high (15%) classifications. Because of the extensive conversion to non-forest riparian use, the sparse canopy cover, and predominantly low near-term LWD recruitment potential, this watershed is rated "poor" for riparian conditions.

Riparian Conditions along the Bertrand and Wiser Lake/Cougar Creek Watersheds

From the mouth to RM 8.1 of Bertrand Creek, there are low percentages of good (60% or more) canopy cover (Table 6), and some Japanese knotweed was noted in the lowest section (data from Nooksack Salmon Enhancement Association Intern Monitoring Program). Canopy cover greatly improves in the three miles of Bertrand Creek that are downstream of the Canadian border, and is also good along the unnamed tributary 01.0208. These data are consistent with the classifications from Coe (2001) who reported canopy cover from 0 to 40% dominating in the lower reaches with a few stretches of 40 to 70% canopy cover and two 70-90% reaches in the upper watershed, although most reaches were at least 40% below target and all were at least 10% below target shade levels. Mixed conditions of near-term LWD recruitment potential that were more predominantly low ("poor") were found along Bertrand Creek (data from Coe 2001). While most of the Bertrand watershed is rated "poor" for riparian conditions, its upper reaches are rated "good".

Near-term LWD recruitment potential was mostly (89%) low along the Wiser Lake/Cougar Creek watershed, and almost all reaches were in the 0 to 20% canopy cover range and at least 40% below target shade levels (data from Coe 2001). This watershed is rated "poor" for riparian conditions.

Table 6. Canopy conditions in Bertrand Creek (data from Nooksack Salmon Enhancement Association Intern Monitoring Program).

Stream Reach	Reach Length	Percent of Good Canopy Cover in Reach
Bertrand Creek 1 and 2	3.3 miles	16% good
Bertrand Creek 3	1.9 miles	30% good
Bertrand Creek 4	1.9 miles	3% good
Bertrand Creek 5	1.0 miles	29% good
Bertrand Creek 6	1.5 miles	76% good
Bertrand Creek 7	1.5 miles	100% good
Bertrand Trib 01.0208	0.1 miles	100% good
Bertrand Trib 01.0208.5	0.1 miles	100% good

Riparian Conditions along the Fishtrap, Kamm Creek, and Scott Ditch Watersheds

Almost all of the Fishtrap and Kamm Creek reaches and all of the Scott Ditch analyzed reaches were classified as low for near-term LWD recruitment potential (Coe 2001). Fishtrap Creek had predominantly "poor" shade conditions with most reaches ranging from 0 to 20% canopy cover (data from Coe 2001). A few sections were classified in the 70 to 90% range ("good"). Scott Ditch had high shade hazards throughout its analyzed reaches with most segments in the 0 to 20% canopy cover range. These classifications result in a "poor" rating for riparian conditions along Fishtrap Creek and Scott Ditch.

Coe (2001) reported that almost all of the reaches along Kamm Creek were at least 40% below target shade levels with most segments in the 0 to 20% canopy cover range. This concurs with an earlier assessment of the Kamm Creek riparian, which notes that less than 10% of its riparian lengths has adequate vegetation (Whatcom Conservation District 1990). Reed canarygrass has invaded the banks and streambed of Kamm Creek, and the resulting siltation has triggered periodic dredging. A very short stretch (the lowest 300 meters) of Kamm Creek has large deciduous trees with an estimated 98% canopy cover; however, invasive Japanese knotweed should be removed from this reach (data from Nooksack Salmon Enhancement Association Intern Monitoring Program). From this reach upstream to 8300 meters from the mouth, Kamm Creek riparian conditions are poor with an estimated canopy cover of predominantly 32-45%. Tributary 01.0222.5 has good canopy cover at 80% (data from Nooksack Salmon Enhancement Association Intern Monitoring Program). Overall, the Kamm Creek watershed is rated "poor" for riparian conditions.

Riparian Conditions along the Anderson and Smith Creek Watersheds

The Anderson Creek WAU includes Anderson Creek and the south side of the mainstem Nooksack River from RM 29 upstream to the Forks. The upper Nooksack valley, which would include the riparian near the mainstem Nooksack River in this area, was historically dominated by western redcedar by basal area and by red alder in number (Collins and Sheikh in prep.). The riparian buffers in this WAU are now predominantly (59%) hardwood or cleared forestland, but significant (29%) conversion to non-forestland has also occurred (Figure 29) (data from Lunetta et al. 1997). Early seral stage conifer comprises 10% of the WAU.

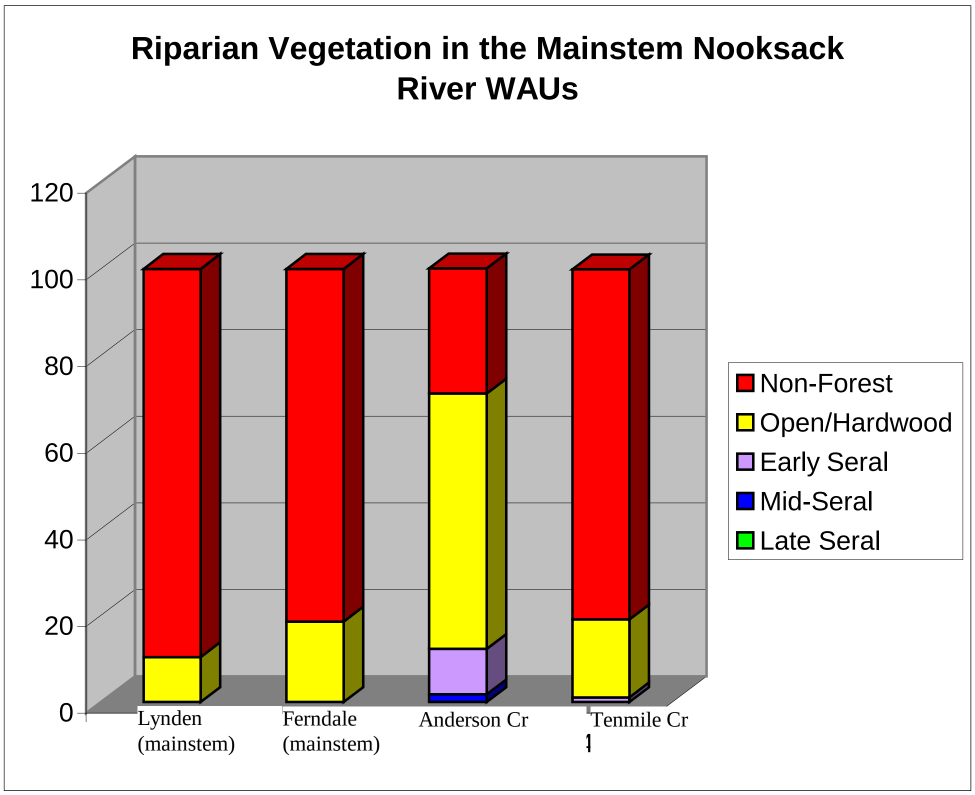
The shade hazard ratings for Anderson Creek ranged from moderate ("fair") to high ("poor"), and near-term LWD recruitment potential was mixed with mostly moderate classifications in the middle reaches and a mix of mostly low and high rated sections in the upper reaches (data from Coe 2001). The mixed conditions result in a rating of "fair" to "poor" for riparian conditions in the Anderson Creek watershed.

Smith Creek had mostly low but with some high ("good") near-term LWD recruitment potential, and shade conditions were predominantly "poor" (0 to 40% canopy cover) along lower McCauley and lower Smith Creeks with moderate (40 to 70%) canopy cover in the upper reaches of both streams (data from Coe 2001). This results in "poor" ratings in the lower reaches and "fair" ratings in the upper reaches for riparian conditions along Smith and McCauley Creeks.

Summary of Riparian Conditions in the Mainstem Nooksack Sub-Basin

The riparian composition data coupled with the shade and near-term LWD recruitment potential analyses provide strong evidence that the mainstem Nooksack River and most of its tributaries have extremely degraded riparian conditions and pose major habitat problems for all types of riparian functions, such as shade, bank erosion, LWD recruitment, and macroinvertebrate inputs. The mainstem Nooksack River serves as a 36.6-mile connection corridor between more extensively used habitat in the Forks and estuarine and nearshore environments needed by anadromous salmonids. The riparian impacts along with the floodplain degradations along the mainstem Nooksack River are likely major limiting factors for salmonid production in the Nooksack Basin. A few riparian reaches along upper Bertrand, Anderson, and Smith Creeks are slightly less degraded than other lower river tributaries.

Figure 29. Riparian vegetation in the WAUs of the mainstem Nooksack River and tributaries (data from Lunetta et al. 1997).



Riparian Conditions along the North Fork Nooksack River and Associated Tributaries

Introduction

In general riparian conditions in the North Fork Nooksack sub-basin are much better than in the mainstem Nooksack sub-basin with the best conditions from Glacier Creek upstream. Degradations in near-term LWD recruitment potential can be found along the lower North Fork Nooksack River mainstem and along Kendall, Hedrick, and upper Racehorse Creeks, which is discussed in detail below. When assessed for stream shade hazard conditions, 39% of the North

Fork Nooksack riparian areas had no shade hazard (mostly due to high elevation), 31% were rated a moderate shade hazard, 19% were a low hazard, 11% were rated a high hazard (data from Coe 2001). Shade conditions are a lesser concern in the North Fork Nooksack Basin due to the high elevations in the upper reaches and the lower water temperatures from glacial input. There is increased concern regarding shade conditions in the lower North Fork Nooksack sub-basin, especially in the tributaries that do not benefit from cool glacial water sources and have degraded riparian conditions.

Japanese knotweed is an additional impact to riparian health along the North Fork Nooksack River and perhaps other streams in WRIA 1. Japanese knotweed has been documented near Welcome Pass Road #3060, and likely exists elsewhere in the basin (Potash 2001 draft). Japanese knotweed is an invasive weed that forms thickets whose shade prevents the growth of native tree species. Of great concern is the subsequent potential impact on the macro-invertebrate population, a major food supply for juvenile salmonids (Potash 2001 draft). In the spring, native plants produce catkins and bud scales that support bacteria serving as food for macro-invertebrates (Sedall et al. 1974). Japanese knotweed does not sprout as early, resulting in a reduction of food and ecosystem function. It is important to survey the stream banks to determine which areas are and are not infested with Japanese knotweed, and then develop an eradication program.

Riparian Conditions along the North Fork Nooksack River

Historically, most of the riparian vegetation in the North Fork Nooksack lowlands consisted of western hemlock and Douglas fir with replacement of Douglas fir by Pacific silver fir at moderate elevations (U.S. Forest Service 1995a). In the lower reaches of the Forks (0 to 64 in the North Fork, 0 to 5 in the Middle Fork, and 0 to 21 in the South Fork) streamside tree composition estimated from historic General Land Office field notes indicate that red alder was not only the most frequently found tree, but also comprised the greatest basal area (data from Collins and Sheikh in prep.).

Currently, only about 10% of the riparian forests have been harvested along the North Fork Nooksack River from RM 55 to the headwaters, and in general, the riparian reaches in the upper North Fork Nooksack sub-basin (from Canyon Creek upstream) are considered to be "good" with the exception of the relatively short lengths exposed to timber harvest. Near-term LWD recruitment potential is predominantly high ("good") along the North Fork Nooksack River upstream from Canyon Creek while canopy cover is generally a mix of moderate (40 to 70%) and "poor" (0 to 40%) reaches (data from Coe 2001). The low canopy cover in the upper reaches might be due to the width of the active channel or due to the higher elevation vegetation that provides naturally low levels of cover. Low canopy cover is also located along the North Fork Nooksack River near Deadhorse Creek and between Glacier and Canyon Creeks (data from Coe 2001), and it is unknown to what extent the canopy conditions have been impacted by human causes. Because of the “good” LWD recruitment potential, these reaches of the North Fork Nooksack River are rated “good” for riparian conditions.

Further downstream, the Warnick WAU riparian buffers are mostly hardwood forests (Figure 30) (data from Lunetta et al. 1997; riparian function data synthesized in Coe (2001). This WAU includes the south side of the North Fork Nooksack mainstem from Glacier Creek downstream to RM 42 (near Kenney Creek) and Gallop, Cornell, Hedrick, and Racehorse Creeks. The Deming WAU includes the north side of the North Fork River from Canyon Creek downstream to the Forks. It also consists of the mainstem Nooksack River from the Forks to RM 29, as well as Smith and Maple Creeks. The riparian buffers in this WAU consist of 54% non-forestland and 40% hardwood or cleared forestland, and the conversion to non-forestland is a considerable impact.

Along the North Fork Nooksack River, near-term LWD recruitment potential from Aldrich Creek to the confluence with the South Fork Nooksack River is a mix of mostly low and moderate conditions with high to moderate reaches between Aldrich and Canyon Creeks (data from Coe 2001). Canopy cover is mostly low (0 to 40%) along the North Fork Nooksack River from Canyon Creek to the South Fork confluence (data from Coe 2001).

The most common classification for near-term LWD recruitment potential in the North Fork Nooksack sub-basin was high (“good”), and this occurred for 44% of the riparian area (Coe 2001). However, low (“poor”) recruitment potential accounted for 32% of the riparian segments, which is a considerable amount. Overall, riparian conditions are rated “poor” along the North Fork Nooksack River from Aldrich Creek downstream, “fair” from Aldrich Creek to Canyon Creek, and “good” upstream from Canyon Creek.

Riparian Conditions along the Tributaries to the Upper North Fork Nooksack River

Near-term LWD recruitment potential is generally high in all of the analyzed reaches of the tributaries to the upper North Fork Nooksack River except for Bagley Creek, for which low comprises about half of the area (data from Coe 2001). The “good” rated tributaries include lower Deadhorse, Wells, Anderson, Swamp, lower Ruth, and White Salmon Creeks. Canopy conditions vary from predominantly moderate (40 to 70% cover) to poor (0 to 40% cover) in these same tributaries, except for “good” cover along most of Anderson Creek and lower Bagley Creek (data from Coe 2001). Because the canopy cover is expected to be naturally low in the higher elevations, the riparian condition ratings are based upon the LWD recruitment potential in this area, resulting in "good" ratings in all tributaries except for Bagley, which is rated "fair".

Riparian Conditions along Glacier, Cornell, Gallop and Hedrick Creeks

High LWD recruitment potential predominant along Glacier, upper Cornell, and upper Gallop Creeks with low to moderate conditions along lower Cornell and lower Gallop Creeks (data from Coe 2001). This results in "good" riparian condition ratings for Glacier, upper Cornell, and upper Gallop Creeks, and "poor" ratings for lower Cornell and Gallop Creeks. Hedrick Creek has generally low near-term LWD recruitment potential, resulting in a "poor" rating for riparian conditions. Canopy cover is a mix of mostly "poor" (20 to 40%) to "fair" (40 to 70%) along these streams with the lower cover in the higher elevations (data from Coe 2001). The lower reaches of Gallop, Cornell, and West Cornell Creeks have also been identified as having high impacts to shade levels in a watershed analysis (Trillium Corporation 1996 draft), contributing to the "poor" ratings for the lower reaches of these streams.

Riparian Conditions along Canyon and Boulder Creeks and the Slide Mountain Streams

Canyon Creek is a North Fork Nooksack tributary, primarily within Forest Service boundaries. Its upper reaches are surrounded by mature conifer that includes old growth, and the lower eight miles have experienced riparian harvest and in the early 1990s, consisted of mostly of small trees (U.S. Forest Service 1995b). In a more recent analysis, Canyon Creek had mostly high near-term LWD recruitment potential and is rated "good" for riparian conditions, and lower Boulder Creek and most of Aldrich Creek had low recruitment potential and are rated "poor" (data from Coe 2001). The other Slide Mountain streams had a mix of high ("good") and low ("poor") near-term LWD recruitment potential. Canopy cover is highly variable in these streams, ranging from 0 to 90% (data from Coe 2001).

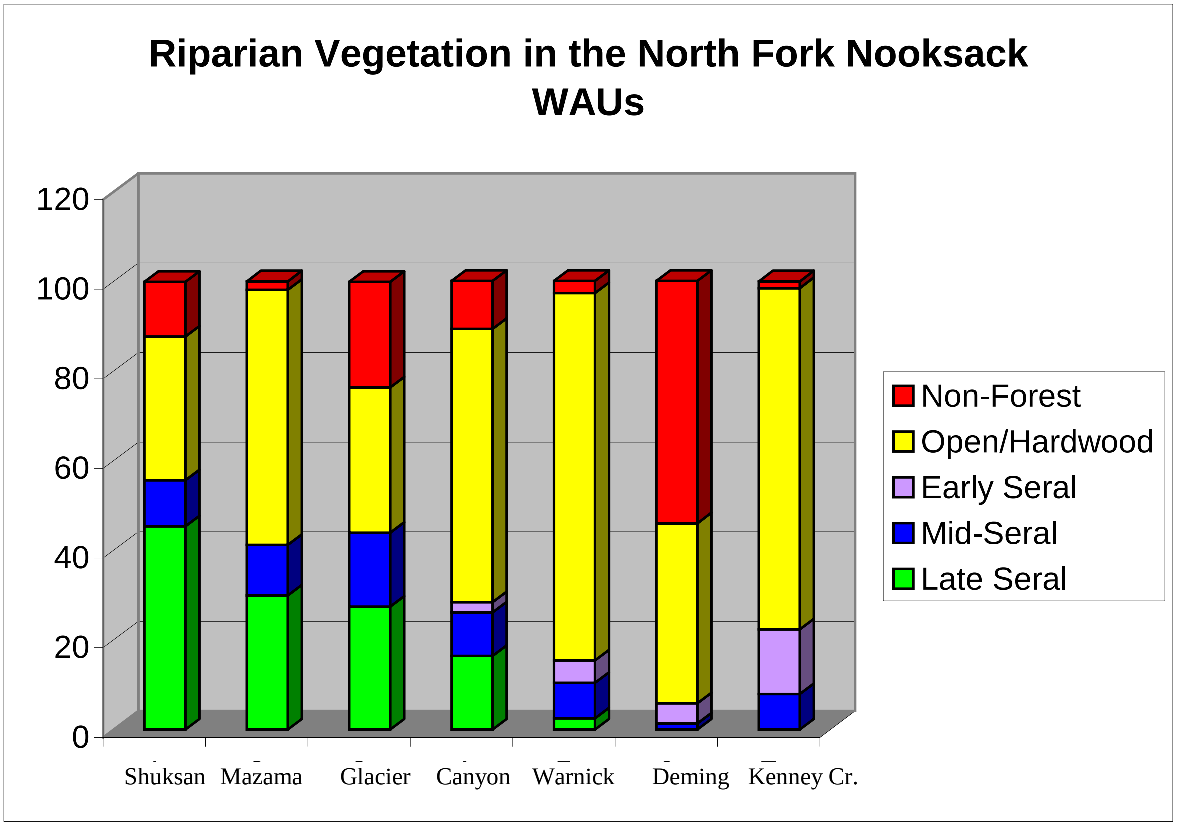
Riparian Conditions along the Tributaries to the Lower North Fork Nooksack River

Near-term LWD recruitment potential is generally low ("poor") along Kendall Creek and upper Racehorse Creek, resulting in "poor" ratings for riparian conditions in these areas. Shade conditions are impacted in these reaches as well with most sections ranging from 0 to 40% canopy cover (data from Coe 2001). Lower Racehorse Creek has high near-term LWD recruitment potential and moderate canopy cover (40 to 70%), resulting in a "good" rating for riparian conditions in the lower reaches.

Maple Creek has a mix of conditions for both near-term LWD recruitment potential and shade, while Coal Creek has mostly high (“good”) LWD recruitment potential with a mix of moderate (40 to 70% cover) to poor (0 to 40%) shade conditions (data from Coe 2001). Coal Creek is rated “fair” for riparian conditions and Maple Creek is rated “poor” to “good”, depending on site-specific reaches. Bells Creek has moderate to high LWD recruitment potential with mostly moderate (40 to 70%) canopy cover, resulting in a “fair” rating for riparian conditions.

The Kenney Creek WAU is small and includes Kenney Creek plus a short segment of the North Fork Nooksack River. Most (76%) of the riparian areas are hardwoods or cleared forestland with most of the remaining buffers consisting of young conifer (Figure 25) (data from Lunetta et al. 1997). Near-term LWD recruitment potential is low (“poor”) in the lower reaches, moderate (“fair”) in the middle reach, and high (“good”) in the upper reaches (data from Coe 2001). Canopy cover is mostly moderate at 40 to 70%, except in the lower reach, which is “good” at greater than 70%. Overall, Kenney Creek is rated “fair” for riparian conditions.

Figure 30. Riparian vegetation in the WAUs of the North Fork Nooksack River (data from Lunetta et al. 1997).



<u>Riparian Conditions in the Middle Fork Nooksack River Sub-Basin</u>

Overview of Riparian Conditions in the Middle Fork Nooksack River Sub-Basin

Historically, the streamside tree composition in the lower reaches of the Forks (RM 36 to 64 in the North Fork, 0 to 5 in the Middle Fork, and 0 to 21 in the South Fork) indicate that red alder was not only the most frequently found tree, but also covered the greatest basal area (data from Collins and Sheikh in prep. estimated from historic General Land Office field notes).

Riparian conditions in the Middle Fork Nooksack sub-basin are generally good. Near-term LWD recruitment potential is high (good) in 47% of the riparian areas in the Middle Fork Nooksack sub-basin, while 34% are rated low (poor) and 19% are moderate (Coe 2001). Shade conditions in the Middle Fork Nooksack sub-basin are rated as follows: 35% of the riparian buffers are above target shade levels (good); 31% are 10-40% below target; 18% are within 10%

of target; and 16% are over 40% below target (data from Coe 2001). The specific conditions for each stream are discussed below.

Riparian Conditions along the Middle Fork Nooksack River

The riparian areas along the mainstem Middle Fork Nooksack River have low recruitment potential along its lowest reaches with a mix of high and moderate potential from Porter upstream to Warm Creek. Upstream of Warm Creek, the LWD recruitment potential along the Middle Fork Nooksack mainstem is mostly low. Canopy cover is low in the lower reaches of the Middle Fork Nooksack River to Heislers Creek, then moderate (40 to 70%) to Warm Creek with lower ranges (20 to 70%) upstream of Warm Creek (data from Coe 2001). Currence (2000) cites data from Duck Creek Associates that list the percentage of large conifers in the riparian zones downstream of the dam as only 0.27%, while the percentage upstream of the dam is 19.6%. The riparian condition along the lower Middle Fork Nooksack River is rated "poor". These data together, result in a "poor" rating for riparian conditions in the lower reaches of the Middle Fork Nooksack River (to Porter Creek). From Porter Creek to Warm Creek, the rating is "good", and upstream of Warm Creek, the rating is "fair".

The uppermost WAU in the Middle Fork Nooksack Basin is the Marmot Ridge WAU. It includes the Middle Fork River upstream of RM 8 and associated tributaries. The riparian vegetation composition is shown in Figure 31. The non-forest reaches are likely glacial areas, and at least some of the hardwood/open category might consist of heather and sedge meadows in the higher elevations. However, most of the hardwood category consists of riparian vegetation impacted from commercial and to a lesser extent, Federal timber harvest (data from Coe 2001).

Riparian Conditions along Canyon Lake, Porter, and Heislers Creeks

Canyon Lake Creek is rated "fair" for riparian conditions because it has a mix of riparian classifications. While it has mostly high near-term LWD recruitment potential along its lower reaches, the recruitment potential is low in the upper reaches (data from Coe 2001). Canopy cover is predominantly low (0 to 40%).

Only the lowest reach of Porter Creek was assessed for LWD recruitment potential and canopy cover. That reach had a mix of conditions that result in a "fair" rating. Near-term LWD recruitment potential was mostly "good" (high) in the lower most reach and low further upstream while canopy cover was mostly moderate (40 to 70%) (data from Coe 2001).

Heislers Creek is also rated “fair” for riparian conditions due to a moderate near-term LWD recruitment potential and moderate canopy cover (data from Coe 2001).

Riparian Conditions along Clearwater and Rocky Creeks

The riparian buffers within the Clearwater Creek WAU consist of 31% late seral and 14% mid-seral stage conifer, and those areas are rated “good” for riparian conditions (Figure 31) (data from Lunetta et al. 1997). An additional 12% consists of early seral stage conifer and are rated “fair”. Near-term LWD recruitment potential is mostly “good” along Clearwater and Rocky Creeks, while canopy cover ranges from moderate (40 to 70%) in the lower reaches to poor (20 to 40%) in the upper reaches (data from Coe 2001). The sparse canopy cover in the higher elevations is thought to be natural conditions. Overall, the riparian conditions in the Clearwater Creek watershed are rated “good”.

Riparian Conditions in the Seymour, Sisters, Warm, Green, Rankin, and Ridley Watersheds

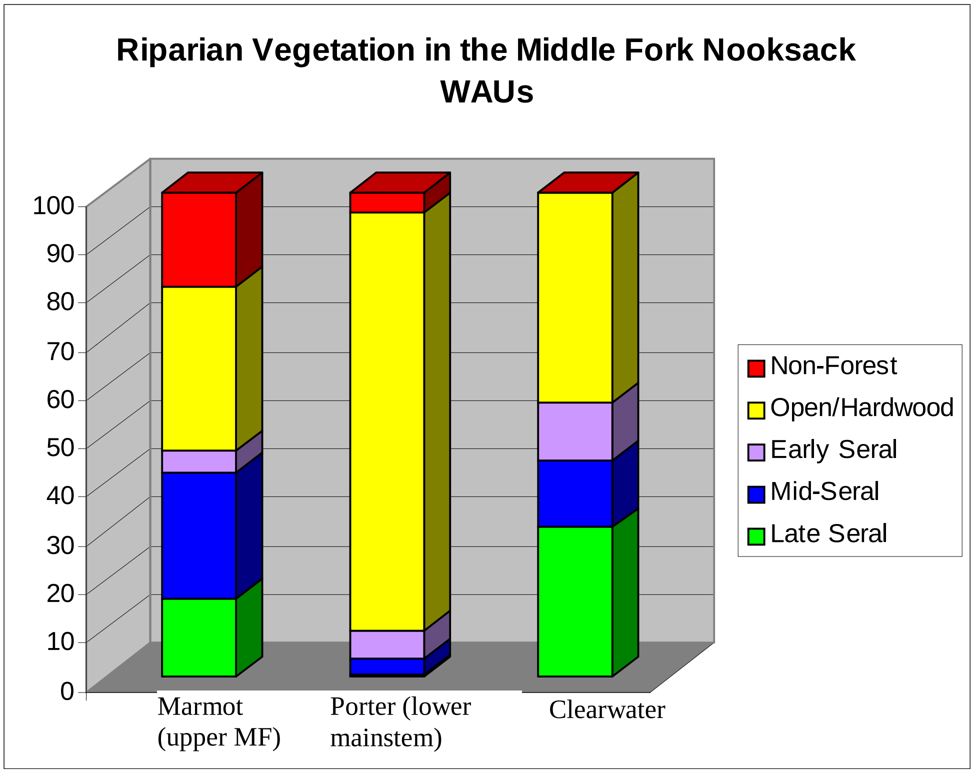
Seymour Creek has generally low canopy cover (0 to 40%), and mostly low near-term LWD recruitment potential, although some reaches have moderate and high recruitment potential, as well (data from Coe 2001). Overall, the watershed is rated “poor” for riparian conditions.

Sisters Creek has low near-term LWD recruitment potential in the lower reaches with mostly high classifications in the upper reaches (data from Coe 2001). Canopy cover is moderate (40 to 70%) in the lower reaches to poor (0 to 40 %) in the upper reaches. The mix of conditions makes this difficult to rate, and it is tentatively rated overall as “fair” because of the mixed conditions.

Warm and Green Creeks are rated “good” for riparian conditions. Warm Creek has mostly high LWD recruitment potential and good canopy cover while Green Creek has mostly good near-term LWD recruitment potential and moderate canopy cover (data from Coe 2001).

Ridley Creek is a high elevation stream with high near-term LWD recruitment potential and low canopy cover that is likely natural (data from Coe 2001). It is rated “good” for riparian conditions. In contrast, Rankin Creek has low LWD recruitment potential with mixed canopy conditions (data from Coe 2001), and is rated “poor” for riparian conditions. Rankin Creek also has a high road density, suggesting sedimentation impacts (see Sediment Chapter).

Figure 31. Riparian vegetation in the WAUs of the Middle Fork Nooksack River (data from Lunetta et al. 1997).



Riparian Conditions in the South Fork Nooksack River Sub-Basin

Overview of Riparian Conditions in the South Fork Nooksack River Sub-Basin

Historic streamside tree composition in the lower 21 miles of the South Fork Nooksack River was estimated from General Land Office field notes (Collins and Sheikh in prep.). These indicate that red alder was the most frequently found tree; a few large western redcedar dominated basal area, followed by red alder, bigleaf maple, and black cootonwood (data from Collins and Sheikh in prep.).

Historically, forests of western hemlock, Douglas fir, and western red cedar comprised the lower South Fork Nooksack drainage (Trillium Corporation 1996 draft). The valley floor was described as swampy, but field notes suggest that it supported large conifer. The valley was cleared beginning in the late 1800s, and now all of the original forests have been converted to agricultural land or regrowth (Trillium Corporation 1996 draft). Timber harvest on the surrounding slopes in the lower drainage began in the 1940s. Currently, the hillsides consist of second growth timber that ranges from 0 to 60 years in age.

In a recent riparian assessment, near-term LWD recruitment potential was rated low for 41% of the South Fork Nooksack sub-basin riparian areas, and was rated high and moderate for 39% and 20% of the sub-basin, respectively (Coe 2001). Warm water temperatures are a major problem in the South Fork Nooksack drainage (see the Water Quality Chapter), and less than adequate shade conditions contribute to this problem. About 38% of the South Fork sub-basin was rated as 10-40% below target shade levels (Coe 2001). Thirty two percent is rated as above target shade levels (high elevation areas) while 18% and 12% are rated as low (within 10% of target) and high (>40% below target) hazards, respectively.

Overall, the lower half of the South Fork Nooksack sub-basin has serious riparian degradations due to conversion of forestland to agricultural use and conversion of conifer riparian zones to hardwoods. These degradations contribute to other problems, such as degraded water quality, increased channel and bank instability, and reduced LWD levels resulting in decreased pool habitat and increased gravel transport.

Riparian Conditions along the South Fork Nooksack River

Most (89%) of the fish-bearing streams in the South Fork Nooksack drainage flow through agricultural land, and the primary type of riparian vegetation in these areas consist of young, sparse, deciduous trees (53%) (Trillium Corporation 1996 draft). Other classes of deciduous trees account for 35% of the Acme WAU in the lower South Fork Nooksack sub-basin, and 12% of the riparian areas in the lower drainage are mixed or conifer. Most of the South Fork Nooksack River to Hutchinson Creek is classified as low for near-term LWD recruitment potential (data from Coe 2001). Canopy cover is reported as most commonly ranging from 0 to 20% in this same reach. For these reasons, the riparian condition along the South Fork Nooksack River from RM 0 to Hutchinson Creek is rated “poor”.

For the South Fork Nooksack River from Hutchinson to Cavanaugh Creeks, the near-term LWD recruitment potential is mostly moderate (“fair”), and canopy cover generally ranges from 0 to 40% (data from Coe 2001), which is considered to be “poor”. Conditions for LWD recruitment potential and canopy cover are primarily “poor” from Cavanaugh to Plumbago Creeks, and are mixed from Plumbago to Howard Creeks (data from Coe 2001). Upstream of Howard Creek, the South Fork Nooksack River has predominantly high LWD recruitment potential and low canopy cover (data from Coe 2001). The sparse canopy cover is expected in higher elevation areas. Because of this, the upper South Fork Nooksack River is rated “good” for riparian conditions.

Riparian Conditions along Black Slough and Hutchinson Creeks

Black Slough is rated “poor” for riparian conditions because it has predominantly low near-term LWD recruitment potential (data from Coe 2001). Canopy cover is mixed, and includes sections that are “poor”, “fair”, and “good”.

Hutchinson Creek is rated “poor” to “fair” for riparian conditions. Historically, the riparian vegetation along the Hutchinson Creek streams consisted of dense mature western red cedar and Sitka spruce, but most were harvested from the mid-1930s through the early 1940s when no forest practice regulations existed to protect riparian trees (DNR 1998). Currently, the Hutchinson Creek watershed has predominantly (65%) hardwood or cleared forestland riparian buffers (Figure 32) (data from Lunetta et al. 1997), which are rated “poor” for riparian conditions. Known highly impacted areas include lower Hutchinson Creek, which is invaded by Japanese knotweed, and lower Nessett Creek, which has been cleared for agriculture (DNR 1998). The next largest component is early seral stage conifer, and those areas rate “fair”. The reasons for the degraded riparian conditions include past riparian harvest, recent selective harvest of large conifer, conversion to agriculture and residential development, and debris torrents (DNR 1998). The Hutchinson Creek watershed has mostly moderate canopy cover and mixed conditions for near-term LWD recruitment potential (data from Coe 2001). The watershed analysis team rated Hutchinson Creek as mostly low for near-term and long-term LWD recruitment potential (DNR 1998).

Riparian Conditions in the Skookum, Edfro, and Cavanaugh Creek Watersheds

The Skookum Creek WAU includes Skookum, Edfro, and Cavanaugh Creeks. The WAU has 50% hardwood or open forestland riparian buffers, and those areas rate “poor” for riparian conditions (Figure 32) (data from Lunetta et al. 1997). However, the region also has 29% mid-seral stage conifer, which rates “good”, and 21% early seral stage conifer, which rates “fair” for riparian conditions. Dense old growth is found along lower Skookum Creek, but scattered reaches of Skookum Creek upstream of RM 5.5 are impacted for shade and LWD recruitment (DNR 1994). Other known riparian impacts include Orsino Creek (a tributary to Skookum Creek) from RM 0.8-3, Arlecho Creek from RM 1.5-2, Cavanaugh Creek from RM 4-7, and Edfro Creek from RM 1.5-2.5 (DNR 1994).

Near-term LWD recruitment potential along the Skookum Creek watershed is primarily high except in the upper reaches, which are low (data from Coe 2001). Canopy cover is generally moderate to good, except along Fish Creek, where very low cover has been reported (data from Coe 2001).

Edfro Creek has mostly high near-term LWD recruitment potential and good canopy cover (greater than 70%) (data from Coe 2001). This results in a "good" rating for riparian conditions. Cavanaugh Creek has mostly good canopy cover and mixed conditions for near-term LWD recruitment potential (data from Coe 2001). Overall, the watershed is rated "fair" because of the LWD recruitment potential impacts.

Riparian Conditions in the Deer, Roaring, and Plumbago Watersheds

Near-term LWD recruitment potential is mostly high ("good") along Deer and Plumbago Creeks and mixed high and low along Roaring Creek (data from Coe 2001). Canopy cover is mostly poor along Plumbago and Roaring Creeks, and moderate to poor along Deer Creek (data from Coe 2001). Deer and Plumbago Creeks are rated "fair" for riparian conditions due to the mixed classifications while Roaring Creek is rated "poor".

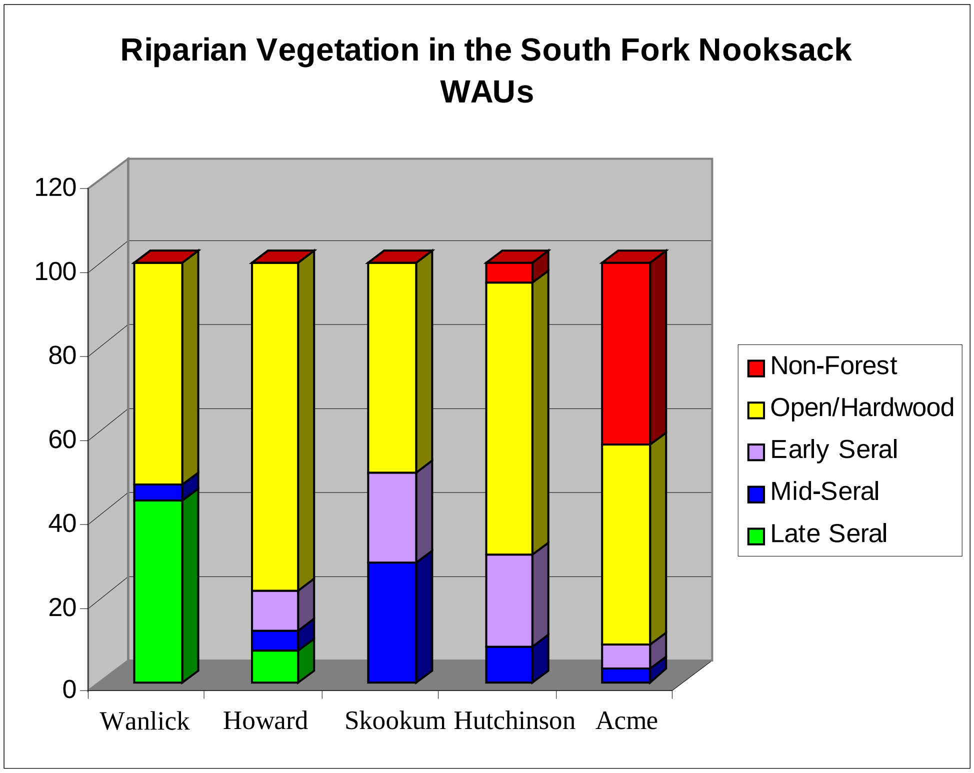
Riparian Conditions in the Howard Creek Watershed

The Howard WAU includes the South Fork Nooksack River from RM 13.5 to 34 and Howard and McGinnis Creeks. While 22% of the WAU has conifer riparian buffers, the remainder is hardwoods or open areas (Figure 32) (data from Lunetta et al. 1997). Near-term LWD recruitment potential is mostly high ("good") along Howard Creek and low ("poor") along McGinnis Creek (data from Coe 2001). Canopy cover is generally moderate (40 to 70%) along Howard Creek and low (0 to 40%) along McGinnis Creek (data from Coe 2001). Overall, riparian conditions are rated "fair" for Howard Creek and "poor" for McGinnis Creek.

Riparian Conditions in the Wanlick, Heart Lake, Bell, and Elbow Lake Watersheds

Near-term LWD recruitment potential is generally "good" for most of the Wanlick, Bell, and Elbow Lake watersheds, while it is low in the Heart Lake watershed (data from Coe 2001). This results in "good" ratings for all of these streams, except for the Heart Lake watershed, which is rated "poor". Canopy cover is moderate to poor in this area, which is expected due to the high elevation.

Figure 32. Riparian vegetation types in the WAUs of the South Fork Nooksack Sub-Basin (data from Lunetta et al. 1997).



Water Quality Conditions in the Nooksack Basin including the Lummi River

<u>General Water Quality Concerns within WRIA 1</u>

Water quality problems are abundant throughout WRIA 1 (Figure 33). At least 33 water bodies in the WRIA do not meet federal water quality standards (DOE 1995). In the forestlands, warm water temperatures are the greatest water quality concern caused by excess sedimentation and a loss of riparian vegetation (DOE 1995). With the new forest practice regulations, these conditions are expected to improve. However, restoration actions might be necessary to assure that riparian re-growth includes adequate conifer for future LWD recruitment. In the lowlands, water quality impacts are more varied and numerous. Problems with ammonia, phosphorous, dissolved oxygen, and fecal coliform levels are common, as well as violations in pH and water temperatures. Agriculture, failing septic systems, and urban storm water runoff are major causes (DOE 1995), particularly because Whatcom County has the highest concentration of dairy farms in Washington State (Dickes 1992). Industrial and commercial activities have increased heavy metals and toxins, especially in the estuarine environment (discussed in the Estuary/Nearshore Chapter). Some of these include phenol, mercury, phthalates, pentachlorophenol, metholphenol, benzoic acid, chlordane, copper, PAHs, lead, and zinc (DOE 1995). Twenty-seven toxic sites are in various cleanup phases in WRIA 1.

There is a close connection between surface and ground water within WRIA 1 (DOE 1995), and ground water contributes significantly to stream flow in the low flow months (Erickson et al. 1995). The largest unconfined aquifer in the region is the Abbotsford-Sumas Aquifer, which underlies the Fraser and Nooksack valleys (Scott and McDowell 1994). Elevated levels of pesticides, nitrates, and volatile organics (1,2 dichloropropane and ethylene dibromide) have been noted in the aquifer, likely the result of industrial, agricultural, and urban activities (DOE 1995). The amount of contamination from Canada is unknown. Overall, ground water contamination (solvents, degreasers, pesticides, and fumigants) has been documented at 25 sites and suspected at another 26 sites (DOE 1995). The annual mean nitrate concentration has been increasing in this major ground water source since 1990 (Hardy et al. 2001). Agriculture accounts for an estimated 85 to 88% of the total nitrate levels in the lower Nooksack Basin ground water supply, while residential and domestic sources supply 6 to 7% (Cox and Kahle 1999).

The known water quality conditions are described in detail below with as much specificity as possible. Conditions are compared to standards that are described in the Assessment Chapter, resulting in “good”, “fair”, or “poor” ratings or described as data gaps if insufficient information exists.

Figure 33. Sites of known water quality impairments within WRIA 1 are marked with red circles. These impairments include those that directly impact salmonids, such as water temperature, dissolved oxygen, sediment, ammonia, and nitrate (data from various sources described in text).

Water Quality Conditions in the Nooksack and Lummi Rivers and Tributaries

Compared to other rivers in the Puget Sound region, the Nooksack River near Ferndale has among the highest levels of nitrogen (including ammonia and nitrate), phosphorous, turbidity, and suspended solids (DOE 1995). From 1979 to 1991, turbidity has increased between 1 to 2% per year in the lower mainstem Nooksack River (Erickson et al. 1995). Increased turbidity can impair growth and rearing, and high levels of ammonia can be toxic to salmonids. Scott and McDowell (1994) report that the lower Nooksack River has elevated levels of metals and fecal coliform due to agriculture, highway runoff, surface mining, and solid waste disposal. Fecal coliform levels in the lower Nooksack River have increased in the last two decades, but this report does not fully discuss fecal coliform because its impacts pertain more to humans than to salmonids.

Three wastewater treatment plants have the following constituents in levels above detection limits in the effluent that is released into the Nooksack River. The Everson plant effluent has the following above detection limits: ammonia (0.26 mg/L), chloride (52 mg/L), aluminum (0.076 mg/L), boron (0.22 mg/L), iron (0.12 mg/L), manganese (0.01 mg/L), oil/grease (3 mg/L), surfactants (512 mg/L), di-n-butylphthalanate (35 ug/L; reporting limit=10 ug/L), and bis(2-ethylhexyl)phthalate (2.8 ug/L; reporting limit = 10 ug/L) (data from Bruce Barbour, Dept. Ecology). In addition, organochlorine pesticides and PCBs have been detected, such as delta-BHC (0.032 ug/L; reporting limit = 0.011 ug/L), gamma-BHC (0.061; reporting limit = 0.011 ug/L) (data from Bruce Barbour, WA Department of Ecology, personal communication).

In Lynden, the following parameters were reported as being at or above detection limit: arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, silver, and zinc (Bruce Barbour, WA Department of Ecology, personal communication). The only one of these that showed a "reasonable potential to pollute" was mercury. One sample was abnormally high (0.88 >ug/L), and further testing is underway to determine if this was an anomaly or not (Bruce Barbour, WA Department of Ecology, personal communication).

In Ferndale, chloride, arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, nickel, selenium, silver, and zinc are above detection limits (Bruce Barbour, Dept. of Ecology, personal communication). Their permit has limits (listed here as monthly average first, then daily maximum) for cadmium (2.54 ug/L and 5.10 ug/L), copper (11.08 ug/L and 22.23> ug/L), lead (2.29 ug/L and 4.6 ug/L), and mercury (0.24 ug/L and 0.48 ug/L) (data from Bruce Barbour, WA Department of Ecology, personal communication).

Warm water temperatures are also a problem in the mainstem Nooksack River. Water temperatures in the Nooksack River near North Cedarville (RM 30.9) were in the "poor" category (warmer than 16°C) for 54% of the samples in 1996 and 1997 (data from USGS 2001). Conditions worsen downstream near Everson (RM 23.2) where 65% of the samples are warmer than 16°C, and the peak temperature was 19°C. Near the mouth (RM 3.4), 60% of the samples were warmer than 16°C in July and August of 1996 and 1997 (data from USGS 2001). The entire length of the mainstem Nooksack River has a severely degraded riparian, which contributes to water quality exceedances. Shade levels were remarkably poor with no mainstem reaches achieving more than 40% of target shade levels, and most reaches had percent canopy cover in the 0 to 20% range (Coe 2001). Other causes include the surrounding agriculture, residential, and urban land use and the increased sedimentation from upstream sources. All of these water quality problems pose serious impacts to salmonids and result in a "poor" water quality rating for the mainstem Nooksack River.

In Schell Creek, a Lummi River tributary, water temperatures as high as 21°C in an upstream site and 30°C downstream with dissolved oxygen levels as low as 4.5 and 5.0mg/l (data from Nooksack Salmon Enhancement Association Intern monitoring program). These water temperatures and dissolved oxygen levels can be lethal to salmonids, and result in a "poor" water quality rating. The Lummi and the mainstem lower Nooksack Rivers are on the 303(d) List for fecal coliform levels (DOE 2000). However, high fecal coliform levels do not directly impact salmonids, and by themselves, would not result in a degraded rating in this report. Also, a Total Maximum Daily Load (TMDL) has been completed for the Nooksack River to address fecal coliform problems.

Several water quality problems have been documented in the Silver Creek watershed. Silver Creek, Anderson Ditch, two unnamed tributaries to Silver Creek (01.10146 and 01.0148), and Tennant Creek are on the 303(d) List for low dissolved oxygen and high fecal coliform levels. Six different sites in Silver Creek (RM 0.5, 1.7, 2.5, 3.0, 3.5, and 4.6) are 303(d) listed for low dissolved oxygen levels, and warm water temperatures have been documented at four of those sites (DOE 2000). In addition, levels of nitrogen (including ammonia) and phosphorous in Silver Creek are among the highest in the Puget Sound region (DOE 1995). These numerous problems result in a "poor" water quality rating for the Silver Creek watershed. The Silver Creek watershed has been impacted by livestock access and failing septic systems (Scott and McDowell 1994). The increased industrial, transportation, and commercial activities are also a concern. Tennant Lake is surrounded by a mix of industrial, agricultural, urban, and low-density rural development (Scott and McDowell 1994). The canopy cover (shade) in the Silver Creek watershed was mostly "poor" at 0 to 20% (data from Coe 2001).

The Tenmile Creek watershed also has water quality problems. High levels of ammonia, phosphates, and fecal coliform, as well as warm water temperatures and low dissolved oxygen levels have been documented. The suspected causes include surface runoff of livestock waste, livestock access, and loss of riparian vegetation (Scott and McDowell 1994; U.S. Dept. Agriculture Soil Conservation Service 1993). Water temperatures and dissolved oxygen levels were measured in Fourmile Creek, a tributary to Tenmile Creek, from 1995 to 2000 (data from Nooksack Salmon Enhancement Association Intern monitoring program), and the worst water quality impact was dissolved oxygen in an upstream site where about half of the samples were less than 6 mg/l. This results in a "poor" rating for water quality in Fourmile Creek. Water temperatures in the upper site were mostly "fair" or "good" with only one sample greater than 16^{o}C. In a downstream site, only 3 out of 118 samples were equal to or warmer than 16^{o}C with a peak temperature of 19.1^{o}C. However, measurements in 1996 and 1997 indicate that 41 to 45% of the July and August samples were in the "poor" category near RMs 3.8 and 4.9 (data from USGS 2001). Dissolved oxygen levels of less than 6 mg/l accounted for 4 out of 115 samples with a low of 4.8 mg/l (data from USGS 2001). Nearly all of the analyzed reaches along Tenmile and Fourmile Creeks had "poor" canopy cover with most in the 0 to 20% range (data from Coe 2001).

Deer Creek, another tributary to Tenmile Creek, is on the 303(d) List for ammonia, dissolved oxygen, pH, and fecal coliform (DOE 2000), and is rated "poor" for water quality. Deer Creek had mostly high shade hazard ratings with canopy cover in the 0 to 40% range (data from Coe 2001). Ground water quality in this area appears to be good. Pesticides are used only on a small area of land, and no pesticides were documented in the early 1990s in this watershed (U.S. Dept. Agriculture Soil Conservation Service 1993).

Severe water quality problems in the Bertrand and Fishtrap Creek watersheds have resulted in fish kills (Scott and McDowell 1994; Hardy et al. 2001 draft). Bertrand Creek is on the 303(d) List for low instream flows, low levels of dissolved oxygen, high levels of ammonia, and high levels of fecal coliform while Duffner Ditch is listed for low dissolved oxygen and high fecal coliform levels (DOE 2000). Potentially toxic levels of ammonia were measured in the Duffner Ditch drainage, and dissolved oxygen levels were exceptionally low at 3 mg/l (Dickes 1992). Warm water temperatures have been documented at two sites in Bertrand Creek, RMs 1.1 and 5.3 (USGS 2001). In the upper site, 38% of the samples were warmer than 16^{o}C ("poor"), while in the lower site, 69% of the samples were in the "poor" range with a peak temperature of 19.4^{o}C in 1996 (data from USGS 2001). The Bertrand Creek watershed has 41 dairy farms (Dickes 1992), which along with the loss of riparian vegetation and failing septic systems are the largest likely contributors to the water quality problems. Canopy cover ranges of 0 to 40% dominate the lower reaches with a few stretches of 40 to 70% canopy cover (Coe 2001). The upper Bertrand Creek watershed has two reaches with "good" canopy cover. Overall, the Bertrand Creek watershed is rated "poor" for water quality.

Summer water temperatures are very warm in Fishtrap Creek. At RM 1.7, 88% of the samples collected in 1996 and 1997 were warmer than 16^{o}C with a peak temperature of 20.7°C (data from USGS 2001). Near Lynden (at RM 5.3) 77% of July and August 1996 samples were warmer than 16°C with a peak temperature of 19.1°C. Fishtrap Creek had predominantly "poor" shade conditions with most reaches ranging from 0 to 20% canopy cover (data from Coe 2001). A few sections were classified as "good", in the 70 to 90% range. Scott Ditch had high shade hazards throughout its analyzed reaches with most segments in the 0 to 20% canopy cover range.

Fishtrap Creek is on the 303(d) List for low instream flows and high levels of fecal coliform (DOE 2000), and the elevated fecal coliform is a likely result of agriculture and failing septic systems (Scott and McDowell 1994); the watershed has 65 dairy farms in the drainage (Dickes 1992). In addition, pesticides have been detected in the stream sediments (Whatcom Conservation District 1988a; Scott and McDowell 1994) and in the surface waters (Erickson et al. 1995).

Several ditches are "tributaries" to Fishtrap Creek also with water quality problems that are transported downstream. The Bender Road Ditch, Benson Road Ditch, and the Depot Road Ditch are on the 303(d) List for low dissolved oxygen and high fecal coliform levels, while the Double Drain Ditch is listed for fecal coliform levels (DOE 2000). High levels of ammonia have also been measured in the Double Ditch drainage (Dickes 1992). For these reasons, the Fishtrap watershed is rated "poor" for water quality. A TMDL has been conducted on Fishtrap Creek to address the fecal coliform problem with the assumption that corrections of livestock waste issues will also address dissolved oxygen levels (Erickson et al. 1995).

Ground water in the Bertrand and Fishtrap watersheds is supplied by a shallow aquifer that has been contamination by the pesticides, ethylene dibromide and 1,2-dichloropropane (which are either currently restricted or not permitted). High levels of nitrogen have also been noted in ground water, and the suspected causes are dairy waste, fertilizer, and failing septic systems (Erickson et al. 1995). The shallow aquifer allows groundwater to contribute to stream flows in the summer, but also increases the risk of ground water contamination (Whatcom Conservation District 1988a). The seasonal high water table brings the water to less than 18" from the surface in 46% of the Fishtrap watershed. The ground water in this area is rated "poor" for water quality.

Kamm Creek and Mormon Ditch, a tributary to Kamm Creek, are on the 303(d) List for dissolved oxygen levels, fecal coliform, and pH (DOE 2000). While several sites in Kamm Creek are 303(d) listed for low dissolved oxygen levels, fecal coliform, and pH, including segments near RMs 0.6, 2.5, 3.1, 4.0 and 5.0, the reach near RM 4.5 is also listed for pH and fecal coliform. In the late 1980s, dissolved oxygen levels were very low (less than 5 mg/l) in June and November, and water temperatures were as high as 16°C with temperatures in a non-shaded site 5.2°C warmer than in a shaded site (Whatcom Conservation District 1990). In 1997, 80% of the water temperature samples near RM 0.8 were warmer than

16°C (“poor”), and the peak temperature was 20.4°C (data from USGS 2001). Recent riparian analysis indicates that all of the reaches along Kamm Creek have high shade hazards with most segments in the 0 to 20% canopy cover range (Coe 2001).

In the early 1980s, high ammonia and phosphorus levels were measured in Kamm Creek, and these conditions can promote an algal bloom that deplete dissolved oxygen levels (Whatcom Conservation District 1986). The elevated nitrogen levels existed throughout the year with higher levels during surface runoff of livestock waste. The phosphate levels were high in the summer and attributed to agriculture and failing septic systems (Whatcom Conservation District 1990). Also, low water temperatures might also be an impact to salmonids (Whatcom Conservation District 1986). The 303(d) listings and recent water temperature data indicate chronic water quality problems. For this reason, Kamm Creek and its tributaries are rated “poor” for water quality. In addition, pesticides, such as ethylene dibromide, have been measured in four wells, and believed to have leached from the crop fields into the shallow aquifer (Whatcom Conservation District 1990), resulting in a “poor” water quality rating for the ground water supply.

Anderson Creek is on the 303(d) List for fine sediments and warm water temperatures (DOE 2000). Recent measurements (1995 to 2000) of dissolved oxygen levels in Anderson Creek indicate that levels less than 8mg/l occurred three times out of a total of 118 samples with one measurement as low as 5.3 mg/l (data from Nooksack Salmon Enhancement Association Intern monitoring program). Water temperatures were a greater problem with 13 out of 118 samples warmer than 16^0C, and the peak documented water temperature was 19.1^0C. The shade hazard ratings for Anderson Creek ranged from moderate (“fair”) to high (“poor”) (data from Coe 2001). The sediment and water temperature problems result in a “poor” water quality rating for Anderson Creek.

Hoff Creek, a Smith Creek tributary, is on the 303(d) List for warm water temperatures, and is rated “poor” for water quality. Shade conditions were predominantly “poor” (0 to 40% canopy cover) along lower McCauley and lower Smith Creeks with moderate (40 to 70%) canopy cover in the upper reaches of both streams (data from Coe 2001).

<u>Water Quality Conditions in the North Fork Nooksack River and Tributaries</u>

The water temperatures in the upper mainstem North Fork River are cool due to the glacial influence, and much of the upper sub-basin is U.S. Forest Service land subjected to less human disturbance. Riparian vegetation conditions were rated “good” from Canyon Creek upstream in the North Fork Nooksack River (see the Riparian Chapter). Average daily maximum temperatures are 11.3°C at RM 63.2 near Glacier Creek (data from USGS 2001), resulting in a “good” water quality rating for the North Fork Nooksack River from Canyon Creek upstream. However, one water quality problem has been documented in this area. The North Fork Nooksack River near RM 60 is on the 303(d) List for fine sediment (DOE 2000), and a full discussion of sediment problems can be found in the Sediment Chapter of this report.

The lower North Fork Nooksack River (RM 41.6) is warmer with a peak high of 17^{o}C in 1996 with 39% of the July and August samples exceeding 16^{o}C, a "poor" water temperature level (data from USGS 2001). Further downstream (RM 37.2), the lower North Fork Nooksack River was in the "poor" category (warmer than 16^{o}C) for 59% of the samples in July and August of 1996. These temperatures result in a "poor" water quality rating for the lower North Fork Nooksack River.

However, the most significant water quality problems with respect to salmonids in the North Fork Nooksack sub-basin are the warm water temperatures in the tributaries. Lower Boulder, Gallop, Canyon, and Cornell Creeks are on the 303(d) List for warm water temperatures while Racehorse Creek is listed for fine sediment and warm water temperatures (DOE 2000). In Racehorse Creek, 95% of the samples exceeded 16^{o}C, 71% exceeded 20^{o}C, and there was a peak high of 24^{o}C (data from Neff 1992). The warmer water temperatures are approaching the lethal limit for some salmonids (Bell 1986). Lower Gallop, Cornell, and Canyon Creeks have been documented with high levels of riparian loss contributing to the increased water temperatures (Trillium Corporation 1996 draft; U.S. Forest Service 1995a and b). Water temperatures as high as 22.5^{o}C and 21^{o}C have been recorded in Cornell and Gallop Creeks, respectively (U.S. Forest Service 1995a). These temperature levels are known to impede the growth of salmon and are lethal to bull trout (Bell 1986; Knowles and Gumtow 1996). West Cornell Creek also has warm water temperature problems with 59% of the July and August samples greater than 16^{o}C and a peak high of 19^{o}C in 1996 (USGS 2001). Hedrick and Kenney Creeks had peak highs of 16.9^{o}C in 1996 (USGS 2001). All of these streams are rated "poor" for water quality.

Generally better water quality conditions are found in the upper reaches of streams whose lower reaches have been degraded by human activities. While lower Canyon Creek is 303(d) listed for warm water temperatures, conditions are better upstream. A reach of Canyon Creek downstream of the 3170 Bridge was monitored in the summer of 1997 for water temperature (U.S. Forest Service, unpublished data 2000) with all readings in the "good" range (less than 14^{o}C). Also, a spot check of water temperature in Thomson Creek (a Glacier Creek tributary) showed an August 1992 temperature of 9.9^{o}C (Neff 1992), and Thompson Creek has been recommended for use as a reference site because of its good habitat conditions (Erickson et al. 1995). In 1992, dissolved oxygen levels in Cornell, Gallop, Thompson, Canyon, Boulder, Maple, Coal, Bells, and Racehorse Creeks were in the "good" category (greater than 8mg/l) (data from Neff 1992).

Data were either lacking or older for many of the North Fork Nooksack tributaries, and this is a data need.

Water Quality Conditions in the Middle Fork Nooksack River and Tributaries

Water temperatures were measured in the mainstem Middle Fork Nooksack River near RM 4.8 in 1996 (USGS 2001), and most (80%) of the temperature samples were "good" (<14^{o}C) with 20% in the "fair" category. However in 1992, water temperatures in the mainstem Middle Fork near the mouth of Canyon Lake Creek peaked at 17.5^{o}C, and 44% of the samples were warmer than 16^{o}C, which is in the "poor" category (data from Neff 1992). Upstream of the Porter Creek confluence, the mainstem Middle Fork temperatures were cooler with a peak of 16.4^{o}C, which is still in the "poor" category (data from Neff 1992). Several reaches of high shade hazards exist along the lower mainstem Middle Fork Nooksack River (Coe 2001). Because of the temperature exceedances and the high shade hazards, the lower mainstem Middle Fork Nooksack River is tentatively rated "poor" for water quality.

In several of the Middle Fork Nooksack River tributaries, water temperature problems are likely because moderate shade hazard ratings have been documented along Canyon Lake, Heislers, Porter, and Sisters Creeks (Coe 2001). However, water temperature data exist for only one of the tributaries, Canyon Lake Creek. Canyon Lake Creek is on the 303 (d) List for warm water temperatures (DOE 2000) with a peak temperature of 22.5^{o}C and 92% of the 1992 samples warmer than 16^{o}C (Neff 1992). This results in a "poor" water quality rating. Dissolved oxygen levels in the mainstem Middle Fork Nooksack River and in Canyon Lake Creek were "good" (data from Neff 1992). Overall, few sites have been monitored for water temperature, turbidity, and dissolved oxygen levels, and these data are needed throughout most of the Middle Fork Nooksack sub-basin.

Water Quality Conditions in the South Fork Nooksack River and Tributaries

Warm water temperatures are a critical problem for salmonids in the South Fork Nooksack River, which is on the 303(d) List not only for warm water temperatures, but also for fine sediments and low instream flows (DOE 2000). In a reach near Van Zandt (RM 2), water temperatures were warmer than 16^{o}C 87% of the time in July and August of 1996 (USGS 2001). Of even greater concern is that 52% of the samples were warmer than 20^{o}C, and the peak temperature was 23.9^{o}C, which approaches the lethal limit for salmon and surpasses the lethal temperature for bull trout (Bell 1986; Knowles and Gumtow 1996). In 1992 near RM 19, the South Fork Nooksack River reached a peak water temperature of 24^{o}C and 94% of the samples were warmer than 16.3^{o}C (Neff 1992). These are the warmest documented water temperatures in the entire Nooksack Basin, and result in a "poor" water quality rating for the mainstem South Fork Nooksack River. The reach at RM 10 also rated "poor" due to water temperatures (DOE 2000).

Warm water temperatures are also a problem in the tributaries to the South Fork Nooksack River. Water temperature measured in Arlecho Creek, a Skookum Creek tributary, had a peak temperature of 17^{o}C with 15% of the samples warmer than 16^{o}C during July and August of 1996 (USGS 2001). These temperatures are in the "poor" category. A lower reach of Cavanaugh Creek and Roaring Creek are on the 303(d) list for warm water temperatures while Howard Creek is listed for fine sediments and warm water temperatures (DOE 2000), resulting in a "poor" water quality rating. The water temperature in Hutchinson Creek approached 16^{o}C three times in 1992 just reaching the "poor" category (Neff 1992). In the upper South Fork Nooksack sub-basin, lower Wanlick Creek was sampled for water temperature from July through September 1998; 17 days had peak temperatures above 16^{o}C, with a maximum temperature of 17.8^{o}C (U.S. Forest Service, unpublished data, 2001).

Many reaches of Black Slough had moderate to high shade hazards (Coe 2001), but no water temperature data were found for this stream. It is likely that water quality is impacted due to the riparian vegetation loss, and future water quality monitoring is recommended. Data regarding dissolved oxygen levels were not found for the South Fork Nooksack sub-basin.

Suspended sediments were high (180 NTUs) in the South Fork Nooksack River in 1992, as well as in Skookum Creek (26 NTUs) (Neff 1992). The suspended sediment levels in the mainstem South Fork levels are higher than in the glacially-fed Middle Fork Nooksack River (76 NTUs) (Neff 1992).

Water Quantity Conditions in the Nooksack Basin including the Lummi River

Basin-Wide Water Flow Issues

Inadequate stream flows for salmonid habitat is a pervasive problem throughout WRIA 1. Many of the lowland streams and tributaries flow through land converted to agricultural or urban use, which has resulted in channelization, water withdrawals, a loss of wetlands, and altered land cover (Figure 34). All of these modifications affect the quantity of water and water storage capabilities. In addition, the surface and ground water connection has implications for stream flow and water quality (DOE 1995).

More than thirty drainages and mainstem reaches are closed to further water allocations in WRIA 1 (Figure 35) (DOE 1995). The stream basin closures are based upon instream incremental methodology (IFIM) modeling results for the North Fork, South Fork, and Middle Fork Nooksack Rivers and for Kendall, Silver, Terrell, and Maple Creeks. For all other streams, the toe-width methodology was used (DOE 1995). These flows are required to support sufficient habitat, survival, and reproduction in the Nooksack River Basin.

The largest surface water users in WRIA 1 are power followed by municipal and industrial users, while agriculture is the largest user of ground water (Figure 36) (DOE 1995). The use of water for power is considered to be non-consumptive except in the by-pass reaches, but power generation often results in altered flow patterns that impact various life history stages of salmonids. The three largest non-power surface water users are 1) the City of Bellingham, which has rights to withdraw 56,250 (gallons per minute) gpm from the Middle Fork Nooksack River, 2) the Cherry Point industry, which obtains water from Whatcom County PUD #1 (two rights for 22, 500 and 12,600 gpm), and 3) the City of Lynden with a right of 5,300 gpm from the Nooksack River (DOE 1995).

Figure 34. Map of land cover vegetation ratings for WRIA 1. Ratings are based on a WAU scale. "Good" areas are green, "poor" areas are salmon colored, and yellow areas denote regions lacking appropriate data.

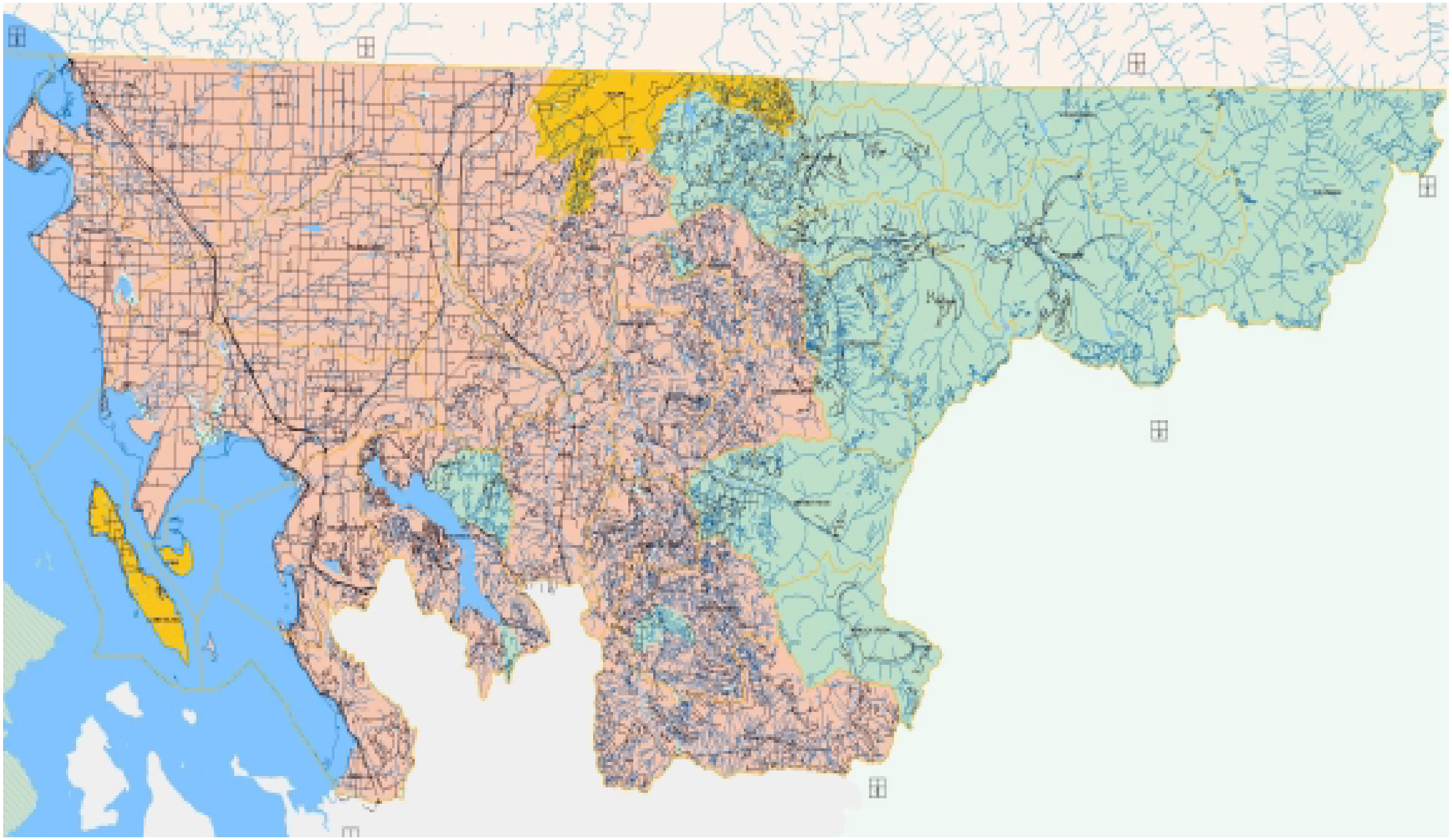
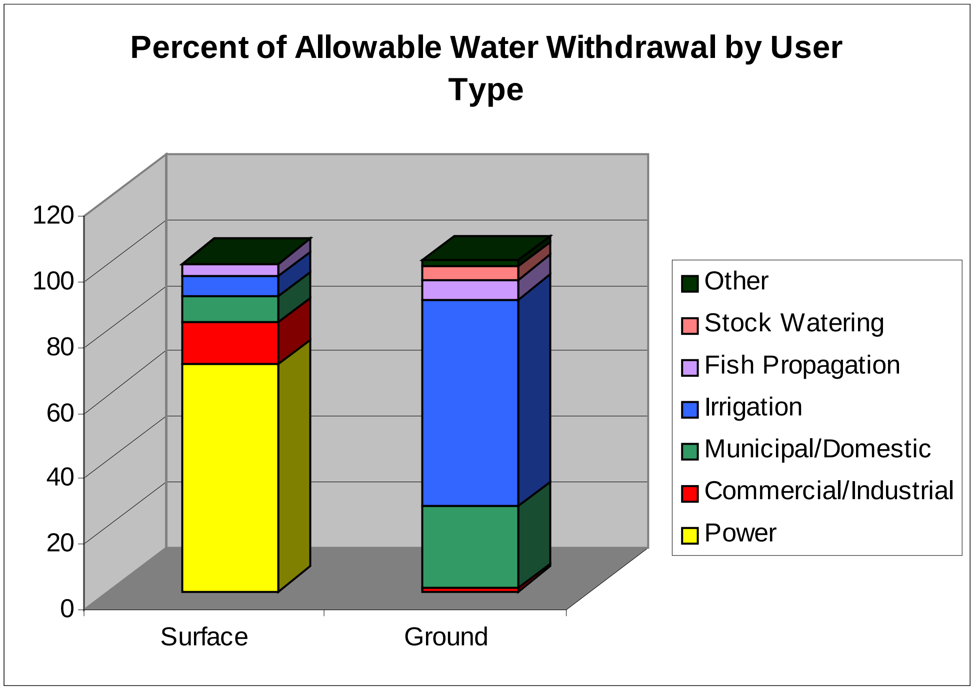


Figure 35. Streams outlined in red denote waters that are closed to further water allocations (data from DOE 1995).

Figure 36. Water use in WRIA 1 by user type based upon instantaneous quantity of water allowed for withdrawal (data from DOE 1995).



Water Quantity Conditions in the Lummi River, Mainstem Nooksack River, and Tributaries Watersheds

The average annual rainfall in the lower Nooksack Basin ranges from 35 to 45", with 70% falling between the months of October through March (U.S. Dept. Agriculture Soil Conservation Service 1993). This results in low stream flows in the summer months, especially in the tributaries. These flows are worsened by the reduction in wetlands, mature conifer, and channel complexity that would normally allow some water storage and recharge. In addition, both surface and ground water withdrawals are numerous and further impact low stream flow conditions. Ground water withdrawals are considered to be degradations to salmonids because the shallow aquifer in the region contributes significant water to streams in the summer months (Erickson et al. 1995). The extent of these impacts is discussed below.

Many of the streams in the Nooksack Basin are closed to further water allocations, at least during the summer and early fall (Figure 35). Silver Creek is closed to further water allocations during the low flow months (DOE 1995) with numerous ground and surface water rights in the upper reaches (Figure 37). Wiser Lake, Tenmile, and Deer Creeks also have water allocation closures (DOE 1995) with many ground water rights and a lesser quantity of surface water rights (Figure 37). Fishtrap, Bertrand, and Kamm Creeks are also closed for further water allocations (Figure 35) (DOE 1995), and Bertrand and Fishtrap

Creeks are on the 303(d) List for low instream flows (DOE 2000). This area has a very dense quantity of surface and ground water rights primarily for agricultural purposes (Figure 37). In this region, irrigation has increased 380% from the late 1950s to the mid-1980s (Whatcom Conservation District 1986), and Tenmile Creek has had 87.5 cfs appropriated with a minimum base flow of 5 cfs (U.S. Dept. Agriculture Soil Conservation Service 1993). Historically, water storage occurred in the numerous wetlands in this area (U.S. Dept. Agriculture Soil Conservation Service 1993). However, drainage and stream channelization has been extensive, particularly in Bertrand, Fishtrap and Kamm Creeks, and this has reduced water storage capacity (Whatcom Conservation District 1988a). Winter high flow impacts have likely increased due to the ditching and channel straightening that speeds water flow.

Smith and Anderson Creeks are closed during the low flow months to further water allocations (Figure 35) (DOE 1995). A few scattered water rights surround Anderson Creek, but are abundant around Smith Creek (Figure 37) (DOE 1995).

The flow through the Lummi River has been severely altered. Historically, much of the Nooksack River flowed through the Lummi River to empty into Lummi Bay (People for Puget Sound 1997). However, in the late 1880s, a diversion was constructed to permanently reroute the Nooksack River to empty into Bellingham Bay. Currently, the Lummi River serves as an overflow channel for the Nooksack River during high flows.

High water flows can also impact salmonids, and those impacts are worsened by land cover changes, ditching, channelization, and bank hardening (ditching, channelization, and bank hardening impacts are discussed in the Floodplain section). In a conifer forest, 24 to 35% of the precipitation is temporarily captured by the mature vegetation (Dingman 1994). The extensive removal of trees or change in age and type of trees can increase the magnitude of high flow events and route water more rapidly to channels. Historically, the valleybottom forest of the lower Nooksack River was mostly covered with western redcedar by area and red alder by frequency (Collins and Sheikh in prep.). The upper mainstem forest had even greater quantities of western redcedar, along with red alder and Douglas fir with its basal area still dominated by western redcedar.

Extensive changes in land cover have occurred. The land cover vegetation along the lowest reaches of the Nooksack River (the Ferndale WAU, which includes the Lummi River and the mainstem Nooksack River from Ferndale to the mouth) has nearly no mature conifer (Figure 38) (data from Lunetta et al. 1997). Most (65%) of the land cover consists of agricultural or urban uses with much (30%) of the remaining land cover classified as hardwood, brush, or cleared forest land. The conversion to non-forest land results in a “poor” rating for hydrologic maturity.

Similar land cover conditions exist throughout the Nooksack Basin downstream of the Forks. The Tenmile Creek WAU has nearly no mature conifers, and the predominate land cover type is non-forest (80%), resulting in a “poor” rating for hydrologic maturity (Figure 38). Much of the original vegetation along Tenmile Creek has been replaced with Reed canarygrass, which has invaded the streambed and contributes to flow problems (U.S. Dept. Agriculture Soil Conservation Service 1993).

The Lynden WAU includes the mainstem Nooksack River from RM 12.5 to 29 and Bertrand, Fishtrap, and Kamm Creeks. The land cover is 90% non-forest, resulting in a “poor” rating for hydrologic maturity. The Anderson Creek WAU is also rated “poor” for hydrologic maturity with 15% mature conifer, 15% conversion to non-forest, 45% hardwoods, brush, or cleared forestland, and 25% young conifer (Figure 38) (data from Lunetta et al. 1997).

Impervious surfaces can also impact salmonids by increasing the rate of water delivery to streams. However, most of this sub-basin rates “good” (less than 3%) for impervious surfaces with “fair” (3-10%) ratings for Wiser Lake, Deer Creek, and Scott Ditch watersheds where more urbanization has occurred (data from Whatcom Conservation District maps, unpublished data, 2000). “Good” impervious surfaces ratings are assigned to the Tenmile, Fourmile, Bertrand, Fishtrap, Kamm, and Anderson Creek watersheds because most of the land cover conversion has been to agriculture rather than urbanization (data from Whatcom Conservation District maps, unpublished data, 2000). The north Bellingham Bay shoreline is discussed in the estuary section and impervious surface ratings for this area is not included here.

Figure 37. Draft water right applications, permits, and certificates. Surface water rights are marked with a triangle and ground rights are denoted with a circle (Figure from DOE 1995).

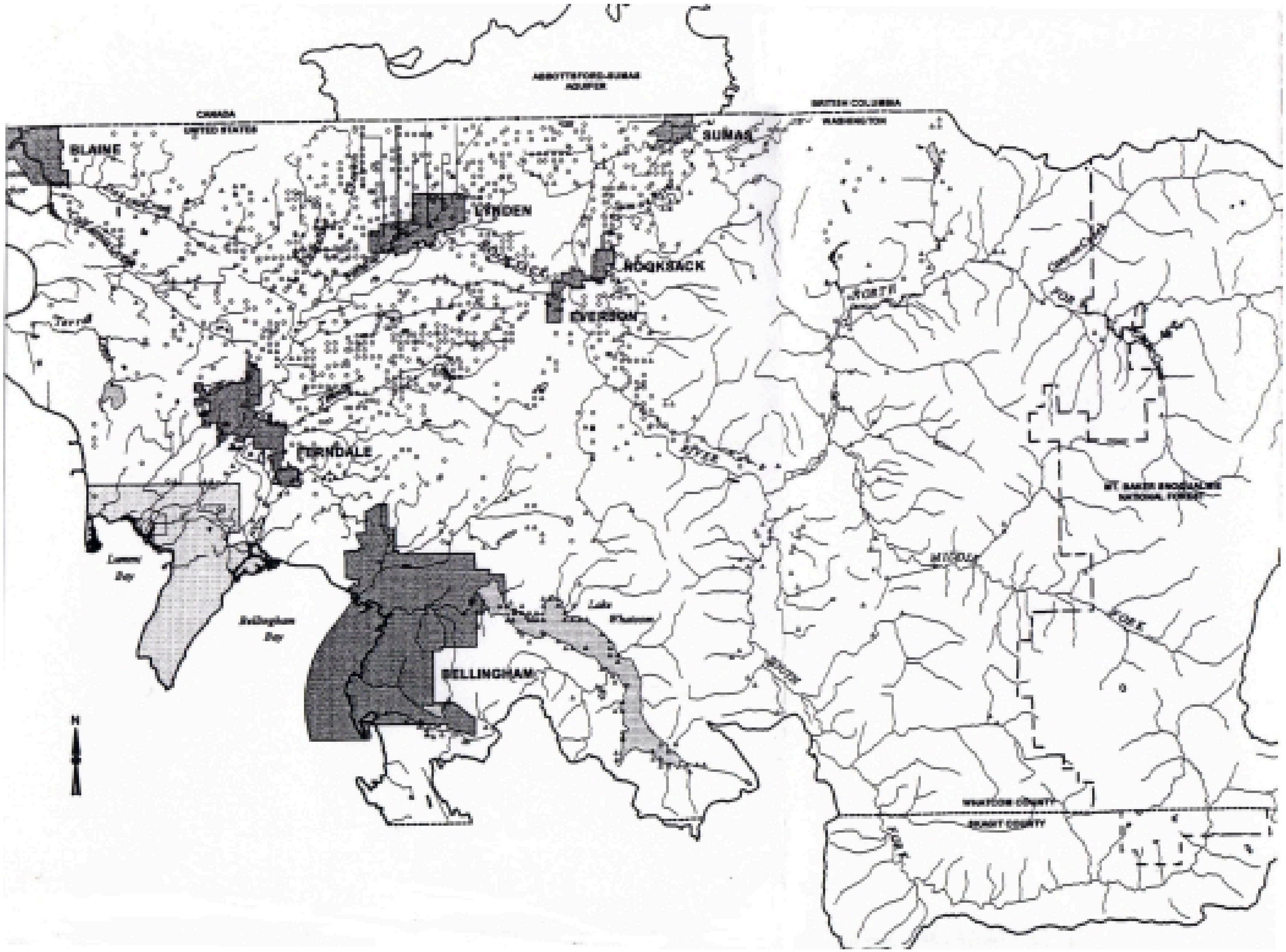
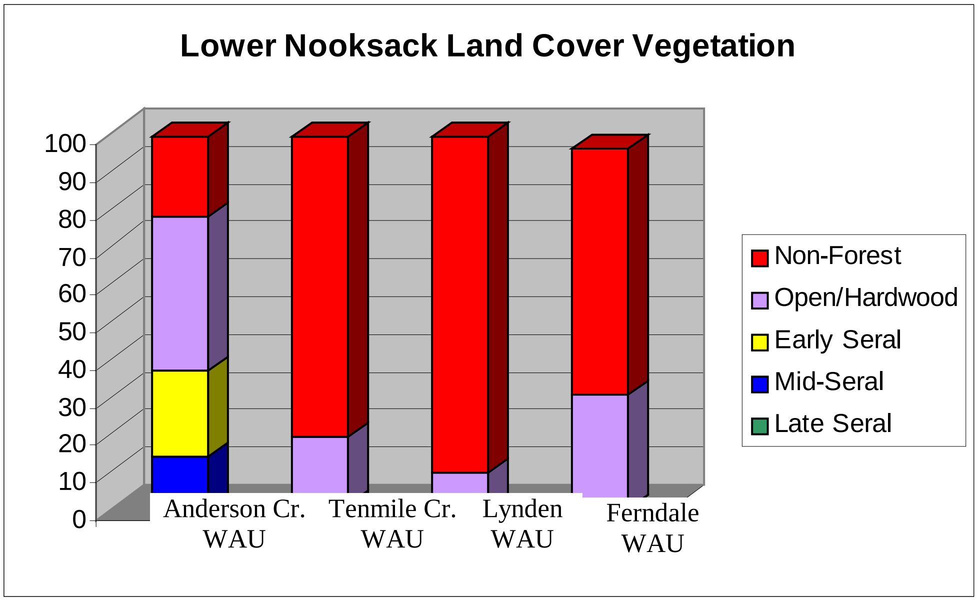


Figure 38. Land cover vegetation in the WAUs of the mainstem Nooksack sub-basin (data from Lunetta et al. 1997).



<u>Water Quantity Conditions in the North Fork Nooksack River and Tributaries</u>

Because of glacial melt, the mainstem North Fork Nooksack River typically has its average peak flow in early summer followed by good flows throughout late summer and early fall. Lower flows exist in the winter when cold temperatures prevent glacial melt (DOE 1995). The mainstem generally responds to large flood events, while the tributaries are more sensitive to smaller storms and disturbances (U.S. Forest Service 1995a). Rain-on-snow events are common from late October through January, and they trigger debris torrents in tributary watersheds, especially in those disturbed by timber harvest and roads. Most of the clearcuts and roading has occurred in the privately owned lands. Because of the timber harvest and road construction on steep slopes and associated high sediment loads (see Sediment section), high flow events that trigger channel changes are a major concern for salmonids that spawn in the mainstem North Fork Nooksack River.

The extent of the impacts varies with location. In the upper Nooksack sub-basin (upstream of the confluence with Canyon Creek), 17% of the land contains 16,000 acres of clear-cut and 900 acres of roads and much of this is on the private lands in the lower portion of this sub-basin (U.S. Forest Service 1995a). In examining flow trend data, no trends were noted over time for frequency or magnitude of peak flows from 1937 through 1991 in the upper North Fork Nooksack River (U.S. Forest Service 1995a). The upper North Fork Nooksack sub-basin has naturally limited water storage capabilities and high runoff rates due to the steep landforms, porous soils, and large areas of non-forested land (bare rock and snow and ice fields). Because of this, clear water tributaries and groundwater fed side-channels provide important refuge habitat for salmonids in the North Fork Nooksack sub-basin.

The Glacier, Mazama, and Shuksan WAUs contain the uppermost reaches of the North Fork Nooksack River. These WAUs consist of 56%, 56%, and 50% mature conifer, respectively with naturally low conifer levels due to glacial and alpine meadow areas in the upper elevations (Figure 39) (data from Lunetta et al. 1997). Because of the relatively natural conditions, these areas are rated “good” for hydrologic maturity. Glacier Creek is very sensitive to rain-on-snow events due to its elevation, resulting in landslides that block channels, causing debris torrents or dam break floods in confined channels (U.S. Forest Service 1995a).

Further downstream, more impacts to the land cover are evident. In the Canyon Creek WAU, the lower valley was clear-cut from 1950 to 1990, and current conditions are unknown and not rated, but are likely not “good”. Upper Canyon Creek is rated “good” as it consists of 83% mature vegetation of mostly silver fir and either western or mountain hemlock that is greater than 200 years old (U.S. Forest Service 1995b).

While overall the Warnick WAU consists of 50% mature conifer (Figure 39), within the WAU the individual watershed conditions vary. Whalen Creek is the only watershed within the Warnick WAU that rates “good” for hydrologic maturity with 69% mature conifer land cover (Figure 40) (data from DNR 1995). “Poor” ratings are given to West Slide, Aldrich, Big Slide, Wildcat, Hedrick, West Cornell, Cornell, and Gallop Creeks (data from DNR 1995). The land cover vegetation in the Kenney Creek WAU also rates “poor” for hydrologic maturity with 31% mature conifer (data from Lunetta et al. 1997).

Historically, the forest in the lower North Fork Nooksack valley was comprised mostly of western redcedar by area and red alder by frequency (Collins and Shiekh in prep.). Currently, the land cover vegetation in lowest portion of the North Fork Nooksack watershed (including part of the upper mainstem Nooksack River) has been significantly converted to other uses with 15% converted to non-forest uses and 45% of the historical conifer forest converted to hardwoods or cleared forestland (Figure 39) (data from Lunetta et al. 1997). Only 15% of the current land cover is hydrologically mature (consists of mature conifer). This results in a “poor” rating for hydrologic maturity.

Impervious surfaces are rated "good" (less than 3%) for all watersheds within the North Fork Nooksack River except for Boyd Creek, which is rated "fair" (percent impervious surfaces are 3.07) (data from Whatcom Conservation District maps, unpublished data, 2000).

There are low flow concerns, as well, in the North Fork Nooksack sub-basin. Many of the streams within the North Fork Nooksack sub-basin are closed to further water allocations (Figure 35). Year-round closures exist for White Salmon, Kendall, and Bell Creeks, while partial-year closures include the North Fork Nooksack mainstem River and Canyon, Thompson, Gallop, Cornell, Maple, and Racehorse Creeks (Figure 35) (DOE 1995). Numerous surface water rights exist for Maple Creek, while several ground water rights are located along Kendall Creek (Figure 37). A few scattered water rights are noted for the lower reaches of other tributaries to the North Fork Nooksack River (DOE 1995).

Figure 39. Land cover vegetation in the North Fork Nooksack WAUs (data from Lunetta et al. 1997).

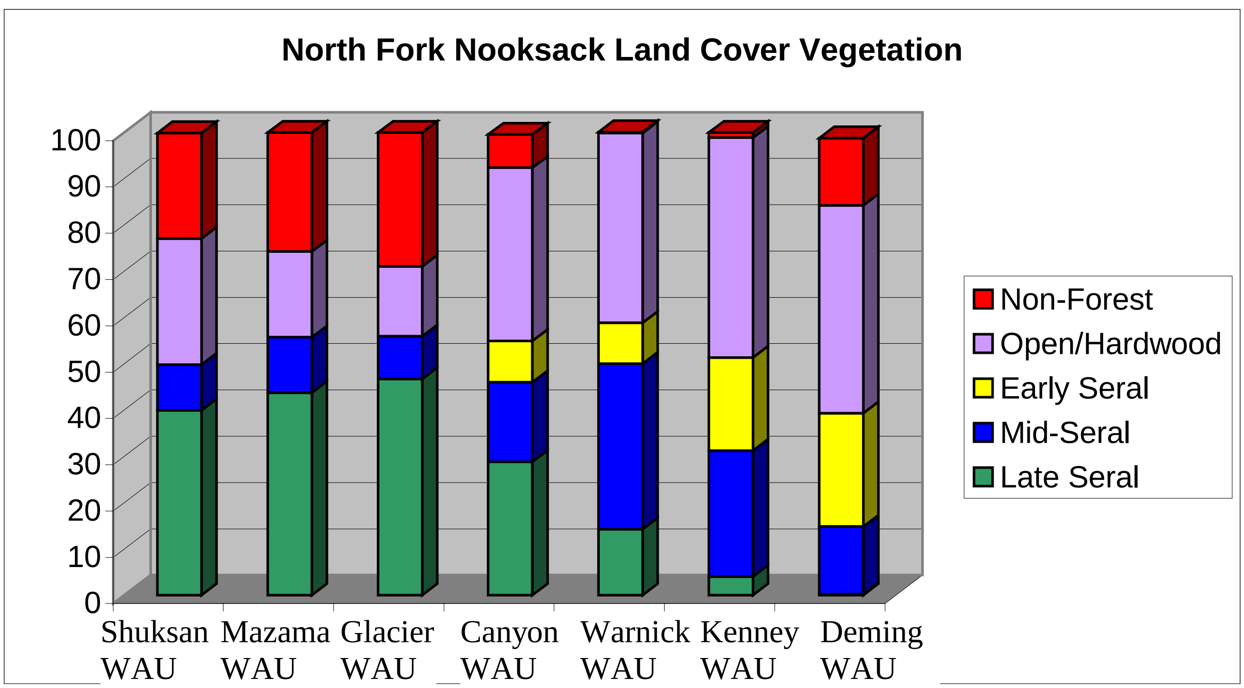
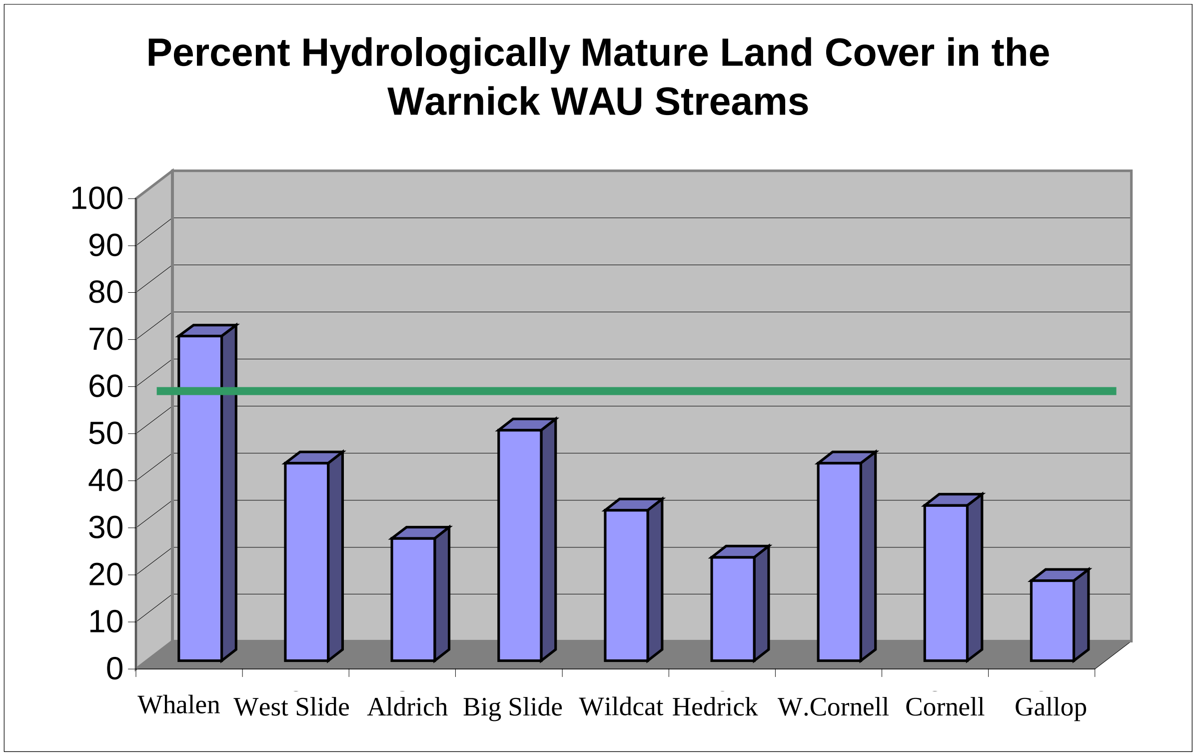


Figure 40. Percent of mature land cover vegetation in the middle region of the North Fork Nooksack sub-basin (data from DNR 1995). The green line denotes the standard that separates "good" (equal or greater than 60% mature conifer) from "poor" ratings.



<u>Water Quantity Conditions in the Middle Fork Nooksack River and Tributaries</u>

The Middle Fork Nooksack River typically has its average high flow in early summer due to glacial melt with good flows throughout late summer and early fall. Lower flows exist in the winter when cold temperatures prevent glacial melt (DOE 1995).

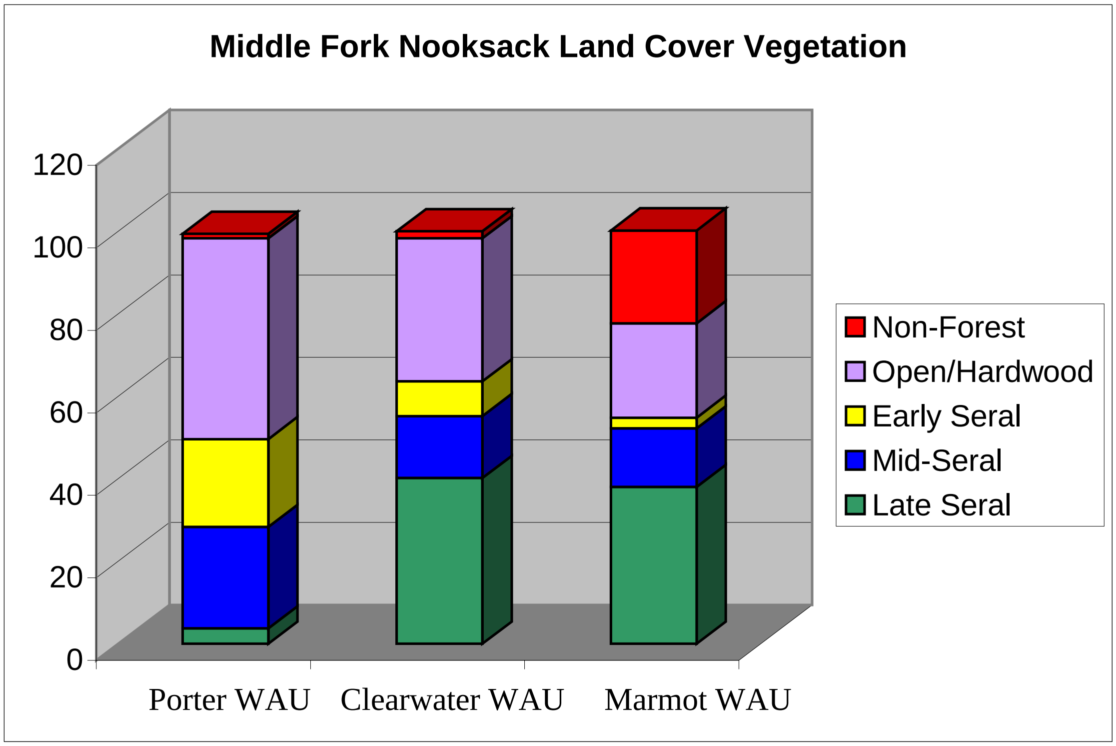
Generally, very little information exists about potential flow impacts within the Middle Fork Nooksack River sub-basin. One of the most apparent impacts has been the diversion dam at RM 7.2, which was constructed in 1960 (Currence 2000). This dam occasionally diverts surface water from the Middle Fork Nooksack River to Lake Whatcom for the City of Bellingham's water supply. In the past, up to 80% of the summer water input to Lake Whatcom originated from the Middle Fork Nooksack River (Walker 1995). However beginning in 1998, the amount of water diverted from the Middle Fork Nooksack River has been reduced to help maintain instream flows in the Middle Fork (Matthews et al. 2001). While currently the impact of the diversion dam on stream flows has been greatly reduced, the dam is still an impact for sediment and LWD transport and to anadromous salmonid passage to the Middle Fork Nooksack sub-basin. These issues are discussed in more detail in other sections (see Access and Sediment chapters).

Low stream flows are a likely problem in Porter and Canyon Creek. Both are closed to further water allocations in the low flow period (Figure 35) (DOE 1995). Overall, few documented surface water rights are noted in the Middle Fork Nooksack River (Figure 37).

Historically, the Middle Fork Nooksack sub-basin was covered with a mature conifer forest. These types of forests can temporarily capture from 24 to 35% of the precipitation to slow the rate of water entering streams and buffer peak stream flow conditions (Dingman 1994). The extensive removal of trees or change in age and type of trees can increase the magnitude of high flow events and route water more rapidly to channels.

The Middle Fork Nooksack River sub-basin consists of three different WAUs. The lower River WAU (Porter Canyon) is rated "poor" for hydrologic maturity with 29% mature conifer, 49% hardwood or cleared forestland, and young conifer comprising most of the remainder (Figure 41) (data from Lunetta et al. 1997). About 52% of the land in the lower Middle Fork is privately owned and 48% is State-owned. Although the Clearwater WAU has better land cover conditions, it is also rated "poor" with 55% mature conifer. Land cover vegetation in the Marmot WAU consists of 52% mature conifer, but also has considerable areas of bare rock and glaciers due to the high elevations (Stan Zyskowski, U.S. National Park Service, personal communication). When these naturally open areas are included with the level of mature conifer, it results in "good" land cover conditions. Only 5 to 10% of the land in the Clearwater and Marmot WAUs is under private ownership with U.S. Forest Service ownership encompassing 46% and 74%, respectively (data from Lunetta et al. 1997). All areas of the Middle Fork Nooksack River have "good" percentages of impermeable surfaces (data from Whatcom Conservation District maps, unpublished data, 2000).

Figure 41. Land cover vegetation in the Middle Fork Nooksack River WAUs (data from Lunetta et al. 1997).



Water Quantity Conditions in the South Fork Nooksack River and Tributaries

The South Fork Nooksack River has a large runoff in winter with a second high flow period in late spring due to snowmelt (DOE 1995). The low flow period spans from late summer through early fall. Low stream flows are a major concern in the South Fork Nooksack sub-basin. The South Fork Nooksack River mainstem is on the 303(d) list for low instream flows (DOE 2000). Deficient stream flows also affect critically warm water summer and fall temperatures and the lack of pool habitat.

As a consequence, the South Fork Nooksack River is closed to further water allocations, including the tributaries of Hutchinson and Skookum Creeks (Figure 35) (DOE 1995). Closures are in effect during the low flow period of late summer to early fall. Most of the documented water rights consist of surface water rights located in the lower reaches of the South Fork Nooksack sub-basin (Figure 37). The 303(d) listing coupled with the extent of “closed” waters results in a “poor” water quantity rating for the South Fork Nooksack River, Skookum Creek, and Hutchinson Creek.

Extensive changes in land cover vegetation have occurred in the sub-basin that may contribute to increases in peak flows. The lower reaches of the South Fork Nooksack sub-basin were once dominated by western redcedar (as measured by basal area) and by red alder (by frequency) (Collins and Sheikh in prep.). Currently, private and State-owned lands comprise most of this area (the Acme WAU), and the primary land cover vegetation type is hardwoods or cleared forestland (44%) (data from Lunetta et al. 1997). Mature conifers account for 21% of the land cover, resulting in a "poor" rating for hydrologic maturity (Figure 42). Young conifer comprises 19% of the land cover while 17% of the land has been converted to non-forest uses.

The Hutchinson WAU includes the Hutchinson Creek watershed and the nearby South Fork Nooksack River. Mature conifers cover 40% of this WAU, resulting in a "poor" rating for hydrologic maturity (data from Lunetta et al. 1997). The watershed analysis has similar results with 41% mature conifer and a note that more logging is expected in the near future because of the mature second growth timber (DNR 1998). Young conifer comprises 23% of the area, while hardwoods and cleared forestland cover 37% of the WAU (Figure 42) (data from Lunetta et al. 1997). Most of this area is under State and private land ownership. Under these vegetation conditions and with average storms, the percent increase in water runoff for a two year event ranges from 1.5 to 14.2% (DNR 1998). The highest percent increase is in the Campground watershed.

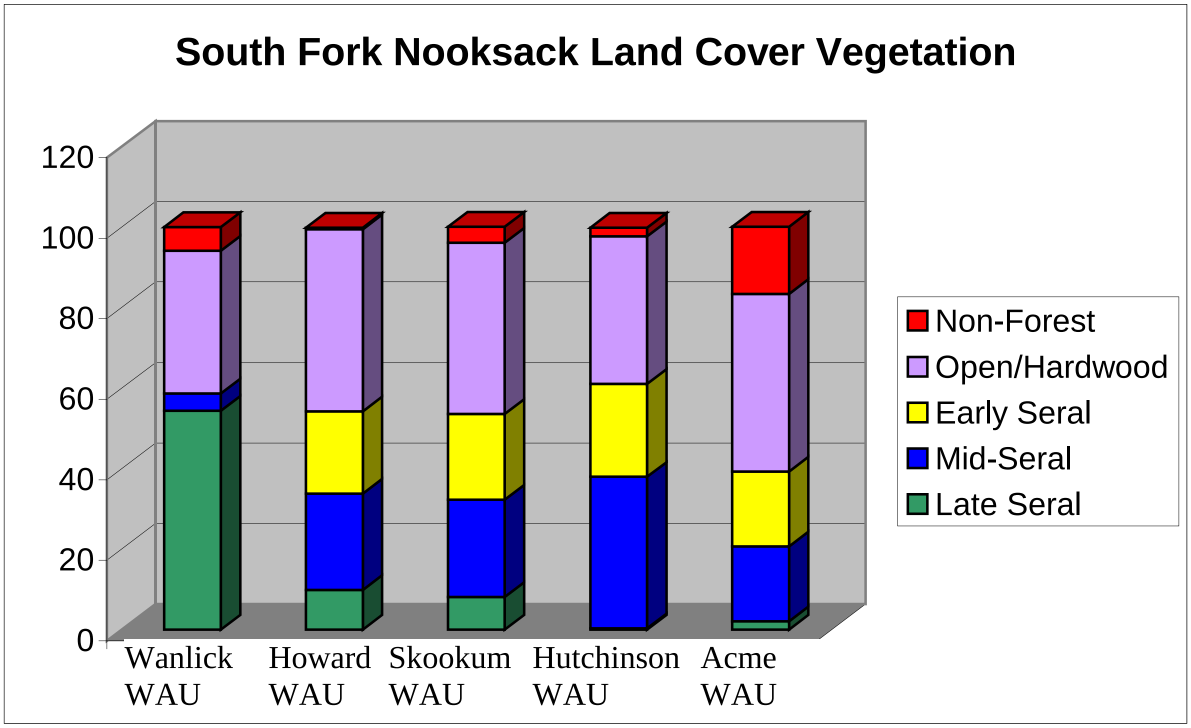
Most of the Skookum Creek WAU is also rated "poor" for hydrologic maturity (Figure 42). The most common vegetation type is "hardwood/cleared forestland", which covers 42% of the WAU (data from Lunetta et al. 1997). Young conifer accounts for 21% of the vegetation. State and private lands comprise 23 and 64% of the ownership, respectively (data from Lunetta et al. 1997). Within the Skookum Creek WAU, Edfro Creek and two unnamed tributaries rate "good" for hydrologic maturity, while most of the other watersheds have very "poor" land cover conditions (Figure 43) (data from DNR 1994). The average percent increase in peak flow was estimated at less than 10% for all of the watersheds in the Skookum WAU for 2, 25, and 100-year events (DNR 1994).

Further upstream, the Howard WAU has similar conditions with 34% mature conifers, 20% young conifers, and 45% hardwood or cleared forestland (Figure 42) (data from Lunetta et al. 1997). This results in a "poor" rating for hydrologic maturity. Most (74%) of this area is under private ownership.

The headwaters for the South Fork Nooksack River are contained in the Wanlick WAU. The WAU consists of 58% mature conifer, and nearly all of the WAU is within U.S. Forest Service boundaries (Figure 42). The area is rated "good" for hydrologic maturity because the open areas are naturally low conifer areas due to high elevations.

Impervious surfaces are not a concern in the South Fork Nooksack sub-basin. The percent impervious surfaces ranges from 0-0.91%, and are rated “good” (data from Whatcom Conservation District maps, unpublished data, 2000).

Figure 42. Land cover vegetation in the South Fork Nooksack WAUs (data from Lunetta et al. 1997.



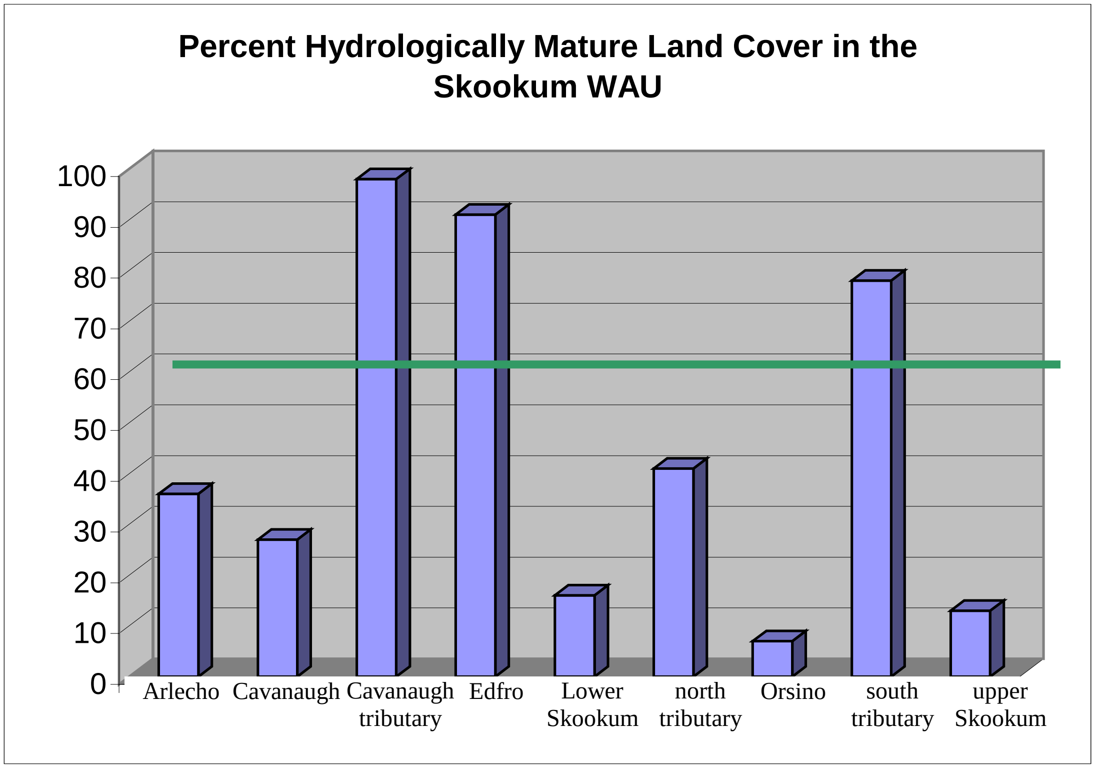


Figure 43. Land cover vegetation conditions in the Skookum Creek WAU (data from DNR 1994). The green line denotes the standard used to separate "good" (equal to or greater than 60% mature conifer) from "poor" conditions.

Habitat Limiting Factors in Dakota, California, and Terrell Creeks

<u>Loss of Access for Anadromous Salmonids in Dakota, California, and Terrell Creeks</u>

Blockages to salmonid habitat have been comprehensively surveyed in the Dakota and California Creek watersheds and are listed in Table 3. The Dakota Creek culverts have been ranked using the Priority Index system (data from Gregg Dunphy, Lummi Indian Nation). Fish habitat blockages are common in the Dakota Creek watershed, with eight listed as "high" priority blockages (PI 20 or higher), six as "medium" priority blockages (PI 10 to 20), and four as "low" priority blockages. This is a considerable impact to salmonid habitat in a relatively small basin, and results in a "poor" rating for access conditions. The culverts identified in California Creek need to be prioritized and cannot be rated.

Floodplain Conditions in Dakota, California, and Terrell Creeks

Wetlands are common in the Drayton Harbor Basin, comprising 16% of the forested areas. If mudflats are included, wetlands total 21% of the area (Nelson et al. 1991). Of these, 34% are freshwater marshes and wet meadows (Nelson et al. 1991). Hydric soils indicate that wetlands covered up to 34% more area than presently. The loss of wetlands in this area is due to artificial drainage, increased runoff, replacement of wetlands with pasture and hayland. The causes of loss from highest to lowest order include draining, filling, excavating, grazing, hay production, buildings and roads (Nelson et al. 1991). These impacts result in a “poor” floodplain rating for Dakota and California Creeks. Floodplain conditions within Terrell Creek are unknown.

Streambed Sediment Conditions in Dakota, California, and Terrell Creeks

The only data relating to sedimentation that was found for this region is a broad-scale estimate of road density. Road density for the Drayton and Birch Bay WAUs is rated “poor” with estimates of 3.6 and 3.3 miles of roads per square mile of watershed, respectively (data from Lunetta et al. 1997). The Drayton WAU includes Dakota and California Creeks, while the Birch Bay WAU contains Terrell Creek. Other indications of sediment impacts include noted erosion from cropland, road construction, and livestock access in the uplands of the Dakota Creek watershed (Whatcom Conservation District 1988b). California Creek has been described has having few gravel spawning areas and many channelized areas (Nelson et al. 1991). However, no quantification of these potential impacts was provided, and a greater examination of sediment and streambed conditions is warranted.

Pool habitat depth was measured in various reaches throughout the Dakota Creek watershed, and only one reach (the lower two miles of North Fork Dakota Creek) had abundant deep pools that were greater than 1 meter (data from Nooksack Salmon Enhancement Association Intern monitoring program). Other North Fork Dakota Creek reaches with “poor” pool habitat are the middle and upper reaches of the North Fork and tributaries 01.0032, 01.0036, and 01.0030.7. Several mainstem Dakota Creek tributaries (01.0004, 01.0005, 01.0008, 01.0009, 01.0010, 01.0021) and one South Fork tributary (01.0033) had very low numbers of deep pools and rate “poor” for pool habitat quality. No pool habitat data for California Creek and no data regarding instream LWD levels for either Dakota or California Creeks were found.

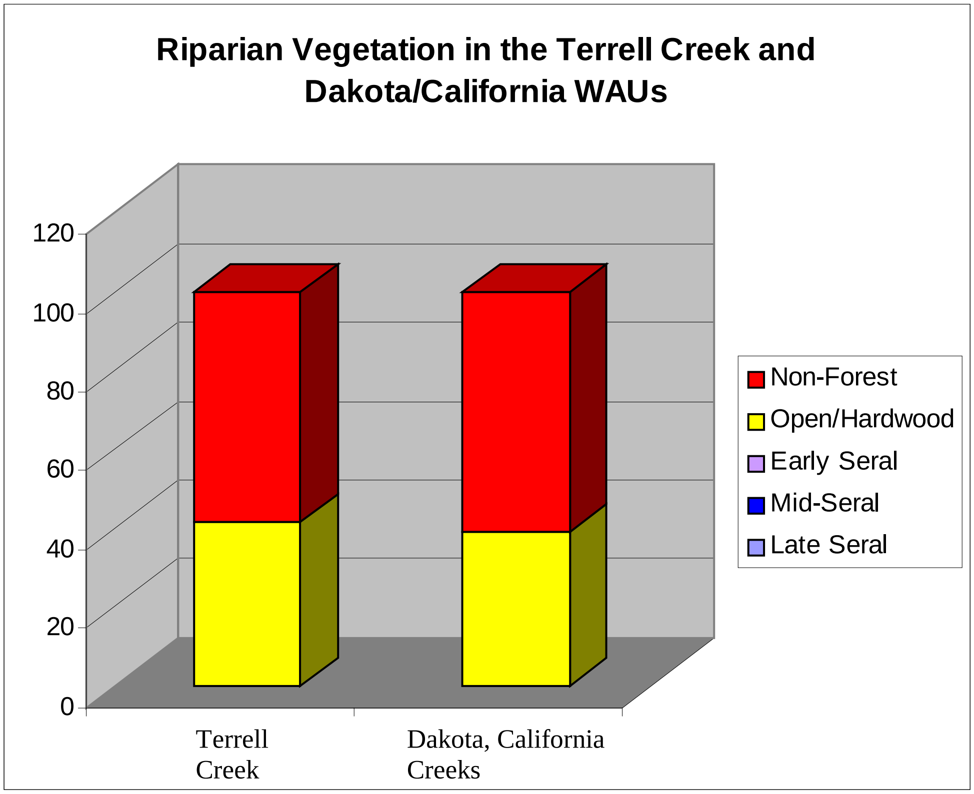
Riparian Conditions in Dakota, California, and Terrell Creeks

Riparian vegetation data for Dakota, California, and Terrell Creeks are only available on a broad-scale (by WAU); reach-specific information was not found. Based upon those data, 58% of the riparian vegetation along the response reaches of the Birch Bay WAU (Terrell Creek) and 61% of the riparian along

Dakota and California Creeks have been converted to non-forestland (Figure 44) (data from Lunetta et al. 1997). Most of the remaining riparian areas are either open or consist of hardwoods or brush. The conversion of riparian zones to non-forest uses results in a “poor” rating for riparian conditions in these streams.

Replacement of a historic conifer riparian with hardwoods also results in a “poor” rating. However, it is likely that some of the hardwood/open category in this WAU includes forested wetland areas that would naturally not sustain conifer. Considerable wetland habitat has been noted in Dakota Creek by Nelson et al. (1991), and a map of hydric soils indicates that both Dakota and California Creek have large areas of partially hydric soils (Whatcom Conservation District maps, unpublished data, 2001). In addition, North Fork Dakota Creek has been described as relatively natural (Nelson et al. 1991), yet the riparian reach data document a lack of conifer. It is unknown whether riparian conditions have been degraded in this stream, whether the area that remains natural is too small to influence the results of a broad-scale analysis, or if there is a predominance of forested wetlands in the area that would result in a natural hardwood-dominated riparian. The “poor” ratings are given because of the conversion to non-forest use with the notation that reach-specific data are a data need to clarify the extent of cleared forestland and the nature (natural or altered) of the hardwood riparian. Also, the "poor" rating is given to the region as a whole with the caveat that some riparian segments within this region are not "poor", but those need to be identified.

Figure 44. Riparian vegetation type in the Birch Bay and Drayton Harbor WAUs data from Lunetta et al. 1997).



Water Quality in Dakota, California, and Terrell Creeks

Dakota Creek is on the 303(d) List for low dissolved oxygen and high fecal coliform levels (DOE 2000). In addition, potentially toxic levels of ammonia have been measured in the North Fork Dakota Creek watershed, and low levels of dissolved oxygen have been documented in both the North Fork and South Fork watersheds (Dickes 1992). Livestock access and waste runoff are the major suspected causes of the water quality problems in Dakota Creek with 29 dairy farms in the watershed (Dickes 1992). Two fish kills (one in the North Fork and another in the South Fork) have occurred due to over-application of dairy animal waste on fields (Nelson et al. 1991). In addition, potentially harmful levels of cadmium have been found in both the sediments and surface waters in Dakota Creek. The source of cadmium is not known, especially because the primary land use is dairy farming (Erickson et al. 1995).

Water temperature and dissolved oxygen levels were measured within Dakota Creek from 1995 through 2000 (data from the Nooksack Salmon Enhancement Association Intern monitoring program). Out of 119 samples, 15 samples were warmer than 16^{o}C with a high reading of 20^{o}C in the downstream site (see the Assessment Chapter for an explanation of our water quality standards). Dissolved oxygen levels were even worse with nearly half of the measurements less than 6 mg/l and a low of 1.8 mg/l. In the upstream sampling site, about 39% of the samples had lower than 6 mg/l dissolved oxygen levels, with one sample less than 1mg/l. Water temperatures in the upper site were better, but still exceeded standards with 8% of the samples greater than 16^{o}C and a high of 17.5^{o}C. The low dissolved oxygen levels, warm water temperatures, and high levels of ammonia result in a "poor" water quality rating for the Dakota Creek watershed.

Many ditches have been constructed to drain into California Creek, and livestock access has been a documented problem along these ditches (Nelson et al. 1991). Livestock waste and failing septic systems are the likely causes for elevated fecal coliform and nutrient levels in California Creek (Nelson et al. 1991; Scott and McDowell 1994). However, specific water quality measurements were not found for California and Terrell Creeks and given the land use surrounding these streams, water quality impacts are likely. Water quality for California and Terrell Creeks is not rated due to a lack of data, but land use patterns suggest that impacts are likely.

Water Quantity in Dakota, California, and Terrell Creeks

The stream flows in these lowland streams closely mirror annual precipitation patterns with low flow concerns in the late summer through early fall (DOE 1995; Whatcom Conservation District 1988b). Average annual precipitation is

40” near the coast and 60” in the hills with about 80% of the precipitation falling from October through mid-June (Nelson et al. 1991). Small tributaries to Dakota Creek dry up in the summer, while high flows during the winter storms create problems with stream bank erosion (Whatcom Conservation District 1988b). In California Creek, extensive ditching, channelization, and wetland drainage have likely increased storm water runoff and decreased recharge (Nelson et al. 1991).

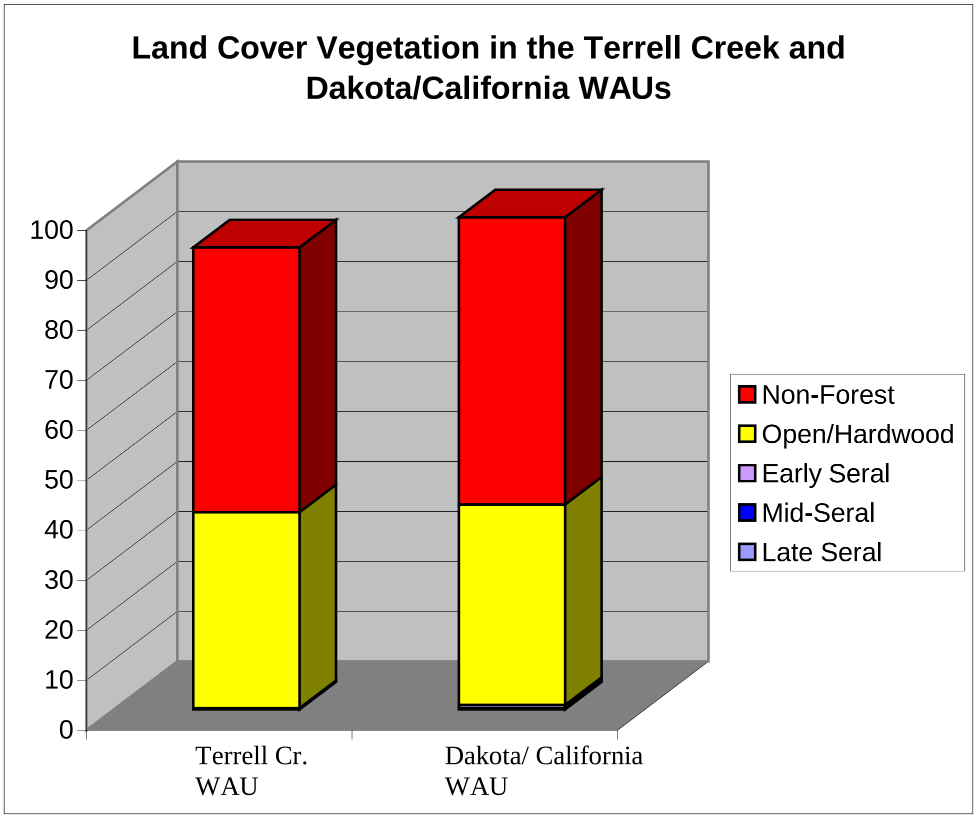
Most of the water rights in Dakota Creek were distributed from the 1920s through the 1950s for irrigation purposes (Nelson et al. 1991). The total of all the surface water rights is 1.76 cfs, while the average flow in the late summer and early fall ranges from 1.5 to 3.0 cfs. In California Creek, many of the water rights were granted from the 1930s though the 1960s, primarily for irrigation with a small amount for domestic use. The total withdrawals account for 2.8 cfs, while the average low flow is 0.5 to 1.0 cfs (Nelson et al. 1991).

All three of these watersheds have closures that limited future water rights (Figure 35) (DOE 1995). Full-year closures exist for Dakota and California Creeks while Terrell Creek is closed to further water appropriations during the summer and early fall months. Numerous ground water right applications, permits, or certificates exist in the California and Dakota Creek watershed while surface water rights are fewer in number (Figure 37) (DOE 1995). Fewer ground water and no surface water rights are shown in the Terrell Creek watershed. The stream closures accentuate the need to preserve stream flows, and the extensive amount of water rights (especially in Dakota and California Creeks) strongly suggest that efforts should be made to reduce water withdrawals. These concerns result in a “poor” rating for low stream flows.

Most of the original land cover vegetation of old growth forests has been converted to agricultural uses and to a lesser extent, urbanization. The loss of mature forest can increase the rate of water entering the streams because mature forests can temporarily capture 24 to 35% of the precipitation (Dingman 1994). In the Dakota and California Creek WAU, 57% of the vegetation has been converted to non-forest uses while in the Terrell Creek WAU, 53% has been converted (Figure 45) (data from Lunetta et al. 1997). Most of the remaining vegetation consists of hardwoods, cleared forestland, or brush (Figure 45). These land cover vegetation changes result in “poor” ratings for hydrologic maturity for all three basins.

Impervious surface percentages have been estimated using land use information, resulting in 19.35% impervious surfaces for Terrell Creek, 6.46% for California Creek, and 2.37% for Dakota Creek (Whatcom Conservation District maps, unpublished data, 2000). In comparing these percentages to the Washington Conservation Commission standards (see Assessment section), Terrell Creek rates “poor”, California Creek rates “fair”, and Dakota Creek rates “good” for percent impervious surfaces.

Figure 45. Land cover vegetation in the Terrell, Dakota, and California Creek WAUs (data from Lunetta et al. 1997).



Habitat Limiting Factors in Squalicum, Whatcom, Padden, and Chuckanut Creeks and the Lake Whatcom Watershed

Loss of Fish Access in Squalicum, Whatcom, Padden, and Chuckanut Creeks and the Lake Whatcom Watershed

In this region, the only comprehensive surveys for fish habitat blockages have been conducted in the Squalicum Creek watershed, and many of these have been prioritized (Table 3). Thirteen "high" priority fish habitat blockages have been documented in the Squalicum Creek watershed with two of these having a PI of more than 70 (data from Greg Dunphy, Lummi Indian Nation). This results in a "poor" rating for fish access conditions in the Squalicum Creek watershed. Three additional culverts in the watershed are ranked as a "medium" priority. A few fish blocking culverts have been documented in Chuckanut and Padden Creeks (Table 3), but these have not been prioritized, and it is unlikely that these watersheds have been comprehensively surveyed. Because of this, fish access conditions in Chuckanut and Padden Creeks are not rated.

Specific surveys of fish blockages in the Lake Whatcom sub-basin have not been completed. Areas of concern include the North Shore, South Bay, Blue Canyon, and Geneva Interbasin areas (DNR 1997) where increased development has occurred and culvert impacts are more likely. Plugged culverts have been noted in Carpenter Creek. Other access problems include sub-surface flows in Carpenter, Olson, Smith, and Brannian Creeks, and while the flow problem could be natural, it is thought to be worsened by excess sedimentation. Excess sediment from upstream sources has created access problems in the past at the mouth of Brannian Creek, requiring excavation. Fish access conditions in the Lake Whatcom sub-basin have not been rated due to a lack of data and analysis.

Floodplain Conditions in Squalicum, Whatcom, Padden, and Chuckanut Creeks and the Lake Whatcom Watershed

Specific floodplain surveys are not available for Squalicum, Whatcom, Padden, and Chuckanut Creeks. However, many sites of riprap were noted in a habitat survey of Squalicum Creek (Nooksack Salmon Enhancement Association Internship Program). This stream is tentatively rated "poor" with the note that quantification of floodplain impacts is needed. Because the soil type surrounding Whatcom Creek is partially hydric (Figure 8) and wetlands have not been documented in these areas, it is likely that historic wetlands have been lost to urban development. However, because of a lack of data, floodplain condition ratings are not provided for Whatcom, Padden, and Chuckanut Creeks.

In the Lake Whatcom sub-basin, off-channel habitat was rated for many streams and those ratings and/or problems are summarized in Table 7 (data from DNR 1997). While most streams in this area are naturally limited in floodplain habitat due to confinement in steep valley walls, significant human-caused problems have been noted. Of particular significance is the impact to the Smith Creek alluvial fan by numerous dikes that were constructed to protect homes. Also, Austin Creek has riprap, a levee, and is artificially entrenched due to excess sediment transport.

Table 7. Floodplain ratings for Lake Whatcom tributaries (data from DNR 1997).

Stream	Off-Channel Habitat Rating	Problem
Carpenter Creek	Poor	Rip-rap; entrenchment
Olson Creek	Poor	Entrenchment
Smith Creek	Poor	Dikes in lower reaches
Blue Canyon Creek (lower)	Poor	Confined channels
Anderson Creek (lower)	Poor	Levee and artificial entrenchment
Fir Creek[1]	Poor	Rip-rap; entrenchment
Brannian Creek	Poor-Fair	
South Bay[1]	Poor	Moderate Entrenchment
Austin Creek	Poor	Rip-rap
Beaver Creek	Poor-Fair	Rip-rap in lower reaches
Silver Beach	Good	
North Shore[1]	Poor	Moderate-High Entrenchment

[1] Ratings for these streams from the Conservation Commission process, not DNR 1997.

<u>Streambed and Sediment Conditions in Squalicum, Whatcom, Padden, and Chuckanut Creeks and the Lake Whatcom Watershed</u>

Squalicum Creek was rated as unstable in two different years of sampling, and serious bank cutting was documented (Schuett-Hames and Schuett-Hames 1984a), resulting in a "poor" rating for channel stability. In addition, livestock access increased bank erosion in Squalicum Creek, and the percent of fine sediment has averaged 11%, which results in a "fair" rating for sediment quality (data from Schuett-Hames and Schuett-Hames 1984b). Road density in the WAU that includes Squalicum and Silver Creeks is rated "poor" at 3.7 mi roads/sq. mi. watershed (data from Lunetta et al. 1997). These sediment data should be updated, and the ratings are provisional until more recent information becomes available.

Pools are generally shallow with most pools less than 1 meter deep (data from Nooksack Salmon Enhancement Association Intern monitoring program). This results in a "poor" rating for pool quality. Large wood was quantified throughout Squalicum Creek and three of its tributaries (Table 8) (data from Nooksack Salmon Enhancement Association Intern monitoring program). All sampled reaches rated “poor” for quantities of LWD. The reach with the greatest quantity of LWD had 0.89 pieces of large wood per bank full width (2-4 pieces/bfw is “good”; 1-2 pieces/bfw is “fair”, and less than 1 piece/bfw is “poor”, see Assessment Chapter for details on standards).

Table 8. Instream LWD and Deep Pool Habitat in Squalicum Creek (data from Nooksack Salmon Enhancement Association Intern monitoring program).

Stream Reach	Number of Deep (1 meter or greater) Pools	Pieces LWD/Bank Full Width	LWD Rating
Squalicum 1, lowest 0.5 miles	4	0.19	Poor
Squalicum reach 3, 0.7 miles	3	0.19	Poor
Squalicum reach 4, 0.6 miles	5	0.08	Poor
Squalicum reach 5, 0.5 miles	4	0.13	Poor
Squalicum reach 6, 0.4 miles	1	0.11	Poor
Squalicum reach 7, 0.8 miles	2	0.12	Poor
Squalicum reach 8, 1.0 miles	8	0.15	Poor
Squalicum reach 9, 0.6 miles	3	0.45	Poor
Squalicum reach 10, 0.9 miles	7	0.47	Poor
Squalicum reach 11, 1.0 miles	0	0.61	Poor
Squalicum reach 12, 0.8 miles	0	0.89	Poor
Squalicum reach 13, 0.9 miles	0	0.26	Poor
Squalicum reach 14, 0.4 miles	0	0.05	Poor
Squalicum reach 15, 0.4 miles	1	0.15	Poor
Squalicum reach 16, 0.4 miles	7	0.01	Poor
Trib. 01.0561, 0.3 miles	3	0	Poor
Trib. 01.0562, 1.7 miles	1	0.19	Poor
Trib. 01.0560, 1.5 miles	1	0.30	Poor
Trib. 01.0554	1	0.09	Poor

In Whatcom Creek, few data were available to assess streambed and sediment conditions. Stream stability in Whatcom Creek was rated as stable in two samples and as moderately unstable in a third sample in the 1980s (Schuett-Hames et al. 1988a), resulting in a tentative "good" rating for stability. The level of fine sediments was "good" at 8.7% in the 1980s. Data regarding instream levels of LWD and pool habitat were not found, and therefore, not rated. Current streambed and sediment data are greatly needed for the Whatcom Creek watershed.

In the tributaries to Lake Whatcom, surface erosion is relatively minor compared to landslide impacts, and most of the landslides are associated with timber harvest on steep slopes or with roads (DNR 1997). Clearcuts less than 20 years old account for 27% of the identified landslides in the watershed while 31% are associated with roads and road/stream crossings (DNR 1997). Geographically, landslides are common in upper Olson, Blue Canyon, Smith, and Austin Creeks, and these areas are rated "poor" for sediment quantity. In Anderson Creek, increased sediments have been introduced through the diversion of the glacial Middle Fork Nooksack River. The amount of water diverted into Anderson Creek has decreased recently, and if the reduction is maintained, the input of fine sediments should be reduced.

The Lake Whatcom WAU has 281 miles of roads; 63% are residential and 56% are paved (DNR 1997). Even though paved roads usually produce less sediment, many of these roads have ditches or storm drains that deliver sediment directly to streams. Significant road sediment problems (>100% over background sediment levels) are found in the Beaver, Carpenter, and Squalicum watersheds while moderate (a 50-100% increase over background levels) problems occur in the Brannian and Geneva watersheds. The types of road/sediment problems include: a high road density, inadequate culverts, poorly drained roads, road surfaces with highly erodible native rock, roads that parallel streams, and recreational use of native surface roads (DNR 1997). The above-mentioned streams are rated "poor" for sediment quantity because of the road problems.

Several of the tributaries to Lake Whatcom have experienced channel impacts. A large dam-break flood occurred in Olson Creek after extensive logging, which resulted in scour and channel instability (DNR 1997). In Smith Creek, numerous scouring debris torrents and dam-break floods have occurred, and most of the tributaries to Smith Creek with the exception of Quiet Creek, have been scoured to bedrock. These impacts have led to the construction of dikes along the Smith Creek alluvial fan to protect homes, creating further salmonid habitat problems (see Floodplain Chapter). Debris flows have also occurred in Blue Canyon and Brannian Creeks while debris torrents have occurred in South Bay, Beaver Creek, and Austin Creek (DNR 1997). Streambed stability ranges from "poor" to "fair" in the Lake Whatcom tributaries. Streams that rate "poor" for scour are lower Carpenter, Blue Canyon, lower South Bay, lower Beaver, and Silver Beach (DNR 1997). "Fair" rated areas for scour include middle Carpenter, middle Olson, Smith, Anderson, Brannian, Austin, and upper Beaver Creeks. No segments rated "good" for scour.

Throughout the Lake Whatcom tributaries, the percent of fine sediments (sediment quality) rated "fair" to "poor". "Poor" rated streams include Carpenter, Olson, mid-to lower Smith, Brannian, and upper Beaver Creeks (data from DNR 1997). "Fair" rated tributaries include upper Smith, Blue Canyon, lower Anderson, lower Fir, and lower Beaver Creeks, and Austin Creek has "fair" to "poor" rated segments throughout.

Most of the sampled reaches in the tributaries to Lake Whatcom are below target levels of LWD (DNR 1997). "Poor" rated streams include Carpenter, Olson, most of Smith, Blue Canyon, lower Cub, lower Anderson, lower Fir, Brannian, Austin, and Beaver Creeks. "Fair" rated streams are middle Anderson Creek and one reach of middle Austin Creek. Percent pool habitat is "poor" in Carpenter, lower Olsen, Blue Canyon, lower Cub, and lower Fir Creeks (data from DNR 1997). "Fair" percent pool habitat is found is middle Olson, Smith, and middle Austin Creeks. "Good" percent pool habitat exists in Anderson, lower Austin, and Beaver Creeks.

<u>Riparian Conditions in Squalicum, Whatcom, Padden, and Chuckanut Creeks and the Lake Whatcom Watershed</u>

The only available riparian information for Whatcom, Padden, and Chuckanut Creeks is a broad-scale analysis based upon WAUs (Lunetta et al. 1997). There are three WAUs in this area. One includes the Squalicum and Silver Creek watersheds, another encompasses Whatcom, Padden, and Chuckanut Creeks, and the third includes Lake Whatcom and tributaries that drain into the lake. All WAUs show extensive conversion of land to non-forest uses (Figures 46 and 47). In the Silver/Squalicum WAU, 61% of the riparian vegetation in the response reaches is non-forestland, and much of the remainder is classified as hardwood or cleared forestland (Figure 46). A mix of rural, agricultural, and urbanized lands surrounds Silver Creek, and lower Squalicum flows through urbanized land, whereas its upper reaches are surrounded by rural land use (Whatcom Conservation District maps, unpublished data, 1991). The extensive amount of riparian land converted to non-forest result in a "poor" rating of riparian conditions for Silver and Squalicum Creeks. The existing data do not allow differentiation of whether the hardwood/open component consists of cleared forestland (a "poor" riparian condition) or naturally occurring hardwood riparian due to the hydric soils (a "good" riparian condition). Reach-specific data are needed to better define riparian conditions.

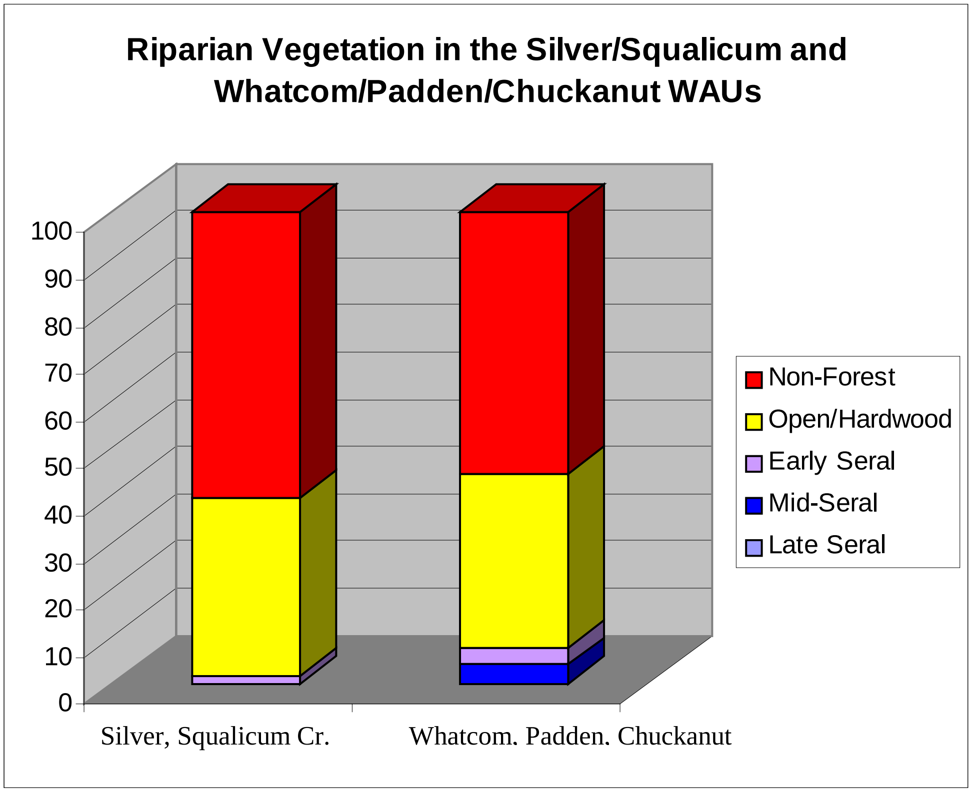
In the Squalicum Creek watershed, habitat surveys provide additional information. Reed canarygrass is heavy near RM 5.9 and 10.5, and canopy cover is summarized in Table 9. Conditions are mixed with predominantly “good’ canopy conditions in upper Squalicum Creek and mostly “poor” conditions downstream. In tributary 01.0560, canopy cover is mostly good, and in stream 01.0554, canopy cover conditions are mixed (data from Nooksack Salmon Enhancement Association Intern Monitoring Program). Canopy cover is one aspect of overall riparian conditions and focuses on shading. Another riparian condition component is LWD recruitment potential, which is not addressed by measuring canopy cover.

Table 9. Estimated Canopy Cover Conditions in Squalicum Creek (data from Nooksack Salmon Enhancement Association Intern monitoring program).

Stream Reach	Percent Canopy Cover	Canopy Cover Rating
Squalicum 1, lowest 0.5 miles	60%	Good
Squalicum reach 2	7%	Poor
Squalicum reach 3, 0.7 miles	12%	Poor
Squalicum reach 4, 0.6 miles	97%	Good
Squalicum reach 5, 0.5 miles	90% in lower; 0% in upper	Good to Poor
Squalicum reach 6, 0.4 miles	20%	Poor
Squalicum reach 7, 0.8 miles	13-58%	Poor
Squalicum reach 8, 1.0 miles	28-40%	Poor
Squalicum reach 9, 0.6 miles	50%	Poor
Squalicum reach 10, 0.9 miles	72%	Good
Squalicum reach 11, 1.0 miles	85-99%	Good
Squalicum reach 12, 0.8 miles	82-100%	Good
Squalicum reach 13, 0.9 miles	88-95%	Good
Squalicum reach 14, 0.4 miles	100%	Good
Squalicum reach 15, 0.4 miles	60-100%	Good
Squalicum reach 16, 0.4 miles	0-26%	Poor
Trib. 01.0561, 0.3 miles	0-50%	Poor
Trib. 01.0562, 1.7 miles	0% lower; 70-95% upper	Poor lower; Good upper
Trib. 01.0553	160-75%	Good
Trib. 01.0563	75-80%	Good
Trib. 01.0559	60-65%	Good

The WAU that includes Whatcom, Padden, and Chuckanut Creeks has 56% non-forested riparian reaches, and most of this non-forestland is likely urban (Figure 46) (data from Lunetta et al. 1997; Whatcom Conservation District maps, unpublished data 1991). The riparian areas surrounding Whatcom, Padden, and lower Chuckanut Creeks are entirely urbanized, but rural lands encompass upper Chuckanut Creek (Whatcom Conservation District maps, unpublished data, 1991). Hardwoods or cleared forestland comprises much of the remaining riparian conditions. The soils surrounding Whatcom and Padden Creeks are classified as partially hydric (Whatcom Conservation District maps, unpublished data, 2001), suggesting that historically, hardwoods may have comprised a significant component of the riparian zone. However, the conversion to urban, non-forest riparian areas results in a “poor” rating for riparian conditions in these streams, but reach-specific data are need, especially for Chuckanut Creek, where some areas of a conifer forest may still exist.

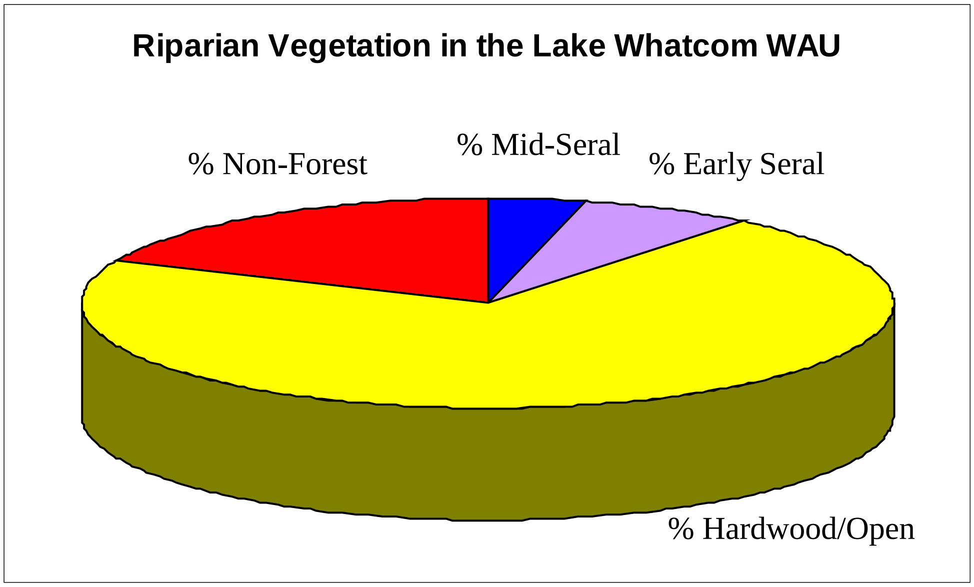
Figure 46. Riparian vegetation in the Silver/Squalicum WAU and the Whatcom/Padden/Chuckanut WAU (data from Lunetta et al. 1997).



The Lake Whatcom WAU includes Lake Whatcom and the tributaries that drain into the lake, such as Austin, Carpenter, Olson, Brannian, Anderson, and Smith Creeks. By 1896, most of the timber surrounding the lake was removed (DNR 1997). Currently, the riparian vegetation is predominantly (71%) hardwood or cleared forestland (Figure 47) (data from Lunetta et al. 1997). Non-forest land comprises 18% of the riparian buffers, and much of this is residential land use. Only 3.9% of the riparian reaches consist of mid-seral stage conifer with no reported late seral stage conifer. Specific areas of impact include lower Carpenter Creek, which is surrounded by residential landscapes and bulkheads, and hardwood riparian stands have been noted along lower Anderson, lower Olsen, parts of Smith, and upper Beaver Creeks (DNR 1997).

Near-term LWD recruitment potential is a mix of moderate (52%) and low (40%) segments throughout the tributaries to the lake (DNR 1997), resulting in "fair" and "poor" ratings. Most (75%) of the riparian reaches are on target for shade, but 25% are below target (DNR 1997). However, because of the significant conversion to non-forest use and the lack of conifers, the area is rated "poor" for riparian conditions.

Figure 47. Riparian vegetation in the Lake Whatcom WAU (data from Lunetta et al. 1997).



Water Quality Conditions in Squalicum, Whatcom, Padden, and Chuckanut Creeks

Several years of sampling have shown "poor" and "fair" ranges of water temperatures and dissolved oxygen levels throughout Squalicum Creek and in lower Baker Creek, a Squalicum tributary (Table 10) (City of Bellingham 1999). Turbidity exceedances have been noted after rainfall in all of the sampled sites with occasional pH problems in the middle reaches of Squalicum Creek and in lower Baker Creek (City of Bellingham 1999). Stream bank modification, the loss of riparian vegetation, urban storm water, and agricultural impacts are some of the likely causes of these water quality problems (Scott and McDowell 1994). Squalicum Creek also has high fecal coliform levels resulting from agriculture, urban storm water runoff, landfills, and failing septic systems (Scott and McDowell 1994; City of Bellingham 1999). Mercury, lead, zinc, and copper have been documented in Squalicum Creek with urban and industrial storm water runoff a suspected source (DOE 1995). For these reasons, Squalicum and Baker Creeks are rated "poor" for water quality.

Whatcom Creek is on the 303(d) List for warm water temperatures and high fecal coliform levels (DOE 2000). The City of Bellingham (1999) sampled water quality parameters at six different locations within the Whatcom Creek watershed, and those results show pervasive warm water temperatures at all three sampling sites within Whatcom Creek (Table 10). Some water temperatures exceed 21^{o}C, which can impede salmon growth (Bell 1986). In some years, low levels of dissolved oxygen also occurred at these sites. Tributaries to Whatcom Creek, such as Cemetery, Lincoln, and Fever Creeks, have warm water temperatures and low dissolved oxygen levels (Table 10), and turbidity exceedances were noted in Fever Creek. Occasionally pH did not meet Class A standards throughout Whatcom Creek and the sampled tributaries.

Mercury, lead, zinc, and copper have been documented in Whatcom Creek, and urban and industrial storm water runoff is the suspected source (DOE 1995). Zinc, lead, and copper have also been found in the hatchery ponds at Maritime Heritage Fish Hatchery, which uses water from Whatcom Creek (Erickson et al. 1995). Mortality of coho salmon has occurred at the hatchery after a first flush storm event. Other toxins such as pentachlorophenol (PCP), have been detected at in the sediments at two different sites in Whatcom Creek, and methylene chloride has been detected at a lower reach site. Samples from the lower site resulted in mortality in a bioassay (Cubbage 1994). Because of the warm water temperatures, low dissolved oxygen levels, turbidity, and toxins, all of these sites are rated "poor" for water quality. The warm water temperatures are a major concern, and the suspected causes include the forty storm water inputs into Whatcom Creek and the loss of riparian vegetation (DOE 1995).

In the Lake Whatcom WAU, the streams that receive residential runoff (Austin Creek, Silver Beach Creek, and Park Place drain) have more degraded water quality conditions compared to those in forested areas (Smith, Wildwood, and Blue Canyon Creeks) (Matthews et al. 2001), but the warm water temperatures in all of the sampled streams result in a "poor" water quality rating. In the forested creeks, 1990 minimum dissolved oxygen levels ranged from 6.9 to 9.0 mg/l ("fair" to "good"), and peak water temperatures ranged from 16.5 to 17.0^{o}C ("poor") (Matthews et al. 2001). In the streams degraded by residential development, the water temperatures were worse with peak 1990 temperatures ranging from 17.0 to 23.0^{o}C and minimum dissolved oxygen levels ranging from 6.4 to 8.0 mg/l. Riparian vegetation impacts exist along many of these streams with high shade hazards noted along Smith, Austin, lower Beaver, parts of Olsen and Carpenter Creeks and along unnamed streams 01.0571 and 01.0572 (DNR 1997). An estimated 50% of the shade problems are attributed to debris torrents, 39% to residential/urban development, and 11% to logging and blow down.

Peak water temperature and minimum dissolved oxygen levels in Anderson Creek were "good" with a measurement of 12.5^{o}C and 10 mg/l (data from Matthews et al. 2001). However, the low peak temperature is probably due to the diversion of cold glacial water from the Middle Fork Nooksack River because high shade hazards have been documented in Anderson Creek (DNR 1997). It is important to continue to monitor water temperature in Anderson Creek because the diverted flow from the Middle Fork Nooksack River has been considerably reduced due to concerns of maintaining adequate flows in the Middle Fork.

Other water quality problems have also been documented in the Lake Whatcom streams (Figure 33). Some of the samples have shown high levels of phosphorous, nitrogen, and fecal coliform levels (Scott and McDowell 1994), and problems with turbidity and dissolved oxygen have also been noted (DOE 1995). Anderson Creek has had elevated turbidity and suspended solids levels in the summer due to inputs from the Middle Fork Nooksack River, and the other streams have higher turbidity in the winter due to storm water runoff (Matthews et al. 2001).

In more recent years, the Park Place drain (an underground storm drain), Austin Creek, and Silver Beach Creek have failed to meet Class AA standards for fecal coliform levels (Matthews et al. 2001), and Silver Beach Creek is on the 303(d) List for fecal coliform (DOE 2000). The Park Place drain has had high levels of ammonia, which is thought to arise from the Park Place storm water treatment pond (Matthews et al. 2001). All of these streams receive residential runoff. In addition, copper, nickel, iron, and zinc have been measured in Austin, Anderson, Silver Beach, Smith, and Blue Canyon Creek, and the Park Place drain, but most measurements were within normal ranges for creeks in residential areas (DOE 1995; Matthews et al. 1999). The source of the metals, fecal coliform, ammonia, and phosphorus is thought to be runoff from the residential developments (DOE 1995).

Lake Whatcom covers 5,000 acres (DNR 1997) and consists of three basins. Basin I is in the northwest end of the lake within the City of Bellingham limits, and is very shallow (Scott and McDowell 1994). Basin II is south of Basin I and is also shallow, but slightly deeper than Basin I. Basin II is becoming increasingly urbanized along its northern area. It serves as the site where the City of Bellingham withdraws water.

The majority of Lake Whatcom is within Basin 3, which is considered to be oligotrophic (Erickson et al. 1995). This basin is very deep with areas that are 18 feet below sea level (Scott and McDowell 1994). The Water District #10 withdrawal occurs in Basin III. In all but the shallowest areas, the lake stratifies in the summer with warm water in the upper layer and cool water containing low oxygen levels comprising the bottom level (Matthews et al. 2001). Even though this stratification is natural, there has been a decreasing trend in oxygen levels at all sampled depths greater than 12m from 1988 to 1999. The trend has no simple, direct relationship to temperature or lake water levels, although these likely play a role in oxygen levels (Matthews et al. 2001). The low oxygen levels can result in a release of phosphorus and nitrogen from the sediments, which can trigger an algal bloom and deplete oxygen levels in the upper layer, leading to a fish kill. Metals and organics can also be released from the sediments in lower oxygen conditions (Matthews et al. 2001). Elevated levels of ammonia, phosphorus, iron, and hydrogen sulfide have been measured in Basins I and II of the lake, and these elevated levels are a symptom of low oxygen conditions. Mercury has also been noted in Basin I (Matthews et al. 2001). The decreasing trend in dissolved oxygen levels results in a “poor” water quality rating for Lake Whatcom.

Padden Creek water temperatures were “poor” in most years at RM 1.5 and in Connelly Creek, a tributary to Padden Creek (Table 10). “Poor” (warm) water temperatures were also documented in two years at the mouth of Padden Creek (data from City of Bellingham 1999). In most years, dissolved oxygen levels were “good” for the Padden Creek sites, but in a few of the years, “poor” and “fair” levels were noted. After a rainfall event, turbidity was documented near the mouth of Padden Creek, and occasionally pH samples exceeded the standard. Fecal coliform levels did not meet Class A standards for most of the years except for the Padden Creek site at 38th Street (City of Bellingham 1999). In addition, mercury, lead, zinc, and copper have been documented in Padden and Connelly Creeks, and urban and industrial storm water runoff is the suspected source (DOE 1995). These water quality problems, especially the warm water temperatures, result in a “poor” rating for water quality in Padden Creek.

Lower Chuckanut Creek (RM 0.2) was sampled from 1990 through 1999. In most years, dissolved oxygen levels were “good”, but levels were in the “poor” range in 1994 and 1995 and in the fair range during 1996 (Table 10) (data from City of Bellingham 1999). Summer water temperatures were in the “fair” range in five years, in the “poor” range for two years, and rated “good” in three years. Some pH exceedances were noted in 1994, and fecal coliform was also a documented problem. Because most of the years would rate “fair” for water temperature in lower Chuckanut Creek, this stream is rated “fair” for water quality.

Table 10. Water temperature and dissolved oxygen sampling summary in Squalicum, Whatcom, Padden, and Chuckanut Creeks (data from City of Bellingham 1999).

Sampling Site	# Years with no water temperature exceedances	# Years with water temperature exceedances in the "fair" range	# Years with water temperature exceedances in the "poor" range	# Years with no dissolved oxygen exceedances	# Years with dissolved oxygen exceedances in the "fair" range	# Years with dissolved oxygen exceedances in the "poor" range
Squalicum RM 0.4	3	5	1	7	1	2
Squalicum RM 2.0	1	5	4	4	4	2
Squalicum RM 5.0	1	1	4	0	1	5
Baker Cr RM 0	3	4	4	7	1	2
Whatcom Cr. RM 0.3	1	1	8	6	4	0
Whatcom Cr. RM 1.1	1	1	8	5	3	2
Whatcom Cr. RM 3.8 (dam)	0	1	9	4	3	2
Cemetery Cr. (Whatcom)	3	3	4	2	3	5
Lincoln Cr. (Whatcom)	1	4	5	3	3	4
Fever Cr. (Whatcom)	1	2	3	2	2	2
Padden Cr. RM 0	2	6	2	6	2	2
Padden Cr. RM 1.5	3	3	4	7	1	2
Connelly Cr. (Padden)	3	2	5	6	1	2
Chuckanut Cr. RM 0.2	3	5	2	7	1	2

Water Quantity Conditions in Squalicum, Whatcom, Padden, and Chuckanut Creeks

Impacts have occurred that worsen both low and high stream flows in each of these streams. Impacts to low flow conditions include the numerous surface water rights documented around Chuckanut Creek, and the ground and surface water rights in the upper Squalicum drainage (Figure 37) (DOE 1995). Few water rights have been documented for Whatcom and Padden Creeks. However, all four streams are closed to further water allocations, which indicates that stream flows need to be preserved (Figure 35).

Changes in land cover vegetation can increase the entry rate of precipitation to streams (Dingman 1994) worsening peak flows. In this region, most of the original land cover vegetation of conifer forest has been converted to agricultural uses and urbanization. In the Whatcom, Padden, and Chuckanut Creek watersheds, 39% of the vegetation has been converted to non-forest uses, while 56% has been converted in the Silver and Squalicum Creek watersheds (Figure 48) (data from Lunetta et al. 1997). Most of the remaining vegetation consists of hardwoods, cleared forestland, or brush (Figure 48). These alterations result in a "poor" rating for hydrologic maturity. Impervious surface percentages were unavailable, but are likely high, particularly for the Squalicum, Whatcom, and Padden Creek watersheds.

The hydrology within the Lake Whatcom WAU has been considerably altered. The natural hydrology consisted of several small tributaries draining into Lake Whatcom with the outflow draining into Whatcom Creek to Bellingham Bay. However, a dam was built near the Whatcom Creek lake outlet in 1911 to stabilize lake levels (DNR 1997) and to buffer high flows into Whatcom Creek (Matthews et al. 2001). In addition, Anderson Creek, a tributary to Lake Whatcom, is used as the channel to divert water from the Middle Fork Nooksack River into Lake Whatcom for municipal uses. Because of this diversion, up to 80% of the water input to the lake in the summer originated from the Middle Fork Nooksack River (Walker 1995). Beginning in 1998, the amount of water diverted from the Middle Fork Nooksack River has been reduced to help maintain instream flows in the Middle Fork (Matthews et al. 2001).

In addition, there are four major water diversions from Lake Whatcom. Georgia Pacific withdraws up to 35 million gallons per day (mgd). The City of Bellingham withdraws 10 to 20 mgd. Whatcom Falls Hatchery withdraws up to 1 to 5 mgd, and Whatcom County Water District #10 withdraws up to 0.1 to 0.5 mgd (DNR 1997). Surface water rights are numerous around Lake Whatcom (Figure 37), but the streams draining into Lake Whatcom are not closed to further water withdrawals (DOE 1995).

Not only has the hydrology of the Lake Whatcom WAU been directly altered by a dam and a major diversion, but indirect impacts to stream flow can occur from the land cover vegetation changes. Historically, the land cover consisted of western hemlock, Douglas fir, western red cedar, red alder, and bigleaf maple (DNR 1997), but significant changes in land cover has occurred. Currently, the Lake Whatcom WAU consists of only 20% mature conifer. Most of the land cover vegetation consists of either hardwoods or cleared forestland (38%) or young conifer (22%) (data from Lunetta et al. 1997). Within individual watersheds, Cub, Fir, Olsen, and Smith Creeks rate "good" for hydrologic maturity and the Beaver, Brannian, Austin, and Carpenter Creek watersheds rate "poor" (Figure 49) (data from DNR 1997). An estimated 6% of the land cover in the Lake Whatcom WAU has been converted to non-forest uses with more conversion to residential use in the Austin and Beaver Creek watersheds (DNR

1997). An estimated 3% impervious surfaces cover the area, resulting in a "fair" rating. (Whatcom Conservation District maps, unpublished data, 2000).

Figure 48. Land cover vegetation in the Silver, Squalicum, Whatcom, Padden, and Chuckanut Creek WAUs (data from Lunetta et al. 1997).

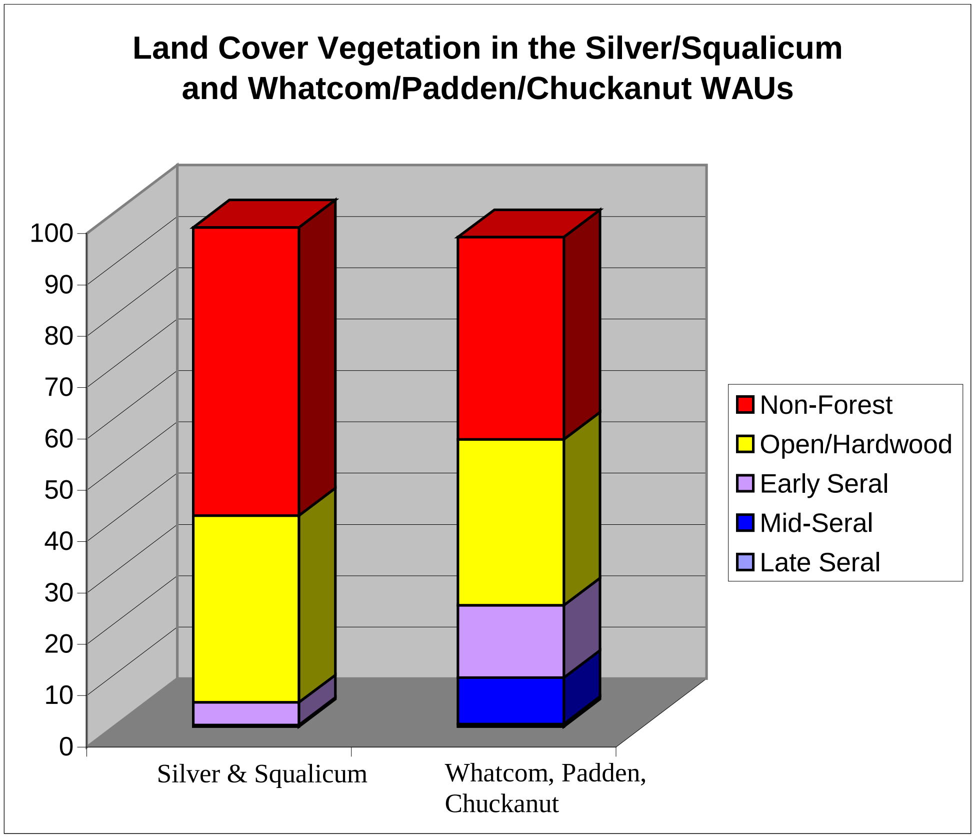
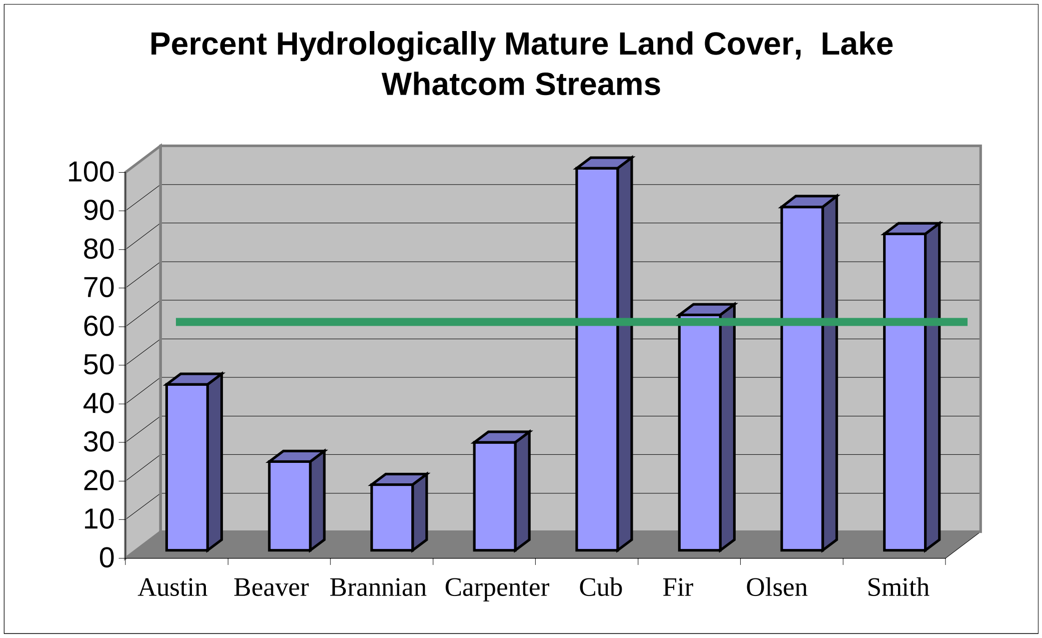


Figure 49. Percent of hydrologically mature land cover in the watersheds draining into Lake Whatcom (data from DNR 1997). The green bar represents the standard (60% or greater hydrologic maturity is rated "good").



Under current vegetation conditions and average storms, the percent increase in the two-year recurrence interval ranges from 0.02 to 9.5% with the highest percent increase for Beaver Creek (DNR 1997). Modeled two-year peak flows show a 0.3 to 11.2 percent increase with the greatest increase for Beaver Creek followed by Brannian (8.4%), Austin (8.3%), Carpenter (7.3%), Fir (5.1%), Smith (3.3%), Olsen (2.0%) and Cub (0.3%) (DNR 1997). If the vegetation is altered to fully immature conditions, Olsen and Smith Creeks are the most sensitive (21% increase in two-year peak flows) with Cub, Austin, Fir, and Beaver Creeks closely behind (18-20%).

Habitat Limiting Factors in Oyster and Colony Creeks

Loss of Fish Access in Oyster and Colony Creeks

No information was found for access conditions in Oyster and Colony Creeks.

Floodplain Conditions in Oyster and Colony Creeks

No data on floodplain conditions were found for Oyster or Colony Creeks. This is a data need and no ratings can be provided at this time.

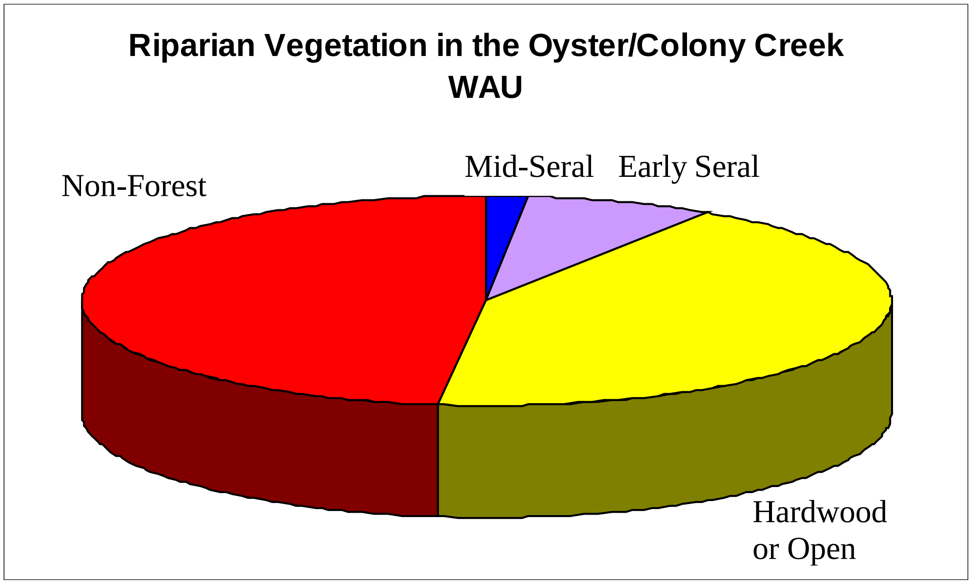
Streambed and Sediment Conditions in Oyster and Colony Creeks

The only information on sediment, LWD, channel condition, and pool habitat for Oyster and Colony Creeks is the broad-scale road density estimate that encompasses the entire WAU. Road density is rated "fair" for the WAU, with a value of 2.4 miles of road/sq. mi. watershed (data from Lunetta et al. 1997). No other ratings can be assigned due to a lack of data.

Riparian Conditions in Oyster and Colony Creeks

About 48% of the riparian response reaches in the Oyster/Colony Creek WAU have been converted to non-forestland (Figure 50) (data from Lunetta et al. 1997). Most of the land conversion has occurred in the lower Colony Creek drainage where agricultural lands predominate (Whatcom Conservation District maps, unpublished data, 1991). The lands surrounding Oyster Creek are classified as forestland with a small quantity of rural areas. Forty three percent of the WAU riparian reaches are documented as hardwood or cleared/open forestland. It is likely that some of the hardwood riparian is a natural condition in the wetland areas of upper Oyster Creek. A very small (2%) percentage of mid-seral conifer riparian was noted and no late seral was documented (Figure 50) (data from Lunetta et al. 1997). Because of the large conversion to non-forest and the low level of mature conifer, the WAU is rated "poor" for riparian conditions with the note that more data are needed. Reach-specific riparian data are needed for these streams with identification of wetland areas expected to support a naturally hardwood riparian.

Figure 50. Riparian vegetation in the Oyster and Colony Creek WAU (data from Lunetta et al. 1997).



<u>Water Quality Conditions in Oyster and Colony Creeks</u>

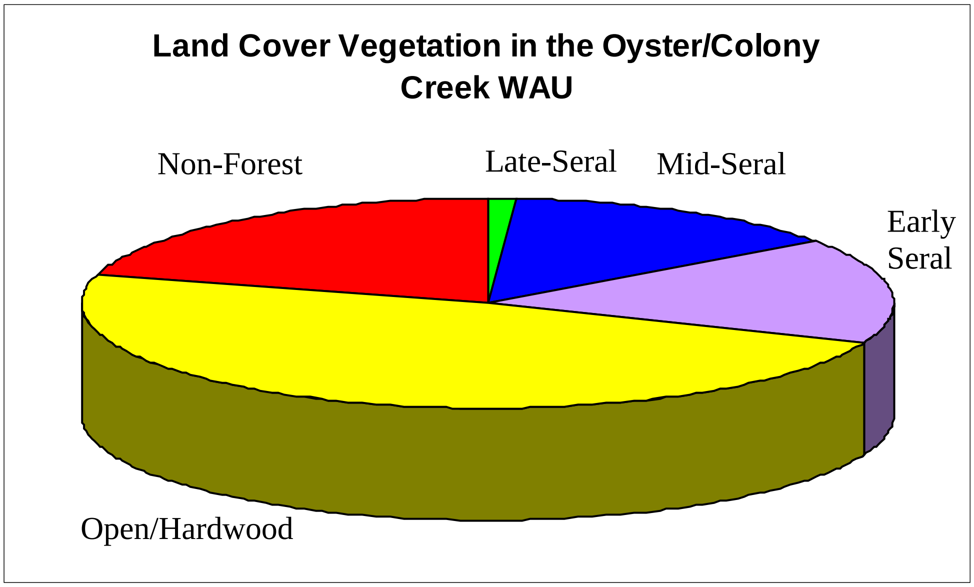
No water quality data were found for these two streams.

<u>Water Quantity Conditions in Oyster and Colony Creeks</u>

Historically, the land cover consisted of old growth forests of Douglas fir and climax communities of western hemlock, cedar, and broad-leafed maple (DOE 1995), while currently much of the land cover vegetation in the Oyster and Colony Creek WAU is hydrologically immature. In this WAU, 45% of the land cover consists of hardwoods or cleared forestland, 19% has been converted to non-forest uses, and 15% is covered with young conifer (Figure 51) (data from Lunetta et al. 1997). Only 14% consists of mature conifer. This results in a "poor" rating for hydrologic maturity. Impervious surface percentages have been estimated using land use information, resulting in 2.6% impervious surfaces for Oyster Creek and 12.6% for Colony Creek (Whatcom Conservation District maps, unpublished data, 2000). In comparing these percentages to the Washington Conservation Commission standards (see Assessment section), Oyster Creek rates "good", and Colony Creek rates "poor" for percent impervious surfaces.

No documented water rights were mentioned for these two watersheds in the review by DOE (1995), but Oyster Creek is closed to further water allocations in the summer to early fall months, indicating that low stream flows are a likely problem.   No other data regarding flow conditions were found for Oyster and Colony Creeks.

Figure 51. Land cover vegetation in the Oyster and Colony Creek WAU (data from Lunetta et al. 1997).



Habitat Limiting Factors in the Sumas River, Chilliwack River, and Damfino, Tomyhoi, Frost, and Silesia Creeks (Washington State Fraser River Tributaries)

<u>Loss of Fish Access in the Sumas River, Chilliwack River, and Damfino, Tomyhoi, Frost, and Silesia Creeks (Washington State Fraser River Tributaries)</u>
In the Sumas River watershed, specific culvert surveys have not been conducted, but some potential blockages include the double culvert at 3rd Street, the System Dairy driveway culvert, a sunken culvert near the ditched area of Sumas Creek, and the City well field access road bridge crossing. Also, steelhead trout access might be impeded into the Sumas River by the pump stating in Abbotsford (David Evans and Associates 1998). There are also some culvert problems in tributaries to the Sumas River (Table 3). These have not been prioritized.

<u>Floodplain Conditions in the Sumas River, Chilliwack River, and Damfino, Tomyhoi, Frost, and Silesia Creeks (Washington State Fraser River Tributaries)</u>
Very limited information was found for floodplain habitat in the Fraser River tributaries. In the Sumas River watershed, little habitat diversity exists in the urbanized reaches of the Sumas River, Johnson Creek, and lower reaches of

Sumas Creek (David Evans and Associates 1998). The urbanized reaches of the Sumas River are also impacted by channel incision. Extensive wetlands provide good habitat in upper Sumas Creek. Another wetland near the mouth of Johnson Creek was documented, but urban impacts to that wetland have occurred. Wetland loss likely occurred throughout the Sumas watershed because extensive amounts of partially hydric soils cover the land, yet few wetlands have been documented (Figures 7 and 8) (maps from Whatcom Conservation District 2001).

<u>Streambed and Sediment Conditions in the Sumas River, Chilliwack River, and Damfino, Tomyhoi, Frost, and Silesia Creeks (Washington State Fraser River Tributaries)</u>

The Sumas River has channel incision, excess fine sediments, and low levels of LWD in its lower reaches (David Evans and Associates 1998). The fines are believed to stem from a landslide in Swift Creek. Quantification of the LWD and fine sediments was not found, and these conditions are assumed to be "poor" based upon the qualitative statements in the David Evans and Associates report (1998).

The tributaries to the Sumas River have variable habitat conditions. Sumas Creek has numerous impacts in its lower reaches where it drains into Johnson Creek, including low levels of LWD and few pools (averaging less than 10% of wettable area) (David Evans and Associates 1998). The pools are also shallow due to fine sediment filling. This information results in "poor" ratings for LWD, pool habitat, and sediment quality. The middle reaches of Sumas Creek are degraded by fine sediments that are believed to arise from upstream dredging activities. This results in a "poor" rating for sediment quality in the middle reaches of Sumas Creek. Upper Sumas Creek has better habitat, with its headwaters arising from a spring-fed wetland. More pools are available and adequate spawning gravel appears to exist. "Good" ratings for pools and sediment quantity are assigned for upper Sumas Creek, but all of these ratings are provisional until more specific data are available.

In general, the salmonid habitat in Johnson Creek is less degraded than in the Sumas River. Impacts include dredging in the upper reaches of Johnson Creek, and a lack of LWD and pools in the urban area. Upper Johnson Creek has adequate pool and LWD components (David Evans and Associates 1998), and are rated "good". North Fork Johnson Creek has good spawning gravel and a good pool:riffle ratio (U.S. Dept. Agriculture Soil Conservation Service 1993), but more data are needed to assign ratings. Bone Creek is lacking spawning gravel, LWD, and pools, and fine sediments have impacted pool habitat (David Evans and Associates 1998). This results in "poor" ratings for these categories in Bone Creek.

Road densities in the Sumas and Vedder WAUs are rated “fair” at 2.3 miles roads/sq. mi. watershed (data from Lunetta et al. 1997). The Sumas WAU includes the Sumas River and all tributaries except for Saar Creek. The Vedder WAU includes Saar and Frost Creeks. The Chilliwack and Silesia WAUs are rated “good” for road density, with estimates of 0 and 0.1, respectively. The Chilliwack WAU includes the upper Chilliwack and associated tributaries and lies within the National Park. The Silesia WAU bounds other tributaries to the Chilliwack River, such as Damfino, Tomyhoi, and Selesia Creeks.

Beginning in 1997, habitat monitoring has occurred in the Chilliwack River by the U.S. Forest Service, National Park Service, Province of British Columbia, and University of British Columbia. The focus of the monitoring has been in reaches of the upper Chilliwack River that have never been disturbed. Because of this, it is expected that the ratings for habitat conditions should be “good”. Preliminary results of the monitoring indicate that most of the substrate is not embedded (43-71% of sampled area not embedded), with 6 to 29% embedded (data from Reed Glesne, National Park Service). Most sampled areas had frequent deep pools, and LWD ranged from an average of 7.6 to 22 pieces per 100 meters. More data should become available as the program continues.

<u>Riparian Conditions in the Sumas River, Chilliwack River, and Damfino, Tomyhoi, Frost, and Silesia Creeks (Washington State Fraser River Tributaries)</u>

The Washington State reaches of the Chilliwack River are within National Park boundaries and in a natural condition. The broad-scale analysis indicates that 69% of the riparian response reaches are in a late-seral conifer stage (Figure 52) (data from Lunetta et al. 1997). The non-forest component of this WAU consists of sub-alpine and alpine meadows or glaciers associated with mountain elevations. This results in a “good” rating for Chilliwack River riparian conditions.

The Washington State reaches of Domfino and Selesia Creeks are mostly within U.S. Forest Service boundaries, except for the uppermost reaches of Selesia Creek, which are in the National Park. Much of the Forest Service land in this WAU is in the Mount Baker Wilderness. Human impact is minimal in these areas, and the watersheds are considered to be natural. Riparian vegetation conditions are rated “good” with 78% in a late seral conifer stage (Figure 52) (data from Lunetta et al. 1997). The non-forest component of this WAU consists of sub-alpine and alpine meadows or glaciers associated with mountain elevations.

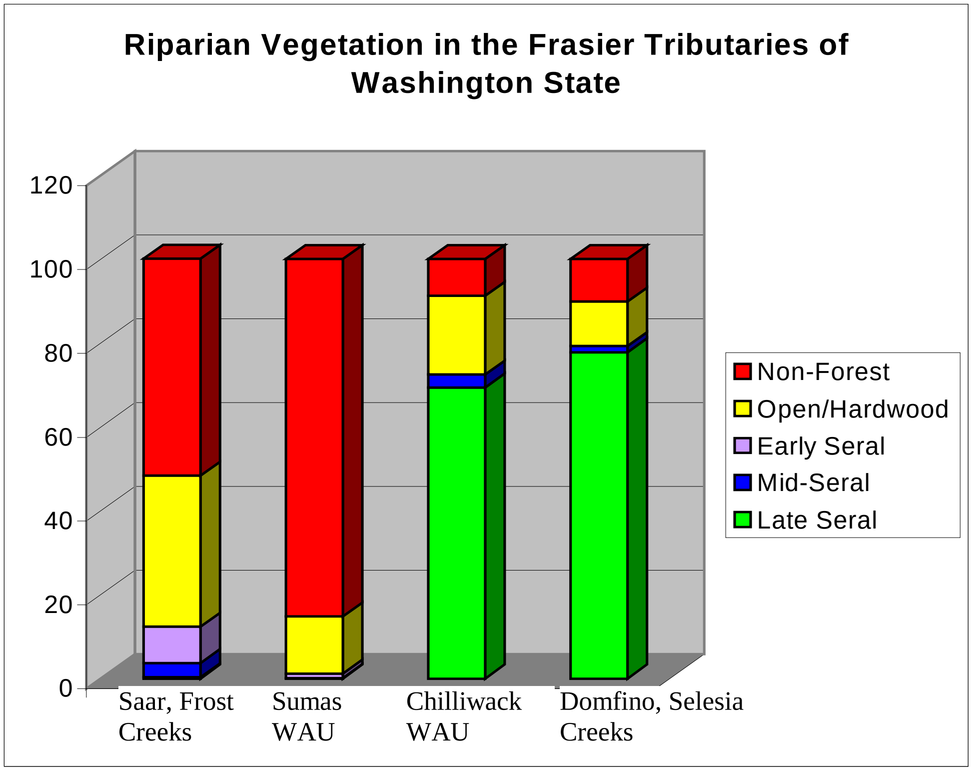
The riparian conditions for Frost Creek and Saar Creek are much more impacted due to the change in terrain from steep mountains to hills and lowlands, which facilitates land conversion from forestry to other uses. The WAU that includes Frost and Saar Creeks has riparian buffers consisting mostly of non-forest lands (52%) followed by hardwood or open forestland (36%) (Figure 52) (data from

Lunetta et al. 1997). Most (84%) of this area is under private ownership (Lunetta et al. 1997), with forest management in the upper reaches and agriculture in the lowlands (Whatcom Conservation District Map, unpublished data, 1991). The extensive conversion of riparian response reaches to non-forest uses results in a “poor” rating for riparian conditions in these streams. It is likely that many of the riparian areas of Saar Creek historically supported a hardwood riparian because of the partially hydric nature of the surrounding soils (Whatcom Conservation District map, unpublished data, 2001).

The Washington State riparian reaches of the Sumas River show an even greater conversion to non-forest use (85%) (Figure 52) (data from Lunetta et al. 1997), which results in a “poor” rating for riparian conditions. Historically, wetland prairies dominated the region (DOE 1995), but currently agriculture and rural residences comprise most of the watershed. Nearly all of the land (92%) is under private ownership (data from Lunetta et al. 1997).

The Sumas River reaches that are within the City of Sumas boundaries are impacted by a loss of riparian and invasion of Reed canarygrass (David Evans & Associates 1998). The riparian vegetation along Sumas Creek is lacking forest canopy cover in the lower and middle reaches where the riparian consists of willows shrubs, Reed canarygrass, and blackberry. Johnson Creek is also lacking riparian vegetation in the urbanized reaches, but has a mix of riparian conditions outside of the urban areas (David Evans & Associates 1998). Bone Creek also has a mix of riparian conditions with some reaches surrounded by Reed canarygrass.

Figure 52. Riparian vegetation by WAU in the Sumas and Chilliwack Rivers and tributaries (data from Lunetta et al. 1997).



Water Quality Issues within the Sumas River, Chilliwack River, and Damfino, Tomyhoi, Frost, and Silesia Creeks (Washington State Fraser River Tributaries)

Levels of nitrogen (including ammonia) and phosphorous in the Sumas River are among the highest levels in the Puget Sound region (DOE 1995), and high levels of nutrients can lead to algal blooms that deplete oxygen levels and lead to fish kills. For this reason, the Sumas River is rated "poor" for water quality. Riparian loss has been noted in the urban areas along the Sumas River and along the middle reaches of Sumas Creek where residential developments exist (David Evans and Associates 1998). However, water temperature data were not found. In addition, the Sumas River is on the 303(d) List for fecal coliform levels, while Sumas Creek is listed for low dissolved oxygen and fecal coliform (DOE 2000). Low dissolved oxygen levels (24% of the samples violated standards) have been measured in the Sumas River near Huntingdon, British Columbia (Erickson et al. 1995).

Johnson and Clearbrook Creeks, Sumas River tributaries, are also on the 303(d) List for low dissolved oxygen and high fecal coliform levels (DOE 2000). In Johnson Creek, nine different stream reaches have been listed, encompassing much of the stream length up to RM 8.0 (Figure 33). High levels of ammonia have also been detected in Johnson Creek (Erickson et al. 1995). Although turbidity decreased after implementation of Best Management Practices (BMP) for livestock management, nitrate, total phosphate, and fecal coliform increased after BMPs were implemented. This indicates that livestock waste is still entering Johnson Creek, and could be due to non-participating farms and/or improper techniques (Erickson et al. 1995). Waste load allocations have also been recommended for the Sumas wastewater treatment plant and for non-point ammonia, BOD, and fecal coliform (Erickson et al. 1995). Additional water quality monitoring is needed to determine if these recommendations are being implemented and are adequate.

Squaw and Pangborn Creeks are on the 303(d) List for low dissolved oxygen, high fecal coliform levels, and pH exceedances, resulting in a “poor” rating for water quality. The main cause for these problems is likely agriculture (Scott and McDowell 1994). Ground water contamination with banned pesticides, such as ethylene dibromide and 1,2-dichloropropane are also a concern (Hardy et al. 2001), resulting in a “poor” rating for ground water quality.

No other water quality data were found for this area. However, the upper Chilliwack, Domfino, and Selesia Creeks have likely “good” water quality conditions because of the low level of human impacts. The surrounding lands are within National Park or U.S. Forest Service boundaries.

Water Quantity Conditions in the Sumas River, Chilliwack River, and Damfino, Tomyhoi, Frost, and Silesia Creeks (Washington State Fraser River Tributaries)

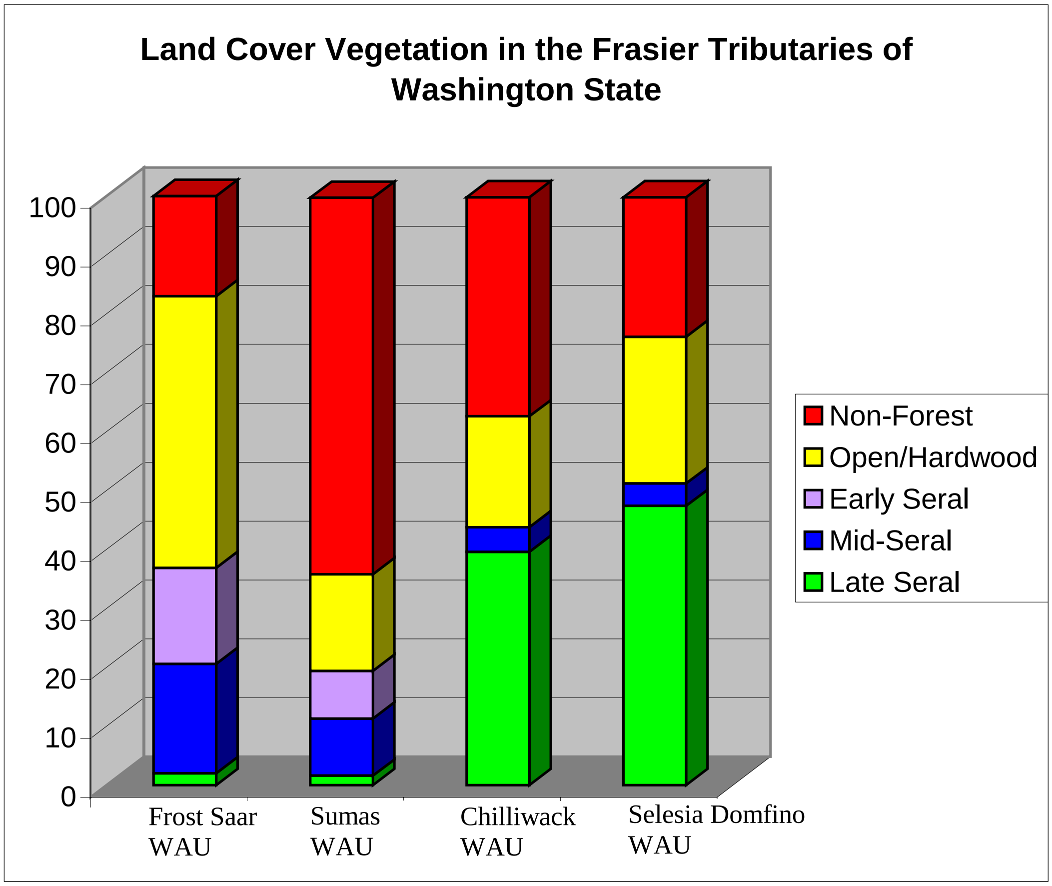
Water quantity conditions are “good” in the Washington portion of the Chilliwack, Damfino, Tomyhoi, and Silesia watersheds. The Chilliwack River is within the North Cascades National Park and is relatively undisturbed, and the Selesia watershed is within the U.S. Forest Service Mt. Baker Wilderness boundaries. The Tomyhoi and Damfino watersheds are also within the U.S. Forest Service boundaries, and have been minimally disturbed. In these forested regions, the percent of mature conifer is 44% for the Chilliwack WAU and 51% for the WAU consisting of Damfino, Tomyhoi, and Silesia watersheds (Figure 53) (data from Lunetta et al. 1997). Although these percentages might appear low for areas that are primarily natural, much of the remaining land cover in these WAUs consists of alpine meadows and glacial areas, which are naturally lacking in mature conifers.

In contrast, most (64%) of the original land cover in the Sumas River WAU has been converted to agricultural uses and to a lesser extent, urbanization (Figure 53) (data from Lunetta et al. 1997). The extensive conversion results in a “poor” rating for the land cover vegetation in the Sumas WAU. Historically, this area consisted of wetland prairies with 200 square miles of wetlands containing low shrubs, ferns, and sedges. Much of this land has been drained and urbanized to develop the Cities of Ferndale and Lynden or converted to agricultural use (DOE 1995). The loss of wetlands is a stream flow impact due to the ability of wetlands to buffer high flows and recharge streams during low flows. However, a hydrologic maturity rating cannot be applied to these areas because they historically did not support conifers. In fact, the word “Sumas” means “land of no trees” (DOE 1995). The Vedder WAU (Saar and Frost Creeks) is not rated for hydrologic maturity because historic versus current conditions are not well documented and the land conversion to non-forest uses is relatively low (17%) (data from Lunetta et al. 1997).

Impervious surface percentages have been estimated using land use information, resulting in “good” ratings of less than 1% impervious surfaces for the Sumas River, Saar Creek, and Johnson Creek watersheds (Whatcom Conservation District maps, unpublished data, 2000). The forested watersheds such as the Chilliwack, Silesia, Tomyhoi, and Damfino drainages are assumed to have “good” impervious surface ratings based upon land ownership by either the U.S. Forest Service or National Park.

Numerous surface and ground water rights exist throughout the Sumas River watershed, and the Sumas River and Saar Creek are closed to further water allocations (Figures 35 and 37) (DOE 1995). This results in a “poor” rating for low stream flows.

Figure 53. Land cover vegetation in the Sumas and Chilliwack River and tributaries (data from Lunetta et al. 1997).



The Condition of Estuarine and Nearshore Habitat in WRIA 1

Estuarine Habitat and Function in WRIA 1

For this report, an estuary refers to the body of water adjacent to freshwater systems where saltwater mixes with freshwater. WRIA 1 currently contains approximately 826 acres of estuarine wetlands (Scott and McDowell 1994; Whatcom County Planning Dept. 1997) primarily associated with Dakota, California, Terrell, Squalicum, Whatcom, Padden, Chuckanut, Oyster, and Colony Creeks, and the Lummi and Nooksack Rivers. The upstream-most extent of estuaries moves with the tides. Estuaries serve many important functions such as providing habitat for smoltification, migration, rearing, and refuge, as well as contributing to habitat complexity and ecological processes, such as detritus cycling (Williams and Thom 2000; Aitkin 1998).

For anadromous fish species, estuaries provide a critical mixing zone of fresh and salt water where juvenile and adult life stages can physiologically transition between freshwater and saltwater habitats. If the habitats necessary for successful rearing and predator refuge are not available within this mixing zone, the survival of these fish is jeopardized.

Estuary habitats produce a host of prey species important to juvenile salmonids and forage fish species that are in turn, prey of adult salmonids. Certain prey items appear to be selectively chosen over others depending on the salmonid life history stage. For example, juvenile chum salmon feed on a certain type of copepod that lives on the bacteria near decaying eelgrass (Simenstad and Salo 1982). In order to support the different prey needs of the different salmon species and life history stages in the estuary, the diverse mosaic of habitat types in an estuary need to be available and hydrologically accessible. The intertidal, shallow sub-tidal, blind channel, and distributary channel habitats in the estuary provide juvenile salmonids with access corridors to estuary habitats producing preferred prey species (Shreffler and Thom 1993). In addition, the interaction of tides and channel habitats provides a delivery system that transports preferred prey species from estuary habitats that are not accessible by juvenile salmonids to obtainable areas.

Intertidal and shallow subtidal habitat provides juvenile salmonids protection and refuge from avian and fish predators, while blind channel and side-channel estuary habitats serve as refuge from high water river discharge events. Distributary channels provide critical migration and movement routes between habitats. Estuaries provide a complex mosaic of shallow water habitats and distributary channels that serve as migration corridors for juvenile salmonids, while deeper water distributary channels serve as migration corridors for adults (Shreffler and Thom 1993).

Vegetative biomass produced in the estuaries is exported as detritus and is the primary fuel source for the estuary and nearshore marine detritus-based food webs upon which juvenile salmonids depend. The complex mosaic of estuary habitats supports salmonid survival by providing a wide variety of rearing and refuge opportunities to accommodate different juvenile out-migration strategies.

Loss of Estuarine Habitat

Dikes, dredging, and fills have resulted in the loss of considerable estuarine habitat and have interrupted the riverine and tidal hydrologic processes that create and support estuary habitats. Migration corridors and suitable rearing habitats have been lost and fragmented, while detritus and salmonid prey production have been lost and reduced (Nightingale and Simenstad 2001a). Dikes have reduced the complexity of habitat types available to juvenile salmonids in the estuary, consequently reducing refuge opportunities and survival options available to juvenile salmonids. Dredging and filling can also re-suspend contaminated sediments, which is a major concern in inner Bellingham Bay (Pacific International Engineering and Anchor Environmental 1999) (see the water and sediment quality section below).

All of the estuaries in WRIA 1 have been impacted by dredging, fills and/or dikes. With the exception of a detailed analysis of inner Bellingham Bay that estimates the loss of intertidal habitats primarily associated with the estuaries of Squalicum, Whatcom and Padden Creeks, there are very little data that quantifies the estuary losses for the smaller streams. In contrast, Bortleson et al. (1980) and more recently, Collins and Sheikh (in prep.) provide detailed estimates of estuary habitat losses for the Lummi River and Nooksack River estuaries.

The Samish Bay delta has been diked to support pastureland with agricultural discharge passed to Samish Bay via tidegates and pumps (Determan 1995; Whatcom County Council of Governments 2000). Subaerial wetlands in Samish Bay have decreased from approximately 1.9 to 0.4 km^2 (data from Pacific International Engineering and Anchor Environmental 1999). These wetland losses result in a “poor” habitat rating for the quantity of estuarine habitat in Samish Bay.

Dikes, dredging, and/or fill have impacted the estuaries of Drayton Harbor, Terrell, Squalicum, Whatcom, Padden, Oyster, and Colony Creeks (Scott and McDowell 1994; Brian Williams, WDFW, personal communication; Pacific International Engineering and Anchor Environmental 1999). However without quantification, no ratings on estuarine habitat quantity are provided for Drayton Harbor and the estuaries of Terrell, Oyster, and Colony Creeks.

In a more detailed comparison of historic to current habitat, there has been an estimated loss of 282 acres of aquatic land in inner Bellingham Bay with most of the lost acreage classified as intertidal (data from Pacific International Engineering and Anchor Environmental 1999). Fills near the mouths of Whatcom, Squalicum, and Padden Creeks are the primary cause of this loss (Pacific International Engineering and Anchor Environmental 1999). The Padden Creek estuary is about one tenth its historical size due to fills for a cedar mill and cannery (Scherrer 2001). The Squalicum Creek estuary has been reduced to less than one acre (Brian Williams, WDFW, personal communication). These estuaries are rated “poor” for estuarine habitat quantity.

Historically, the lower Nooksack and Lummi Rivers were associated with numerous estuarine and tidally-influenced riverine wetlands, but much of this habitat was drained and diked for conversion to agricultural use (People for Puget Sound 1997; Collins and Sheikh in prep.). Estuarine and riverine-tidal wetlands were especially extensive on the Lummi River side, which was the dominant outlet of the Nooksack River in recent history before the mid 1880s (Collins and Sheikh in prep.). In contrast, the Nooksack River delta has been less altered by dikes, dredging, and fills compared to other estuaries in Puget Sound (People for Puget Sound 1997).

The subaerial wetlands in Lummi Bay have decreased from an estimated 5.8 to 0.3 km^2, while the Lummi Bay intertidal area has remained at about the same as historic levels (Bortleson et al. 1980). One of the impacts includes the conversion of about 750 acres of tideflat to subtidal habitat for the Lummi Sea Ponds (S. Seymour, WDFW, personal communication). These wetland losses result in a "poor" habitat rating for the quantity of estuarine habitat in Lummi Bay.

This same analysis reports an increase in intertidal wetlands in the Nooksack estuary and Bellingham Bay from 6.7 to 8.5 km^2 with subaerial wetlands remaining about the same as historic levels (Bortleson et al. 1980). The increased intertidal wetlands are thought to be at least partially the result of the 1860s diversion of the Nooksack River into Bellingham Bay. Prior to 1860, a sizeable portion of the Nooksack River drained into Lummi Bay, but in 1860, a dam was constructed to divert most of the Nooksack River into Bellingham Bay (People for Puget Sound 1997). Because of this, the Nooksack delta in Bellingham Bay is relatively young and is increasing in size, while the reduced sediment input through the Lummi River has led to regression of the Lummi Bay shoreline (People for Puget Sound 1997).

However, another possible explanation for the reported increase in intertidal wetlands is that the rapid progradation of the Nooksack delta sandflats into Bellingham Bay (when a 1916 U.S. Coast and Geodetic Survey chart is compared to present day) is the result of an accelerated sediment bedload due to logging in steep and erodible soils that are found in the upper Nooksack watershed (Mike MacKay, Lummi Indian Nation, personal communication). While the data might indicate a net gain in intertidal habitat, the quality of the new habitat may be poor as it consists of sandflats exposed to high wind/wave energy. Anecdotal reports from tribal elders would suggest also that the nearshore water is more turbid in recent decades due to this high erosion rate, and that the distribution of eelgrass and other light sensitive macro-algae may have been reduced near the mouth of the river due to the influence of the turbid Nooksack river plume (Mike MacKay, Lummi Indian Nation, personal communication).

An analysis of Bellingham Bay by Pacific International Engineering and Anchor Environmental in 1999 has estimated a loss of 282 acres of aquatic land in inner Bellingham Bay with most of the lost acreage classified as intertidal This same analysis estimated a loss of 1328 aquatic acres in the Nooksack River delta, with most of the loss (715 acres) in intertidal lands and another 613 acres of lost shallow sub-tidal land (Pacific International Engineering and Anchor Environmental 1999). A net gain of 434 acres of aquatic lands in outer Bellingham Bay was also estimated, which includes a gain of 1507 acres of intertidal land and a loss of 1073 of shallow sub-tidal land (Pacific International Engineering and Anchor Environmental 1999). The loss of intertidal land in inner Bellingham Bay results in a “poor” rating for estuarine habitat quantity. The changes in outer Bellingham Bay are not rated, due to insufficient information on how these changes relate to salmonids. However, because estuarine habitat types are greatly dependent on depth, the conversion of shallow sub-tidal to intertidal land is a concern that warrants further study.

In an assessment by Collins and Sheikh (in prep.), the greater Nooksack delta, including the Lummi River delta, has shown decreases in estuarine wetlands by 74-75% (600 to 154 hectares) and an 87% (1150 to 154 hectares) decrease in riverine-tidal wetlands from 1880 to 1938. During that same time period, palustrine wetlands increased by 900% (100 to 1000 hectares), and agricultural lands increased from none to 2800 hectares (data from Collins and Sheikh, in prep.).

Tidegates constitute another type of estuarine loss by isolating significant estuary habitat and disconnecting the riverine and tidal hydrologic processes that create and support estuary habitats (Brian Williams, WDFW, personal communication). Migration corridors, rearing habitats, and refuge habitats for juvenile salmonids have been lost and fragmented. Tidegates have not been quantified in WRIA 1, but several are known along Lummi Bay (ACOE 2000).

Nearshore Habitat and Function in WRIA 1

The nearshore environment is the interface between marine and terrestrial habitats, and extends from the outer limit of the photic zone to coastal landforms such as bluffs, sand spits, and coastal wetlands, including the riparian zone on or adjacent to any of these areas. WRIA 1 currently contains approximately 134 miles of marine shoreline and 186 acres of marine wetlands (Scott and McDowell 1994; Whatcom County Planning Dept. 1997). Nearshore habitat functions as important migration corridors, rearing and refuge habitat, habitat for prey species, and detritus input (Williams and Thom, 2000).

Specifically, the nearshore intertidal and shallow sub-tidal habitats provide a critical migration corridor for juvenile salmonids, which use these areas for feeding, shelter from predators, and rearing. The nearshore riparian, intertidal, and shallow sub-tidal habitats produce a host of prey species important to juvenile salmonids and forage fish species. The nearshore terrestrial, salt marsh, eelgrass, and macro-algae habitats are a valuable source of detritus that fuels the nearshore detritus-based food chain (Thom and Williams 2001). In addition, juvenile salmonids are dependent upon the intertidal, shallow sub-tidal, and marine vegetation communities for refuge from avian and fish predators until they transition to deep-water habitats.

The nearshore intertidal, eelgrass, and macro-algae habitats provide valuable spawning habitats for forage fish species that are important prey for juvenile and adult salmonids, while the complex mosaic of intertidal, shallow sub-tidal, and sub-tidal habitats provides a wide range of diverse rearing and refuge opportunities to accommodate different juvenile chinook out-migration and survival strategies (Cederholm et al. 2000).

Shoreline Modifications in the Nearshore Habitat in WRIA 1

Shoreline modifications can be detrimental to nearshore and estuarine processes by fragmenting the nearshore intertidal and shallow sub-tidal habitats, reducing nearshore habitat complexity, reducing sediment recruitment (erosion), and disrupting longshore sediment transport processes that support and sustain the physical character and biological productivity of the upper intertidal habitats (Clark 1996). Shoreline modifications can also result in a loss of intertidal habitats and associated prey and detritus production.

Shoreline modifications such as bulkheads, rip-rap, or fills cover an estimated 34% of the shoreline length in Whatcom County (Berry et al. 2001). Out of the 14 counties included in the inventory, Whatcom County ranks 8th in the percentage of modified shoreline miles. Areas with extensive (greater than 40% by miles) shoreline modifications in WRIA 1 include the segments within the Peace Arch area, Blaine, Birch Bay, Sandy Point Shores, Lummi Bay, Bellingham Bay, and Samish Bay (Figures 54 and 55) (Map S1) (data from Berry et al. 2001). Rip-rap is the most common modification along the Peace Arch area, Sandy Point Shores, Lummi Bay, Bellingham Bay, and Samish Bay. A mix of bulkheads, rip-rap, and landfill modify the Blaine and Birch Bay shorelines; bulkheads and rip-rap also impact the shoreline along Lummi Bay and Sandy Point Shores. The areas with highly modified shorelines are rated "poor". Point Roberts is also considerably modified (30 to 40%), but less so than the above mentioned areas, and is rated "poor".

"Fair" rated (10-30% modified miles) segments can be found in limited areas of Drayton Harbor, Peace Arch, Neptune Beach, and Lummi Bay (Figures 54 and 55) (Map S1), but in most cases, the overall rating is different from "fair" due to the presence of other conditions from other segments in the same section. The individual segment ratings, which provide the most detail, can be seen on Map S1. Neptune Beach contains a mix of ratings as seen on Map S1, and when all data are taken together, they result in an overall impact of 30 to 40%. Semiahmoo Spit has a mix of "good" and "poor" segments (Map S1), that when taken together, result in a "fair" (10-30% modified miles) rating (Figure 55).

Shorelines with few modifications include Birch Point, Point Whitehorn, Cherry Point, Lummi Island, Portage Island, Eliza Island, the Nooksack River Delta, and Govenors Point area (Figures 54 and 55) (Map S1) (data from Berry et al. 2001). These are rated "good" for shoreline modifications.

Whatcom County has initiated a pilot study "Shoreline Reach Coastal Processes Analysis" to characterize the coastal processes and historical shoreline erosion and accretion trends for discrete shoreline reaches. Causes of erosion, the need for shore protection, and suitability of soft shore protection approaches will also be evaluated. If successful, it is anticipated that the pilot study analysis design will be applied broadly to the marine shoreline in Whatcom County and will eventually provide a tool that will assist in shoreline management decisions (personal communication Brian Williams, WDFW).

Figure 54. Shoreline modifications in WRIA 1 (data from Berry et al. 2001).

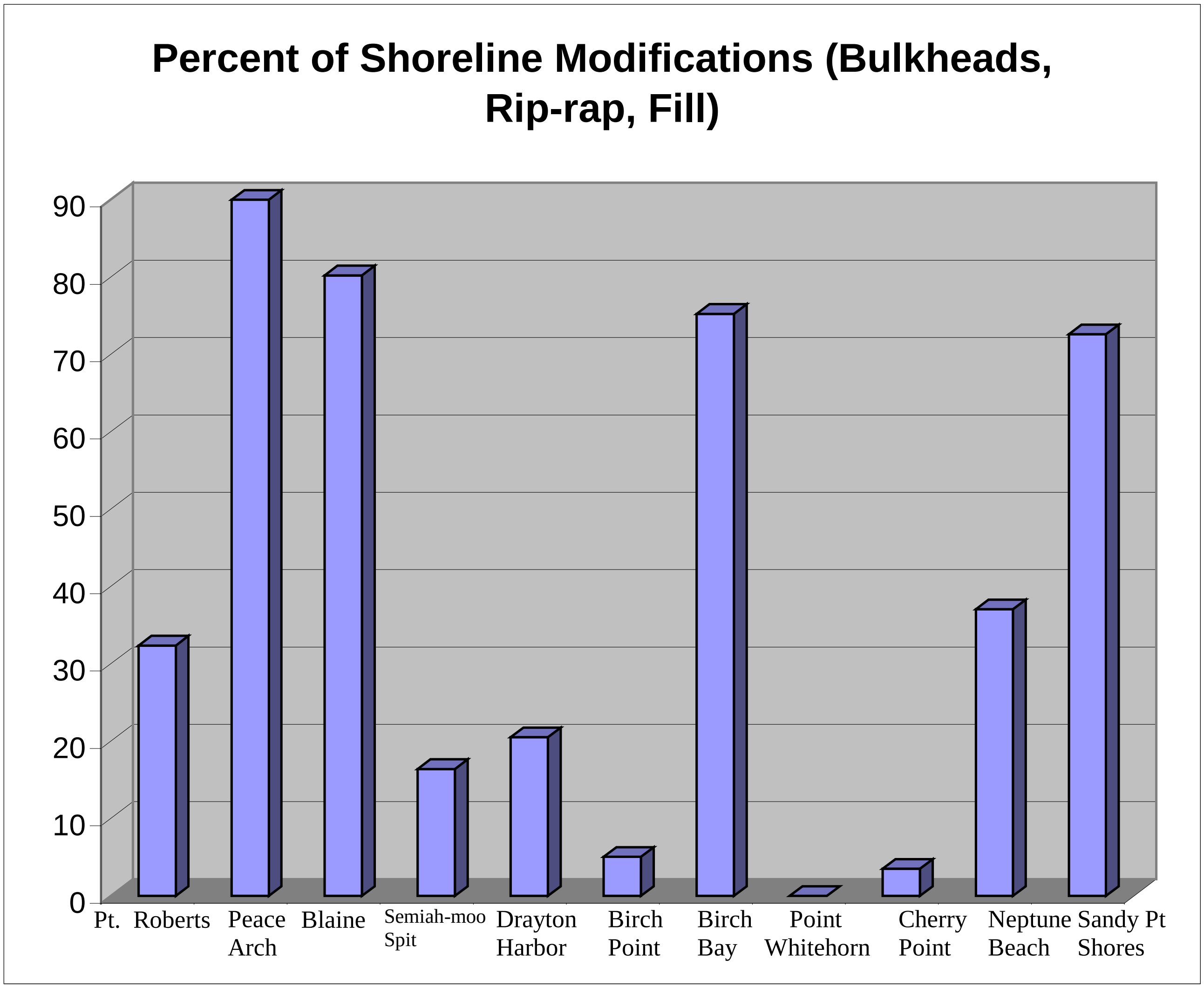
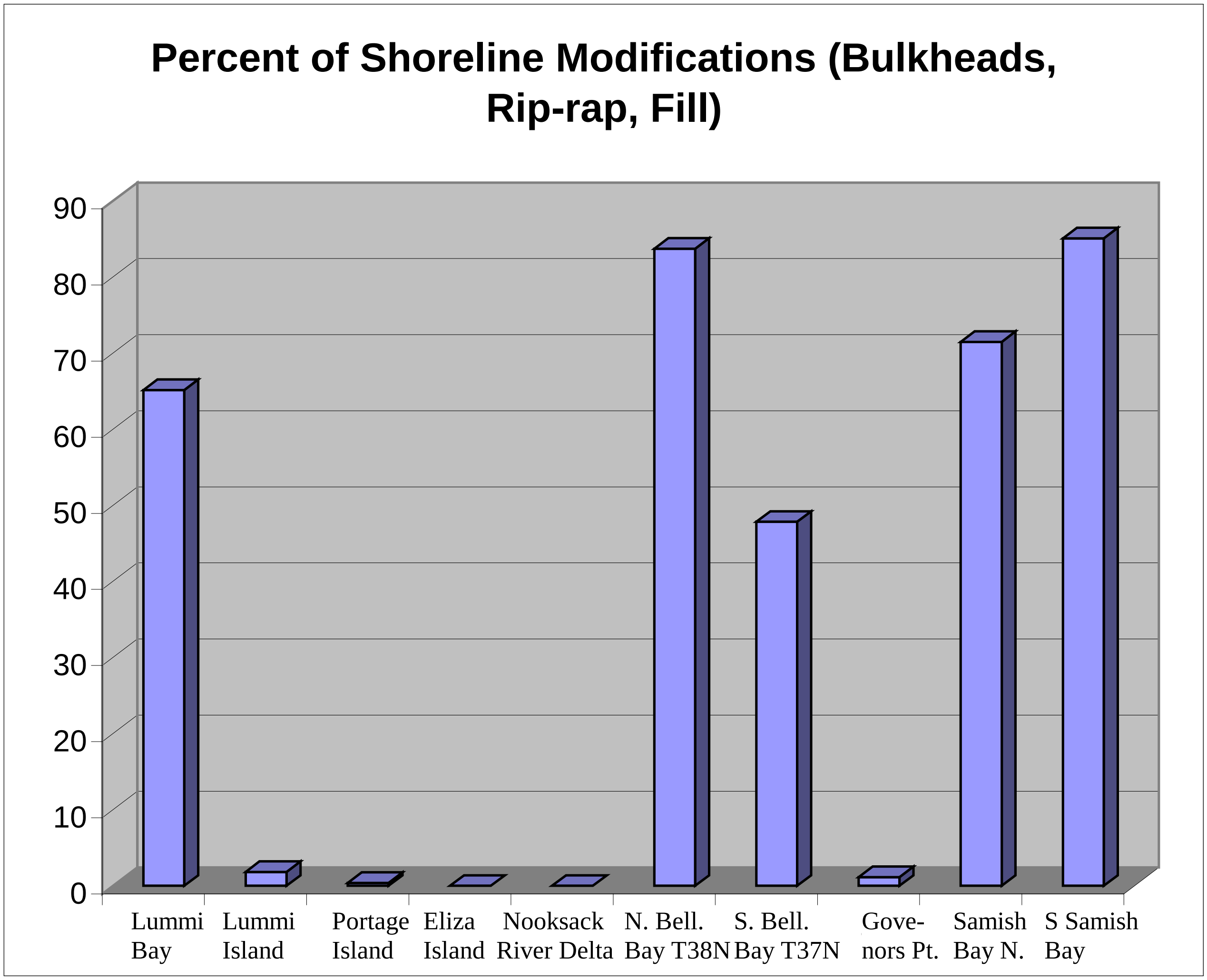


Figure 55. Shoreline modification in WRIA 1 (data from Berry et al. 2001).



Overwater Structures and Eelgrass Habitat Conditions in WRIA 1

Additional impacts to nearshore habitat can occur from overwater structures. The shadow cast by overwater structures fragments the nearshore intertidal and shallow sub-tidal habitats (reviewed in Nightengale and Simenstad 2001). The shadow cast by overwater structures has also been shown to change juvenile salmonid nearshore migration, and this altered behavior can potentially increase the risk of predation by avian and fish species, as well as reduce feeding success (reviewed in Nightingale and Simenstad 2001b). The shadow reduces the light available for photosynthesis thus impacting the health, survival and productive functions of the epiphyte, eelgrass, and macro-algae habitats and reducing the production of prey and detritus (Fresh et al. 1995; reviewed in Nightingale and Simenstad 2001b). Examples where commercial structures are known to occur include the Arco Pier, Intalco Pier, British Petroleum Pier, Gooseberry Point Ferry Terminal, Lummi Island Ferry Terminal, and inner Bellingham Bay (Brian Williams, WDFW, personal communication). In addition to these, boat ramps, piers, and slips have been inventoried and are mapped on Map S2. These types of structures are numerous at Point Roberts Marina (712 ramps, piers, slips), Blaine Marina (228 ramps, piers, slips), Birch Bay Marina (178 ramps, piers, slips), Sandy Point Shores Marina (325 ramps, piers, slips), and Squalicum Marina (1163 ramps, piers, slips), and are rated "poor" for overwater structures.

One of the major concerns with overwater structures is their effect on eelgrass beds. Eelgrass provides several benefits for salmonids, including nursery habitat, food, protection from predators, and shoreline stabilization (Levings and Thom 1994). It is also an important component of nutrient cycling. Chum salmon feed on copepods that live on the bacteria near decaying eelgrass (Simenstad and Salo 1982), and eelgrass provides spawning substrate for herring, another prey item of salmonids (Humphreys and Hourston 1978). Dredging, increased sediment (turbidity), and overwater structures are common types of impacts to eelgrass beds. Ratings for eelgrass beds are not generally provided in this report unless there are quantified or known impacts. However, structures that provide shade are rated above, and these can relate to eelgrass production and distribution in areas that historically provided eelgrass habitat.

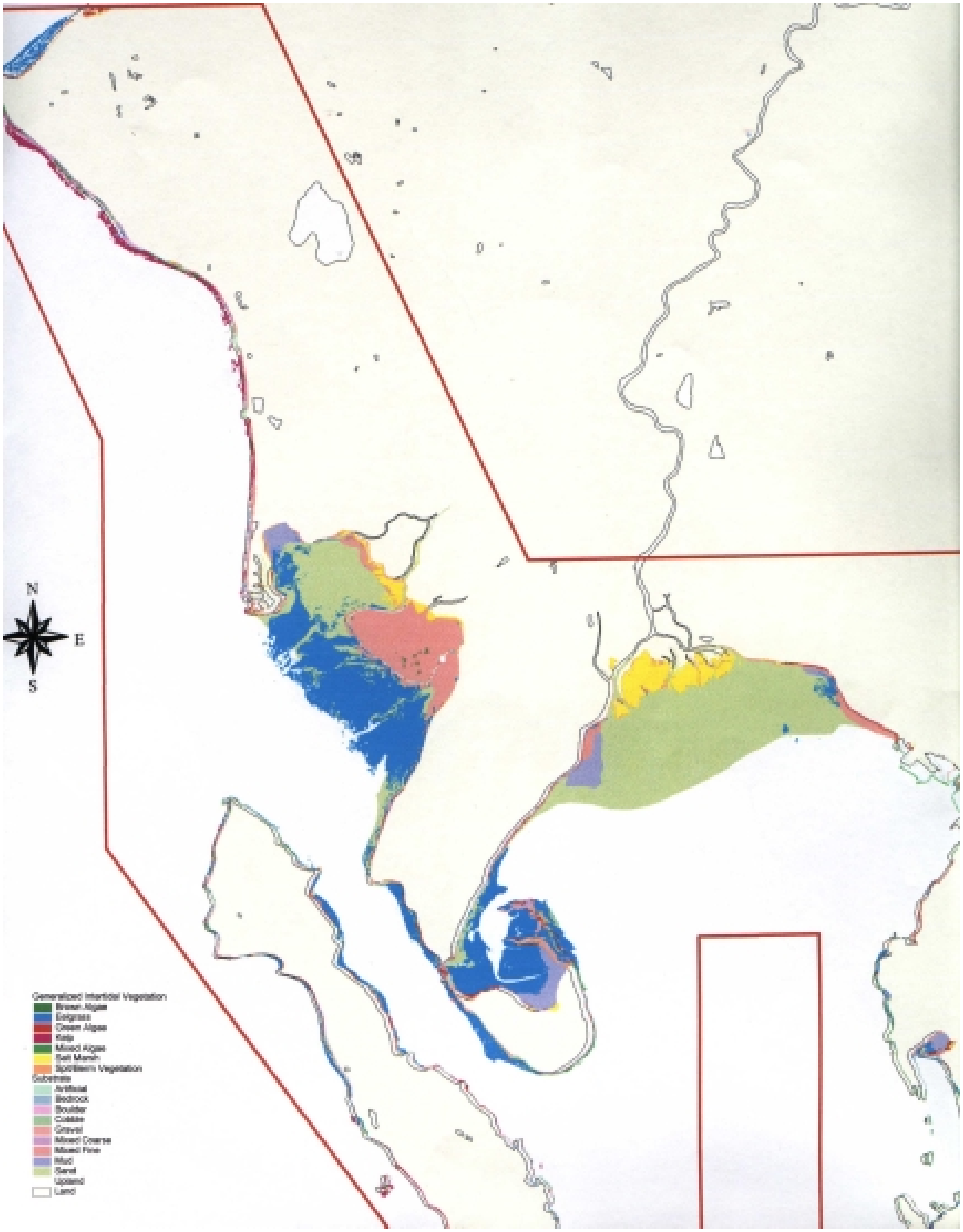
Of the 147 miles of Whatcom County shoreline inventoried by the Department of Natural Resources, 55% contained eelgrass (Berry et al. 2001). In addition, they classified areas has having either continuous, patchy, or null (absent) eelgrass beds, and those results are described as follows and are shown in Map S3. Continuous beds of eelgrass are located near the Peace Arch, Blaine, Semiahmoo Spit, Birch Point, Birch Bay, and in Samish Bay, as well as along scattered segments within the Lummi Island, Portage Island, and Goosberry Point sections (Map S3) (Berry et al. 2001). Patchy eelgrass beds are located near Point Roberts, with important beds in Boundary Bay (Levings and Thom 1994). Patchy eelgrass beds are common along Point Whitehorn, Neptune Beach, Lummi Bay, and in the Chuckanut/Pleasant Bay area (Berry et al. 2001). A mix of patchy and continuous beds were estimated for south Bellingham Bay (T37N), Cherry Point, and along Lummi, Portage, and Eliza Islands. However, even though continuous eelgrass beds were described for Samish Bay, some of those beds are routinely plowed for Pacific oyster cultivation (West 1997). For that reason, the Samish Bay eelgrass beds are downgraded to a "poor" rating. Because of the importance of eelgrass beds to salmonid production, all eelgrass habitat (patchy or continuous) should be protected throughout WRIA 1.

Several nearshore areas in WRIA 1 are lacking in eelgrass, but in many cases, it is not clear whether the lack of eelgrass is due to natural or human-caused conditions and for this reason, will not be rated. In the DNR inventory, three out of ten areas in Drayton Harbor had continuous eelgrass beds and one had patchy eelgrass beds. The remaining units had no eelgrass beds (Map S3) (Berry et al.

2001), although eelgrass is thought to be more abundant than stated in the inventory (Steve Seymour, WDFW, personal communication). Blaine Marina is also periodically dredged (Scott and McDowell 1994), which would impact eelgrass if historically present. Birch Bay Marina, Sandy Point Shores, parts of the Lummi Island shoreline, and the Nooksack River delta were also lacking in eelgrass (Figure 56), although the quantity of eelgrass in the Nooksack River delta is probably due to the dynamic nature of the area rather than direct human impact. One known impact on historic eelgrass beds is in inner Bellingham Bay, where eelgrass has declined by 30% due to dredging and filling (Thom and Hallum 1990). This results in a "poor" rating.

In addition to eelgrass beds, the Whatcom County shoreline consists of 7% (by miles) of floating kelp, 18% non-floating kelp, and 34% sargassum (Berry et al. 2001). Kelp beds provide food and shelter for a variety of species, including salmonids, and floating vegetation mats provide transport in addition to food and shelter (Simenstad et al. 1991; Shaffer et al. 1995). Kelp provides a spawning substrate for herring (Harrold et al. 1988).

Figure 56. Locations of eelgrass beds, algae, and substrate types in WRIA 1 (Figure from Andrew Phay, Whatcom Conservation District, 2000).



Fill and Dredging Impacts to Nearshore Environments in WRIA 1

Nearshore fills and dredging fragment the nearshore intertidal and shallow sub-tidal habitats, and can result in a loss of intertidal habitats including eelgrass and macro-algae habitats and the loss of associated prey and detritus production (Nightingale and Simenstad 2001a). They can also result in a loss of intertidal shallow refuge habitats, reduced nearshore habitat complexity, and a loss or reduction of sediment recruitment (erosion) and longshore sediment transport processes that support and sustain the physical character and biological productivity of the upper intertidal habitats. Nearshore fills and dredging have been shown to be an obstacle to juvenile salmonid nearshore migration (Nightingale and Simenstad 2001a). When the migration behavior of juvenile salmonids is altered, the risk of predation by avian and fish species is potentially increased.

Fills have occurred along the nearshore as a result of the Blaine Marina, Birch Bay Marina, Intalco, Lummi Sea Pond, inner Bellingham Bay, Post Point Burlington Northern Railroad Trestle, Chuckanut Bay Burlington Northern Railroad Trestle, and Oyster Creek Oyster Farm (Brian Williams, WDFW, personal communication). Known areas where dredging has occurred include Point Roberts Marina, Blaine Marina, Birch Bay Marina, Sandy Point Marina, and inner Bellingham Bay, including the Whatcom Creek waterway, the I and J Street waterway, and the Squalicum Creek waterway (Brian Williams, WDFW, personal communication; ACOE 2001). Railroads are closely aligned with the WRIA 1 shoreline from Samish Bay through most of Bellingham Bay. Their impacts on the shoreline and salmonid resources need to be quantified.

Sand beaches provide spawning substrate for surf smelt and sand lance and are dependent on the longshore transport of sediment from feeder bluffs (Clark 1996). Large increases and decreases in the level of sedimentation can have impacts on the food web that supports salmonids. Excess sediment from land alterations is likely detrimental for certain plants, surf smelt, and herring (Levings and Moody 1976; Morgan and Levings 1989). The densities of algae were significantly different following a landslide along Puget Sound that resulted in a sediment plume that lasted weeks (Shaffer and Parks 1994).

Sediment transport processes are known to be disrupted by shoreline modifications, filling, and dredging, as discussed above. However, specific sediment transport analyses are needed in WRIA 1. The only sediment data found are observed estimates of sediment abundance with no quantification and no details regarding transport processes. Those observations indicate that abundant levels of sediment were estimated near the Peace Arch, Semiahmoo Spit, Birch Bay, Point Whitehorn, Lummi Bay, Sandy Point Shores (except at the marina), and Samish Bay, with moderate to abundant sediment levels along Point Roberts, Birch Point, Cherry Point, and Portage Island (data from Berry et al. 2001). Sparse sediment levels were reported along the shorelines of Blaine, Drayton Harbor, Eliza Island, and Bellingham Bay, and moderate levels near Neptune Beach and the Nooksack River delta. Mixed moderate to sparse sediment levels were estimated along Lummi Island and the Chuckanut/Pleasant Bay area. The sediment levels were not rated in this report due to a lack of additional information such as trends in time and impacts to salmonids and their food supply.

Riparian Conditions in the Estuarine and Nearshore Environments of WRIA 1

The riparian vegetation along estuarine and nearshore environments constitutes a transition zone between tidally-influenced aquatic habitat and terrestrial habitat, and provides several important functions. These can include shade, detritus input, marsh plant colonization, bank stability, wave energy deflection and absorption, large woody debris (LWD), and terrestrial insects which serve as salmonid prey (Volk et al. 1984; Simenstad and Wissmar 1985; Everett and Ruiz 1993; Whitehouse et al. 1993; Maser and Sedell 1994), depending on the type of vegetation. Numerous species of marine riparian vegetation can be found, depending on environmental conditions such as salinity and soils. Pentilla (2001b) compared the effect of shade on surf smelt egg survival, noting 36% dead eggs in shaded areas compared to 60% in non-shaded areas.

Residential bulkheads, residential view corridors, commercial shoreline armoring, dikes, culverts, and commercial fills are among the more common types of impacts that reduce riparian vegetation. All of the highly modified shoreline areas discussed above (Peace Arch area, Blaine, Birch Bay, Sandy Point Shores, Lummi Bay, Bellingham Bay, and Samish Bay) contain very little (less than 10% of shoreline length) overhanging riparian vegetation (Figures 57 and 58) (Map S4) (data from Berry et al. 2001).

In contrast, the shorelines with fewer modifications (Birch Point, Point Whitehorn, parts of Portage Island, Eliza Island, Lummi Island, the Nooksack River Delta, and Govenors Point) generally contained a greater percentage of overhanging riparian vegetation, with the exception of the Nooksack River delta and Govenors Point (Figures 57 and 58) (Map S4) (data from Berry et al. 2001). The Nooksack River delta is an exception, likely due to its growing, dynamic character, increased by water flow and sediment when the diversion of the Nooksack River from Lummi Bay to the northern Bellingham Bay occurred.

Figure 57. Percent of overhanging riparian vegetation along shorelines in WRIA 1 (data from Berry et al. 2001).

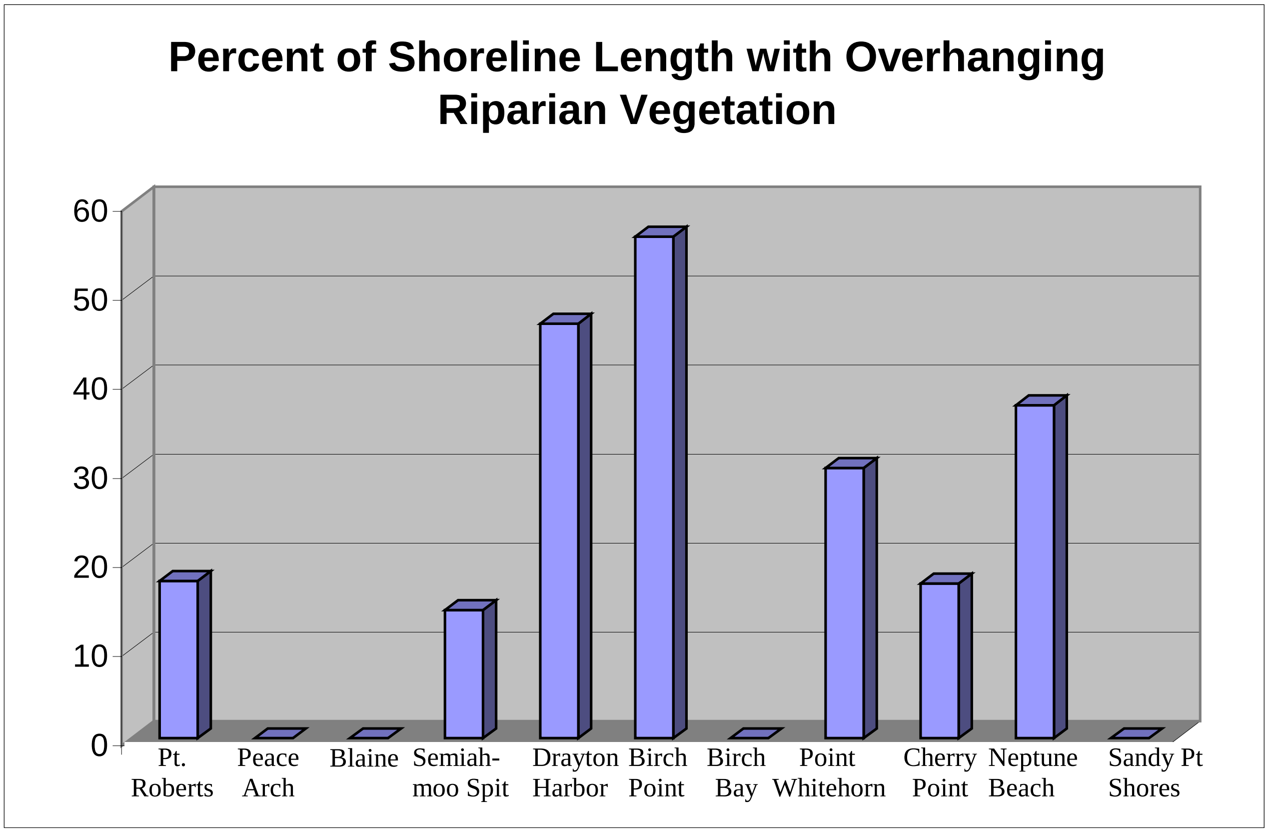
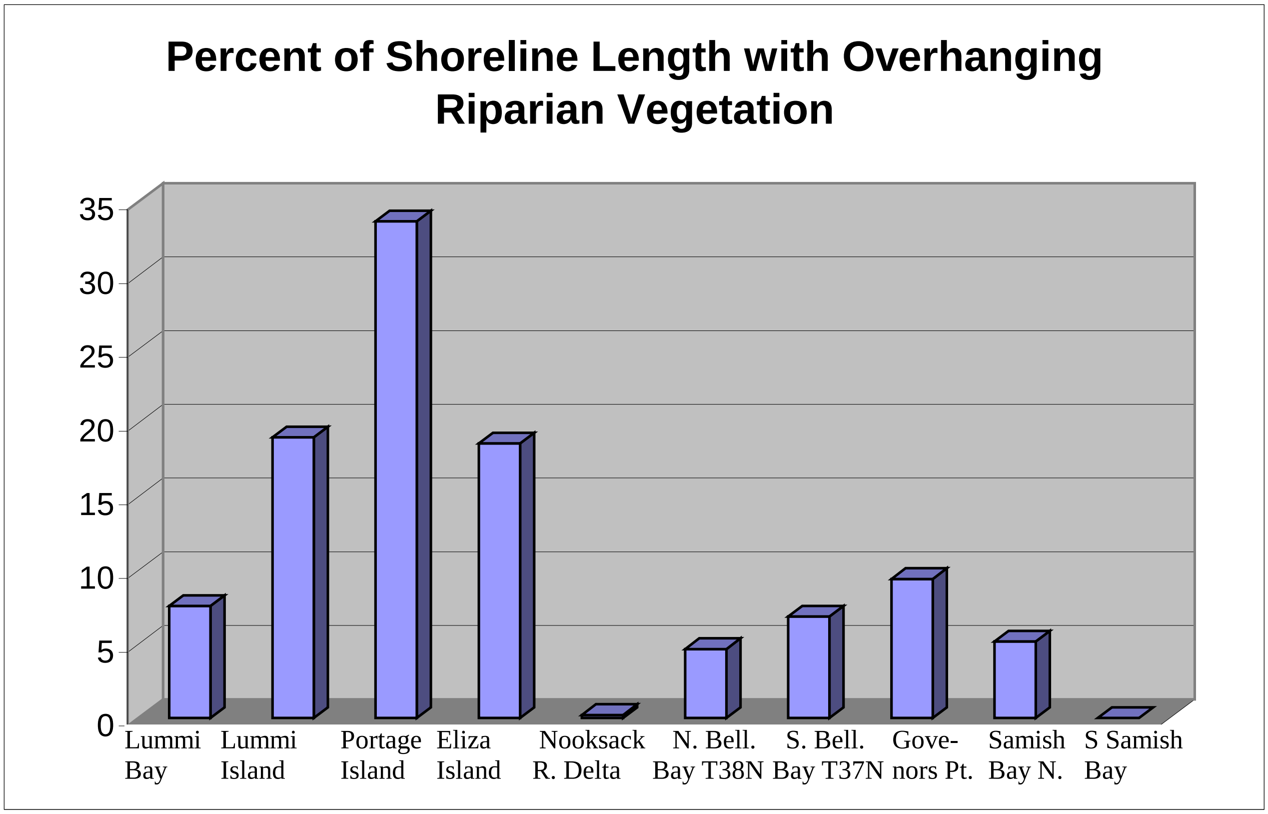


Figure 58. Percent of overhanging riparian vegetation along shorelines in WRIA 1 (data from Berry et al. 2001).



<u>Water and Sediment Quality Conditions in the Estuarine and Nearshore Environments of WRIA 1</u>

Numerous water and sediment quality problems exist in localized WRIA 1 estuarine and nearshore areas and are related to industrial, urban, and agricultural activities. The most serious WRIA 1 water quality problems are contaminated sediments in small, localized areas of inner Bellingham Bay, which are rated "poor" for water/sediment quality. The areas near Whatcom Creek and the I&J Waterways are on the 1998 303(d) List for elevated levels of mercury, arsenic, copper, lead, zinc, acenaphtene, fluorene, phenanthrene, anthracene, 2-methylnaphthalene, fluoranthene, pyrene, benz(a)anthracene, chrysene, benzo(b,k)fluoranthenes, benzo(a)pyrene, indo(1,2,3-c,d)pyrene, dibenzo(a,h)anthracene, benzo(g,h,I)perylene, bis(2-ethylhexyl)phthalate, dibenzofluran, phenol, PCBs, 2,4-dimetholphenol, pentachlorophenol, pH, and fecal coliform (DOE 2000). Squalicum Harbor has phenol levels (associated with decaying wood) above the marine standard, and dibenzofuran and retene have been detected (Cubbage 1994). The phenol levels in Squalicum Harbor result in a "poor" water/sediment quality rating.

Increased levels of organochlorines such as PAHs and PCBs can be toxic, and accumulate in tissue, causing tumors and suppressing the immune systems in salmonids (Varanasi et al. 1993). These chemicals can also be lethal to benthic organisms, which serve as food for salmonids, resulting in a potential reduction of prey, and the toxins accumulate in benthic organisms, contaminating the food web. At least two studies have indicated that these toxins can impact herring (see EVS Environment Consultants 1999).

In a recent list of contaminated sediment sites in Puget Sound, 9 of 134 total sites needing cleanup were located in Bellingham Bay (Dept. of Ecology 2001). These include the Whatcom Waterway, Harris Avenue Shipyard, Georgia Pacific outfall, BB4, Olivine-Hilton Avenue, Squalicum Shipyard, BB&, BB8, and the Cornwall Avenue landfill. All of these were industrial-caused except for the Cornwall Avenue site, which was a historic municipal landfill (Dept. of Ecology 2001). The nine sites cover a total of 213 acres that require cleanup with 190 acres in the Whatcom Waterway site. Currently, the status of cleanup is in the initial planning and negotiation stages (Dept. of Ecology 2001).

Forty potential sources for water and sediment contamination were identified in or near Bellingham Bay (Figure 59) (Pacific International Engineering and Anchor Environmental 1999). Ten of these sites require National Pollutant Discharge Elimination System (NPDES) permits, 12 are suspected or confirmed contaminated sediment sites, and 18 are surface water drainage outfalls. The sources of contamination are believed to be from past practices (Elardo 2001). One major source of the mercury is thought to be from the Georgia-Pacific choloralkali plant, and mercury levels have dropped in the last twenty years, although levels are still high enough to warrant a listing (Erickson et al. 1995). Peripheral areas to inner Bellingham Bay have shown past contamination, but these have been capped.

Outer Bellingham Bay is on the 1998 303(d) list for pH and fecal coliform (DOE 2000), but because fecal coliform does not directly impact salmonids, it will not be further discussed. Bellingham Bay also has persistent stratification, which makes it susceptible for algal blooms and results in lower oxygen levels in deeper waters (Erickson et al. 1995). It has also been rated as an area of “high” concern for marine water quality due to the stratification, low dissolved oxygen and nitrogen dissolved nutrients, and moderate ammonia and fecal coliform levels (DOE 2002a). The lowest levels of dissolved oxygen were less than 2 mg/L near Point. Frances.

Other water quality problem areas include Drayton Harbor, Samish Bay, and Lummi Bay/Hale Passage, which are on the 1998 303(d) List for high fecal coliform levels (DOE 2000). Drayton Harbor has been important for shellfish production and Pacific herring spawning habitat, but high fecal coliform levels have resulted in closures of shellfish harvest (Nelson et al 1991). Contamination is likely the result of agriculture and failing septic systems along Dakota and

California Creeks and from urban run-off from the City of Blaine. Although elevated fecal coliform levels indicate degraded water quality conditions, they are not known to directly impact salmonids.

However, several other problems that can impact salmonids have been documented in Drayton Harbor. Sampled sites had both significant toxicity and contamination (benzoic acid, phenols) (Long et al. 1999). In 1997, stratification with low dissolved oxygen and elevated ammonia levels were recorded in Drayton Harbor (Hirsch Consulting Services 2000). Also, DOE has rated Drayton Harbor as an area of "high" concern for marine water quality issues due to limiting nitrogen dissolved nutrients and seasonal stratification (DOE 2002a). This results in a "poor" rating for water/sediment quality.

One formerly high priority area has been the Intalco site near the Strait of Georgia, which ranked 3 out of 49 for contaminated sediment problems in Puget Sound in 1996 (Dept. of Ecology 2001). The 1998 303(d) List shows contaminated sediment exceedances for PCBs, cadmium, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benz(a)anthracene, chrysene, benzo(b,k)fluoranthenes, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenzo(a,h)anthracene, benzo(g,h,i)perylene, and dibenzofuran (DOE 2000). In two out of four herring embryotoxicity studies at Cherry Point, greater levels of mortality and deformed larvae were recorded for some stations in the Cherry Point area compared to laboratory controls (Kocan and MacKay 1991, Kocan 1991, Kocan 1992, Kocan 1998). These studies suggest that there may be episodic nearshore water quality problems that significantly affect developing herring embryos. However, recent and extensive testing of sediments in the Cherry Point area indicates no significant toxicity or contamination above State standards (Long et al. 1999). Various explanations are possible for the sporadic herring embryotoxicity, such as elevated water temperatures and the possible impact of small intermittent chronic oil spills (Mike MacKay, Lummi Indian Nation, personal communication). Further assessment is needed to clarify this problem. In addition to the Intalco site, a more localized contamination of coal tar epoxy has been documented near the steel structure of the ARCO pier (EVS Environment Consultants 1999).

South Boundary Bay had "slight to moderate" degrees of contamination (mercury) in an extensive sampling effort by NOAA and DOE (Long et al. 1999). This results in a "poor" water quality/sediment rating. In contrast, several areas had "good" water quality results, including Semiahmoo, West Boundary Bay, Cherry Point (discussed in previous paragraph) and outer Bellingham Bay (Long et al. 1999).

Several sewer treatment and industrial outfalls have permits to release effluent into the estuarine or nearshore waters. They include the sewer treatment outfalls from the City of Blaine, Birch Bay, Ferndale, Lummi Sandy Point, Lummi Gooseberry, and the City of Bellingham (Brian Williams, WDFW, personal communication). Industrial outfalls include Arco, Intalco, British Petroleum, Georgia Pacific, and fish processors in Blaine. The Lummi Hatchery also releases effluent into Lummi Bay.

Other serious impacts to water quality conditions in WRIA 1 are from preservative-treated wood structures. Creosote-treated products contain 65 to 85% polycyclic aromatic hydrocarbons (PAHs) with smaller percentages of phenolic compounds and nitrogen- sulfur- or oxygenated heterocyclics (EPRI 1995, Brooks 1994). These chemicals can impact fish through toxicity, carcinogenesis, and disturbance of immune or hormone regulation (Krahn et al. 1986; Meyer et al. 1990; van Brummelen et al. 1998; Karrow et al. 1999; Johnson 2000). In addition, 100% of the Pacific herring embryos that survived to hatch after exposure to creosote-treated wood were abnormal (Vines et al. 2000). The effects of creosote on aquatic life are also long lasting. After 40 years, pilings can still release creosote into the environment (Vines et al. 2000). The Department of Ecology has conducted an inventory of creosote treated materials from Larrabee State Park to Birch Bay, and plan to remove 350 tons this summer from the Whatcom County shoreline (Barry Wenger, DOE, personal communication).

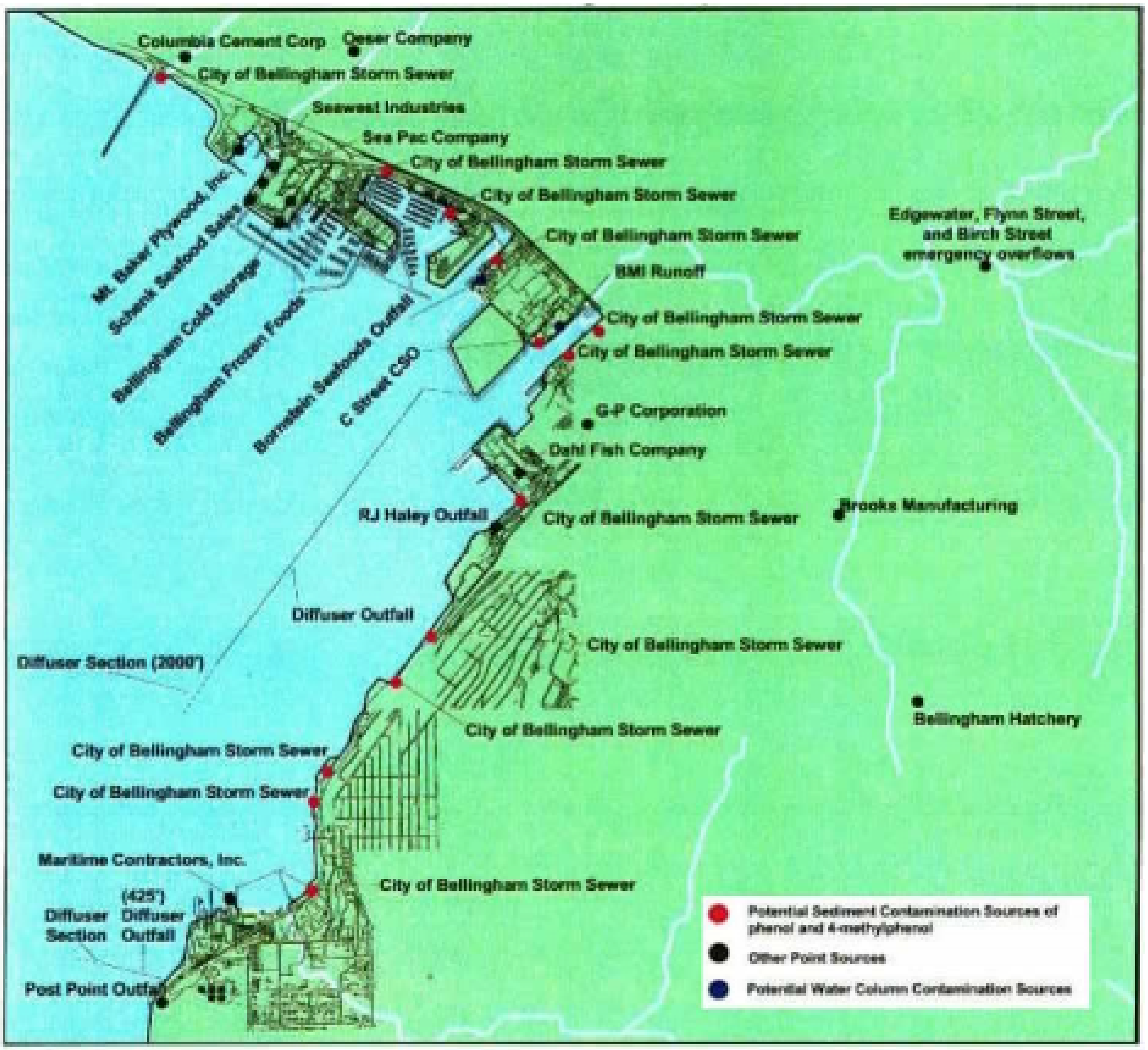
Wood treated with ammoniacal copper zinc arsenate and chromated copper arsenate release trace metals (copper, zinc, chromium, and arsenic) into the environment, but do so initially and for a much shorter duration than the release of PAHs by creosote-treated wood (Poston 2001). However, each of these metals has toxic effects on salmonids, and protective water quality standards have been developed for each. Contamination to salmonids can be direct or indirect (through the food chain).

Another water quality issue is the potential risk of a major oil spill near or in WRIA 1 waters. Tank ships or barges that transport petroleum products are the greatest concern, and 3,515 entering transits with petroleum products have been estimated for Puget Sound in the year 2001 (DOE 2002b). The number of tank ships bound for Washington ports via the Strait of Georgia or Haro Strait was 27 in 2001, but the number of tank barges was not reported. The number of cargo or passenger ships bound for Puget Sound or Canadian ports via Puget Sound waters (including the Strait of Juan de Fuca and Strait of Georgia) was estimated at 4,808 in the year 2001 with 565 bound for Washington ports via the Strait of Georgia or Haro Strait (DOE 2002b). Commercial fishing vessels or processors made 145 transits for Washington ports via the Strait of Georgia or Haro Strait, with 374 transits within Puget Sound. Ferries accounted for 168,960 transits within Puget Sound waters in 2001 (DOE 2002b).

A potential water quality concern exists regarding the Fraser River. The Fraser River has a profound influence on water flow and quality within the Strait of Georgia. The annual amount of freshwater entering Puget Sound is 10-20% of the amount entering the Strait of Georgia, most via the Fraser River (Blocking

1997). Peak discharges from the Fraser River are generally in June and July due to snowmelt (Waldichuck 1957). The Ministry of Water, Land, and Air Protection (2002) has rated most of the Fraser River Basin as “fair”, indicating that some impairment in water quality has occurred with a few watersheds rating “poor” or “good”. The average total discharge of all municipal, industrial, and agricultural wastewaters into the Fraser River estuary is estimated to be 908 million cubic meters annually (B.C. Ministry of Environment, Lands and Parks and Environment Canada 1993). Some of the problems include increased fecal coliform, ammonia, and phosphorous and sediment contamination from mercury and manganese (Hall et al. 2002). The effect of these problems on water quality in the Strait of Georgia is not well known and deserves further attention. Another important issue is the effect that Fraser River flow changes have on the Strait of Georgia, including natural and human caused changes.

Figure 59. Potential contaminant sources in Bellingham Bay (Figure from Pacific International Engineering and Anchor Environmental 1999).



Biological Processes Associated with the Estuarine and Nearshore Areas of WRIA 1

Estuaries are extremely dynamic ecosystems, both spatially and temporally, resulting in a broad diversity of habitats and food resources. Maintaining habitat connectivity and diversity is vital to provide the maximum opportunities for a variety of salmonid life history strategies. Corridors between the estuarine and open water environments aid in salmonid migration, encounter with prey items, reduction of predation on salmonid juveniles, and allows for the exchange of energy and materials (Shreffler and Thom 1993). Several sites near the mouth of Whatcom Creek and along south Bellingham Bay have been identified as needing restoration actions to re-establish habitat corridors (dark green areas near Whatcom Creek, Figure 60) (Figure from Anchor Environmental 2000).

Estuarine and nearshore ecosystems have detritus-based food webs that begin with primary productivity, the rate which plants convert sunlight to food (Simenstad 2001). It is known that the timing of juvenile chum salmon to seawater correlates with plankton blooms (Salo 1991). In the summer, winds, river discharges, and tidal cycles alter the level of productivity by vertically mixing nutrients, and winds are the most variable of these factors (Yin et al. 1997). However, not much information is available regarding local levels of productivity, changes in productivity with time, and potential impacts to productivity. There is also a lack of understanding of how primary productivity relates to salmonid production, as well as what effects primary productivity might have on estuarine entry timing and salmonid growth and mortality. This information would be useful to more fully understand salmonid habitat issues in the marine environment.

As plant material grows and decays, it supplies food for micro-organisms. The coating of micro-organisms on dead plant material is called detritus, and this is a major source of food supply for small invertebrates. Many juvenile salmonids and forage fish feed on these invertebrates. Declines in available prey have been shown to result in small juvenile salmonids migrating more quickly to other areas in search of prey (Simenstad et al. 1980). The expenditure of extra energy for this migration is thought to slow the growth, leading to an increased risk of predation.

The health of forage fish populations, such as herring, long-finned smelt, surf smelt, and anchovy are important because they are the primary food components of salmonids. All of these forage fish species have been noted in this area (Table 11) (Bargmann 1998; Pentilla 2001a), and concerns regarding the Pacific herring population near Cherry Point have resulted in the listing of that stock as a Washington State Candidate Species of Concern (WDFW 2000). The Cherry Point herring stock historically comprised about half of the Pacific herring population in Washington State, but numbers have declined by 91% since the early 1970s (Bargmann et al. 1999; EVS Environment Consultants 1999).

Spawning distribution of Cherry Point herring has been reduced as well. In the past, spawning occurred throughout Birch Bay and along the nearshore down to Lummi Bay. Currently, the distribution is reduced to three linear miles of coastline near Cherry Point (WDFW 1998b). A review of potential causes for the herring stock decline led to three likely sources: warmer sea surface temperatures, declining food supply, and organic contaminants (EVS Environment Consultants 1999), such as those described above in the Water Quality section.

Figure 60. Proposed reserves (in green) as developed by the Bellingham Bay Demonstration Pilot Work Group (Figure from Anchor Environmental 2000).

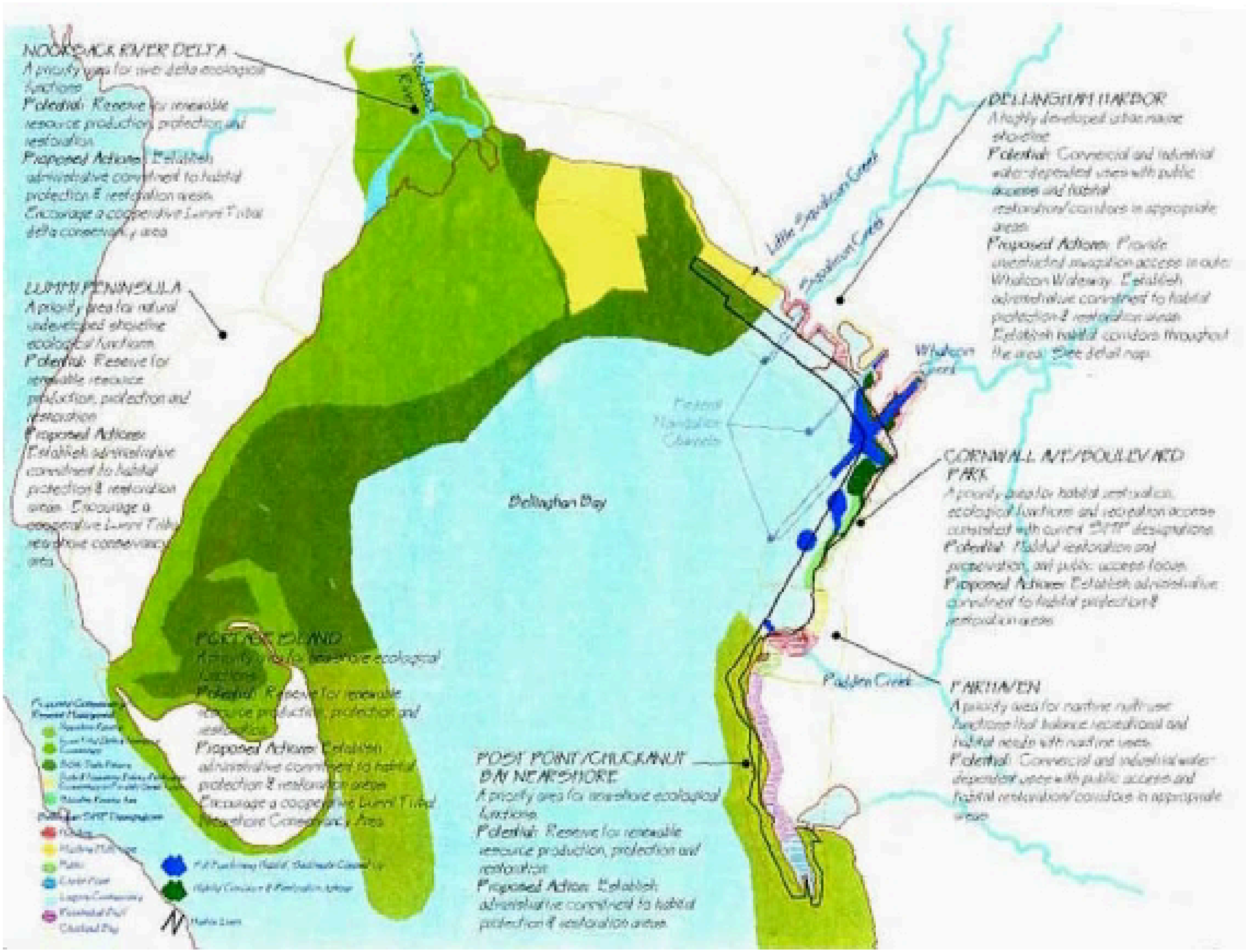


Table 11. Number and spawning locations of baitfish stocks in WRIA 1 (data from Pentilla 2001a).

Baitfish Stocks	Spawning areas
Semiahmoo Bay Herring Stock	From U.S./Canada border south through most of Birch Bay and along eastern Pt. Roberts.
Cherry Point Herring Stock	Historically from U.S./Canada border south through Portage Island shoreline, including Pt. Roberts. Not including inner Birch Bay, Drayton Harbor, or innermost Lummi Bay.
Samish/Portage Bay Herring Stock	Around Portage Island and in Samish Bay.
Surf Smelt	Pt. Roberts, Semiahmoo Bay, Birch Pt., Pt. Whitehorn, south of Cherry Point, Portage Bay, Bellingham Bay, north Samish Bay.
Sand Lance	Eastern shore of Pt. Roberts, Semiahmoo Spit, Portage Bay, and Bellingham Bay.

Estuarine and Nearshore Habitat Recommended for Protection

The Washington DNR recently designated a 3,000-acre Cherry Point Reserve area to prevent further development of this prime herring spawning ground. The reserve extends from the southern boundary of Birch Bay State Park to the northern boundary of the Lummi Indian Reservation (WA DNR 2000). It includes either -70 feet from mean low water or ½ mile from shore, whichever is greater. Current leases and private tidelands are excluded from the reserve.

In addition, several proposed reserves have been recommended along Portage Island, the south side of Lummi Peninsula, north Bellingham Bay, and Post Point/Chuckanut Bay as part of a comprehensive Bellingham Bay plan (Pacific International Engineering and Anchor Environmental 1999). These areas are shown in Figure 60 (Figure from Anchor Environmental 2000). The goals of the Reserve Program are to maintain natural biodiversity, restore and protect ecosystem function, and maintain appropriate access for educational, scientific, and recreational uses (DNR 2002).

ASSESSMENT OF HABITAT LIMITING FACTORS

Under the Salmon Recovery Act (passed by the legislature as House Bill 2496 and later revised by Senate Bill 5595), the Washington Conservation Commission (WCC) is charged with identifying the habitat factors limiting the production of salmonids throughout most of the state. This information should guide lead entity groups and the Salmon Recovery Funding board in prioritizing salmonid habitat restoration and protection projects seeking state and federal funds. To provide the best guidance possible, current, known habitat conditions were identified and rated. Rating habitat limiting factors requires a set of standards that can be used to compare the significance of different factors and consistently evaluate habitat conditions in each WRIA throughout the state.

To develop a set of standards to rate salmonid habitat conditions, several tribal, state, and federal documents that use some type of habitat rating system (Table 1) were reviewed. The goal was to identify appropriate rating standards for as many types of habitat limiting factors as possible, with an emphasis on those that could be applied to readily available data. Based on the review, it was decided to rate habitat conditions into three categories: “good”, “fair”, and “poor”. For habitat factors that had wide agreement on how to rate habitat condition, the accepted standard was adopted by the WCC. For factors that had a range of standards, one or more of them were adopted. Where no standard could be found, a default rating standard was developed, with the expectation that it will be modified or replaced as better data become available.

These ratings adopted by the WCC are presented in Tables 2-3. These ratings are not intended to be used as thresholds for regulatory purposes, but as a coarse screen to identify the most significant habitat limiting factors in a WRIA. They also will hopefully provide a level of consistency between WRIAs that allows habitat conditions to be compared across the state. However, for many habitat factors, there may not be sufficient data available to use a rating standard or there may be data on habitat parameters where no rating standard is provided. For these factors, the professional judgment of the TAG should be used to assign the appropriate ratings. In some cases there may be local conditions that warrant deviation from the rating standards presented here. This is acceptable as long as the justification and a description of the procedures used are clearly documented in the limiting factors report.

A summary of the habitat conditions for WRIA 1 is presented in Tables 4 and 5. These represent generalized conditions within that stream. There are likely some reaches of the stream that will be better or worse condition than the rating suggests. In many cases, insufficient data and knowledge about the conditions was found. For those instances, the rating is left blank. The conditions are based upon the standards in Tables 2-3, and are described in more detail in the Habitat Limiting Factors chapter. In the following chapter, recommendations and data needs are described in more detail.

Table 12. Source documents for the development of standards.

Code	Document	Organization
WSP	Wild Salmonid Policy (1997)	Washington Department of Fish and Wildlife
PHS	Priority Habitat Management Recommendations: Riparian (1995)	Washington Department of Fish and Wildlife
WSA	Watershed Analysis Manual, v4.0 (1997)	Washington Forest Practices Board
NMFS	Coastal Salmon Conservation: Working Guidance (1996)	National Marine Fisheries Service
Skagit	Skagit Watershed Council Habitat Protection and Restoration Strategy (1998)	Skagit Watershed Council
Hood Canal	Hood Canal/Eastern Strait of Juan de Fuca Summer Chum Habitat Recovery Plan (1999)	Point No Point Treaty Council and Washington Department of Fish and Wildlife

Table 13. Salmonid habitat condition standards.

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
Access and Passage						
Artificial Barriers	% known/potential habitat blocked by artificial barriers	All	>20%	10-20%	<10%	WCC
Floodplains						
Floodplain Connectivity	Stream and off-channel habitat length with lost floodplain connectivity due to incision, roads, dikes, flood protection, or other	<1% gradient	>50%	10-50%	<10%	WCC
Loss of Floodplain Habitat	Lost wetted area	<1% gradient	>66%	33-66%	<33%	WCC

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
Channel Conditions						
Fine Sediment	Fines < 0.85 mm in spawning gravel	All – Westside	>17%	11-17%	≤11%	WSP/WSA / NMFS/Hood Canal
	Fines < 0.85 mm in spawning gravel	All – Eastside	>20%	11-20%	≤11%	NMFS
Large Woody Debris	pieces/m channel length	≤4% gradient, <15 m wide (Westside only)	<0.2	0.2-0.4	>0.4	Hood Canal/Skagit
	or use Watershed Analysis piece and key piece standards listed below when data are available					
	pieces/channel width	<20 m wide	<1	1-2	2-4	WSP/WSA
	key pieces/channel width*	<10 m wide (Westside only)	<0.15	0.15-0.30	>0.30	WSP/WSA
	key pieces/channel width*	10-20 m wide (Westside only)	<0.20	0.20-0.50	>0.50	WSP/WSA

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
	* Minimum size	BFW (m)	Diameter (m)	Length (m)		
	to qualify as a key	0-5	0.4	8		
	piece:	6-10	0.55	10		
		11-15	0.65	18		
		16-20	0.7	24		
Percent Pool	% pool, by surface area	<2% gradient, <15 m wide	<40%	40-55%	>55%	WSP/WSA
	% pool, by surface area	2-5% gradient, <15 m wide	<30%	30-40%	>40%	WSP/WSA
	% pool, by surface area	>5% gradient, <15 m wide	<20%	20-30%	>30%	WSP/WSA
	% pool, by surface area	>15 m	<35%	35-50%	>50%	Hood Canal
Pool Frequency	channel widths per pool	<15 m	>4	2-4	<2	WSP/WSA

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
	channel widths per pool	>15 m	-	-	chann width / pools/mile / cw/pool 50’ 26 4.1 75’ 23 3.1 100’ 18 2.9	NMFS
Pool Quality	pools >1 m deep with good cover and cool water	All	No deep pools and inadequate cover or temperature, major reduction of pool volume by sediment	Few deep pools or inadequate cover or temperature, moderate reduction of pool volume by sediment	Sufficient deep pools	NMFS/WSP/WSA
Streambank Stability	% of banks not actively eroding	All	<80% stable	80-90% stable	>90% stable	NMFS/WSP
Sediment Input						
Sediment Supply	$m^3/km^2/yr$	All	> 100 or exceeds natural rate*	-	< 100 or does not exceed natural rate*	Skagit

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
	* Note: this rate is highly variable in natural conditions					
Mass Wasting/Landslide Density		All	Significant increase over natural levels for mass wasting events that deliver to stream. >3 events/square mile, human-induced.	1-3 landslide events/square mile, human-induced.	No increase over natural levels for mass wasting events that deliver to stream. Less than 1 landslide/square mile.	WSA (increase over natural levels)
Road Density	mi/mi^2	All	>3 with many valley bottom roads	2-3 with some valley bottom roads	<2 with no valley bottom roads	NMFS
	or use results from Watershed Analysis where available					
Riparian Zones						

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
Riparian Condition	riparian buffer width (measured out horizontally from the channel migration zone on each side of the stream) riparian composition	Type 1-3 and untyped salmonid streams >5' wide	• <75' or <50% of site potential tree height (whichever is greater) OR Dominated by hardwoods, shrubs, or non-native species (<30% conifer) unless these species were dominant historically.	75'-150' or 50-100% of site potential tree height (whichever is greater) AND Dominated by conifers or a mix of conifers and hardwoods (≥30% conifer) of any age unless hardwoods were dominant historically.	>150' or site potential tree height (whichever is greater) AND Dominated by mature conifers (≥70% conifer) unless hardwoods were dominant historically	WCC/WSP
	buffer width riparian composition	Type 4 and untyped perennial streams <5' wide	<50' with same composition as above	50'-100' with same composition as above	>100' with same composition as above	WCC/WSP
	buffer width riparian composition	Type 5 and all other untyped streams	<25' with same composition as above	25'-50' with same composition as above	>50' with same composition as above	WCC/WSP

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
Water Quality						
Temperature	degrees Celsius	All	>15.6° C (spawning) >17.8° C (migration and rearing)	14-15.6° C (spawning) 14-17.8° C (migration and rearing)	10-14° C	NMFS
Dissolved Oxygen	mg/L	All	<6	6-8	>8	ManTech
Hydrology						
Flow	hydrologic maturity	All	<60% of watershed with forest stands aged 25 years or more	-	>60% of watershed with forest stands aged 25 years or more	WSP/Hood Canal
		or use results from Watershed Analysis where available				
	% impervious surface	Lowland basins	>10%	3-10%	≤3%	Skagit
Biological Processes						

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
Nutrients (Carcasses)	Number of stocks meeting escapement goals	All Anadromous	Most stocks do not reach escapement goals each year	Approximately half the stocks reach escapement goals each year	Most stocks reach escapement goals each year	WCC
Lakes (further work needed)						
Estuaries – See Table 3 Below						

Table 14. System for rating estuarine habitat conditions

Impact	**Poor**	**Fair**	**Good**
Wetland Loss	30% or greater loss of habitat	10-30% loss	Less than 10% loss
Water Quality	Any exceedance above standard of a parameter known to directly impact salmonids.	An exceedance above standard of a parameter that impairs water quality, but not known to directly impact salmonids.	No exceedances of known standards.
Shoreline Modification	30% or greater modified shoreline length.	10-30% modified shoreline length.	Less than 10% modified shoreline length.
Eelgrass Habitat and Man-Made Shade Structures	50 or more shade structures, or 30% or more loss of historic eelgrass.	25-50 shade structures, or 10-30% loss of historic eelgrass.	Continuous eelgrass beds with less than 10% historic loss.

Table 15. Summary of estuarine and nearshore conditions in WRIA 1.

Region	Wetland Loss	Water Quality/Sediment Contamination	Shoreline Modification	Boat Ramps, Slips, Piers
Point Roberts	DG	DG	Poor	Poor
Peace Arch	DG	DG	Poor	Good
Blaine	DG	DG	Poor	Poor
Semiahoo Spit	DG	DG	Fair	Good
Drayton Harbor	DG	Poor	Fair	Good
Birch Bay	DG	DG	Poor	Poor
Birch Point	DG	DG	Good	Good
Point Whitehorn	DG	DG	Good	Good
Cherry Point	DG	Questionable	Good	Good
Neptune Beach	DG	DG	Poor	Good
Sandy Point Shores	DG	DG	Poor	Poor
Lummi Bay	Poor	DG	Poor	Good
Lummi Island	DG	DG	Good	Good

Portage Island	DG	DG	Good	Good
Eliza Island	DG	DG	Good	Good
Nooksack River Delta	Good	DG	Good	Good
North Bellingham Bay (T38N)	Poor	Poor (inner)	Poor	Poor
South Bellingham Bay (T37N)	Poor	Poor (inner)	Poor	Poor
Chuckanut/Pleasant Bay	DG	DG	Mixed	Poor in southern portion
North Samish Bay (to Wendy Pt.)	Poor	Fair	Poor	Good
Samish Bay from Wendy Pt to south of Colony Creek.	Poor	Fair	Poor	Good

Table 16. Summary of WRIA 1 Freshwater Limiting Factors Results

	Fish Passage	Floodplain Conditions	Sediment: gravel quantity	Sediment: gravel quality	Road Density	Channel Stability	Current Instream LWD (quantity)	Riparian	Water Quality	Water Quantity
Nooksack Basin										
Mainstem Nooksack R.		Poor	DG	DG	NA	DG	DG	Poor	Poor	Poor
Lummi River	DG	Poor	Poor	DG	NA	DG	DG	Poor	Poor in Schell Cr.	Poor
Silver Creek	Poor (DG)	Poor in lower	DG	Poor (DG)	NA	DG	DG	Poor	Poor	Poor
Bertrand Cr.	Poor (DG)	Poor	DG	Poor (DG)	NA	Poor (DG)	Variable	Mostly Poor; Good in upper	Poor	Poor
Tenmile Cr.	DG	Poor	DG	Poor (DG)	NA	DG	Poor	Poor	Poor	Poor
Fourmile Cr.	DG	DG	DG	DG	NA	DG	DG	Poor	Poor	DG

	Fish Passage	Floodplain Conditions	Sediment: gravel quantity	Sediment: gravel quality	Road Density	Channel Stability	Current Instream LWD (quantity)	Riparian	Water Quality	Water Quantity
Fishtrap Cr.	DG	Poor	DG	Fair (DG)	NA	Fair (DG)	DG	Poor	Poor	Poor
Kamm Cr.	Poor (DG)	Poor	DG	Poor (DG)	NA	Poor (DG)	Poor	Poor	Poor	Poor
Anderson Cr.	Fair (DG)	DG	DG	Poor (DG)	DG	Poor (DG)	DG	Fair to Poor	Poor	Poor
Smith Cr.	DG	DG	DG	DG	Fair	DG	Good in Mc-Cormick	Poor in lower; Fair in upper	Poor in Hoff Cr. (DG)	Poor
North Fork Nooksack R.	DG	Poor in certain areas. Needs quantifi-cation	DG (likely impacts from tributaries in lower-mid reaches.	Fair (DG)	Poor below Falls	DG	DG	Poor in lower; Fair from Aldrich to Canyon; Good in upper	Poor in lower	Poor in lower
Kenney Cr.	Poor (DG)	DG	Good	DG	Poor	Poor (DG)	DG	Fair	Poor	Poor

	Fish Passage	Floodplain Conditions	Sediment: gravel quantity	Sediment: gravel quality	Road Density	Channel Stability	Current Instream LWD (quantity)	Riparian	Water Quality	Water Quantity
Bells Cr.	DG	DG	Fair	DG	Poor	DG	DG	Fair	DG	Poor
Coal Cr.	DG	DG	Poor	DG	Poor	DG	DG	Fair	DG	DG
Racehorse Cr.	DG	DG	Poor	Poor (DG)	Poor	Poor (DG)	DG	Good along lower; Poor along upper	Poor	Poor
Kendall Cr.	DG	DG	Fair	DG	Poor	DG	DG	Poor	DG	Poor
Aldrich Cr.	DG	Poor (DG)	Fair	Good	Poor	DG	Poor	Mostly Poor	DG	Poor
Big Slide Cr.	DG	Poor in lower (DG)	Fair	Variable	Poor	DG	Poor	Mostly Poor	DG	Poor
Maple Cr.	DG	DG	Good (DG)	Fair to Good	Poor	DG	DG	Mixed	DG	DG
Boulder Cr.	DG	DG	Poor	Fair (DG)	Poor	Poor (DG)	DG	Poor in lower (DG)	Poor in lower	DG

	Fish Passage	**Floodplain Conditions**	**Sediment: gravel quantity**	**Sediment: gravel quality**	**Road Density**	**Channel Stability**	**Current Instream LWD (quantity)**	**Riparian**	**Water Quality**	**Water Quantity**
Canyon Cr.	DG in lower; Needs priorities in upper	DG	Fair	Good (DG)	Extensive road improve-ments have occurred. More recent data are needed.	Poor in lower (DG)	Poor	Mostly Good, some impacts in lower	Poor in lower; Good in upper	Good in upper; likely impacts in lower
Hedrick Cr.	DG	Poor in parts (DG)	Fair	Variable	Poor	DG	Poor	Poor	Poor	Poor
Gallop Cr.	DG	Poor in lower (DG)	Poor	Fair	Poor	Poor	Poor	Poor in lower; Good in upper	Poor in lower	Poor
Cornell Cr.	DG	Poor in parts (DG)	Poor	Good (DG)	Poor	Poor-Fair (DG)	Poor	Poor in lower; Good in upper	Poor	Poor

	Fish Passage	Floodplain Conditions	Sediment: gravel quantity	Sediment: gravel quality	Road Density	Channel Stability	Current Instream LWD (quantity)	Riparian	Water Quality	Water Quantity
Glacier Cr.	DG	Poor in lower (DG)	Fair in tribs; Good in ms	DG	Poor in lower; Good in upper	Poor in lower; Fair in mid to upper	Poor	Good; Little Creek mostly poor.	DG	DG
Thompson Cr.	DG	DG	DG	Good (DG)	DG	Good (DG)	DG	Good	Good	DG
Wells Cr.	DG	DG	Good	DG	Poor in lower; Good upper	DG	DG	Good	DG	DG
Deadhorse Cr.	Good	DG	Good	Fair (DG)	Poor in lower; Good upper	Variable	DG	Good in lower (DG)	DG	DG
Upper NF Nooksack Sub-Basin (Upstream of Falls)	DG	DG	Good	DG	Poor in Bagley; Fair in Swamp; Good in others	DG	DG	Good	Good	Good

	Fish Passage	Floodplain Conditions	Sediment: gravel quantity	Sediment: gravel quality	Road Density	Channel Stability	Current Instream LWD (quantity)	Riparian	Water Quality	Water Quantity
Middle Fork Nooksack R.	Poor (DG)	DG	Fair (DG)	DG	Poor	Poor (DG)	DG	Poor in lower; Good in middle; Fair in upper	Poor in lower (DG)	Poor in lower; Good in upper
Canyon Lake Cr.	DG	DG	Poor	DG	Poor	Poor (DG)	DG	Fair	Poor	Poor (DG)
Porter Cr.	DG	DG	Poor	Fair (DG)	Poor	DG	DG	Fair (DG)	DG	Poor (DG)
Heislers Cr.	DG	DG	Fair	DG	Poor	DG	DG	Fair	DG	DG
Falls Cr.	DG	DG	Poor	DG	Poor	DG	DG	DG	DG	DG
Clearwater Creek	DG	DG	Poor	DG	Poor	DG	DG	Good	DG	Poor
Galbraith Cr.	DG	DG	Poor	DG	Poor	DG	DG	DG	DG	DG
Seymour Cr	DG	DG	Fair	DG	DG	DG	DG	Poor	DG	DG
Warm Cr.		DG	Fair	DG	Good	DG	DG	Good	DG	DG

	Fish Passage	**Floodplain Conditions**	**Sediment: gravel quantity**	**Sediment: gravel quality**	**Road Density**	**Channel Stability**	**Current Instream LWD (quantity)**	**Riparian**	**Water Quality**	**Water Quantity**
Upper Middle Fork Nooksack R.	DG	DG	Good	DG	Poor in Rankin and upper MF mainstem Good in Sisters, Wallace, Ridley, and Green Creeks	DG	DG	Good in Ridley and Green; Fair in Sisters; Poor in Rankin Creek	DG	Good
South Fork Nooksack R.		Poor	Poor	Poor (DG)	Fair in lower; Poor in middle reaches	Poor (DG)	Poor (DG)	Poor in lower; Mixed in middle reaches	Poor	Poor
Black Slough	Poor (DG)	Poor	Poor (DG)	DG	Fair	DG	DG	Poor	DG	DG

	Fish Passage	Floodplain Conditions	Sediment: gravel quantity	Sediment: gravel quality	Road Density	Channel Stability	Current Instream LWD (quantity)	Riparian	Water Quality	Water Quantity
Hutchinson Cr	Poor (DG)	Poor	Poor	Poor	Poor	Poor in lower; Good elsewhere	Fair to Poor	Poor to Fair	Poor	Poor
Skookum and Cavanaugh Cr.	DG	DG	Poor	DG	Poor	Poor (DG) in Skookum	Poor in larger streams	Mixed	Poor in tribu-taries	Poor
Edfro Cr	DG	DG	Fair	Fair to Poor	Poor	Good	Poor	Good	DG	Good
Howard	DG	DG	Poor	Fair (DG)	Poor	Poor (DG)	DG	Fair	Poor	Poor
Upper South Fork Nooksack R.	DG	DG	Poor	DG	Poor along SF; Good in Wanlick, Bell, Heart L., Elbow Lk	DG	DG	Good along ms, Wanlick, Bell, Elbow Lk; Poor in Heart Lk	DG for most reaches Poor in Wan-lick Cr.	Good
Dakota Cr.	Poor (DG)	Poor (DG)	DG	DG	Poor	DG	DG	Poor (DG)	Poor	Poor

	Fish Passage	Floodplain Conditions	Sediment: gravel quantity	Sediment: gravel quality	Road Density	Channel Stability	Current Instream LWD (quantity)	Riparian	Water Quality	Water Quantity
California Cr	DG	Poor (DG)	DG	DG	Poor	DG	DG	Poor (DG)	DG	Poor
Terrell Cr.	DG	DG	DG	DG	Poor	DG	DG	Poor (DG)	DG	Poor
Squalicum Cr.	Poor (DG)	Poor (DG)	DG	Fair	Poor	Poor	Poor	Poor (DG)	Poor	Poor
Whatcom Cr.	DG	DG	DG	Good	Poor	Good	DG	Poor (DG)	Poor	Poor
Lake Whatcom Sub-Basin	DG							Poor (DG)	Poor in Lake What-com	Poor for Lake Whatcom
Olsen Cr.	DG	Poor	Poor in upper	Poor	DG	Fair in middle	Poor	DG	DG	Good
Smith Cr.	DG	Poor	Poor	Poor in mid-lower reaches; Fair in upper	DG	Fair	Poor	DG	Poor	Good

	Fish Passage	**Floodplain Conditions**	**Sediment: gravel quantity**	**Sediment: gravel quality**	**Road Density**	**Channel Stability**	**Current Instream LWD (quantity)**	**Riparian**	**Water Quality**	**Water Quantity**
Anderson Cr.	DG	Poor	DG	Fair in lower;	DG	Fair	Poor in lower; Fair in middle	DG	Poor	DG
Beaver Cr.	DG	Poor-Fair	Poor	Fair in lower; Poor in upper	DG	Poor in lower; Fair in upper	Poor	DG	DG	Poor
Brannian	DG	Poor-Fair	Poor	Poor	DG	Fair	Poor	DG	DG	Poor
Austin	DG	Poor	Poor	Fair to Poor	DG	Fair	Poor	DG	Poor	Poor
Carpenter	DG	Poor	Poor	Poor	DG	Poor in lower; Fair in middle	Poor	DG	DG	Poor
Padden Cr	DG	DG	DG	DG	Poor	DG	DG	Poor (DG)	Poor	Poor
Chuckanut Cr.	DG	DG	DG	DG	Poor	DG	DG	Poor (DG) in lower	Fair	Poor

	Fish Passage	**Floodplain Conditions**	**Sediment: gravel quantity**	**Sediment: gravel quality**	**Road Density**	**Channel Stability**	**Current Instream LWD (quantity)**	**Riparian**	**Water Quality**	**Water Quantity**
Oyster Cr.	DG	DG	DG	DG	Fair	DG	DG	Poor (DG)	DG	Poor (DG)
Colony Cr.	DG	DG	DG	DG	Fair	DG	DG	Poor (DG)	DG	Poor (DG)
Sumas R.	DG	DG; likely impacts	DG	Poor (DG)	Fair	Poor (DG)	Poor (DG)	Poor (DG)	Poor	Poor
Saar Cr.	DG	DG	DG	DG	DG	DG	DG	Poor (DG)	DG	Poor
Johnson Cr.	DG	DG	DG	DG	DG	DG	Good in upper; Poor in urban reaches	Poor in urban; Mixed elsewhere	Poor	DG
Frost	DG	DG	DG	DG	Fair	DG	DG	Poor (DG)	DG	DG
Selesia	DG	DG	DG	DG	Good	DG	DG	Good (DG)	Likely Good	Good

	Fish Passage	Floodplain Conditions	Sediment: gravel quantity	Sediment: gravel quality	Road Density	Channel Stability	Current Instream LWD (quantity)	Riparian	Water Quality	Water Quantity
Chilliwack/ Tomyhoi/Damfino	Good	Likely Good	Likely Good (DG)	Good	Good	DG	Good	Good (DG)	Likely Good	Good

DG= Data Gap; When a DG accompanies a rating of good, fair, or poor, it means that the rating is provisional and additional assessments are needed.

NA=Not Applicable

RECOMMENDATIONS AND DATA GAPS FOR WRIA 1 HABITAT LIMITING FACTORS

Introduction

The known, current salmon and steelhead habitat conditions for WRIA 1 have been identified and assessed as “good”, “fair”, or “poor” when sufficient data have been available. In addition, the impacts, sources of impact, and species impacted have been described in the Habitat Limiting Factors Chapter. Based upon this assessment, the following action recommendations and data needs for habitat improvements and protection are listed first for the Nooksack Basin, then for the smaller basins in WRIA 1. They are organized by type of factor (fish access, floodplain, sediment, riparian, water quality, water quantity, and nearshore/estuarine).

This is not a comprehensive list, and should be used in conjunction with the Assessment Ratings Summary Table (Tables 4 and 5 in Assessment Chapter), which lists ratings for specific streams. "Poor" ratings often represent high priority problems. "Good" ratings represent high priority areas for maintenance/conservation. Data Gaps (DG) in the table represent areas where assessments are needed, and many of those data needs are listed in this chapter. While these recommendations and data needs represent potential areas for projects and assessments, other types of projects that scientifically address high priority problems and data needs should also be considered. Actions that protect or restore watershed processes are a high priority recommendation throughout WRIA 1.

This report was limited in its ability to clarify and prioritize some habitat impacts because of key data gaps. Other identified data needs, especially those related to specific reaches and watersheds, are highlighted within the various limiting factors sections. The following is a partial list of data needs that have been identified by the TAG. These data would greatly aid in developing recovery plans and to monitor the effectiveness of salmon habitat projects. The studies will also help better identify habitat limiting factors for salmonid production in the future. This list should be used in conjunction with Tables 4 and 5 in the Assessment Chapter, which lists major data gaps.

Recommendations and Data Needs for Salmonid Habitat Restoration Actions in the Nooksack Basin

<u>Recommended Data Needs for Salmonid Information in the Nooksack Basin</u>

- Data regarding fish utilization of habitat types and locations are greatly needed. One example includes identifying the habitat used by yearling chinook in the Nooksack Basin.

- Assess the direct contact impacts from humans to salmonids in the Nooksack Basin. Examples include rafting, in-stream hiking, etc.

Recommended Actions and Data Needs for Salmonid Access Conditions in the Nooksack Basin

Action Recommendations

Provide fish passage for the Middle Fork Nooksack River diversion dam.

- Remove or replace identified high priority salmonid-blocking culverts and floodgates with fish-friendly alternatives. Watersheds with known high priority index barriers include Silver, Kamm, Black Slough, Kenny, Bertrand, and Hutchinson Creeks. Another need is to improve access through the Lummi River tidegates.

Data Needs

- Culvert and floodgate surveys and assessments are needed throughout the Nooksack Basin. Currently, considerable work has been done in Kamm, Anderson, Bertrand, Kenney, Hutchinson, and Black Slough Creeks, and on all Forest Service property. SRFB funding has been approved to conduct the remaining surveys in the near future, and timber companies will be identifying fish habitat blockages on their property in their road maintenance plans in the next five years.

- Prioritize (using the Priority Index system) all salmonid-blocking culverts and floodgates in the Nooksack Basin. Many identified barriers in Kamm, Bertrand, Kenney, and Black Slough Creeks have been prioritized, but blockages in other streams have not been prioritized in a consistent manner.

Recommended Actions and Data Needs for Floodplain Conditions in the Nooksack Basin

Action Recommendations

- Reduce bank hardening throughout the basin. High impact areas include the entire mainstem Nooksack River, the South Fork Nooksack River from the Hutchinson Creek confluence to the mouth, and along parts of the North Fork Nooksack River.

- Investigate areas for potential dike removal or set-backs. High impact areas include the mainstem Nooksack River, the South Fork Nooksack River, and the lower reaches of lower river tributaries.

- Remove or modify dikes and levees, which disconnect the floodplain in the lower reaches lowland tributaries, such as Kamm, Fishtrap, Tenmile, and Bertrand Creeks, and Duffner Ditch, Scott Ditch, and Schneider Ditch.

- Reduce constraints along the streams in the South and Middle Fork Nooksack River sub-basins. These include railroad and floodplain road impacts. Examples include Mosquito Lake Road, Rutsatz Road, and the railroad.

- Reduce bridge constraints to Nooksack River streams. One noteworthy bridge constraint is where Highway 9 crosses the North Fork Nooksack River.

- Reduce floodplain constraints by floodplain roads in the North Fork Nooksack River. The Mount Baker Highway constrains the floodplain in several locations, including constraints on tributaries to the North Fork Nooksack River, such as Canyon and Boulder Creeks.

- Prevent further losses of wetlands, and restore previously lost or degraded wetlands. High impact areas include the Nooksack Basin downstream of the Forks, the lower South Fork Nooksack River, and Black Slough. Removing tidegates will restore estuarine wetlands and aid in mainstem Nooksack River flood storage.

Data Needs

- Assessments of impacts to floodplain conditions are needed for the mainstem Nooksack River and associated tributaries, and the North, Middle, and South Fork Nooksack Rivers. Assessments should identify loss of side-channel and off-channel habitat (wetlands), impacts, and prioritization of impacts, including roads in the floodplains, bank hardening, dikes/levees, old railroad grades, dredging, and channelization.

<u>Recommended Actions and Data Needs for Streambed/Sediment Conditions in the Nooksack Basin</u>

Action Recommendations

- Decommission or treat roads that are at a moderate to high risk of mass wasting potential in the North, South, and Middle Fork Nooksack sub-basins. Timber companies will likely address many of these through the road maintenance plans.

- Decommission or treat orphan roads that are at a moderate to high risk of mass wasting potential.

- Enforce Critical Areas Ordinances in WRIA 1. These will likely be changed in the next few years.

- Reduce the invasion of exotic plants, such as Reed canarygrass and Japanese knotweed.

- Enforce Best Management Practices for agricultural land.

- Reduce human-caused sediment delivery to lowland streams.

- Restore lowland streams to more natural systems (sinuosity, sediment delivery, etc.) in historically-important fish producing streams.

- Dredging projects related to slope-derived sedimentation need to take into account sediment sources, sediment supply, and impacts to fish habitat.

- Increase instream large woody debris (LWD) in appropriate areas.

- Increase the quantity and quality of large woody debris in the North and South forks to improve channel stability, complexity and pool formation.

Data Needs

- Conduct assessments on lateral and vertical channel stability, gravel quality, and instream LWD quantities in the tributaries to the mainstem, North Fork, Middle Fork, and South Fork Nooksack Rivers.

- Develop sediment budgets for the mainstem, North, South, and Middle Fork Nooksack Rivers, and tributaries with known sediment issues and a lack of data, such as Smith Creek.

- Assess the potential sedimentation effects by failures in the upper mainstem sub-basin from the Forks downstream to below Nugent's Bridge.

- Analyze low gradient streams for the restoration potential to more natural systems (sinuosity, habitat complexity, sedimentation, etc.).

<u>Recommended Actions and Data Needs for Riparian Conditions in the Nooksack Basin</u>

Action Recommendations

- Maintain and protect existing functional riparian vegetation throughout the Nooksack Basin. This passive form of intervention is most applicable in the forestlands.

- Restore degraded riparian conditions throughout the Nooksack Basin, including tributaries. High priority areas are listed in Coe (2001), and include the South Fork Nooksack River and its tributaries and the mainstem Nooksack River and tributaries. Use historic information to restore with the appropriate plant species, and consider the stream size for a functional riparian buffer.

- Eliminate non-native plants from riparian zones, and revegetate with native species. Known non-native invaders include blackberry, Japanese knotweed and Reed canarygrass.

- Reduce riparian wood removal, including removal by private citizens, through education and regulatory actions.

Data Needs

- Assess the impact of wood removal in riparian areas, including removal by private citizens.

<u>Recommended Actions and Data Needs for Water Quality Conditions in the Nooksack Basin</u>

Action Recommendations

- A high priority recommendation is to reduce industrial and urban pollution inputs into the mainstem Nooksack River, including stormwater run-off.

- Warm water temperatures are a severe problem in several streams. For those resulting from riparian degradations (especially common in the South Fork and mainstem Nooksack River sub-basins), prioritize riparian restoration to help improve water temperatures.

- Increase frequency and extent of cool-water refuges in the South Fork Nooksack during summer low-flow periods.

- Remove creosote-treated wood from the basin.

- Improve water quality throughout the Nooksack Basin by addressing riparian, sedimentation, instream flow, and wetland loss conditions. These are further described in their respective sections.

- Implement agriculture's best management practices to reduce nutrient run-off and livestock waste delivered to streams.

- Address failing septic systems throughout the Nooksack Basin, including the known problems in Silver, Tenmile, Fourmile, Deer, Bertrand, Duffner Ditch, Fishtrap and associated ditches, and Kamm Creeks.

Data Needs

- Monitor and assess benthic invertebrate populations throughout the Nooksack Basin to determine which streams likely have water quality problems. Then, focus more expensive water quality monitoring on streams with probable impacts.

- Monitor stream delivery of industrial, urban, and domestic chemical compounds and their impacts to salmonids in the Nooksack Basin.

- Water quality parameters (temperature, dissolved oxygen, toxins, metals, pesticides, and other contaminants) should be monitored in the mainstem and North Fork Nooksack River tributaries that are lacking data or have other characteristics that suggest water quality problems (altered benthic invertebrate population, degraded riparian, etc).

- Water quality parameters (temperature, dissolved oxygen, pesticides, and other contaminants) should be monitored in several Middle Fork Nooksack River tributaries that are lacking data, especially in the Porter and Clearwater watersheds, which have poor riparian conditions.

- Water quality parameters (temperature, dissolved oxygen, pesticides, and other contaminants) should be monitored in all of the South Fork Nooksack River tributaries that are lacking data or have other characteristics that suggest water quality problems (altered benthic invertebrate population, degraded riparian, etc).

- Develop a temperature model for the South Fork Nooksack sub-basin to ascertain the relative impacts of different processes and conditions to water temperature. Water temperature is a major problem in this sub-basin.

- In areas near heavy traffic, monitor the quantity of diesel and gasoline exhaust that is delivered to streams.

<u>Recommended Actions and Data Needs for Water Quantity Conditions in the Nooksack Basin</u>

Action Recommendations

- Low stream flows are a problem in many of the streams in the lower Nooksack River and tributaries and in the middle and lower South Fork Nooksack Basin. In those areas, actions are needed to restore and protect wetlands, reduce surface water withdrawals, increase stream sinuosity, and increase native vegetative land cover.

- Low stream flows have been a problem in some of the alluvial fans of tributaries in the Forks where sediment build-up has occurred. In the areas where excess sedimentation has altered stream flow, take actions to address the sedimentation at its sources.

- Protect and maintain areas that are important for aquifer recharge.

- Implement and enforce instream flows where they are set.

- Enforce regulations regarding illegal water withdrawals.

- Follow the recommendations that develop from the Watershed Planning (2514) process.

- Reduce urban stormwater delivery to streams, for example, by retrofitting and low impact development.

Recommendations and Data Needs for Salmonid Habitat Restoration Actions in the Lummi River and tributaries

<u>Fish Access Conditions in the Lummi River Watershed</u>

Action Recommendations

- Improve salmonid access to the Lummi River and its sloughs.

- Remove or replace identified high priority salmonid-blocking culverts, tidegates, and floodgates with fish-friendly alternatives.

Data Needs

- Conduct culvert and floodgate surveys and assessments. Currently, SRFB funding has been approved to conduct surveys in the near future.

- Prioritize (using the Priority Index system) all salmonid-blocking culverts and floodgates across the entire WRIA.

<u>Floodplain Conditions in the Lummi River Watershed</u>

Action Recommendations

- Reduce bank hardening throughout the watershed.

- Reconnect isolated tidal floodplains, marsh, wetlands and sloughs to tidal actions.

- Investigate areas for potential dike removal or setbacks.

- Reconnect the floodplain in impacted areas.

- Reduce constraints along the Lummi River, including floodplain roads such as Red River Road.

- Prevent further losses of wetlands, and restore previously lost or degraded wetlands. Removing tidegates will restore estuarine wetlands and aid in flood storage.

Data Needs

- Assessments of impacts to floodplain conditions are needed for the Lummi River and associated tributaries. Assessments should identify loss of side-channel and off-channel habitat (wetlands), impacts, and prioritization of impacts, including roads in the floodplains, bank hardening, dikes/levees, old railroad grades, dredging, and channelization.

<u>Streambed/Sediment Conditions in the Lummi River Watershed</u>

Action Recommendations

- Enforce Critical Areas Ordinances in WRIA 1. These will likely be changed in the next few years.

- Restore native plant communities on floodplains, along sloughs, and tributaries. Monitor for presence of *Spartina* on the Lummi Bay flats.

- Restore lowland streams to more natural systems (sinuosity, sediment delivery, etc.) in historically important fish producing streams.

- Increase channel complexity by addition of instream large woody debris (LWD) in appropriate areas.

<u>Riparian Conditions in the Lummi River Watershed</u>

Action Recommendations

- Maintain and protect existing functional riparian vegetation.

- Restore degraded riparian conditions. Use historic information to restore with the appropriate plant species, and consider the stream size for a functional riparian buffer.

- Eliminate non-native plants from riparian zones, and revegetate with native species.

- Reduce riparian wood removal, including removal by private citizens, through education and regulatory actions.

Water Quality Conditions in the Lummi River Watershed

Data Needs

- Monitor and assess benthic invertebrate populations in the Lummi River watershed to determine which streams likely have water quality problems. Then, focus more expensive water quality monitoring in those areas.

- Water quality parameters (temperature, dissolved oxygen, toxins, metals, pesticides, and other contaminants) should be monitored in the Lummi River and tributaries that are lacking data or have other characteristics that suggest water quality problems (altered benthic invertebrate population, degraded riparian, etc).

Water Quantity Conditions in the Lummi River Watershed

- Protect and maintain areas that are important for aquifer recharge.

- Follow the recommendations that develop from the Watershed Planning (2514) process.

Recommendations and Data Needs for Salmonid Habitat Restoration Actions in Dakota, California, and Terrell Creeks

Fish Access Conditions in Dakota, California, and Terrell Creeks

Action Recommendations

- Remove or replace identified high priority salmonid-blocking culverts and floodgates with fish-friendly alternatives in the Dakota, California, and Terrell Creek Basins.

Data Needs

- Conduct surveys of all fish habitat blockages in Dakota, California and Terrell Creeks. Many of the blockages in Dakota Creek have been identified and initially prioritized. Currently, SRFB funding has been approved to conduct surveys in the near future. In addition, timber companies will be identifying fish habitat blockages on their property in their road maintenance plans in the next five years.

- Prioritize (using the Priority Index system) all salmonid-blocking culverts and floodgates.

Floodplain Conditions in Dakota, California, and Terrell Creeks

Action Recommendations

- Reduce bank hardening throughout the watershed.
- Reconnect the floodplain in impacted areas.
- Reduce constraints along these streams, including those caused by bridges or floodplain roads such as Kickerville.
- Work with local industry (e.g. ARCO BP, ALCO) in the Terrell Creek watershed to improve floodplain and riparian conditions.
- Protect the H street wetland and Haynie Pond complexes and consider storage augmentations to improve summer low flows.
- Work with County Roads to replace Haynie Creek bridge on Haynie Road in Blaine.

Data Needs

- Assessments of impacts to floodplain conditions are needed for each of these watersheds. Assessments should identify historic versus current conditions, loss of side-channel and off-channel habitat (wetlands), impacts, and prioritization of impacts, including roads in the floodplains, bank hardening, dikes/levees, old railroad grades, dredging, and channelization.

Streambed and Sediment Conditions in Dakota, California, and Terrell Creeks

Action Recommendations

- Enforce Critical Areas Ordinances in WRIA 1. This will likely be changed in the next few years.
- Reduce the invasion of Reed canarygrass.
- Reduce human-caused sediment delivery to lowland streams.
- Restore lowland streams to more natural systems (sinuosity, habitat complexity, sediment delivery, etc.) in historically important fish producing streams.
- Dredging projects related to slope-derived sedimentation need to take into account sediment sources, sediment supply, and impacts to fish habitat.
- Increase instream large woody debris (LWD) in appropriate areas.

Data Needs

- Assess sediment processes in Dakota, Haynie, California, and Terrell Creeks.

- Analyze low gradient streams for the restoration potential to more natural systems.

<u>Riparian Conditions in Dakota, California, and Terrell Creeks</u>

Action Recommendations

- Maintain and protect existing functional riparian vegetation throughout these streams. The Dakota Creek watershed has known good riparian areas.

- Restore degraded riparian conditions using historic information to restore with the appropriate plant species, and consider the stream size for a functional riparian buffer.

- Eliminate non-native plants from riparian zones, and revegetate with native species.

- Reduce riparian wood removal, including removal by private citizens, through education and regulatory actions.

Data Needs

- Analyze riparian conditions on a reach scale for Dakota, California, and Terrell Creeks.

- Survey and analyze levels of instream LWD and LWD recruitment potential (as part of the riparian assessment).

<u>Water Quality Conditions in Dakota, California, and Terrell Creeks</u>

Action Recommendations

- Remove creosote-treated wood from the basin.

- Improve water quality throughout these streams by addressing riparian, sedimentation, instream flow, and wetland loss conditions. These are further described in their respective sections.

- Implement agriculture's best management practices to reduce nutrient run-off and livestock waste delivered to streams.

- Address failing septic systems throughout these watersheds.

- Reduce urban pollution inputs, including stormwater, into the California Creek watershed.

Data Needs

- Use benthic invertebrate assessment as a first level analysis for potential water quality problems.

- In areas with potential water quality problems as assessed by benthic invertebrate monitoring, monitor water quality parameters (temperature, dissolved oxygen levels, toxins, pesticides, metals, and other contaminants).

<u>Water Quantity Conditions in Dakota, California, and Terrell Creeks</u>

Action Recommendations

- Protect and maintain areas that are important for aquifer recharge, such as the extensive wetlands north of H street and the Haynie Creek headwaters.

- Implement and enforce instream flows where they are set.

- Enforce regulations regarding illegal water withdrawals.

- Follow the recommendations that develop from the Watershed Planning (2514) process.

- Reduce urban stormwater delivery to streams, for example, by retrofitting and low impact development.

Recommendations and Data Needs for Salmonid Habitat Restoration Actions in Squalicum, Whatcom, Padden, Chuckanut, Oyster, and Colony Creeks and the Lake Whatcom Tributaries

<u>Fish Access Conditions in Squalicum, Whatcom, Padden, Chuckanut, Oyster, and Colony Creek Watersheds</u>

Action Recommendations

- Remove or replace identified high priority salmonid-blocking culverts and floodgates with fish-friendly alternatives. Several are known in the Squalicum Creek Basin.

Data Needs

- Conduct surveys of all fish habitat blockages in the Lake Whatcom tributaries and throughout the Squalicum, Whatcom, Padden, Chuckanut, Oyster, and Colony Creek watersheds. Additional work might still be needed in the Squalicum Creek watershed, although much work has been done. Currently, SRFB funding has been approved to conduct surveys in the near future, and timber companies will be identifying fish habitat blockages on their property in their road maintenance plans in the next five years.

- Prioritize (using the Priority Index system) all salmonid-blocking culverts and floodgates.

<u>Floodplain Conditions in Squalicum, Whatcom, Padden, Chuckanut, Oyster, and Colony Creek Watersheds</u>

Action Recommendations

- Investigate areas for floodplain reconnection opportunities.
- Reduce constraints along the streams, including floodplain roads.
- Prevent further losses of wetlands, and restore previously lost or degraded wetlands.
- Reduce bank-hardening impacts. Significant known impacts exist in the developed reaches of the Lake Whatcom tributaries and along Squalicum Creek.

Data Needs

- Assessments of impacts to floodplain conditions are needed for each of these watersheds. Assessments should identify historic versus current conditions, loss of side-channel and off-channel habitat (wetlands), impacts, and prioritization of impacts, including roads in the floodplains, bank hardening, dikes/levees, old railroad grades, dredging, and channelization.

<u>Streambed/Sediment Conditions in Squalicum, Whatcom, Padden, Chuckanut, Oyster, and Colony Creek Watersheds</u>

Action Recommendations

- Reduce livestock access to the Squalicum, Chuckanut, Colony, and Oyster Creek watersheds.
- Reduce human-caused sediment inputs into Brannian, Olsen, Blue Canyon, Smith, Austin, Beaver, and Carpenter Creeks.
- Enforce Critical Areas Ordinances in WRIA 1. These will likely be changed in the next few years.
- Reduce the invasion of Reed canarygrass.

- Dredging projects related to slope derived sedimentation need to take into account sediment sources, sediment supply, and impacts to fish habitat.

- Increase instream large woody debris (LWD) in appropriate areas.

- Reduce human-caused sediment delivery to lowland streams.

- Restore lowland streams to more natural systems (sinuosity, habitat complexity, sediment delivery, etc.) in historically important fish producing streams.

Data Needs

- Assess sediment processes in the Squalicum, Whatcom, Padden, Chuckanut, Oyster, and Colony Creek watersheds.

- Analyze low gradient streams for the restoration potential to more natural systems.

- Conduct habitat surveys for instream conditions such as LWD, pool habitat, and substrate conditions. The City of Bellingham is in the process of analyzing data collected for Squalicum, Whatcom, Padden, and Chuckanut Creeks, but data are lacking for Oyster and Colony Creeks (sporadic LWD data exist for Colony Creek).

<u>Riparian Conditions in the Squalicum, Whatcom, Padden, Chuckanut, Oyster, and Colony Creek Watersheds</u>

Action Recommendations

- Maintain and protect existing functional riparian vegetation. This passive form of intervention is most applicable in the forestlands.

- Restore degraded riparian conditions in areas that are degraded. Streams with extensive degradations include Squalicum, Whatcom, Oyster, Colony, and the Lake Whatcom tributaries. Use historic information to restore with the appropriate plant species, and consider the stream size for a functional riparian buffer.

- Eliminate non-native plants from riparian zones, and revegetate with native species.

- Reduce riparian wood removal, including removal by private citizens, through education and regulatory actions.

Data Needs

- Analyze riparian conditions on a reach scale for Squalicum, Whatcom, Padden, Chuckanut, Oyster, and Colony Creeks.

- Survey and analyze levels of instream LWD and LWD recruitment potential (as part of the riparian assessment) in Whatcom, Padden, Chuckanut, Oyster, and Colony Creeks.

<u>Water Quality Conditions in the Squalicum, Whatcom, Padden, Chuckanut, Oyster, and Colony Creek Watersheds</u>

Action Recommendations

- A high priority recommendation is to reduce industrial and urban pollution inputs into Whatcom Creek. In addition, stormwater inputs are a known problem in Squalicum, Whatcom, and Padden Creeks and the Lake Whatcom tributaries, and these impacts should be reduced.

- Warm water temperatures are a severe problem in several streams. For those resulting from riparian degradations, prioritize riparian restoration to help improve water temperatures.

- Remove creosote-treated wood from the basin.

- Improve water quality throughout these watersheds by addressing riparian, sedimentation, instream flow, and wetland loss conditions. These are further described in their respective sections.

- Implement agriculture's best management practices to reduce nutrient run-off and livestock waste delivered to streams.

Data Needs

- Monitor stream delivery of industrial, urban, and domestic chemical compounds and their impacts to salmonids in the streams surrounded by greater development, such as Squalicum, Whatcom, Padden, Chuckanut, and the lower reaches of the Lake Whatcom tributaries.

- Water quality parameters (temperature, dissolved oxygen, toxins, metals, pesticides, and other contaminants) should be monitored in streams that are lacking data (Oyster and Colony Creeks) or have other characteristics that suggest water quality problems (altered benthic invertebrate population, degraded riparian, etc). Whenever possible, use benthic invertebrate assessments to make an inexpensive first level assessment for a potential water quality problem.

- In areas near heavy traffic, monitor the quantity of diesel and gasoline exhaust that is delivered to streams.

Water Quantity Conditions in the Squalicum, Whatcom, Padden, Chuckanut, Oyster, and Colony Creek Watersheds

Action Recommendations

- Protect and maintain areas that are important for aquifer recharge.
- Implement and enforce instream flows where they are set.
- Enforce regulations regarding illegal water withdrawals.
- Follow the recommendations that develop from the Watershed Planning (2514) process.
- Reduce urban stormwater delivery to streams, for example, by retrofitting and low impact development.
- Seek opportunities to reduce water withdrawals from Squalicum, Padden, and Chuckanut Creeks.
- Take actions to prevent further increases in impermeable surfaces in the Whatcom, Padden, and Squalicum watersheds.

Data Needs

- Monitor instream flow conditions and water use in Oyster and Colony Creeks.

Recommendations and Data Needs for the Fraser River Tributaries in Washington State

Fish Access Conditions in the Fraser Tributaries

Action Recommendations

- Remove or replace identified high priority salmonid-blocking culverts and floodgates with fish-friendly alternatives.

Data Needs

- Survey and assess fish habitat blockages throughout these streams. Impacts are likely in the Sumas River watershed. Currently, SRFB funding has been approved to conduct surveys in the near future, and timber companies will be identifying fish habitat blockages on their property in their road maintenance plans in the next five years.

- Prioritize (using the Priority Index system) all salmonid-blocking culverts and floodgates.

<u>Floodplain Conditions in the Fraser Tributaries</u>

Action Recommendations

- Prevent further wetland loss.
- Restore previously lost wetlands.
- Reduce bank-hardening impacts.
- Investigate areas for floodplain reconnection opportunities.
- Reduce constraints along the streams, including floodplain roads.

Data Needs

- Assessments of impacts to floodplain conditions are needed for each of these watersheds. Assessments should identify historic versus current conditions, loss of side-channel and off-channel habitat (wetlands), impacts, and prioritization of impacts, including roads in the floodplains, bank hardening, dikes/levees, old railroad grades, dredging, and channelization.

<u>Streambed/Sediment Conditions in the Fraser Tributaries</u>

Action Recommendations

- Reduce livestock access to the Sumas River and tributaries.
- Enforce Critical Areas Ordinances in WRIA 1. These will likely be changed in the next few years.
- Reduce the invasion of Reed canarygrass.
- Reduce human-caused sediment delivery to lowland streams.
- Restore lowland streams to more natural systems (sinuosity, habitat complexity, sediment delivery, etc.) in historically important fish producing streams.
- Dredging projects related to slope derived sedimentation need to take into account sediment sources, sediment supply, and impacts to fish habitat.

- Increase instream large woody debris (LWD) in appropriate areas.

Data Needs

- Assess sediment processes in the Sumas River watershed.
- Develop a sediment budget for Saar Creek.
- Analyze low gradient streams for the restoration potential to more natural systems.
- Conduct instream habitat surveys to assess substrate, LWD, and pool conditions throughout the Washington State portion of the Sumas watershed and Frost Creek.

<u>Riparian Conditions in the Fraser Tributaries</u>

Action Recommendations

- Maintain and protect existing functional riparian vegetation throughout the Nooksack Basin. This passive form of intervention is most applicable in the forestlands.
- Restore degraded riparian conditions in highly degraded areas such as along the Sumas River and Frost Creek streams. Use historic information to restore with the appropriate plant species, and consider the stream size for a functional riparian buffer.
- Eliminate non-native plants from riparian zones, and revegetate with native species.
- Reduce riparian wood removal, including removal by private citizens, through education and regulatory actions.

Data Needs

- Analyze riparian conditions on a reach scale for the Sumas River and tributaries and for Frost Creek.
- Survey and analyze levels of instream LWD and LWD recruitment potential (as part of the riparian assessment) in the Sumas River and Frost Creek watersheds.

Water Quality Conditions in the Fraser Tributaries

Action Recommendations

- Reduce livestock access and livestock waste inputs into the Sumas River and tributaries.
- Reduce urban pollution inputs, including stormwater, into the Sumas River and its tributaries.
- Remove creosote-treated wood from the basin.
- Improve water quality throughout the Sumas River and Frost Creek watersheds by addressing riparian, sedimentation, instream flow, and wetland loss conditions. These are further described in their respective sections.
- Implement agriculture's best management practices to reduce nutrient run-off and livestock waste delivered to streams.
- Address failing septic systems throughout the Sumas River watershed.

Data Needs

- Monitor and assess benthic invertebrate populations throughout the Washington State portion of the Fraser River tributaries. Then, focus more expensive water quality monitoring on those streams that indicate potential water quality problems.
- Monitor stream delivery of industrial, urban, and domestic chemical compounds and their impacts to salmonids in the urbanized areas such as the Sumas River and tributaries.
- Where potential water quality problems have been identified, measure temperature, dissolved oxygen, toxins, metals, pesticides, and other contaminants as appropriate.

Water Quantity Conditions in the Fraser Tributaries

Action Recommendations

- Protect and maintain areas that are important for aquifer recharge.
- Implement and enforce instream flows where they are set.
- Enforce regulations regarding illegal water withdrawals.

- Follow the recommendations that develop from the Watershed Planning (2514) process.

- Reduce urban stormwater delivery to streams, for example, by retrofitting and low impact development.

- Reduce water withdrawals from the Sumas River and tributaries and Saar Creek.

WRIA 1 Estuary and Near Shore Action Recommendations and Data Needs

Many of the recommendations for Bellingham Bay actions are from the Bellingham Bay Demonstration Pilot Project, and are cited as such (Pacific International Engineering and Anchor Environmental 1999). A team of federal, state, tribal, and local stakeholders developed these recommendations, and issued an EIS for the Bellingham Bay comprehensive strategy to help guide future decisions regarding water quality, sediment quality, habitat restoration, and in-water and shoreline land uses. This strategy and associated work products provide the most comprehensive and detailed list of recommendations for Bellingham Bay. Some of the recommendations for salmonid habitat are listed below, along with other recommendations developed by the TAG for nearshore and estuarine actions and data needs.

<u>WRIA-Wide Nearshore and Estuarine Action Recommendations</u>

- Restore, protect, or enhance the natural habitat forming features that create and maintain habitat, such as longshore transport, etc. (Pacific International Engineering and Anchor Environmental 1999).

- Reduce and minimize shoreline armoring.

- Control point and non-point sources of contamination throughout WRIA 1.

- Restore, enhance, or protect viable habitat that provides connective corridors between riverine and estuarine habitats and between estuarine and open water.

- Remove shoreline fills that result in a net gain in in-water habitat.

- Protect eelgrass habitat.

- Improve shoreline riparian vegetation.

- Prevent invasive plant and animal infestations through aggressive monitoring.

- Monitor tidelands for *Spartina* infestations and treat if observed.

- Restore access to blocked habitat (ex. Lummi River Delta).

- Develop a ballast water management plan.

- Increase aquatic area and function (Pacific International Engineering and Anchor Environmental 1999).

- Remove creosote-treated wood.

- Protect forage fish spawning and rearing areas.

- Reduce in-water structures or modify structures to reduce impacts to biological resources.

<u>Bellingham Bay Action Recommendations (in addition to WRIA-wide recommendations listed above)</u>

- Facilitate the designation of Habitat Reserve Areas as described in the Comprehensive Strategy (Figure 42) (Pacific International Engineering and Anchor Environmental 1999).

- 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 (Pacific International Engineering and Anchor Environmental 1999).

- Restore or enhance estuarine habitat of Squalicum, Whatcom, Padden, and Little Squalicum Creeks (Pacific International Engineering and Anchor Environmental 1999).

- Contain or remove shoreline landfills. The Cornwall Landfill has been identified as a high priority through the Bellingham Bay Demonstration Pilot.

- Restore the former eelgrass beds in inner Bellingham Bay (Pacific International Engineering and Anchor Environmental 1999).

<u>WRIA 1 Nearshore and Estuarine Data Needs</u>

- Quantify lost estuarine habitat in areas outside of Lummi, Samish, and Bellingham Bays, identifying the type of impact (dredging, fills, etc.).

- Evaluate coastal shoreline processes to determine causes of erosion, need for shore protection and suitability of soft shore protection techniques along discrete shore reaches.

- Assess primary productivity throughout WRIA 1, especially in Bellingham Bay, to develop a better understanding of our biological resources.

- Analyze the influence of the Fraser River on conditions in WRIA 1, including human-caused water quality issues and natural hydrology changes.

- Quantify current water quality conditions throughout WRIA 1 as they pertain to salmonid survival. Data are especially sparse outside of Bellingham Bay. Needed data include water temperatures, dissolved oxygen levels, herbicide levels, pesticide levels, potential impacts from diesel spills and exhaust, and other types of water quality impacts from boats.

- Study the effects of stormwater inputs.

- Quantify lost habitat due to tidegates and prioritize for restoration actions.

- Quantify and prioritize lost nearshore habitat due to fills and dredging.

- Define, map, and prioritize where connective corridors have been lost or disrupted.

- Develop a risk analysis for Canadian and Whatcom County ship traffic (oil spill risk).

- Study the impacts imposed on salmonid resources and nearshore/estuarine habitat as a result of shoreline railroads.

- Assess possible impacts from the Lummi Sea Ponds on wild salmonids, including altered hydrology and water temperatures.

- Inventory surf smelt, sand lance, macro algae, eelgrass, and longfin smelt resources (including forage fish spawning habitats) throughout WRIA 1.

- Investigate the abundance and resource use of juvenile chinook salmon in the estuaries and nearshore environments of WRIA 1.

- Analyze potential impacts of mooring buoys in WRIA 1.

- Analyze potential impacts from invasive species infestations (including *Spartina*) in WRIA 1.

- Develop a monitoring plan for capped contaminated sediments (Pacific International Engineering and Anchor Environmental 1999).

LITERATURE CITED

ACOE. 2001. Nooksack-Sumas River Basins. http://www.nws.asace.army.mil/pal/wrd/noframe/b-nook.html

Aitkin, J.K., 1998. The importance of estuarine habitats to anadromous salmonids of the Pacific Northwest: A literature review. U.S. Fish and Wildlife Service, Aquatic Resources Division, in cooperation with the U.S. Fish and Wildlife Service, Puget Sound Program.

Anchor Environmental. 2000. Map of Bellingham Bay after implementation of Comprehensive Strategy. EIS.

B.C. Ministry of Environment, Lands and Parks and Environment Canada. 1993. State of the environment report for British Columbia. Vancouver. 127 pp.

Ballerini, M. 1993. The Jim Creek slide: an analytical investigation. From the U.S. Forest Service. 33 pp.

Bargmann, G. 1998. Forage fish management plan. Washington Department of Fish and Wildlife, Olympia, Washington.

Bargmann, G. and eleven other authors. 1999. Washington contribution to the 1999 meeting of the technical sub-committee (TSC) of the Canada-U.S. Groundfish Committee. Washington Department of Fish & Wildlife, Olympia, Washington.

Bell, M.C. 1986. Fisheries handbook of engineering requirements and biological criteria. U.S. Army Corps of Engineers. North Pacific Division Fish Passage Development and Evaluation Program. Portland, Oregon.

Benda, L. and C. Coho. 1999 draft. Acme watershed analysis mass wasting module. Acme Watershed Analysis, Department of Natural Resources Forest Practices Division, Olympia, Washington. 37 pp.

Berry, H.D., J.R. Harper, T.F. Mumford, Jr., B.E. Bookheim, A.T. Sewell, and L.J. Tamayo. 2001. The Washington State ShoreZone Inventory User's Manual. Nearshore Habitat Program, Washington State Department of Natural Resources, Olympia, WA.

Blocking, R. C. 1997. A portrait of a mighty river. University of Washington Press, Seattle, Washington. 294 pp.

Bortleson, G.C., M.J. Chrzastowski, and A.K. Helgerson. 1980. Historical changes of shoreline and wetland at eleven major deltas in the Puget Sound Region, Washington. U.S. Dept. of the Interior, Geological Survey.

Brooks, K. M. 1994. Literature Review, Computer Model and Assessment of the Environmental Risks Associated with Creosote Treated Wood Products Used in Aquatic Environments. August 30, 1994. Aquatic Environmental Sciences, Port Townsend, WA. 136 pp. (Reissued in 1997)

Burgner, R. L., J.T. Light, L. Margolis, T. Okazaki, A. Tautz, and S. Ito. 1992. Distributions and origins of steelhead trout (*Oncorhynchus mykiss*) in offshore waters of the North Pacific Ocean. International North Pacific Fish. Comm. Bulletin 51, 92 pp.

Busby, P.J., T.C. Wainwright, G.J. Bryant, L.J. Lierheimer, R.S. Waples, F. W. Waknitz, and I.V. Lagomarsino. 1996. Status Review of West Coast Steelhead from Washington, Idaho, Oregon, and California. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-27, 261 pp.

Cederholm, C.J. and W.J.. Scarlett. 1981. Seasonal immigrations of juvenile salmonids into four small tributaries of the Clearwater River, Washington, 1977-1981. Pages 98-110 *in* E.L. Brannon and W.O. Salo, editors. Proceedings of the Salmon and Trout Migratory Behavior Symposium. School of Fisheries, University of Washington, Seattle, Washington.

Cederholm, C.J., D.H. Johnson, R.E. Bilby, L.G. Dominguez, A.M. Garrett, W.H. Graeber, E.L. Greda, M.D. Kunze, B.G. Margot, J.F. Palmisano, R.W. Plotnikoff, W.G. Pearcy, C.A. Simenstad, and P.C. Trotter, 2000. Pacific Salmon and Wildlife - Ecological Contexts, Relationships, and Implications for Management. Special Edition Technical Report, Prepared for D.H. Johnson and T.A. O'Neil (Manag. Dirs.), Wildlife-Habitat Relation-ships in Oregon and Washington. Washington Department of Fish and Wildlife, Olympia.

Chapman, D.W. 1965. Net production of juvenile coho salmon in three Oregon streams. Transactions of the American Fisheries Society 94:40-52.

City of Bellingham Public Works. 1999. Urban stream monitoring report 1999. City of Bellingham, Whatcom County, Washington.

Clark, J.R. 1996. Coastal Zone Management Handbook. Lewis Publishers, Boca Raton, Florida.

Coe, T. 2001. Nooksack River watershed riparian function assessment. Nooksack Indian Tribe Report #2001-001.

Cox, S.E. and S.C. Kahle. 1999. Hydrogeology, ground-water quality, and sources of nitrate in lowland glacial aquifers of Whatcom County, Washington and British Columbia Canada. U.S. Geological Society Investigations Report 98-4195, Tacoma, Washington.

Cubbage, J. 1994. Drainage basin tracing study: phase II chemicals found in storm drains, Whatcom Creek, and Squalicum Harbor in Bellingham, Washington. Washington Department of Ecology Publication No. 94-90, Olympia, Washington. 16 pp.

Currence, N. 2000. Middle Fork Nooksack anadromous salmonid potential upstream of the diversion dam. Nooksack Indian Tribe, Deming, Washington. 9 pp.

David Evans and Associates, Inc. 1998. Fish habitat reconnaissance assessment for City of Sumas. City of Sumas, Washington. 25 pp.

Department of Conservation. 1960. Water resources of the Nooksack River Basin and certain adjacent streams. Water Supply Bulletin No. 12. Department of Conservation, Division of Water Resources, Olympia, Washington.187 pp.

Department of Ecology (DOE). 1995. State of the Nooksack River watershed. Department of Ecology Nooksack Initiative Office, Bellingham, Washington.

Dept. of Ecology (DOE). 2000. Ecology's final 1998 list of impaired and threatened waterbodies- the 303(d) List. http://www.wa.gov/ecology/wq/303d/index.html

Department of Ecology (DOE). 2001. Sediment cleanup status report. Washington State Department of Ecology Toxics Cleanup Program. Publication number 01-09-046. Olympia, Washington. 21 pp.

Department of Ecology (DOE). 2002a. Marine water quality monitoring. http://www.ecy.wa.gov/programs/eap/mar_wat/gradientofconcern.html

Department of Ecology (DOE). 2002b. Vessel entries and transits for Washington waters VEAT 2001. Washington Dept. of Ecology Spills Program. Olympia, Washington. Publication 02-08-003. 6 pp.

Department of Natural Resources (DNR). 1992 draft. Van Zandt block plan. Dept. Natural Resources, Olympia, Washington. 54 pp.

Department of Natural Resources (DNR). 1994. Skookum Creek watershed analysis. Dept. Natural Resources, Olympia, Washington.

Department of Natural Resources (DNR), initiated by DePaul, Inc. and Trillium Corporation. 1995. Warnick watershed analysis. Dept. Natural Resources, Olympia, Washington.

Department of Natural Resources (DNR). 1997. Lake Whatcom watershed analysis. Department of Natural Resources Northwest Region, Sedro Woolley, Washington.

Department of Natural Resources (DNR). 1998. Hutchinson watershed analysis. Department of Natural Resources Northwest Region, Sedro Woolley, Washington.

Department of Natural Resources. 2000. Belcher names DNR's first aquatic reserves. May 22, 2000 Press Release. Olympia, Washington.

Department of Natural Resources. 2002. Aquatic reserves: creating tools for education, science, and the environment. http://www.wa.gov/dnr/htdocs/aqr/reserves/reserves.htm

Determan, T. 1995. Watershed briefing paper: shellfish issues. Washington Department of Ecology Watershed Management Section, Olympia, Washington.

Dickes, B. 1992. Water quality screening in the Dakota, Bertrand, and Fishtrap Creek watersheds Whatcom County, Washington. Department of Ecology, Olympia, Washington.

Dingman, S. L. 1994. Physical Hydrology. Macmillan Publishing Company, New York. 575 pp.

Easterbrook, D.J. 1971. Geology and geomorphology of Western Whatcom County. Western Washington University Press, Bellingham. 68 pp.

Elardo, P. 2001. Bellingham Bay contaminated sediments total maximum daily load. Washington Dept. Ecology Water Quality Program. Publication 99-58-WQ. 46 pp.

EPRI. 1995. Management Practices for Used Treated Wood, Final Report. EPRI TR-104966. Electric Power Research Institute, Pleasant Hill, California.

Erickson, K, and nine other authors. 1995. Watershed briefing paper for the Nooksack water resource inventory area. Washington Department of Ecology Publication No. 95-321, Olympia, Washington. 47 pp.

EVS Environment Consultants. 1999. Cherry Point screening level ecological risk assessment. For the Washington Dept. of Natural Resources, Olympia, Washington.

Everett, R.A. and G.M. Ruiz. 1993. Coarse woody debris as a refuge from predation in aquatic communities: an experimental test. Oecologia 93:475-486.

Fox, S. and J. Greenberg. 1994. Hydrologic and fisheries resources of the Nooksack Basin. Whatcom County Planning and Development Services, Bellingham, Washington. 40 pp.

Fresh, K.L., B.Williams, and D. Pentilla. 1995. Overwater structures and impacts on eelgrass in Puget Sound. Washington Puget Sound Research 1995 Proceedings. Puget Sound Water Quality Authority. Seattle, Washington

Gustafson, R.G. and G.A. Winans. 1999. Distribution and population genetic structure of river- and sea-type sockeye salmon in western North America. Ecology of Freshwater Fish 1999: 8: 181-193.

Hale, J.W. 1992. Report: South Fork Nooksack drainage mass-wasting history inventory. U.S. Forest Service, Mount Baker Ranger District, Sedro Woolley, Washington. 28 pp.

Hall, K., G. Larkin, D. McCallum, and P. Zandbergen. 2002. Brunette River watershed: the impacts of urbanization. http://www.ire.ubc.ca/ecoresearch/brunette.html

Hardy, McKee, Kaluarachchi, Kemblowski, Tarboton, Stevens, Pack. May 7, 2001 draft. WRIA 1 watershed management project phase II technical study results: executive summary. Utah Water Research Laboratory. Prepared for the WRIA 1 Watershed Management Project.

Harr, R.D. and R. A. Nichols. 1993. Stabilizing forest roads to help restore fish habitats: a northwest Washington example. Fisheries Vol. 18, No. 4, pp. 18-22.

Harrold, C., J. Watanabe, and S. Lisin. 1988. Spatial variation in the structure of kelp forest communities along a wave exposure gradient. Marine Ecology 9(2): 131-156.

Hirsch Consulting Services. 2000. Drayton Harbor shellfish protection district water quality. Prepared for The Whatcom County Drayton Harbor Shellfish Protection District.. Bellingham, Washington.

Hoar, W.S. 1958. The evolution of migratory behaviour among juvenile salmon of the genus Oncorhynchus. Journal of Fisheries Research Board Canada 15:391-428.

Humphreys, R.D. and A.S. Hourston. 1978. British Columbia herring spawn deposition survey manual Fisheries and Marine Service Miscellaneous Special Publication No. 38. Canadian Fisheries and Marine Service 38. 40 pp.

Hunter, J.G. 1959. Survival and production of pink and chum salmon in a coastal stream. Journal of Fisheries Research Board Canada 16:835-886.

Ivankov, V.N. and V.L. Andreyev. 1971. The South Kuril chum (*Oncorhynchus keta*) ecology, population structure and the modeling of the population. Journal of Ichthyology 11:511-524.

Johnson, L. L. 2000. An analysis in support of sediment quality thresholds for polycyclic aromatic hydrocarbons (PAH) to protect estuarine fish. National Marine Fisheries Service, Seattle, Washington (Draft white paper).

Johnston, J. 2000. Lake Whatcom water quality presentation. From the February 7, 2000 Forum, “How Healthy is Lake Whatcom”. The Clean Water Alliance, Bellingham, Washington.

Karrow, N. A., H. J. Boermans, D. G. Dixon, A. Hontella, K. R. Solomon, J. J. Whyte, and N. C. Bols. 1999. Characterizing the immunotoxicity of creosote to rainbow trout (Oncorhynchus mykiss): a microcosm study. Aquat. Toxicol. 45:223-239.

Kirtland, J.A. 1995. Sediment production and delivery in the upper South Fork Nooksack River Northwest Washington 1940-1991. Masters Thesis. Western Washington University Bellingham, Washington.

Knowles, C.J. and R.G. Gumtow. 1996. Saving the bull trout. The Thoreau Institute, Oak Grove, Oregon. Available at: http://www.ti.org/gumtow.html.

Kocan, R.M. 1991. *In situ* and laboratory assessment of herring embryo survival at Cherry Point, Washington, May 1991. School of Fisheries, University of Washington, Seattle, Washington.

Kocan, R.M. 1992. Final Report - Cherry Point herring embryo study. Prepared for Intalco Aluminum Corp., BP Oil Company, ARCO Products Company, Texaco, Cherry Point Industrial Park Ltd., and the Lummi Indian Nation.

Kocan, R.M. 1998. Herring embryo-larval success evaluation at Cherry Point: Comparison of *in situ* exposures with laboratory controls. Prepared for Washington Department of Natural Resources. School of Fisheries, University of Washington, Seattle, Washington.

Kocan, R.M. and M.T. MacKay. 1991. *In situ* and laboratory assessment of herring embryo survival at Cherry Point, Washington, April/May 1990. School of Fisheries, University of Washington, Seattle, Washington.

Krahn, M. M., L. D. Rhodes, M. S. Meyers, L. K. Moore, W. D. MacLeod, and D.C. Malins. 1986. Associations between metabolites of aromatic hydrocarbons in bile and the occurrence of hepatic lesions in English sole (Parophyrs vetulus) from Puget Sound, Washington. Arch. Environ. Contam. Toxicol. 15 :61-67.

Larkin, P.A. 1977. Pacific Salmon. Pages 156-186 *in* J.A. Gulland, editor. Fish Population Dynamics. J. Wiley & Sons, New York, New York.

Levings, C.D. and A.I. Moody. 1976. Studies of intertidal vascular plants, especially sedge (*Carex lyngbyei*), on the disrupted Squamish River delta, British Columbia. Fish. Mar, Serv. Tech. Rept. 606. 56 pp.

Levings, C.D. and R. M. Thom. 1994. Habitat changes in the Georgia Basin: implications for resource management and restoration. British Columbia/Washington Symposium on the marine environment Puget Sound and Juan de Fuca Strait. Pp. 330-349.

Long, E.R., and 13 other authors. 1999. Sediment Quality in Puget Sound Year 1 - Northern Puget Sound December 1999. NOAA NOS NCCOS CCMA No. Technical Memo No. 139 and Washington State Department of Ecology Publication No. 99-347.

Lunetta, R.S., B.L. Cosentino, D.R. Montgomery, E.M. Beamer, and T.J. Beechie. 1997. GIS-Based evaluation of salmon habitat in the Pacific Northwest. Photogrammetric Engineering & Remote Sensing. Vol. 63, No. 10, pp.1219-1229.

Matthews, R.A, M. Hilles, and G.B. Matthews. 1999. Lake Whatcom monitoring project, 1997/1998 final report. City of Bellingham Public Works, Bellingham, Washington.

Matthews, R.A., M. Hilles, J. Vandersypen, R.J. Mitchell, and G.B. Matthews. 2001. Lake Whatcom monitoring project, 1999/2000 final report. City of Bellingham Public Works, Bellingham, Washington. 246 pp.

Marshall, A.R., C. Smith, R. Brix, W. Dammers, J. Hymer, L. Lavoy. 1995. Genetic diversity units and major ancestral lineages for chinook salmon in Washington. *In* Genetic Diversity Units and Major Ancestral Lineages of Salmonid Fishes in Washington. Washington Department of Fish and Wildlife. Technical Report Number RAD 95-02.

Maser, C. and J.R. Sedell. 1994. From the Forest to the Sea. The Ecology of Wood in Streams, Rivers, Estuaries, and Oceans. St. Lucie Press, Delray Beach, Florida.

Meehan, W.R., F.J. Swanson, and J.R. Sedell. 1977. Influences of riparian vegetation on aquatic ecosystems with particular reference to salmonid fishes and their food supply. Pages 137-145 *in* R.R. Johnson and D. A. Jones, editors. Importance, Preservation and Management of Riparian Habitat: A Symposium held at Tucson, Arizona, July 9, 1977. U.S. Forest Service General Technical Report RM-43.

Meyer, J. and S. Brinkman. 1995. Water-quality conditions in the Lake Ozette Watershed and potential impacts on salmonids. Draft Report. Olympic National Park, Port Angeles, Washington. 57 pp.

Meyer, M. S., J. T. Landahl, M. M. Krahn, L. L. Johnson, and B. B. McCain. 1990. Overview of studies on liver carcinogenesis in English sole from Puget Sound; Evidence for a xenobiotic chemical etiology I: Pathology and epizootiology. Sci. Total Environ. 94:35-50.

Meyers, J.M., R.G. Kope, G.J. Bryant, D. Teel, L.J. Lierheimer, T.C. Wainwright, W.S. Grant, F.W. Waknitz, K. Neely, S.T. Lindley, and R.S. Waples. 1998. Status review of chinook salmon from Washington, Oregon, Idaho, and California. U.S. Dept. Commerce, NOAA Technical Memo. NMFS-NWFSC-35. 443 pp.

Miller, R. R. 1965. Quaternary freshwater fishes of North America. Pages 569-581 *in* The Quaternary of the United States. Princeton University Press, Princeton, New Jersey.

Ministry of Water, Land, and Air Protection. 2002. Government of British Columbia. http://wlapwww.gov.bc.ca/soerpt/07-2-surface-water.html

Morgan, J.D. and C.D. Levings. 1989. Effect of suspended sediment on eggs and larvae of lingcod (*Ophiodon elongates*), Pacific herring (*Clupea harengus pallasi*), and suft smelt (*Hypomesus pretiosus*). Can. Tech. Rept. Fish. Aquat. Sci. 1729. 31 pp.

Neave, F. 1949. Game fish populations of the Cowichan River. Bulletin of the Fisheries Research Board Canada 84:1-32.

Neff, D.A. 1992. A comparison of temperature, dissolved oxygen, and turbidity measurements in the upper watershed of the Nooksack River to Washington State water quality standards. Lummi Fisheries Technical Report #93-02. Bellingham, Washington. 11 pp.

Nelson, T., L. Adkins, J. Heller, B. McIntosh, and T. Granger. 1991. Drayton Harbor Watershed Whatcom County Washington. Whatcom County Council of Governments, Bellingham, Washington.

Nightingale, B. and C. Simenstad. 2001a. Dredging activities: marine issues. Prepared for: the Washington Department of Fish and Wildlife, Washington Department of Ecology, and the Washington Department of Transportation. 182 pp.

Nightingale, B. and C. Simenstad. 2001b. Overwater structures: marine issues. White Paper. Prepared for the Aquatic Habitat Guidelines Steering Committee and joingtly published by the Washington Dept. of Fish and Wildlife, Washington Dept. of Ecology, and Washington Dept. of Transportation. Olympia, Washington. 133 pp.

Nooksack Recovery Team. 2001. Nooksack Recovery Team Database CD. Whatcom County and 9 other agencies. Bellingham, Washington.

Nooksack Spring Chinook Technical Team. 1986. Draft Nooksack River spring chinook report. Washington State Department of Fisheries, U.S. Fish and Wildlife Service, Lummi Indian Nation, and Nooksack Indian Tribe.

Pacific International Engineering and Anchor Environmental. 1999. Bellingham Bay demonstration pilot. Final habitat restoration documentation report. For the Bellingham Bay Demonstration Pilot Work Group. Bellingham, Washington.

Peak Northwest, Inc. 1986. Nooksack River Basin erosion and fisheries study. Washington State Department of Ecology, Olympia, Washington.

Pentilla, D. 2001a. Documented spawning areas of the Pacific herring, *clupea*, the surf smelt, *hypomesus*, and the Pacific sand lance, *ammodytes*, in Whatcom County, Washington. Washington Dept. Fish and Wildlife, Marine Resources Division, LaConner, Washington. 17 pp.

Pentilla, D. 2001b. Effects of shading upland vegetation on egg survival for summer spawning surf smelt on upper intertidal beaches in Puget Sound. In: Proceedings on Puget Sound Research 2001. 9 pp.

People for Puget Sound. 1997. The loss of habitat in Puget Sound. Http://www.pugetsound.org/habitat/reportfolder/default.html

Peterson, N.P. 1980. The role of spring ponds in the winter ecology and natural production of coho salmon (*Oncorhynchus kisutch*) on the Olympic Peninsula, Washington. Master's Thesis. University of Washington, Seattle, Washington. 96 pp.

Phay, A. 2000a. Intertidal habitat 1995 study map. Whatcom Conservation District, Lynden, Washington.

Phay, A. 2000b. Land use 1991 Nooksack Watershed Map. Whatcom Conservation District, Lynden, Washington.

Phelps, S., J. Uehara, D. Hendrick, J. Hymer, A. Blakley, and R. Brix. 1995. Genetic diversity unites and major ancestral lineages for chum salmon in Washington. *In* Genetic Diversity Units and Major Ancestral Lineages of Salmonid Fishes in Washington (C. Busack and J.B. Shaklee, eds). Technical Report RAD 95-02, Washington Dept. Fish and Wildlife, Olympia, Washington.

Phinney, D. and Williams. 1975. A catalog of Washington streams and salmon utilization. Vol. 1 Puget Sound. Washington Department of Fisheries, Olympia, Washington.

Poston, T. 2001. Treated Wood Issues Associated with Overwater Structures in Marine and Freshwater Environments. White Paper submitted to: Washington Department of Fish and Wildlife, Washington Department of Ecology, and Washington Department of Transportation, Olympia, Washington. 85 pp.

Potash, L. 2001 draft. Riparian health restoration: control of Japanese knotweed in the Western Cascades. White paper for the U.S. Forest Service, Mount Baker Ranger District, Sedro Woolley, Washington. 15 pp.

Richert, D.A., G.L. Beach, J.E. Jackson, D.M. Anderson, H.H. Hazen, and E.Suwijn. 1978. Oregon's procedure for assessing the impacts of land management activities on erosion related nonpoint source problems. Oregon 208 Nonpoint Source Assessment Project. Oregon State Dept. of Environmental Quality. Portland, Oregon. 219 pp.

Salmon and Steelhead Habitat Inventory and Assessment Program (SSHIAP). 1995 to present. MS Access Database; ESRI ArcInfo Coverages. Northwest Indian Fisheries Commission, Olympia, WA. http://www.nwifc.org/sshiap2/index.asp

Salo, E. O. Life history of chum salmon. In: Groot, C. and L. Margolis (editors). Pacific Salmon Life Histories. UPC Press Vancouver, British Columbia, pp. 233-309.

Scherrer, W. 2001. After 100 years, Padden Creek may again see daylight. Whatcom Watch, May 20, 2001. Volume 10, Issue 5.

Schuett-Hames, J. and D. Schuett-Hames. 1984a. Spawning gravel fine sediment levels and stream channel stability ratings for salmonid streams in the Nooksack Basin, Washington, 1982 and 1983. Lummi Tribal Fisheries Department, Bellingham, Washington. 26 pp.

Schuett-Hames, D. and J. Schuett-Hames. 1984b. Juvenile salmonid survey of lowland Whatcom County streams, spring 1983. Lummi Tribal Fisheries Department, Bellingham, Washington. 10 pp.

Schuett-Hames, D. and J. Schuett-Hames. 1987. North Fork Nooksack spring chinook surveys 1986 survey results. A historical count review and habitat observations. U.S. Fish and Wildlife Service, Olympia, Washington and Lummi Tribal Fisheries Department, Bellingham, Washington. 20 pp.

Schuett-Hames, D, J. Schuett-Hames, and P. Stevenson. 1988a. North Fork Nooksack spring chinook surveys: 1987 survey and redd survival results. U.S. Fish and Wildlife Service, Olympia, Washington. 6 pp.

Schuett-Hames, D., J. Schuett-Hames, M. MacKay, P. Wampler, and K. Doughty. 1988b. An assessment of the availability and quality of spring chinook holding and spawning habitat in the South Fork Nooksack River, 1986. Lummi Tribal Fisheries Department, Bellingham, Washington. 116 pp.

Scott, G.R. and J.D. McDowell. 1994. Whatcom County comprehensive plan: environmental impact statement, existing conditions report. Whatcom County Planning and Development Services Dept. Bellingham, Washington. 136 pp.

Scrivener, J.C. and B.C. Andersen. 1982. Logging impacts and some mechanisms which determine the size of spring and summer populations of coho salmon fry in Carnation Creek. Pages 257-272 *in* G.F. Hartman, editor. Proceedings of the Carnation Creek Workshop: a Ten Year Review. Pacific Biological Station, Nanaimo, British Columbia.

Sedell J., F. Triska, J.Hall, N. Anderson, and J. Lyford. 1974. Sources and fates of organic inputs in coniferous forest streams. *In* University of Washington, Coniferous Forest Biome (R.Waring and R. Edmonds, eds) Bulletin 5, Seattle.

Shaffer, J.A. and D.S. Parks. 1994. Seasonal variation in and observations of landslide impacts on the algal composition of a Puget Sound nearshore kelp forest. Botanica Marina. 37: 315-323.

Shaffer, J.A., D.C. Doty, R.M. Buckley, and J.E. West. Crustacean community composition and trophic use of the drift vegetation habitat by juvenile splitnose rockfish *Sebastes diploproa*. Marine Ecology Progress Series 123:13-21

Shaklee, J.B., J. Ames, and D. Hendrick. 1995. Genetic diversity units and major ancestral lineages for pink salmon in Washington. *In* Genetic Diversity Units and Major Ancestral Lineages of Salmonid Fishes in Washington (C. Busack and J.B. Shaklee, eds). Technical Report RAD 95-02, Washington Dept. Fish and Wildlife, Olympia, Washington.

Shapovalov, L., and A.C. Taft. 1954. The life histories of the steelhead rainbow trout (*Salmo gairdneri gairdneri*) and silver salmon (*Onchorhynchus kisutch*) with special reference to Waddell Creek, California, and recommendations regarding their management. California Department of Fish & Game Fish Bulletin 98. 375 pp.

Shreffler, D.K. and R. Thom. 1993. Restoration of urban estuaries: new approaches for site location and design. Prepared for Washington Dept. of Natural Resources, Olympia, Washington. 107 pp.

Simenstad, C.A. and E.O. Salo. 1982. Foraging success as a determinant of estuarine and near-shore carrying capacity of juvenile chum salmon (*Oncorhynchus keta*) in Hood Canal, Washington. Pages 21-37 *in* B.R. Meltreff and .A. Neve, editors. Proceedings of the North Pacific Aquaculture Symposium. Alaska Sea Grant Rep. 82-2.

Simenstad, C.A. and R.C. Wissmar. 1985. Delta^{13}C evidence of the origins and fates of organic carbon in estuarine and nearshore food webs. Mar. Ecol. (Progress Series) 22:141-152.

Simenstad, C.A., W.J. Kinney, S.S. Parker, E.O. Salo, J.R. Cordell, and H. Buechner. 1980. Prey community structure and trophic ecology of outmigrating juvenile chum and pink salmon in Hood Canal, Washington: a synthesis of three years' studies, 1977-1979. Fisheries Research Institute, University of Washington, Seattle, Washington.

Simenstad, C. A., J. R. Cordell, and L. A. Weitkamp. 1991. Effects of substrate modification on littoral flat meiofauna: Assemblage structure changes associated with adding gravel, FRI-UW-9124. University of WA, Seattle, WA.

Simenstad, C.A. 2001. The relationship of estuarine primary and secondary productivity to salmonid production: bottleneck or window of opportunity? NOAA-NMFS-NWFSC Publication TM-29: Estuarine and Ocean Survival of Northeastern Pacific Salmon.

Thom, R.M. and L. Hallum. 1990. Long-term changes in the areal extent of tidal marshes, eelgrass meadows and kelp forests of Puget Sound. Environmental Protection Agency 910/9-91-005.

Thom, R.M. and G.D. Williams. 2001. Executive summary: marine and estuarine shoreline modification issues. http://www.wa.gov/wdfw/hab/ahg/execsl.pdf.

Trillium Corporation. 1996 draft. Acme watershed analysis. Trillium Corporation, Bellingham, Washington.

U.S. Department of Agriculture Soil Conservation Service. 1993. Tenmile Creek watershed. Watershed plan environmental assessment. Available through Whatcom Conservation District, Lynden, Washington.

U.S. Fish and Wildlife Service. 1998. Bull trout interim conservation guidance. U.S. Fish and Wildlife Service, Lacey, Washington. 50 pp.

U.S. Forest Service. 1995a. North Fork Nooksack River Watershed Analysis. Mount Baker Ranger District, Sedro Woolley, Washington.

U.S. Forest Service. 1995b. Pilot watershed analysis for the Canyon Creek watershed Mt. Baker-Snoqualmie Forest. Mount Baker Ranger District, Sedro Woolley, Washington. 276 pp.

U.S. Forest Service. 1998. North Fork Nooksack River Water Quality Limited Segment (WA-01-1080) 1996 303(d) List. Argument for delisting above Glacier Creek (approximately RM. 58). Mount Baker Ranger District, Sedro Woolley, Washington. 10 pp.

U.S. Forest Service and U.S.D.I. Bureau of Land Management. 1994. Draft environmental assessment for the implementation of interim strategies for managing anadromous fish producing watersheds in Oregon, Washington, Idaho, and portions of California. Portland, Oregon.

U.S.G.S. 2001. Nooksack River Basin temperature sites. http://wa.water.usgs.gov/pugt/nooksack/nookmap.html

U.S.G.S. 2002. Classification of wetlands and deepwater habitats of the United States. http://www.npwrc.usgs.gov/resource/1998/classwet/wetlands.htm

van Brummelen, T. C., B. van Hattum, T. Crommentuijn, and D. F. Kalf. 1998. Bioavailability and Ecotoxicty of PAH. In: Neilson, A. H. (ed.). PAH and Related Compounds – Biology. (Vol. 3-J, The Handbook of Environmental Chemistry). Springer-Verlag, Berlin Heidenberg. pp. 203-263.

Van Siclen, C.C. 1994. Geologic, hydrologic, and climatic factors influencing Glacier Creek basin, Whatcom County, Washington. Master's Thesis, Western Washington University, Bellingham, Washington. 271 pp.

Varanasi, U., McClain, B.B., Stein, J.E. and Chan, S.L. 1993. Effects of coastal pollution on living marine resources. In: Transactions of the Fifty-Eighth North American Wildlife and Natural Resources Conference. Washington DC, 19-24 Mar. 1993, pp. 271-286.

Vines, C. A., T. Robbins, F. J. Griffin, andG. N. Cherr. 2000. The effects of diffusible creosote derived compounds on development in Pacific Herring (*Clupea pallasi*). In: Aquatic Toxicology. 51:225-239.

Volk, E.C., R.C. Wissman, C.A. Simenstad, and D.M. Eggers. 1984. Relationship between otolith microstructure and the growth of juvenile chum salmon (*Oncorhynchus keta*) under different prey rations. Canadian Journal of Fisheries and Aquatic Sciences 41:126-133.

Waldichuck, M. 1957. Physical oceanography of the Strait of Georgia, British Columbia. Journal of Fisheries Research Board Canada 14:321-486.

Walker, S.J. 1995. A hydrologic model for the Lake Whatcom watershed-development, implementation, and assessment. M.S. Thesis, Western Washington University, Bellingham, Washington. 141 pp.

Washington Department of Fish and Wildlife. 1998a. Salmonid Stock Inventory. Appendix Bull Trout and Dolly Varden. Olympia, Washington. 437 pp.

Washington Department of Fish and Wildlife. 1998b. WSR 98-08-045 emergency rules. Washington Department of Fish and Wildlife, Olympia, Washington.

Washington Dept. of Fish & Wildlife. 2000a. Salmonid stock inventory (SaSI): coastal cutthroat trout. Olympia Washington.

Washington Dept. of Fish & Wildlife. 2000b. Species of concern in Washington State. http://www.wa.gov/wdfw/wlm/diversity/soc/soc.htm

Washington Department of Fisheries, Washington Department of Wildlife, and Western Washington Indian Tribes. 1993. 1992 Washington State salmon and steelhead stock inventory. Olympia, Washington. 212 pp.

Washington Department of Fisheries, Washington Department of Wildlife, and Western Washington Indian Tribes. 1994. 1992 Washington State Salmon and Steelhead Stock Inventory. Appendices. Olympia, Washington.

Watts, W.M. 1996. Upslope erosion assessment for: South Fork Nooksack River watershed- Skookum Creek to Howard Creek, Howard Creek watershed, Hutchinson Creek watershed. Lummi Natural Resources Department, Bellingham, Washington. 26 pp.

Watts, W.M. 1997. North Fork Nooksack River watershed: preliminary upslope erosion assessment. Lummi Natural Resources Department, Bellingham, Washington. 26 pp.

Watts, W.M. 1998. Middle Fork Nooksack River watershed: preliminary upslope erosion and channel assessment. For: Lummi Natural Resources Department, Bellingham, Washington. 31 pp.

Weitkamp, L.A., T.C. Wainwright, G.J. Bryant, G.B. Milner, D. J. Teel, R.G. Kope, and R.S. Waples. 1995. Status review of coho salmon from Washington, Oregon, and California. U.S. Dept. Commerce, NOAA Technical Memo. NMFS-NWFSC-24. 258 pp.

West, J.E. 1997. Protection and restoration of marine life in the inland waters of Washington State. Puget Sound/Georgia Basin Environmental Report Series: Number 6. Puget Sound Water Quality Action Team, Olympia, Washington.

Westbrook, M. 1988. Wells Creek hydroelectric project FERC #4628. Erosion and sedimentation field study report. Western Power, Inc., Seattle, Washington. 70 pp.

Wetherall, J.A. 1971. Estimation of survival rates for chinook salmon during their downstream migration in the Green River, Washington. Doctoral dissertation. College of Fisheries, University of Washington, Seattle, Washington. 170 pp.

Whatcom Conservation District. 1986. Agricultural impacts on water resources in Kamm watershed Whatcom County. Whatcom Conservation District, Lynden, Washington.

Whatcom Conservation District. 1988a. Livestock impacts on water resources in Bertrand and Fishtrap Creek watersheds. Whatcom Conservation District, Lynden, Washington.

Whatcom Conservation District. 1988b. Agricultural impacts on water resources in Dakota Creek watershed. Whatcom Conservation District, Lynden, Washington.

Whatcom Conservation District. 1990. Kamm Creek watershed management plan. Whatcom Conservation District, Lynden, Washington.

Whatcom Council of Governments. 2000. State Route 11 Chuckanut Drive corridor management plan. Whatcom County, Bellingham, Washington.

Whatcom Department of Public Works. 1999. Lower Nooksack River comprehensive flood hazard management plan. For the Whatcom County Flood Control Zone District. Bellingham, Washington.

Whatcom County Planning and Development Services. 1997. Whatcom County comprehensive plan. Whatcom County Planning and Development Services Dept. Bellingham, Washington.

Whitehouse, T.R., C.D. Levings, and J.S. Macdonald. 1993. Chironomid (Diptera) insects from natural and transplanted estuarine marshes in British Columbia, p. 500-524. In: Leighton, D (editor). Proceedings of the 1993 Canadian Coastal Conference, Vancouver, May 4-7, 1993. Coastal Zone Engineering Program, National Research Council Canada. Ottawa, Ontario.

Williams, G.D., and Thom, R., 2000. White Paper: Development of Guidelines for Aquatic Habitat Protection and Restoration – Marine and Estuarine Shoreline Modification Issues (Review Draft). Prepared for the Washington State Department of Transportation, the Washington Department of Fish and Wildlife, and the Washington Department of Ecology.

Withler, I.L. 1966. Variability in life history characteristics of steelhead trout (*Salmo gairdneri*) along the Pacific coast of North America. Journal of the Fishery Research Board Canada 23 (3): 365-393.

Yin, K., R.H. Goldblatt, P. J. Harrison, M.A. St. John, P.J. Clifford, and R.J. Beamish. 1997. Importance of wind and river discharge in influencing nutrient dynamics and phytoplankton production in summer in the central Strait of Georgia. Marine Ecology Progress Series 161:173-183.

Zander, A.D. 1996. Road inventory for the South Fork Nooksack River watershed. For the Lummi Natural Resources Department, Bellingham, Washington. 54 pp.

Zander, A.D. 1997. Road inventory for the North Fork Nooksack River watershed. For the Lummi Natural Resources Department, Bellingham, Washington. 60 pp.

Zander, A.D. 1998. Road inventory and preliminary upslope erosion and channel assessment for the Middle Fork Nooksack River watershed. For the Lummi Natural Resources Department, Bellingham, Washington. 57 pp.

APPENDIX 1 – NOOKSACK BASIN STREAM CHANNEL TYPES AND SLOPE STABILITY DATA

Appendix 1. Spreadsheet with slope stability indices and sediment source, transport, or response reaches (Mike Maudlin, Lummi Indian Nation using the DNR SHALSTAB model).

ID	AREA	PERI-METER	SQ_MILE_1	DRAIN_NA_1	STRM_DENSI	STREAM_LEN	PERC_SOURC	PERC_TRANS	PERC_RESPO	SLOPE__HIG	SLOPE__MED	SLOPE__LOW	SLOPE_NODA	SlopeStabi
0	32.010	38.052	33	Kendall	0.77	132520	42.7	20.1	37.2	14	12	74	0	140
1	11.906	18.368	12	Maple	3.40	217300	52.4	13.1	34.5	19	15	66	0	153
2	4.403	10.600	4	Upper Can	1.00	23500	70.2	29.8	0.0	29	19	53	0	178
3	7.135	13.095	7	Clean	1.86	71125	47.1	30.5	22.4	25	21	54	0	171
4	7.996	14.146	8	Boulder	4.74	203400	58.8	40.3	0.9	18	21	61	0	157
5	4.910	10.200	5	Jim	3.39	89375	68.9	27.9	3.2	23	24	53	0	170
6	5.842	10.913	6	Bearpaw M	2.05	64400	53.3	19.1	27.6	28	21	51	0	177
7	2.592	6.668	3	Whistler	1.54	21400	51.9	45.3	2.8	32	23	45	0	187
8	21.178	31.507	22	Slide Mou	3.99	453828	55.7	15.0	29.3	15	19	65	0	148
9	7.491	14.018	8	Swamp	1.63	65500	57.1	28.4	14.5	29	27	44	0	185
10	2.703	7.842	3	Kidney	1.75	25400	66.5	33.5	0.0	34	25	42	0	194
11	17.320	27.075	18	Upper Nor	1.89	175275	62.5	14.2	23.3	26	23	51	0	175
12	2.718	7.880	3	Lower Can	4.51	65700	70.3	22.8	6.8	27	26	48	0	181
13	18.364	31.759	19	Middle No	3.14	309625	63.2	10.5	26.3	24	26	50	0	174
14	6.374	12.386	6	Lower Rut	1.93	65950	68.8	24.4	6.8	36	31	33	0	203
15	6.126	12.495	6	Upper Rut	2.40	79000	68.0	20.4	11.6	38	29	33	0	205
16	4.755	11.937	5	Coal	2.70	68900	52.4	47.6	0.0	15	21	64	0	151
17	24.047	48.167	24	Nooksack	2.04	263656	41.7	15.2	43.0	6	12	82	0	124
18	5.295	11.725	5	Lower Wel	0.97	27550	34.3	42.5	23.2	28	28	44	0	184
19	2.443	8.908	2	Lower Dea	2.97	38925	65.3	34.7	0.0	24	26	50	0	174
20	4.270	9.705	4	Anderson/	1.29	29525	42.6	34.7	22.7	33	29	39	0	196
21	1.346	6.182	1	Barometer	1.87	13550	100.0	0.0	0.0	33	28	39	0	194
22	3.895	12.093	4	Lower Shu	1.68	35200	18.2	6.5	75.3	28	25	47	0	181
23	2.038	8.152	2	Hedrick	3.69	40300	85.1	14.9	0.0	25	22	53	0	172
24	5.466	11.839	6	Cornell	3.95	115860	70.9	24.8	4.3	28	23	50	0	180
25	19.613	22.775	20	Glacier	3.77	396440	76.1	17.6	6.3	26	25	48	0	176
26	5.431	11.637	6	Bagley	1.25	36300	25.3	59.0	15.7	26	25	48	0	176
27	11.064	20.061	11	Smith	3.03	179990	63.1	12.4	24.5	11	18	71	0	140
28	2.439	9.707	2	Gallup	4.26	55760	74.4	25.6	0.0	26	22	52	0	174
29	11.303	21.204	11	Racehorse	4.33	262200	75.6	19.1	5.3	30	22	47	0	181

Appendix 1. Spreadsheet with slope stability indices and sediment source, transport, or response reaches (Mike Maudlin, Lummi Indian Nation using the DNR SHALSTAB model).

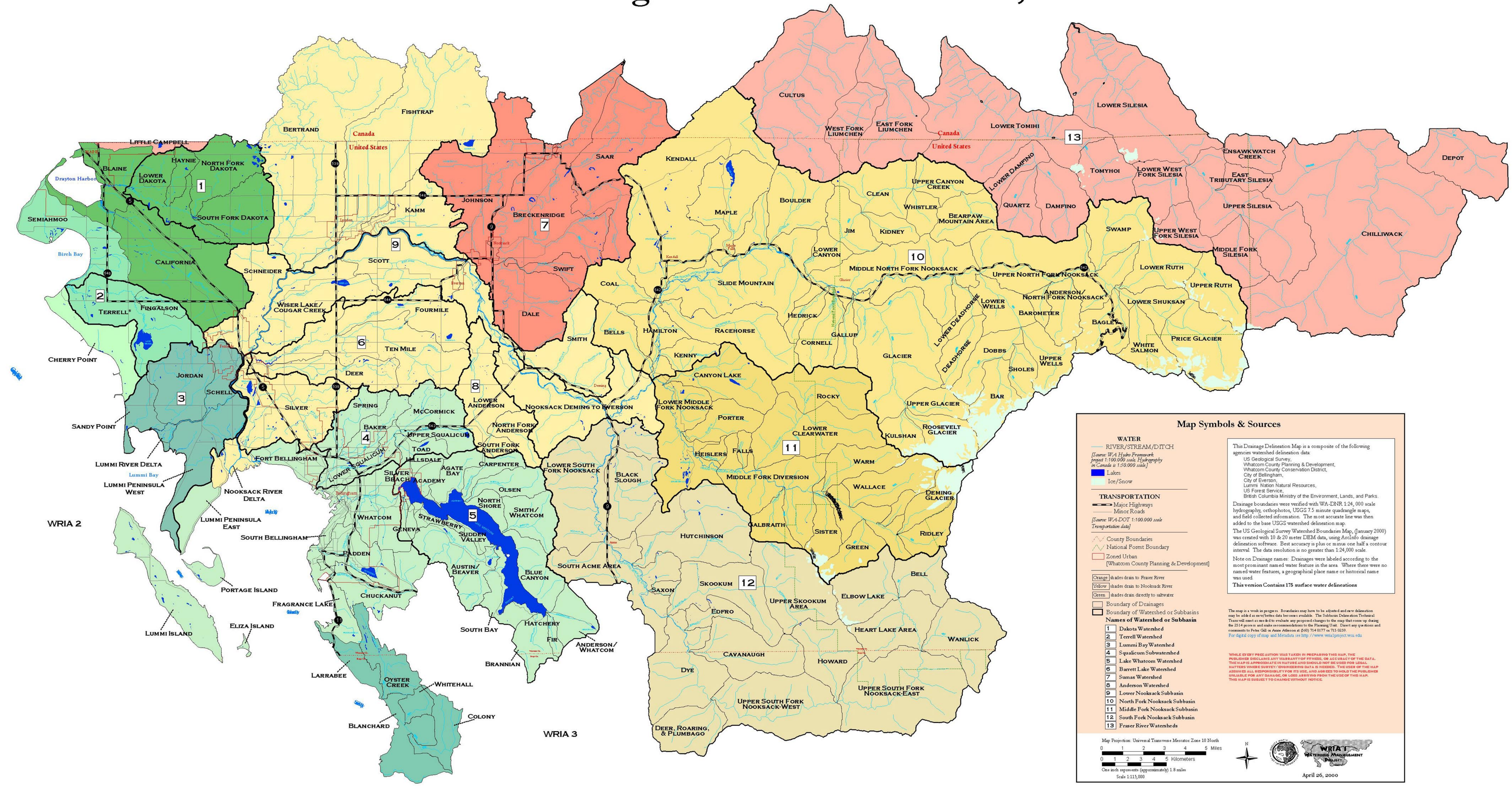
ID	AREA	PERI-METER	SQ_MILE_1	DRAIN_NA_1	STRM_DENSI	STREAM_LEN	PERC_SOURC	PERC_TRANS	PERC_RESPO	SLOPE__HIG	SLOPE__MED	SLOPE__LOW	SLOPE_NODA	SlopeStabi
30	5.782	16.179	6	Hamilton	2.73	84825	28.1	10.7	61.2	8	17	74	0	132
31	11.771	15.065	12	Price Gla	1.73	109075	57.3	20.5	22.2	35	32	33	0	202
32	4.810	12.317	5	Bells	3.25	83825	51.8	44.6	3.6	13	23	64	0	149
33	5.180	12.005	5	White Sal	1.20	33300	48.9	51.1	0.0	34	27	40	0	196
34	3.850	10.061	4	Deadhorse	1.87	38575	59.3	40.7	0.0	29	23	48	0	181
35	8.801	21.420	9	Lower And	1.38	65375	0.0	0.0	100.0	1	3	96	0	105
36	4.995	11.794	5	Upper Wel	1.60	42925	41.5	48.5	10.0	29	24	47	0	182
37	4.978	12.674	5	Dobbs	1.11	29600	22.6	54.1	23.3	26	21	53	0	173
38	2.718	8.731	3	Kenny	3.15	45850	41.1	43.4	15.5	16	25	60	0	158
39	8.730	16.430	9	Canyon La	3.95	185100	81.1	12.9	6.0	25	22	53	0	172
40	2.817	8.248	3	Sholes	1.36	20600	92.2	7.8	0.0	30	24	46	0	184
41	6.082	12.539	6	Bar	0.52	16900	60.4	39.6	0.0	28	26	45	0	181
42	8.042	14.718	8	Rocky	2.96	127850	60.5	37.7	1.9	25	22	53	0	172
43	3.213	8.042	3	Upper Gla	2.10	36200	85.1	14.9	0.0	31	23	46	0	185
44	12.998	19.626	13	Lower Cle	3.01	210050	68.8	26.2	5.0	31	24	45	0	186
45	4.591	11.000	5	Porter	4.49	110400	86.1	11.0	3.0	31	24	45	0	186
46	3.078	8.116	3	Kulshan	1.74	28775	55.6	44.4	0.0	30	20	50	0	180
47	5.574	11.046	6	Roosevelt	0.58	17300	68.2	31.8	0.0	28	27	46	0	184
48	3.518	10.737	4	North For	3.10	58450	53.1	30.3	16.6	9	24	67	0	142
49	17.879	26.336	18	Lower Sou	3.07	294755	49.4	18.2	32.4	17	16	67	0	150
50	0.895	4.688	1	Falls	3.17	15250	100.0	0.0	0.0	37	32	31	0	206
51	12.449	25.510	13	Middle Fo	4.15	277250	65.8	23.2	11.0	26	23	51	0	175
52	1.866	6.284	2	South For	3.51	35225	81.2	8.9	9.9	11	25	64	0	147
53	1.055	5.378	1	Heislers	4.26	24075	29.8	70.2	0.0	21	18	61	0	160
54	5.018	12.144	5	Warm	1.92	51600	70.5	29.5	0.0	33	24	44	0	191
55	8.510	14.519	9	Black Slo	2.82	128695	31.9	15.6	52.4	9	10	81	0	128
56	6.760	13.782	7	Wallace	0.91	33125	46.2	53.8	0.0	30	26	44	0	186
57	4.571	12.258	5	Deming Gl	0.70	17125	35.8	64.2	0.0	33	29	38	0	195
58	5.730	20.953	6	Upper Mid	1.75	53700	30.9	37.4	31.7	26	23	51	0	175
59	17.429	22.470	18	Hutchinso	4.43	414480	64.8	16.5	18.7	14	19	67	0	147
60	3.288	9.943	3	Galbraith	5.97	105350	65.0	32.0	2.9	10	26	64	0	146
61	1.026	6.014	1	Rankin	1.84	10125	69.1	30.9	0.0	34	19	47	0	187
62	3.645	9.678	4	Sister	3.63	70925	73.0	23.3	3.7	33	26	41	0	192

Appendix 1. Spreadsheet with slope stability indices and sediment source, transport, or response reaches (Mike Maudlin, Lummi Indian Nation using the DNR SHALSTAB model).

ID	AREA	PERI-METER	SQ_MILE_1	DRAIN_NA_1	STRM_DENSI	STREAM_LEN	PERC_SOURC	PERC_TRANS	PERC_RESPO	SLOPE__HIG	SLOPE__MED	SLOPE__LOW	SLOPE_NODA	SlopeStabi
63	3.710	10.125	4	Ridley	2.12	42125	79.5	20.5	0.0	27	20	52	0	173
64	4.356	10.717	4	Green	1.08	25200	37.7	57.5	4.8	35	26	40	0	197
65	13.290	30.249	14	South Acm	3.68	262095	51.0	14.1	34.8	8	16	76	0	132
66	11.400	16.111	12	Upper Sko	5.57	340848	82.9	16.9	0.0	27	25	47	0	178
67	7.279	12.848	7	Elbow Lak	1.17	45900	37.7	48.1	14.2	34	24	42	0	192
68	4.884	11.597	5	Bell	1.44	37625	54.2	39.4	6.4	35	23	42	0	193
69	10.466	19.907	11	Lower Sko	6.12	343608	81.2	14.6	4.2	21	21	58	0	163
70	0.710	4.198	1	Saxon	5.53	21040	58.5	34.2	7.3	9	24	66	0	141
71	8.117	14.361	8	Heart Lak	1.68	73325	26.3	35.5	38.2	27	25	48	0	179
72	2.774	10.966	3	Edfro	6.95	103475	64.8	25.3	9.9	10	18	71	0	137
73	9.547	15.005	10	Wanlick	1.98	101200	51.2	31.8	17.0	33	22	45	0	188
74	11.920	20.237	12	Dye	4.52	289080	69.3	13.4	17.3	18	17	65	0	153
75	9.442	16.792	10	Cavanaugh	6.01	304500	75.4	19.5	5.0	17	23	60	0	157
76	7.584	13.115	8	Howard	4.40	179010	73.8	24.2	2.0	27	20	52	0	173
77	19.587	20.093	20	Upper Sou	3.48	365765	69.4	18.2	12.4	18	22	59	0	157
78	14.575	18.782	15	Upper Sou	4.82	376830	73.4	14.2	12.5	21	17	62	0	159
79	6.361	11.175	6	Deer, Roa	4.15	141425	71.1	25.8	3.1	25	17	57	0	166
80	11.002	23.720	11	Lower Mid	3.34	196910	43.8	9.1	47.2	17	17	66	0	151

APPENDIX 2 – WATERSHED DELINEATIONS FOR THE ROAD DENSITY ANALYSIS BASED UPON THE WRIA 1 WATERSHED MANAGEMENT PROCESS

Surface Water Drainage Boundaries in WRIA 1, Version 1



GLOSSARY

Adaptive management: Monitoring or assessing the progress toward meeting objectives and incorporating what is learned into future management plans.

Adfluvial: Life history strategy in which adult fish spawn and juveniles subsequently rear in streams, but migrate to lakes for feeding as subadults and adults. Compare fluvial.

Aggradation: The geologic process of filling and raising the level of the streambed or floodplain by deposition of material eroded and transported from other areas.

Anadromous fish: Species that are hatched in freshwater mature in saltwater, and return to freshwater to spawn.

Aquifer: Water-bearing rock formation or other subsurface layer.

Basin: The area of land that drains water, sediment and dissolved materials to a common point along a stream channel.

Basin flow: Portion of stream discharge derived from such natural storage sources as groundwater, large lakes, and swamps but does not include direct runoff or flow from stream regulation, water diversion, or other human activities.

Bioengineering: Combining structural, biological, and ecological concepts to construct living structures for erosion, sediment, or flood control.

Biological Diversity (biodiversity): Variety and variability among living organisms and the ecological complexes in which they occur; encompasses different ecosystems, species, and genes.

Biotic Integrity: Capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region; a system's ability to generate and maintain adaptive biotic elements through natural evolutionary processes.

Biological oxygen demand: Amount of dissolved oxygen required by decomposition of organic matter.

Braided stream: Stream that forms an interlacing network of branching and recombining channels separated by branch islands or channel bars.

Buffer: An area of intact vegetation maintained between human activities and a particular natural feature, such as a stream. The buffer reduces potential negative impacts by providing an area around the feature that is unaffected by this activity.

Carrying capacity: Maximum average number or biomass of organisms that can be sustained in a habitat over the long term. Usually refers to a particular species, but can be applied to more than one.

Channelization: Straightening the meanders of a river; often accompanied by placing riprap or concrete along banks to stabilize the system.

Channelized stream: A stream that has been straightened, runs through pipes or revetments, or is otherwise artificially altered from its natural, meandering course.

Channel Stability: Tendency of a stream channel to remain within its existing location and alignment.

Check dams: Series of small dams placed in gullies or small streams in an effort to control erosion. Commonly built during the 1900s.

Confluence: Joining.

Connectivity: Unbroken linkages in a landscape, typified by streams and riparian areas.

Critical Stock: A stock of fish experiencing production levels that are so low that permanent damage to the stock is likely or has already occurred.

Depressed Stock: A stock of fish whose production is below expected levels based on available habitat and natural variations in survival levels, but above the level where permanent damage to the stock is likely.

Debris torrent: Rapid movements of material, including sediment and woody debris, within a stream channel. Debris torrents frequently begin as debris slides on adjacent hillslopes.

Degradation: The lowering of the streambed or widening of the stream channel by erosion. The breakdown and removal of soil, rock and organic debris.

Deposition: The settlement of material out of the water column and onto the streambed.

Distributaries: Divergent channels of a stream occurring in a delta or estuary.

Diversity: Variation that occurs in plant and animal taxa (i.e., species composition), habitats, or ecosystems. See *species richness.*

Ecological restoration: Involves replacing lost or damaged biological elements (populations, species) and reestablishing ecological processes (dispersal, succession) at historical rates.

Ecosystem: Biological community together with the chemical and physical environment with which it interacts.

Ecosystem management: Management that integrates ecological relationships with sociopolitical values toward the general goal of protecting or returning ecosystem integrity over the long term.

Endangered Species Act: A 1973 Act of Congress that mandated that endangered and threatened species of fish, wildlife and plants be protected and restored.

Endangered Species: Means any species which is in endanger of extinction throughout all or a significant portion of its range other than a species of the Class Insecta as determined by the Secretary to constitute a pest whose protection under would provide an overwhelming and overriding risk to man.

Escapement: Those fish that have survived all fisheries and will make up a spawning population.

Estuarine: A partly enclosed coastal body of water that has free connection to open sea, and within which seawater is measurably diluted by fresh river water.

Eutrophic: Water body rich in dissolved nutrients, photosynthetically productive, and often deficient in oxygen during warm periods. Compare *oligotrophic.*

Evolutionary Significant Unit (ESU): A definition of a species used by National Marine Fisheries Service (NMFS) in administering the Endangered Species Act. An ESU is a population (or group of populations) that is reproductively isolated from other conspecific population units, and (2) represents an important component in the evolutionary legacy of the species.

Extirpation: The elimination of a species from a particular local area.

Flood: An abrupt increase in water discharge.

Floodplain: Lowland areas that are periodically inundated by the lateral overflow of streams or rivers.

Flow regime: Characteristics of stream discharge over time. Natural flow regime is the regime that occurred historically.

Fluvial: Pertaining to streams or rivers; also, organisms that migrate between main rivers and tributaries. Compare *adfluvial*.

Gabion: Wire basket filled with stones, used to stabilize streambanks, control erosion, and divert stream flow.

Genetic Diversity Unit (GDU) is defined as: A group of genetically similar stocks that is genetically distinct from other such groups. The stocks typically exhibit similar life histories and occupy ecologically, geographically and geologically similar habitats. A GDU may consist of a single stock

Geomorphology: Study of the form and origins of surface features of the Earth.

Glides: Stream habitat having a slow, relatively shallow run of water with little or no surface turbulence.

Healthy Stock: A stock of fish experiencing production levels consistent with its available habitat and within the natural variations in survival for the stock.

Hydrograph: Chart of water levels over time.

Hydrology: Study of the properties, distribution, and effects of water on the Earth's surface, subsurface, and atmosphere.

Intermittent stream: Stream that has interrupted flow or does not flow continuously. Compare *perennial stream*.

Intraspecific interactions: Interactions within a species.

Large Woody Debris (LWD): Large woody material that has fallen to the ground or into a stream. An important part of the structural diversity of streams. LWD is also referenced to as "coarse woody debris" (CWD). Either term usually refers to pieces at least 20 inches (51 cm) in diameter.

Limiting Factor: Single factor that limits a system or population from reaching its highest potential.

Macroinvertebrates: Invertebrates large enough to be seen with the naked eye (e.g., most aquatic insects, snails, and amphipods).

Mass failure: Movement of aggregates of soil, rock and vegetation down slope in response to gravity.

Native: Occurring naturally in a habitat or region; not introduced by humans.

Non-Point Source Pollution: Polluted runoff from sources that cannot be defined as discrete points, such as areas of timber harvesting, surface mining, agriculture, and livestock grazing.

Parr: Young trout or salmon actively feeding in freshwater; usually refers to young anadromous salmonids before they migrate to the sea. See *smolt*.

Plunge pool: Basin scoured out by vertically falling water.

Rain-on-snow events: The rapid melting of snow as a result of rainfall and warming ambient air temperatures. The combined effect of rainfall and snow melt can cause high overland stream flows resulting in severe hillslope and channel erosion.

Rearing habitat: Areas required for the successful survival to adulthood by young animals.

Recovery: The return of an ecosystem to a defined condition after a disturbance.

Redds: Nests made in gravel (particularly by salmonids); consisting of a depression that is created and the covered.

Resident fish: Fish species that complete their entire life cycle in freshwater.

Riffle: Stream habitat having a broken or choppy surface (white water), moderate or swift current, and shallow depth.

Riparian: Type of wetland transition zone between aquatic habitats and upland areas. Typically, lush vegetation along a stream or river.

Riprap: Large rocks, broken concrete, or other structure used to stabilize streambanks and other slopes.

Rootwad: Exposed root system of an uprooted or washed-out tree.

SASSI: Salmon and Steelhead Stock Inventory.

SSHIAP: A salmon, steelhead, habitat inventory and assessment program directed by the Northwest Indian Fisheries Commission.

Salmonid: Fish of the family salmonidae, including salmon, trout chars, and bull trout.

Salmon: Includes all species of the family Salmonid

Sediment: Material carried in suspension by water, which will eventually settle to the bottom.

Sedimentation: The process of sediment being carried and deposited in water.

Side channel: A portion of an active channel that does not carry the bulk of stream flow. Side channels may carry water only during high flows, but are still considered part of the total active channel.

Sinuosity: Degree to which a stream channel curves or meanders laterally across the land surface.

Slope stability: The degree to which a slope resists the downward pull of gravity.

Smolt: Juvenile salmon migrating seaward; a young anadromous trout, salmon, or char undergoing physiological changes that will allow it to change from life in freshwater to life in the sea. The smolt state follows the parr state. See *parr*.

Stock: Group of fish that is genetically self-sustaining and isolated geographically or temporally during reproduction. Generally, a local population of fish. More specifically, a local population – especially that of salmon, steelhead (rainbow trout), or other anadromous fish – that originates from specific watersheds as juveniles and generally returns to its birth streams to spawn as adults.

Stream order: A classification system for streams based on the number of tributaries it has. The smallest unbranched tributary in a watershed is designated order 1. A stream formed by the confluence of 2 order 1 streams is designated as order 2. A stream formed by the confluence of 2 order 2 streams is designated order 3, and so on.

Stream reach: Section of a stream between two points.

Stream types:

Type 1: All waters within their ordinary high-water mark as inventoried in "Shorelines of the State".

Type 2: All waters not classified as Type 1, with 20 feet or more between each bank's ordinary high water mark. Type 2 waters have high use and are important from a water quality standpoint for domestic water supplies, public recreation, or fish and wildlife uses.

Type 3: Waters that have 5 or more feet between each bank's ordinary high water mark, and which have a moderate to slight use and are more moderately important from a water quality standpoint for domestic use, public recreation and fish and wildlife habitat.

Type 4: Waters that have 2 or more feet between each bank's ordinary high water mark. Their significance lies in their influence on water quality of larger water types downstream. Type 4 streams may be perennial or intermittent.

Type 5: All other waters, in natural water courses, including streams with or without a well-defined channel, areas of perennial or intermittent seepage, and natural sinks. Drainage ways having a short period of spring runoff are also considered to be Type 5.

Sub Watershed: One of the smaller watersheds that combine to form a larger watershed.

Thalweg: Portion of a stream or river with deepest water and greatest flow.

Watershed: Entire area that contributes both surface and underground water to a particular lake or river.

Watershed rehabilitation: Used primarily to indicate improvement of watershed condition or certain habitats within the watershed. Compare *watershed restoration*.

Watershed restoration: Reestablishing the structure and function of an ecosystem, including its natural diversity; a comprehensive, long-term program to return watershed health, riparian ecosystems, and fish habitats to a close approximation of their condition prior to human disturbance.

Watershed-scale approach: Consideration of the entire watershed in a project or plan.

Weir: Device across a stream to divert fish into a trap or to raise the water level or divert its flow. Also a notch or depression in a dam or other water barrier through which the flow of water is measured or regulated.

Wild Stock: A stock that is sustained by natural spawning and rearing in the natural habitat regardless.

Disclaimer

The Water Resource Inventory Area (WRIA) 1 Habitat Limiting Factors report summarizes existing readily available literature on general habitat conditions that can limit the ability of natural spawning salmonid populations in WRIA 1 to sustain themselves. This report provides an overview of existing habitat information and does not provide a quantifiable habitat limiting factors analysis. Due to the age of portions of the available data it should be used in a conservative manner. Salmon recovery planners are encouraged to consult the specific reference documents identified in the report as well as new information when it becomes available.

In the time available for preparation of this report it was not possible to review every document in its entirety, therefore reports that were already summarized provide the nucleus of this report. When additional information was made available by TAG members, the information was analyzed and included. Several comprehensive basin wide assessments are currently underway and that material should be utilized in conjunction with this report as it becomes available