SALMON

HABITAT LIMITING FACTORS

FINAL REPORT

WATER RESOURCE INVENTORY AREA 5

STILLAGUAMISH WATERSHED

WASHINGTON STATE

CONSERVATION COMMISSION

July 1999

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AGENCY AND ORGANIZATIONAL ABBREVIATIONS

ACOE	Army Corps of Engineers
EPA	United States Environmental Protection Agency
GIS	Geographic Information Systems
HPA	Hydraulic Project Approval
MBSNF	Mt. Baker-Snoqualmie National Forest
NMFS	National Marine Fisheries Service
NWIFC	Northwest Indian Fisheries Commission
PPS	People for Puget Sound
PSAT	Puget Sound Action Team
PSWQA	Puget Sound Water Quality Authority
SASSI	Washington State Salmon and Steelhead Stock Inventory
SCD	Snohomish Conservation District
SCIS	Snohomish County Information Systems
SCNWB	Snohomish County Noxious Weed Board
SIRC	Stillaguamish Implementation Review Committee
SWM	Snohomish County Surface Water Management Division
TAG	Technical Advisory Group
URS	URS Consulting
USFS	United States Forest Service, Department of Agriculture
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WCC	Washington Conservation Commission
WDOE	Washington Department of Ecology
WDF	Washington Department of Fisheries (superceded by WDFW)
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington Department of Natural Resources
WDOH	Washington Department of Health
WRIA	Water Resource Inventory Area
WSDA	Washington State Department of Agriculture
WSDOT	Washington State Department of Transportation
WWTIT	Western Washington Treaty Indian Tribes

UNITS OF MEASUREMENT AND OTHER ABBREVIATIONS

°C	Degrees Celsius	m^3/yr	Cubic meters per year
cm	Centimeter	mg/l	Milligrams per liter
DO	Dissolved oxygen	RM	River Mile
m^3/s	Cubic meters per second	TMDL	Total Maximum Daily Load
ha	Hectare	m	Meter
km	Kilometer	km^2	Square Kilometer

EXECUTIVE SUMMARY

This report is an assessment of the habitat factors limiting the production of salmon in the Stillaguamish watershed, also known as Water Resource Inventory Area (WRIA) 5. The Stillaguamish River drains a 1,774-km2 watershed on the west slope of the North Cascades, and is the fifth largest tributary to Puget Sound. Between 1956 and 1965, the Stillaguamish is estimated to have contributed about 21 % of the anadromous fish production in Puget Sound. Land cover data from 1991 show over 76 % of land use in forested lands, 17 % in rural residential, 5 % in agriculture, and 2 % in urban.

This document focuses on all Stillaguamish stocks identified in the 1992 *Washington State Salmon and Steelhead Stock Inventory* (SASSI): chinook, coho, chum, and pink salmon, steelhead, and bull trout. Searun cutthroat and sockeye salmon are also discussed. The SASSI currently lists the Stillaguamish summer and fall chinook and Stillaguamish coho as depressed stocks. The Deer Creek summer steelhead is listed as critical. In March 1999, the Puget Sound chinook stocks were designated as threatened under the federal Endangered Species Act. In June 1998, the US Fish and Wildlife Service (USFWS) proposed the federal listing of the Puget Sound bull trout as threatened.

Historic Condition and Losses

Logging of the Stillaguamish watershed began in the lower mainstem of the river in the early 1860s. The floodplain forests of most of the mainstem and riparian areas bordering much of the remaining anadromous streams in the watershed were harvested by the turn of the century. By the early 1940s, the entire anadromous channel network, with the exception of a few areas had been logged.

The historic Stillaguamish estuary was also impacted by European settlement. Between 1870 and 1968, about 85 % of the Stillaguamish tidal marsh was converted to agriculture. Two-thirds of this conversion occurred between 1870 and 1886. By 1968, only 3 km^2 of the original salt marsh existed. In recent decades the estuary has been increasing in size, possibly as a result of upland sediment impacts. Between 1947 and 1974, the Stillaguamish delta increased from 50.5 km^2 in 1947 to 64.8 km^2 in 1974, a 28 % change. The newly accreted areas (mostly sand and mudflats) are of less value to salmon than the original salt marsh habitat.

Beaver pond habitat within the anadromous zone of the Stillaguamish watershed has been reduced between 81 and 96 % of historic levels in the anadromous zone. The total estimated historic area of beaver ponds was between 2.37 km^2 to 11.84 km^2. It is now estimated to be 0.44 km^2. Beaver ponds provide important rearing habitat for coho and other juvenile salmonids. Stream systems with extensive beaver ponds and wetlands, accessible to coho, have been recorded to have significantly higher smolt yields than other systems in the basin. Seventy-eight percent of historic wetlands have been impacted or lost. The Stillaguamish watershed historically supported 11,795 ha of wetlands. The current total wetland area is estimated to be 2,537 ha. Wetlands provide several functions that directly impact salmonids.

Habitat Limiting Factors

There are several habitat limiting factors negatively affecting salmon and their ecosystems in the Stillaguamish watershed. The major factors are discussed below.

In the floodplains of the Stillaguamish, the mainstem Stillaguamish has lost more than 31 % of its side channel habitat (between 1933 and 1991), primarily from the construction of dikes and revetments. The side channels of the North and South Forks have been decreased by about one-third of historic levels. The losses are mainly due to filling, and can be attributed to the combined effects of revetments, agriculture, and railroad and road construction. Side channels provide critical rearing and refuge habitats.

The riparian forests of floodplains and upland areas are also a limiting factor. Today, only 11 % of the Stillaguamish riparian forests are in an "intact" fully functional condition. Eleven of the 27 sub-basins identified in the Stillaguamish watershed have more than 70 % degraded riparian forests. Eight of these sub-basins have more than 90 % riparian degradation. Riparian zones associated with agriculture and rural residential land use are the most severely degraded.

The loss of riparian forests has resulted in a dramatic decrease in large woody debris and associated pool habitat, both of which are key to productive salmon habitat. At best, only 41 % of the Stillaguamish riparian forests bordering anadromous streams will be fully functioning to provide large woody debris by the end of the 21st century. The average and maximum number of pieces of wood per 100 meters in agricultural stream channels is 70 % less than what is found in forested and rural residential lands.

The loss of pool area is associated with the removal and reduction of large wood debris, increases in sediment supply, and increased peak flows. Channel slope also influences the stability of the wood once it has entered the stream. Generally speaking, the spacing between pools in the Stillaguamish decreases with an increase in wood pieces and a decrease in channel slope. The mainstem has the highest average percent pool area (45 %) followed by the South Fork (35 %) and North Fork (28 %).

Sedimentation problems have been a concern to fish biologists in the Stillaguamish since at least the late 1950s. Landslides associated with human land uses are the primary source of sediment. A total of 1080 landslides have been inventoried for the period from the early 1940s to the early 1990s. Seventy-four percent of the inventoried landslides in the Stillaguamish result from logging roads (22 %) or clearcuts (52 %), while 98 % of the volume of sediment is associated with these two sources. A total of 851 landslides delivered sediment to stream channels, and of these, at least 40 % delivered sediment directly to fish-bearing waters. Sixty-one percent of the 851 slides delivering sediment to streams occurred in the North Fork drainage, 36 % in the South Fork drainage, and 3 % in the mainstem drainage.

Increases in peak streamflows exacerbate sediment problems. Streamflow measurements from the North Fork show a systematic increase in peakflows. Because this trend is not found in the

South Fork streamflow data, it suggests a relationship between land use activities more prevalent in the North Fork. Between 1928 and 1995, ten of the largest peak flows recorded by the North Fork gage occurred between 1980 and 1995. Peak flows can scour gravel beds containing salmon eggs. The scoured sediment may be re-deposited over downstream salmon redds, smothering the eggs. Peak flows can also flush out juvenile salmon from normally quiet rearing areas.

Low streamflows are problematic in the Stillaguamish from July through September. The cumulative effect of groundwater withdrawals and loss of wetlands can also contribute to low flows. Known low flow problem areas include: the lower mainstem and estuary, Church Creek, North Fork (from Oso to Whitehorse), Pilchuck Creek, Harvey/Armstrong Creek, Tributary 30. The low summer flows also permit saline waters from the Sound to move further upstream in the mainstem Stillaguamish than in historic times when summer flows were larger. Low flows can cause salmon to be stranded, limit or impede salmon migration, and contribute to a decrease in dissolved oxygen, an increase in water temperature, and an increase in the concentration of pollutants.

Nonpoint source pollution is a major cause of water quality pollution in the Stillaguamish, with agricultural practices, onsite sewage disposal, development and urban runoff, and forest practices being the major sources. Violations of water quality standards for temperature, dissolved oxygen, fecal coliform and other parameters have been measured at several locations in the Stillaguamish watershed. For salmonids, high water temperature and low dissolved oxygen are the main water quality problems. Water temperatures above 21 degrees Celsius (optimum is 12 to 14 degrees Celsius) are frequent in the estuary during the hot summer months. High temperatures can lower dissolved oxygen, impair the immune system of salmon, and give non-native warmwater species a competitive edge over native salmonids.

Nearshore and Estuary Habitats

The Stillaguamish watershed, as defined by WRIA 5 boundaries, includes 22 miles of marine shoreline. This is less than one percent of the total nearshore habitat contained within the 19 watersheds of Puget Sound. Generally speaking, the nearshore habitat associated with the Stillaguamish is in relatively good condition when compared to the urbanized nearshore areas of Puget Sound. Residential development is the primary threat. There are currently no measures in place to ensure that the nearshore areas remain intact. All species of juvenile salmon use nearshore habitats in Puget Sound at either the fry and/or smolt life stages. Returning adult salmon also use nearshore habitats.

In addition to the sedimentation and water quality problems already mentioned, the Stillaguamish estuary is experiencing an invasion of non-native cordgrasses (*Spartina).* The primary areas targeted for *Spartina* control include: Kayak Point to Warm Beach (less than 1 acre); Warm Beach (less than 2 acres); Port Susan: Hat's Slough to South Pass (100 to 150 acres); Leque Island (less than 10 acres); South Pass (less than 10 acres); Stillaguamish River (7 acres 2.5 miles upstream); West Pass and Skagit Bay (over 300 acres); and Davis Slough (5 acres). Cordgrass invasions eliminate native salt marsh vegetation, displace native plants and animals, raise the elevation of the estuary substrate, and lead to an increase in flooding. The

Stillaguamish estuary provides habitat for juvenile salmon to make a physiological transition between freshwater and saltwater environments and for adult salmon to transition between saltwater and freshwater. The blind channels found in the salt marshes provide critical rearing habitat for juvenile salmon, particularly chum, chinook, and pink.

Data Gaps

Twenty-five general data gaps are identified in this report for the purpose of guiding future inventory and research needs. The data gaps were compiled from the information sources used to prepare this document and with assistance from the Stillaguamish Technical Advisory Group. High priority items are related to estuary and nearshore inventories, basin-wide physical habitat survey, landslides and sedimentation, instream flows and water rights, peak flows, chinook studies, road network survey, diking history (for restoration purposes), and acquisition priorities. Numerous reach-specific data gaps are also compiled from the work of the Stillaguamish Implementation Review Committee.

Best Functioning Habitat

Properly functioning habitat is the most cost-effective habitat to protect. The ability to restore degraded habitat back to its proper function is limited by our technical knowledge of the complex interactions associated with the different habitat types. Within the Stillaguamish watershed, the vast majority of the habitat has been impacted, at some level, by human activities. Habitat in need of protection within the watershed are those areas that still retain a significant portion of their original habitat functions or contain a good potential for re-establishing functions. Sub-basins were ranked for protection using five habitat factors: the current condition of the riparian area, level of recent landslide activity, beaver habitat, wetland conditions, and fish production. The sub-basins that received the highest ranking for protection include Squire Creek, Harvey/Armstrong, Upper South Fork, and Lower Pilchuck.

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INTRODUCTION

This report is an assessment of the habitat factors limiting the production of salmon in the Stillaguamish watershed, also known as Water Resource Inventory Area (WRIA) 5 (Map 1). It was written pursuant to Engrossed Substitute House Bill (ESHB) 2496, the Salmon Recovery Act, a key piece of the 1998 Washington State Legislature's salmon recovery effort (Revised Code of Washington (RCW) 75.46).

The Stillaguamish watershed is serving as the pilot watershed for the north Puget Sound region because a considerable amount of detailed habitat-related information (including published reports, databases, and information useable by Geographic Information Systems (GIS)) exists in a format that is readily available. Also, the biologists who work in this watershed have been working collaboratively and effectively together for a decade or more on salmon-related issues, and have been highly cooperative in sharing information for this project.

Purpose and Scope of Work

There are two primary purposes of this report: 1) to assist the lead entity's citizen committee with the development of a prioritized list of habitat restoration and protection projects; and 2) to help funding agencies direct limited dollars to the most effective and economical projects. This document may also be used to assist with the development of habitat recovery plans for federally listed threatened and endangered species. This analysis is a compilation and synthesis of the most recent and pertinent sources of existing data and information relevant to the salmonids using the freshwater, estuarine and nearshore environments in and proximate to the Stillaguamish watershed. It is not, however, an exhaustive assessment of *all* information that is available; that is beyond the scope of work. Readers of this document are encouraged to consult the many scientific sources of information cited herein for more specific information.

In addition to chinook salmon, this report focuses on all Stillaguamish stocks identified in the *Washington State Salmon and Steelhead Stock Inventory* (SASSI), co-authored by the Washington Department of Fish and Wildlife (WDFW) and the Western Washington Treaty Indian Tribes (WWTIT) (WDFW and WWTIT 1992; WDFW 1998) (Table 1). To date, the Stillaguamish SASSI stocks include four species of Pacific salmon as well as steelhead and bull trout. Searun cutthroat trout may be added to SASSI in the future, and so they were also considered. Sockeye salmon, though few in number and not listed in SASSI, are also discussed where information is available.

Table 1. Stillaguamish SASSI stocks (WDFW and WWTIT 1992).

Species	Stock	Origin	Production	Status
Chinook	Summer	Native	Composite	Depressed
	Fall	Unknown	Wild	Depressed
Coho	Stillaguamish	Mixed	Wild	Depressed
	Deer Creek	Native	Wild	Unknown
Chum	North Fork Fall	Native	Wild	Healthy
	South Fork Fall	Native	Wild	Healthy
Pink	North Fork	Native	Wild	Healthy
	South Fork	Native	Wild	Healthy
Steelhead	Stillaguamish Winter	Native	Wild	Healthy
	South Fork Summer	Non-native	Wild	Unknown
	Deer Creek Summer	Native	Wild	Critical
	Canyon Creek Summer	Mixed	Wild	Unknown
Bull Trout	Stillaguamish	Native	Wild	Unknown

Technical Assistance

A Technical Advisory Group (TAG) comprised mainly of professional fisheries biologists from tribal, federal, state, and local resource management agencies provided considerable assistance with the development of this report. The TAG's function is to identify the conditions that limit the ability of habitat to fully sustain populations of salmon. Pursuant to RCW 75.46.090, the TAG was established by the Washington State Conservation Commission in consultation with the Stillaguamish Tribe of Indians and Snohomish County Surface Water Management which share the "lead entity" designation in WRIA 5. In the Stillaguamish watershed, the TAG members also serve on the technical group responsible for preparing a recovery plan in response to the recent federal listing of Puget Sound chinook salmon as a threatened species.

Watershed Characteristics

The Stillaguamish river is the fifth largest tributary to Puget Sound, ranking behind the Skagit, Snohomish, Puyallup, and Nooksack river systems (Miller and Somers 1989). The river drains a 1,774-km^2 watershed on the west slope of the North Cascades (Embry 1987). The mainstem of the river enters Puget Sound near the town of Stanwood, 25 km north of Everett (Collins 1997). This watershed includes more than 1,432 km of anadromous stream habitat, just less than one-third of the total stream network (Pess et al., in press).

The Stillaguamish watershed can be divided into three large sub-basins: the North Fork, the South Fork, and the lower mainstem (Map 2). The mainstem divides into two distributary channels near its mouth: Hat Slough (originally called Hatt's Slough), and the old

Stillaguamish channel. The latter drains into Skagit Bay via West Pass and into Port Susan via South Pass.

The North and South Forks join together at Arlington, 28 river kilometers from the mouth (Collins 1997). The North Fork drains 736 km^2 (42 %) of the Stillaguamish Watershed. The South Fork is slightly smaller, draining 660 km^2 (37 %) of the watershed. The three largest tributaries include: Pilchuck Creek, draining to the mainstem and accounting for 11 % of the watershed area; Deer Creek, draining to the North Fork, and accounting for 10 % of the watershed area; and Canyon Creek, draining to the South Fork, and accounting for 8 % of the total watershed area.

The Stillaguamish watershed has been divided into 27 sub-basins for management use by tribal, state, and local natural resource agencies (Pollock and Pess 1998) (Map 2). The major streams in each sub-basin are shown in Table 2. The sub-basins range in size from 10 km^2 to 176 km^2. The total length and area of the anadromous and non-anadromous zones for each sub-basin is shown in Table 3. In this analysis, the information is often reported in relation to specific streams or sub-basins.

Topography and Geology

The geology of the Stillaguamish watershed and adjacent areas is a complex combination of continental and alpine glacial deposits, and marine and non-marine interglacial deposits that have been influenced by volcanism, faulting, and erosion (Thomas et al. 1997). The east-west trending basin transects two physiographic provinces. The North Cascade province forms the foothills and jagged alpine peaks throughout the central and eastern part of the watershed. The flat, low elevation portion of the western part of the watershed lies in the Puget Trough province. Elevations in the watershed range from sea level to about 2,086 m on Whitehorse Mountain in the North Fork sub-basin. The North and South Forks converge at an elevation of approximately 804 m, and from there the valley gradually slopes westward towards Puget Sound.

High grade Mid-Cretaceous to Paleocene melange rocks dominate west of the Darrington Fault. East of the fault the dominant rock unit is the Darrington Phyllite, a metamorphic rock type that dominates the upper North Fork Stillaguamish. This rock is particularly prone to erosion, which is a major problem in this watershed. Crystalline rocks of the Oligocene Squire Creek stock form the south side of the North Fork and the north side of the upper South Fork Stillaguamish.

Glacial outwash from the Puget Lobe of the Cordilleran ice sheet forms the terraces in the forks and the topography of the lower watershed. Younger alluvial deposits are inset within the terraces in the wider portions of the valleys of the forks. The mainstem of the Stillaguamish flows through an alluvium-floored valley 1.5-3 km wide, inset within terraces of glacial outwash. The clay, silt and sand deposits of glacial and lake origin are the main source of the significant sediment production in the watershed (Perkins and Collins 1997). In the steeper sloped areas, these deposits are particularly prone to landslides, which are a significant problem for fisheries in this drainage.

Table 2. Major streams of the 27 Stillaguamish sub-basins.

Mainstem Sub-basins	Tributaries	North Fork Sub-basins	Tributaries	South Fork Sub-basins	Tributaries
Armstrong	Armstrong	Boulder Ridge	Boulder	Arlington Area	South Fork
	Harvey		Fortson	Burn Hill Area	Jordan
Church	Church		French		South Fork
Hat Slough	Hat Slough		Gerkman	Canyon	Baldy
Jackson Area	Jackson Slough		Moose		Canyon
Lower Pilchuck	Pilchuck	Deer Creek	Deer		7-mile
Portage	Portage		Little Deer		Meadow
Stanwood	Stillaguamish	Ebey Hill	North Fork		Saddle
Stillaguamish Floodplain	Stillaguamish	Frailey Mountain	Grant		Tiger
Tributary 30	Tributary 30	Grandview	Rock	Gold Basin	Bear
		Hell-Hazel	Hell		Black
			Montague		Boardman
		Higgens Ridge	Dicks		Gordon
			Rollins		Hemple
			Segelson		Wiley
		Squire	Ashton	Jim	Bear
			Browns		Cub
			Buckeye		Little Jim
			Furland		Porter
			Squire		Siberia
		Upper North Fork	North Fork	Upper South Fork	Beaver
					Blackjack
					Buck
					Coal
					Deer
					Mallardy
					Marten
					Palmer
					Perry

Climate and Hydrology

The climate is typically maritime with cool wet winters and mild summers. Rainfall is highly variable throughout the watershed. Average annual rainfall ranges from 76 cm in the western lowlands to more than 356 cm in the forested eastern region (Embry 1987). The average annual runoff is over 2.8 million acre-feet.

Approximately 75 % of the precipitation falls between October and March (US Army Corps of Engineers (ACOE) 1997). Precipitation and stream flows are the highest in late autumn and winter as a result of rainstorms and rain-on-snow events. Because much of the watershed is at a

Table 3. Length and area of anadromous and non-anadromous zones of sub-basins in the Stillaguamish watershed (modified from Pollock and Pess 1998).

Sub-basin	Anadromous Length (km)	Non-anadromous Length (km)	Total Length (km)	Anadromous Area (km^2)	Non-anadromous Area (km^2)	Total Area (km^2)
Mainstem						
Armstrong Creek	17.5	20.7	38.2	11.3	17.7	29
Church Creek	31.3	7.3	38.6	21.8	7.8	29.6
Hat Slough South	2.7	13.7	16.4	1.6	11.7	13.4
Jackson Area	1.3	8.3	9.6	2.8	6.8	9.6
Lower Pilchuck Creek	70.7	63.4	134.1	30.8	47	77.8
Portage Creek	64.9	14.6	79.5	38.4	13.5	51.9
Stanwood City	11.6	0	11.6	9.9	0	9.9
Stillaguamish Floodplain	116.1	7	123.1	48.2	6.8	55
Tributary 30	8.6	10.4	19	4.5	5.8	10.3
Upper Pilchuck Creek	0	309.5	309.5	0	119.1	119.1
Sub-basin Total	**324.7**	**454.9**	**779.6**	**169.3**	**236.2**	**405.6**
South Fork						
Arlington Area	3	10.8	13.8	9.7	4.2	14
Burn Hill	43	26.1	68.7	31.3	18.6	49.9
Canyon Creek	82.7	332	414.7	36.7	126.9	163.6
Canyon Drainages	29.8	33.8	63.7	18.5	17.2	35.7
Gold Basin Drainages	84	150	234	20.3	55.9	76.3
Jim Creek	90.1	179.3	269.4	43.4	78.3	121.7
Robe Valley Drainages	82.4	62.7	145.1	29.8	33.3	63.1
Upper South Fork	168.7	353.9	522.6	42.1	103.2	145.3
Sub-basin Total	**583.7**	**1148.6**	**1732**	**231.8**	**437.6**	**669.6**
North Fork						
Boulder Ridge	43	207.9	250.9	19.2	87	106.1
Deer Creek	171.7	364.7	536.4	42.2	133.7	175.9
Ebey Hill Drainages	36.2	38.4	74.6	13.2	20.9	34.1
Frailey Mountain Drainages	15	83.7	98.6	10.2	31.2	41.5
Grandview Area	19.6	54.7	74.3	11.5	22	33.5
Hell-Hazel Drainages	57.7	51.6	109.3	23.5	20.9	44.4
Higgins Ridge Area	93	146	238.9	37.4	60.4	97.7
Squire Creek	62.5	145.8	208.3	24	43.7	67.7
Upper North Fork	18.2	345	363.3	8.9	131.8	140.7
Sub-basin Total	**516.9**	**1437.8**	**1954.6**	**190.1**	**551.6**	**741.6**
Total	**1432.9**	**3033.2**	**4466.1**	**591.2**	**1225.3**	**1816.5**

relatively low elevation, snow is more susceptible to melting and contributing to surface runoff. Flooding is common during this time and can contribute to the scouring of gravels containing recently spawned salmon eggs.

The lowest streamflows occur during the dry summer dry months, generally from July through September. The lowest daily average flow at the North Fork Stillaguamish River (near Arlington) was 3.3 m^3/s on September 23, 1938 (US Geological Survey (USGS) 1999). As discussed later in this document, low flows are also problematic for salmon.

Vegetation

Three coniferous vegetation zones comprise most of the landscape (Pollock 1998). The western hemlock (*Tsuga heterophylla*) zone is found to elevations of about 700 m. The silver fir (*Abies amabilis*) zone occupies the elevations between 700 and 1,300 m. The mountain hemlock (*Tsuga mertensiana*) zone is found at higher elevations between 1,300 and 1,700 m. The western hemlock zone is the most prevalent, and is dominated by western hemlock, Douglas fir (*Pseudotsuga menziesii*), western red cedar (*Thuja plicata*), and at lower elevations, Sitka spruce (*Picea sitchensis*).

Land Use and Population Growth

The Stillaguamish watershed is mostly within the boundaries of Snohomish County (1329 km^2). A portion (498 km^2) of the Pilchuck Creek, Deer Creek, Upper North Fork, Higgins Ridge, and Frailey Mountain sub-basins are located in Skagit County (Map 3). Land cover data from 1991 show over 76 % of land use in forested land, 17 % in rural residential, 5 % in agriculture, and 2 % in urban. Within the anadromous zone, 60 % of land use adjacent to streams in forestry, 22 % in rural residential, 15 % in agriculture, and 2 % in urban (Pess et al., in press). The Mt. Baker-Snoqualmie National Forest manages the federal forest lands. Timber production and dispersed recreation are the predominant land uses in the upper watershed. Agricultural farms and dairies are concentrated in the valley bottoms along the mainstem, forks, and the larger tributaries. Hobby farms are increasing throughout all rural areas of the watershed.

Between 1980 and 1990, the population of Snohomish County increased by 38 % and has been projected to grow by an additional 27 % by the year 2000 (Thomas et al. 1997). In the Stillaguamish watershed, Arlington and Stanwood are the largest communities, with 1998 populations of 6,635 and 3,130, respectively (Snohomish County Planning Department 1999). The two smaller communities of Granite Falls and Darrington are estimated to have 1,985 and 1,235 people in 1998.

Condition of Salmonid Populations

The Stillaguamish river has been estimated to have contributed about 21 % of the anadromous fish production in Puget Sound between 1956 and 1965 (Mt. Baker-Snoqualmie National Forest (MBSNF) 1996). Today the river system supports both wild and hatchery stocks of salmonids. This includes five species of salmon (chinook, coho, pink, chum, and sockeye), two species of anadromous trout (steelhead and cutthroat), and many non-commercial resident species (including cutthroat and rainbow trout, and native char) (Miller and Somers 1989). The Stillaguamish is managed for wild coho and chinook stocks, however hatcheries have supplemented wild runs of summer chinook, chum, and coho on this river since 1939 (ACOE 1997). Hatchery-raised chinook, coho, and pink salmon were introduced to the upper South Fork above Granite Falls after 1954 with the construction of the Granite Falls Fishway. The timing of freshwater life stages for each of the species discussed in this report is shown in Table 4

Current Distribution

The known (and presumed) distribution of each of the salmonids discussed in this report is shown in Maps 4a through 4i. This information was gathered from existing data sources and from the field knowledge and expertise of federal, state, and tribal fisheries biologists who have worked in the watershed for many years. When reviewing these maps, note that the coarseness of the mapping scale makes it impossible to show salmonid distribution in every water body. Any tributary associated with known or presumed spawning or rearing habitat that has no blockage to fish passage may be used at some lifestage during normal or flood events.

Of the species discussed in this report, chinook and coho have been the most intensively studied. An interagency technical group is currently conducting a more intensive analysis of the factors limiting chinook production and writing a recovery plan in response to the recent listing of the Puget Sound chinook on the federal threatened and endangered species list. Coho have been the focus of a detailed limiting factors analysis (Pess et al., in press). This report has benefited significantly from both of these efforts. The historic and current status of the salmonids emphasized in this report is discussed below.

Historic and Current Status

Chinook. There are two known stocks of chinook salmon (*Oncorhynchus tshawytscha)* in the Stillaguamish watershed (Map 4a). They are distinguished by temporal, and to a lesser degree, spatial differences in spawning, but are managed as a single unit (WDFW and WWTIT 1992). In March 1999, these and other Puget Sound chinook stocks were designated as threatened under the federal Endangered Species Act. The SASSI lists both stocks as depressed. The North Fork summer chinook stock is genetically distinct from other Puget Sound stocks and is related to Sauk river chinook stocks (Killebrew 1999). The South Fork fall chinook stock is also genetically distinct. It is related to Skykomish river fall stocks (Killebrew 1999). The escapement goal of 2,000 summer/fall chinook has not been attained since 1976 (Figure 1).

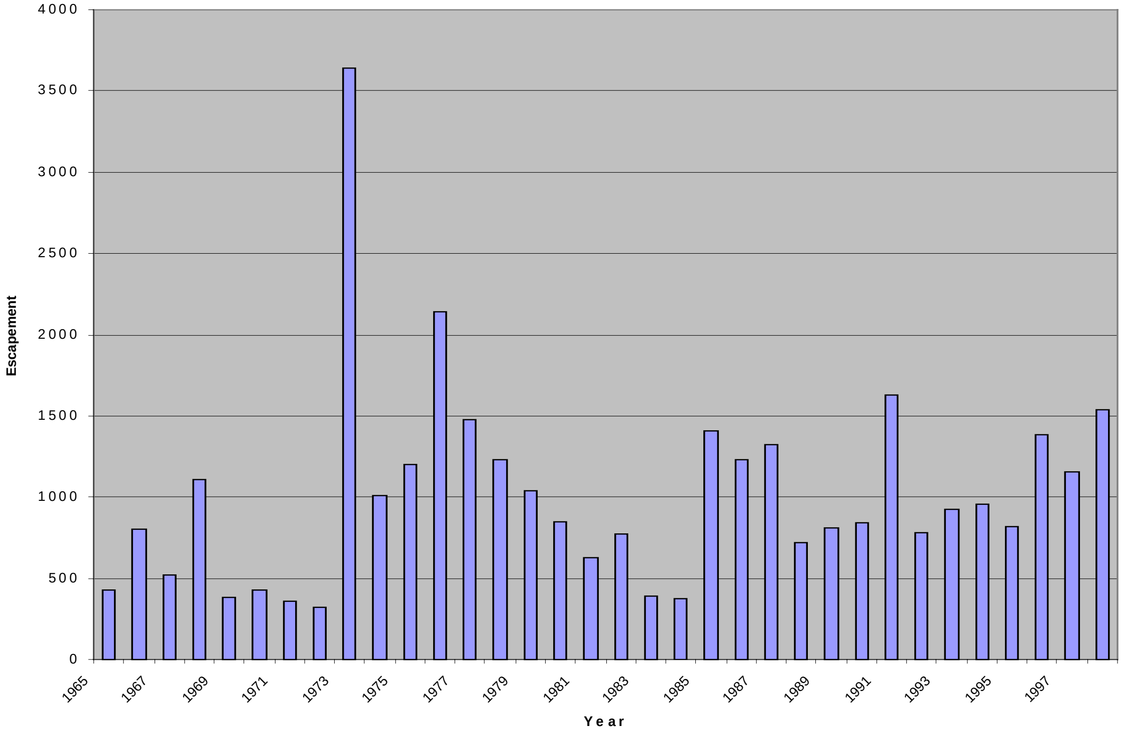
Chinook use the mainstem, North Fork and South Fork, as well as several of the larger tributaries (Pilchuck, Jim, Canyon, Squire, French, and Boulder). They begin entering the river in June and spawn from mid-August through October. The summer stock spawns mainly in September in the North Fork while the fall stock spawns mainly in October in the mainstem and South Fork (WDFW and WWTIT 1992). Currently some of the most important chinook spawning habitat is located in the main channel of the North Fork between the mouth of Deer Creek and the mouth of Squire Creek (Nelson 1999).

Juvenile chinook rear throughout the river system. Fry spend from one to five months in fresh water before migrating to the estuary (Nelson 1999). Outmigration for both stocks occurs from mid-March through June. A small percentage (less than 10 %) of the Stillaguamish chinook are stream type and they rear for one year.

Table 4. General timing of life stages of salmonids in the Stillaguamish watershed (modified from MBSNF 1996; Hendrick 1999).

Species	Life Phase	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chinook	Upstream migration						----	----	----	----	----		
	Spawning								----	----	----		
	Incubation	----	----						----	----	----	----	----
	Juvenile rearing	----	----	----	----	----	----	----	----	----	----	----	----
	Smolt outmigration			----	----	----	----						
Coho	Upstream migration									----	----	----	
	Spawning	----									----	----	----
	Incubation	----	----	----	----						----	----	----
	Juvenile rearing	----	----	----	----	----	----	----	----	----	----	----	----
	Smolt outmigration			----	----	----	----						
Pink	Upstream migration								----	----			
	Spawning								----	----	----		
	Incubation	----	----	----	----				----	----	----	----	----
	Juvenile rearing			----	----	----							
	Smolt outmigration			----	----	----							
Chum	Upstream migration									----	----	----	----
	Spawning	----									----	----	----
	Incubation	----	----	----	----						----	----	----
	Juvenile rearing			----	----	----	----						
	Smolt outmigration			----	----	----	----						
Sockeye	Upstream migration							----	----	----			
	Spawning								----	----	----		
	Incubation	----	----						----	----	----	----	----
	Juvenile rearing	----	----	----	----	----	----	----	----	----	----	----	----
	Smolt outmigration			----	----	----	----						
Steelhead Summer	Upstream migration				----	----	----	----	----	----	----		
	Spawning		----	----	----	----							
	Incubation		----	----	----	----	----						
	Juvenile rearing	----	----	----	----	----	----	----	----	----	----	----	----
	Smolt outmigration				----	----	----						
Steelhead Winter	Upstream migration	----	----	----	----							----	----
	Spawning			----	----	----	----						
	Incubation			----	----	----	----	----					
	Juvenile rearing	----	----	----	----	----	----	----	----	----	----	----	----
	Smolt outmigration				----	----	----						
Char	Upstream migration						----	----	----	----			
	Spawning									----	----	----	
	Incubation	----	----	----	----					----	----	----	----
	Juvenile rearing	----	----	----	----	----	----	----	----	----	----	----	----
	Smolt outmigration				----	----	----						
Sea-run Cutthroat	Upstream migration							----	----	----	----	----	
	Spawning		----	----	----	----							
	Incubation		----	----	----	----	----						
	Juvenile rearing	----	----	----	----	----	----	----	----	----	----	----	----
	Smolt outmigration				----	----	----	----					

Figure 1. Stillaguamish fall/summer chinook escapement (WDFW and WWTIT 1992).

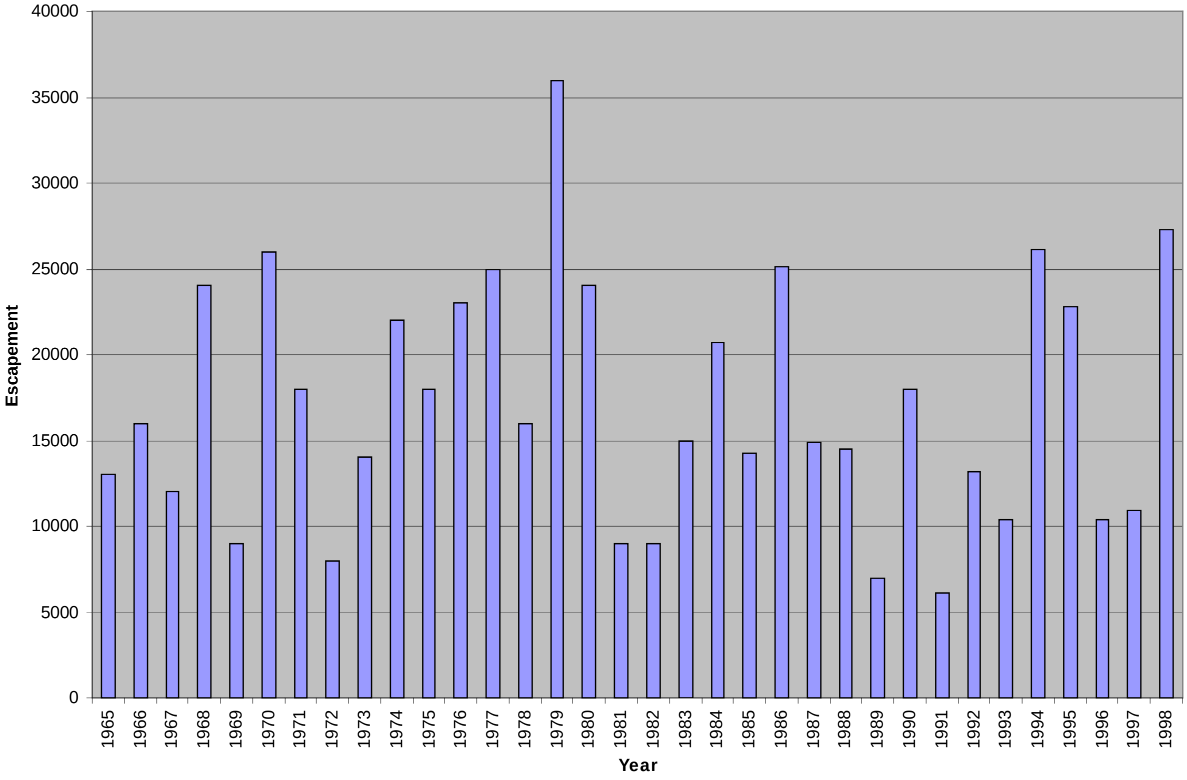


Coho. The SASSI identifies two distinct coho (*Oncorhynchus kisutch*) stocks: Stillaguamish and Deer Creek (WDFW and WWTIT 1992) (Map 4b). The former is considered a mixture of native and non-native fish because of releases of hatchery coho from the early 1950s to 1981. The stock is classified by SASSI as depressed. The Deer Creek stock is a native stock. Its stock status is unknown. The Stillaguamish Tribe operates a coho brood stock program with fish derived from naturally and hatchery spawned adults. The coho escapement goal is 17,000 (Figure 2).

Coho return to the Stillaguamish in September and October, and generally spawn from mid-November through January (WDFW and WWTIT 1992). They spawn in almost all accessible tributary streams in the Stillaguamish river system, preferring smaller streams with stable streamflow and gravel-sized substrate (Miller and Somers 1989).

Squire and Fortson Creeks have produced over 50 % of the coho escapement since 1984 (Pess 1999). Spawning escapement estimates have been calculated for nine other tributary streams: Church, Fish, Armstrong, McGovern, Tiger, Cranberry, Trout, Heather, and Triple (Nelson et al. 1997). Of these, the highest mean escapements were found in Fish (402) and Tiger (355) Creeks, while the lowest mean estimates were observed in Triple (31) and Heather (45) Creeks. The largest spawning populations were observed in the tributaries to the lower Stillaguamish and in Tiger Creek. Tributaries to the South Fork Stillaguamish exhibited the greatest

Figure 2. Stillaguamish coho escapement (WDFW and WWTIT 1992).

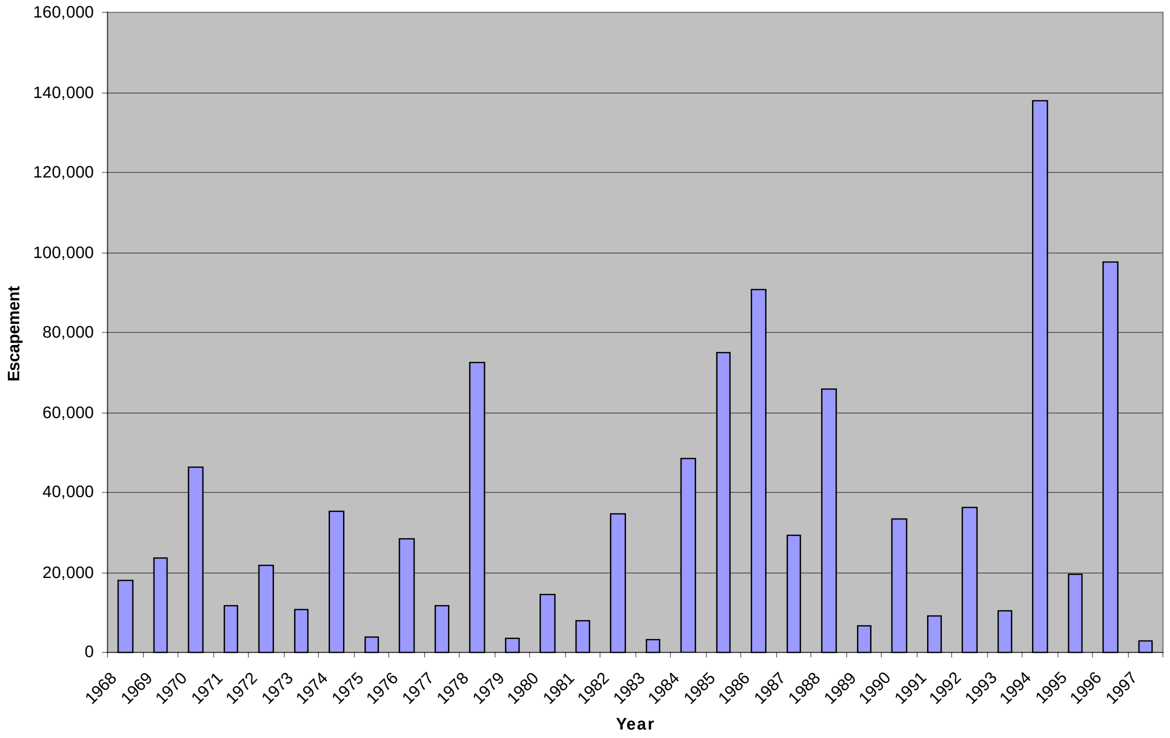


year-to-year variation in numbers. This is believed to be due to periodic passage difficulties in a canyon on the South Fork, downstream of the tributaries.

Coho fry emerge in March and April, and spend a full year in the watershed before migrating as smolts to salt water (Miller and Somers 1989). Juvenile coho rear throughout the watershed, preferring quiet waters such as side channels, stream margins, and beaver ponds. Between 1986 and 1989, the annual coho smolt production estimates from the Stillaguamish watershed averaged 649, 081 and ranged from a high of 826,297 (1986) to a low of 514,680 (1989) (Nelson et al. 1997).

Chum. The Stillaguamish chum salmon (*Oncorhynchus keta*) are geographically separated into two stocks: North Fork and South Fork (Map 4c). There is also some difference in the timing of spawning (WDFW and WWTIT 1992). Both stocks are genetically separated from other Puget Sound chum stocks, though they are related to Skagit and Snohomish chum. Stillaguamish chum are believed to be native in origin, though Grays Harbor chum were introduced in 1916 (WDFW and WWTIT 1992). The SASSI escapement goals are 33,100 for even years and 13,100 for odd years (Figure 3). The odd-year escapement levels are lower due to competition with pink salmon.

Figure 3. Stillaguamish chum escapement (WDFW and WWTIT 1992).

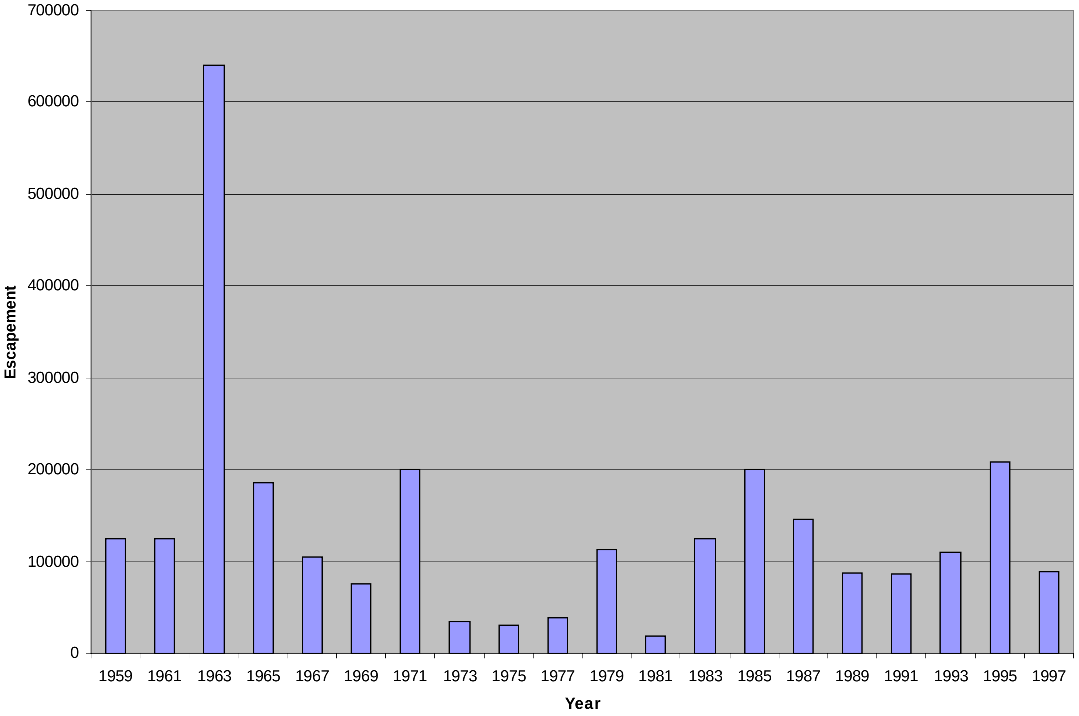


Chum salmon enter the river from September through December. Spawning occurs from mid- to late October through December. Chum prefer to spawn in the upper North Fork, lower South Fork, in side channels, and in larger tributary streams. In the North Fork, Squire and Grant Creeks are important spawning areas. The lower portion of Jim Creek provides spawning habitat in the South Fork drainage. The relative importance of the mainstem South Fork to spawning chum has been difficult to determine due to poor water visibility.

Chum fry emerge in March through May, and like pink salmon, they leave the freshwater system almost immediately (Miller and Somers 1989). Here the two species part ways, however, as juvenile chum may linger in the estuary for up to 3 months before migrating into Puget Sound.

Pink. Pink salmon (*Oncorhynchus gorbuscha*) in the Stillaguamish watershed are geographically and temporally separated into two stocks, North Fork and South Fork (WDFW and WWTIT 1992) (Map 4d). The genetic distinctions between the two stocks are unknown. This species is believed to be native to the Stillaguamish. There is no record of hatchery introductions. Pink salmon are listed by SASSI as healthy (WDFW and WWTT 1992), however a biological review team formed by the National Marine Fisheries Service (NMFS) is concerned about a consistent decline in their body size (MBSNF 1996). This trend may negatively impact reproductive potential and the species’ ability to respond to environmental changes. The escapement goal is 155,000 (Figure 4).

Figure 4. Stillaguamish pink escapement (WDFW and WWTIT 1992).



Pink salmon enter the river on odd-numbered years from early August through early October. They are found in the river on even-numbered years, but they are few in number. The spawning season for pink salmon begins in late August and peaks in mid-October. Spawning mainly occurs in the North Fork and the South Fork and in larger tributaries (especially Squire, Boulder, Jim, and Pilchuck). Other tributaries are also used for spawning when sufficient flow is present. Pink salmon fry emerge from the gravels in March and leave the river almost immediately.

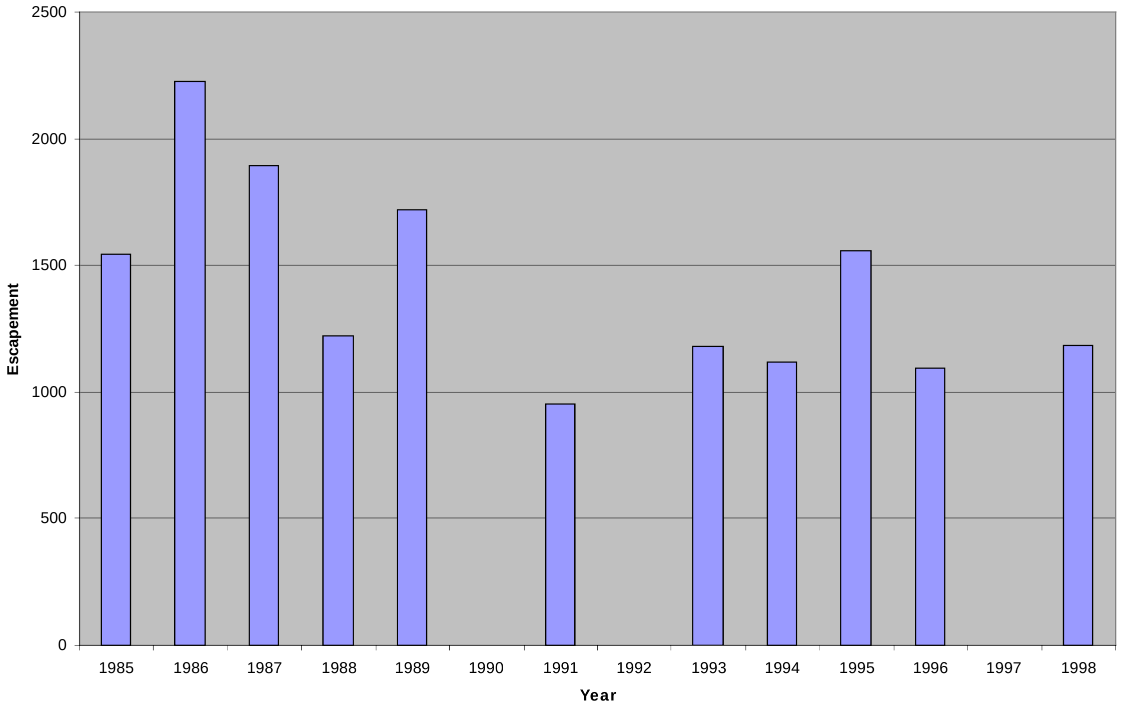
Steelhead. Four steelhead (*Oncorhynchus mykiss*) stocks have been identified in the Stillaguamish watershed, including one winter run and three summer runs. Juvenile steelhead rear between one and three years in freshwater before departing for Puget Sound (Miller and Somers 1989). The pools of small quiet streams are important for the young fry, but as the fish grow in size they are able to use the higher energy stream environments. Smolts migrate out of the river from March through late June.

The winter steelhead stock is native in origin and is listed by SASSI as healthy (WDFW and WWTIT 1992) (Map 4e). Approximately 100,000 to 130,000 hatchery winter steelhead smolts are annually released into the Stillaguamish river. The potential for the wild stock to interbreed with the returning winter hatchery stock is believed to be small since the hatchery fish spawn in

January and February prior to the native spawning season in March and April (WDFW and WWTIT 1992). The escapement goal for the winter stock is 950 for WDFW index areas (Figure 5). The years without data in Figure 5 indicate time periods during which no surveys were undertaken.

Winter steelhead enter the river from early November through April to spawn. Spawning occurs mainly in the North Fork and South Fork. The primary spawning tributaries include: Pilchuck, Boulder, Squire, Jim and Canyon.

Figure 5. Stillaguamish winter steelhead escapement for index areas (Kraemer 1999).

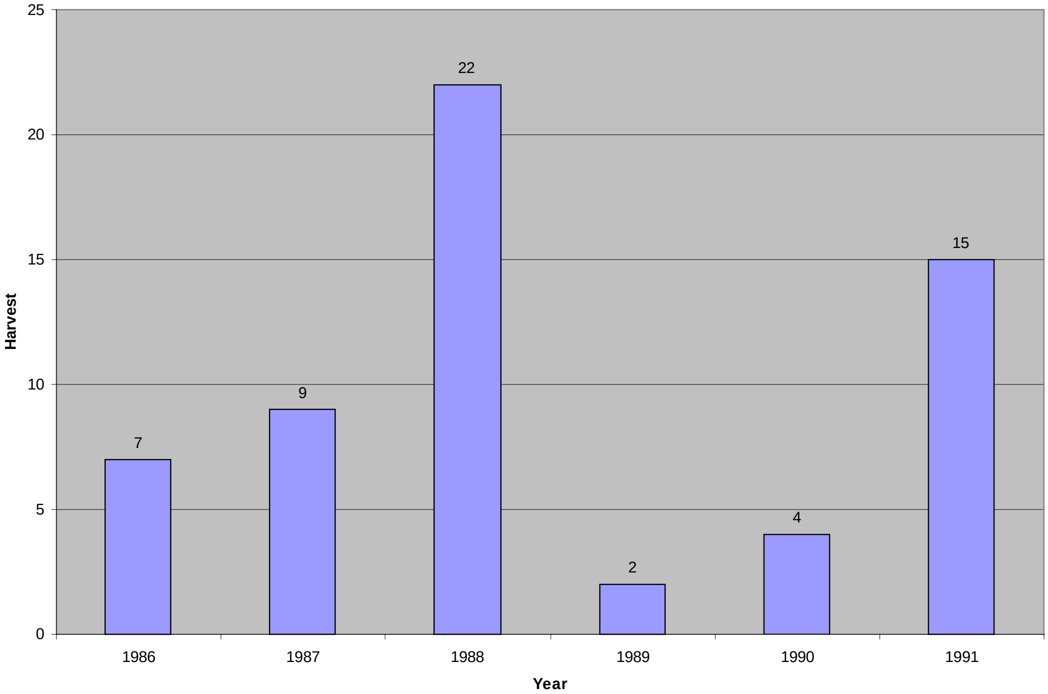


The summer steelhead runs include: the native Deer Creek stock, a mixed wild/hatchery Canyon Creek stock, and the non-native South Fork stock (Map 4f). Summer steelhead enter the river from May through October and spawn from mid-February through mid-May the following year. The preferred spawning habitat includes the main channels of the North and South Forks and most tributary streams (Miller and Somers 1989).

The Deer Creek summer stock is geographically isolated from the other steelhead stocks. The run may have historically numbered between 1,000 to 2,000 fish, but now is believed to be at only about 5 to 10 % of that level. The Deer Creek fishery has been closed since the late 1930s. This run is listed as critical in SASSI (WDFW and WWTIT 1992). There are no population data available.

The Canyon Creek stock is geographically isolated from the other summer stocks. The run is small; fewer than a few dozen fish are annually harvested. The SASSI lists its status as unknown. Escapement is not monitored, but there are some harvest data (Figure 6).

Figure 6. Stillaguamish Canyon Creek summer steelhead harvest (Kraemer 1999).

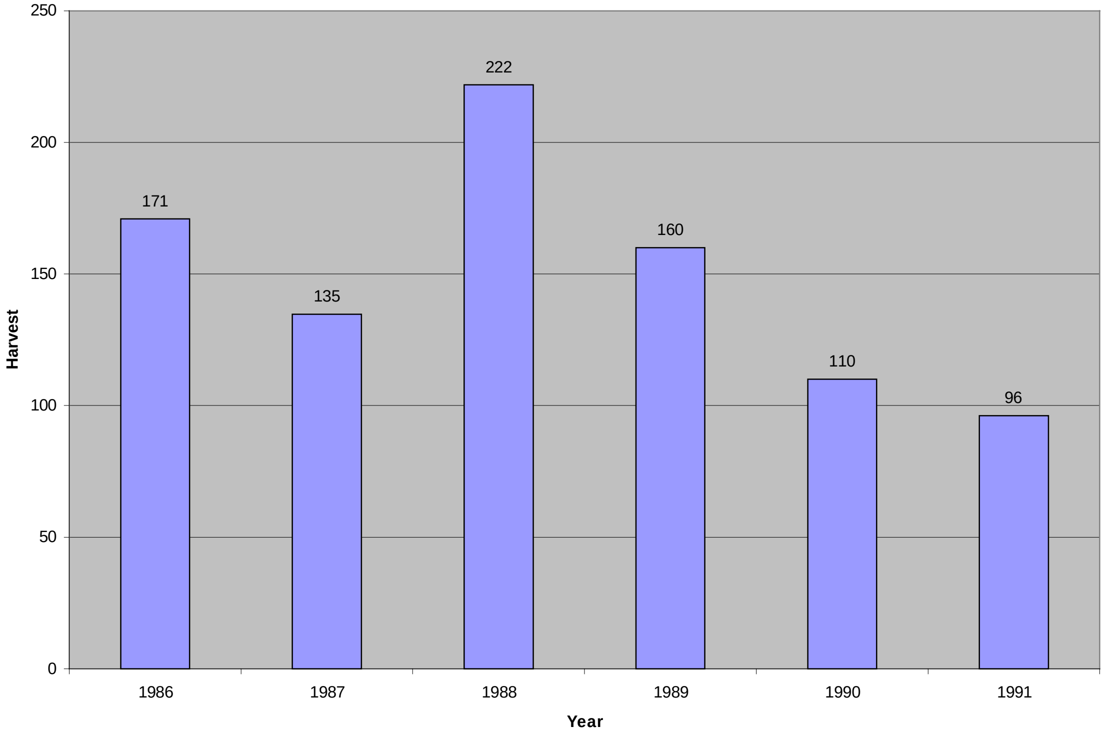


The South Fork stock originated from hatchery steelhead fry and smolts introduced to the upper South Fork watershed subsequent to the construction of the Granite Falls fishway in the mid-1950s (MBSNF 1995). Approximately 80,000 hatchery summer steelhead smolts are annually released into the river. There is no escapement goal for this stock but there are some harvest data available (Figure 7). The SASSI stock status of the South Fork run is listed as unknown.

Sockeye. There is a small population of river sockeye salmon (*Oncorhynchus nerka*) inhabiting the Stillaguamish (Map 4g). Whether they are strays from other watersheds or a genetically distinct stock is not known. Preliminary information from other watersheds with river-spawning sockeye suggests that the populations have no genetic relationship to lake-spawning populations (Hendrick 1999). Much of the information about the Stillaguamish sockeye has been collected incidentally as part of other fisheries work. The Stillaguamish sockeye are not listed in SASSI and there are no published escapement data. They are known to spawn in the upper North Fork, as well as several tributaries including Jim, Deer, Squire and Boulder. The sockeye generally enter the river from July through September and spawn from August through October (Hendrick 1999). Smolts migrate out of the river from March through June.

Bull trout. Native char include both Dolly Varden (*Salvelinus malma*) and bull trout (*Salvelinus confluentus*) (Map 4h). Anadromous, fluvial and resident char are presumed to be found throughout the watershed and to use many habitat types during their life cycle (WDFW 1998; MBSNF 1995). The SASSI stock status is listed as unknown (WDFW and WWTIT 1998). The population is believed to be stable or expanding with the exception of the Deer Creek and Canyon Creek segments (MBSNF 1996). There has been no systematic survey of bull trout in the Stillaguamish watershed although the US Forest Service and the Washington Department of Fish and Wildlife have collected some site-specific data in recent years. In June 1998, the US Fish and Wildlife Service (USFWS) proposed the listing of the Puget Sound bull trout as threatened under the federal Endangered Species Act.

Figure 7. Stillaguamish South Fork summer steelhead harvest (Kraemer 1999).



Most bull trout are believed to reside in the upper South Fork and its headwater streams. They are also found in Boulder, Squire and Deer Creek in the North Fork drainage. Native char have been incidentally observed in Armstrong, McGovern, Fortson, Tiger, Trout, and Big Four Creeks as part of a late 1980s coho study (Nelson et al. 1997).

Searun Cutthroat. Sea-run (*Oncorhynchus clarki clarki*) and resident stocks of cutthroat are found throughout the Stillaguamish watershed (Map 4i), though there has been no systematic inventory of their populations. Sea-run cutthroat are known to be present in the mainstem, North Fork and South Fork below Granite Falls. Cutthroat are also known to use Church and Portage Creeks (mainstem), and presumed to use Jim and Canyon Creeks (South Fork). Cutthroat trout (including resident and searun) are believed to be the predominant trout species present in mainstem tributaries; with resident rainbows tending to replace cutthroat as the predominant trout species in tributaries to the North and South Forks (Nelson et al. 1997). Resident cutthroat, along with rainbow trout and brook trout, have been stocked in many lakes in the watershed (MBSNF 1995).

Searun cutthroat begin entering the Stillaguamish in late July. Spawning occurs in mid-February through mid-May. Searun cutthroat typically rear from two to four years in freshwater before migrating to salt water, where they spend about two to five months before returning to the watershed (Spence et al. 1995).

HISTORIC CONDITIONS AND LOSSES

Estuary Habitat

The history of land use impacts to the Stillaguamish estuary has been documented by Bortleson et al. (1980) and more recently by Collins (1997b). The latter researcher reports that prior to European settlement (around 1870), there was approximately 18 km^2 of salt marsh habitat. Roughly one-half of this was in Skagit Bay contiguous with the Stillaguamish River distributaries. More than one-third (6 km^2) was on the delta and south of Hat's slough. The remainder was on the island defined by Davis slough (connects Skagit Bay and Port Susan), West Pass, and South Pass.

Between 1870 and 1968, about 85 % of the Stillaguamish tidal marsh was converted to agriculture through the construction of dikes (Table 5) (Collins 1997b). Two-thirds of this conversion occurred between 1870 and 1886. By 1886, only one-third of the original salt marsh remained. By 1968, only 3 km^2 of the original salt marsh existed, with a concomitant loss in blind tidal channels (which are important for juvenile rearing).

Table 5. Estimates of historic and current salt marsh habitat reclaimed by dikes on the Stillaguamish river delta and newly accreted areas (Collins 1997b).

Site	Pre-Settlement (1870)	1886	1968
	acres (hectares)	acres (hectares)	acres (hectares)
South of Hatt's Slough	487 (197)	94 (38)	99 (40) new
Stillaguamish Delta	1045 (423)	170 (69)	99 (40) original; 386 (156) new
Leque's Island	475 (192)	214 (87)	85 (34) original; 220 (89) new
East of Douglas Slough	1293 (523)	211 (85)	114 (46) original; no new
West of Douglas Slough	673 (272)	496 (201)	369 (19) original; no new
Camano Island	466 (189)	292 (118)	no original; 158 (64) new
Total	4439 (1796)	1477 (598)	667 (270) original; 863 (349) new; 1530 (619) total

Between 1886 to 1968, an area of approximately 4 km^2 was accreted into Port Susan and Skagit Bay, but the more recently formed sand and mud flats do not have the same well developed blind channel system as the historic salt marsh habitat (Collins 1997b). Accordingly, this type of habitat is less productive and useful to salmon than other types of estuary habitats. The newly accreted area is believed to have resulted from the human-induced shift from the Old Mainstem into Hat's Slough, which occurred around the turn of the century. Upland land use patterns may have also increased the rate of accretion, but this remains to be evaluated.

Mainstem and Forks

Log-Rafts and Snags

Large woody debris, such as log jams and snags, are a critical component of a river's ecosystem, and are especially important to salmon (refer to the discussion pertaining to habitat limiting factors). Giant rafts of logs are described in the history of Puget Sound settlements and were once present in the lower Stillaguamish river. Six log raft jams were located in a 16-km stretch of the mainstem prior to the turn of the century (Collins 1997b). All were removed by settlers, probably to improve navigation, and to allow for the settlement of upstream areas. Giant snags were also systematically removed from the lower mainstem for navigation purposes. By 1900, over one thousand snags and leaning riparian trees were removed, mainly downstream of Hat's Slough in the Old Mainstem. The removal of the giant log rafts may have contributed to: the destabilization of the heads of floodplain sloughs, a decrease in the frequency and magnitude of overbank flooding, downcutting of the mainstem channel, and an increase in the amount of sediment reaching Port Susan (Collins 1997b).

Floodplain and Upland Forests

The present-day forests in the Stillaguamish landscape are dramatically different in character than those present prior to European settlement. The General Land Office surveys from 1873 provide the best information about the character of the Stillaguamish floodplain and upland forests prior to the onset of most logging activity (Pollock 1998).

Decidous trees (alder, bigleaf maple, willow, cottonwood, and vine maple) predominated in the floodplain forests, accounting for just over 60 % of the trees surveyed in the floodplain in the mid-1870s (Pollock 1998). This high percentage of deciduous trees is indicative of the extent of flood disturbance and a river channel prone to migration. Conifers accounted for the remainder and included hemlock, Douglas fir, cedar and spruce. The conifers tended to be clustered in the mainstem floodplain and more evenly mixed among deciduous trees in the floodplains of the North and South Forks.

The diameter of the trees, particularly conifers, was also much larger at that time than they are today. Spruce and cedar represented the largest individuals (exceeding one meter at chest height) in floodplain forests. There was also an abundance of small hardwoods in the floodplain, another indication of a dynamic river prone to frequent lateral movement. The migrating river was responsible for the formation of side channels, sloughs, gravel bars, and oxbow lakes, all of which provide important spawning and rearing habitat for salmonids.

The forests outside of the floodplain were dominated by conifers, accounting for almost 80 % of the surveyed trees (Pollock 1998). Hemlock (40 %), Douglas fir (21 %), and cedar (16 %) were most common in these areas. Alder was the dominant deciduous species in the uplands, comprising 9 % of the surveyed trees. Late-successional forests (old growth) accounted for 42 % of the surveyed forest types. In these upland areas, fire played its natural disturbance role in regenerating forest habitats.

Logging of the Stillaguamish watershed began in the lower mainstem of the river in the early 1860s (Colllins 1997b). The floodplain forests of most of the mainstem, and riparian forests bordering much of the remaining anadromous streams in the watershed had been harvested by the turn of the century. By the early 1940s, all of the anadromous channel network, with the exception of the middle and upper portions of Deer Creek (North Fork), and the uppermost parts of Jim and Canyon Creeks (South Fork) had been logged. Impacts (such as increases in sediment and peak flows, and loss of riparian habitat) from forestry activities are discussed later in this document.

Beaver Ponds and Wetlands

Beaver ponds provide important rearing and overwintering habitat for coho and other juvenile salmonids (Pollock and Pess 1998). The broad, glacially carved valley through which the Stillaguamish flows contains many small streams ideally suited to beaver. Beaver ponds have been estimated to have historically covered between 2.37 km^2 to 11.84 km$^{2\ \mathrm{in}}$ the Stillaguamish watershed (Pollock and Pess 1998). It is now estimated to be 0.44 km^2, and by 81 % to 96 % of historic levels in the anadromous zone. These losses have mainly been attributed to as a result of conversion to agricultural cropland, residential housing, and trapping (Pollock and Pess 1998).

Wetlands provide several functions that directly impact salmonids: sediment storage, flood flow storage and desynchronization, temperature maintenance, nutrient removal and transformation, groundwater recharge, and refuge and rearing habitats. The Stillaguamish watershed historically supported an estimated 11,795 ha of wetland habitat (Gersib 1997). The current total wetland area is estimated to be 2,537 ha, indicating that 78 % of historic wetlands have been impacted or lost.

DESIRED FUTURE CONDITIONS

To protect, restore and enhance the diversity of salmonid stocks and their ecosystems in the Stillaguamish watershed to a naturally functioning system that will sustain fisheries, non-consumptive fish benefits, and other ecological and social values. The scientific literature provides data to support measurable thresholds for many of the habitat characteristics (such as stream temperature, dissolved oxygen concentration, percent pool habitat, riparian buffer width, large woody debris, percent fine sediment and other criteria) associated with functioning ecosystems. Such thresholds will be used to monitor the health of the watershed and the progress of restoration efforts. In some cases, they may vary between species and life history stages.

HABITAT LIMITING FACTORS

For the purpose of this report, the Washington Conservation Commission developed a general template to provide for a consistent and comprehensive assessment of habitat limiting factors in watersheds across the state, and to compare and contrast, where possible, habitat conditions between watersheds. This section identifies the existing information pertaining to the eight habitat factors listed in the template that potentially could limit salmon production. These include: 1) access to spawning and rearing habitat; 2) floodplain connectivity; 3) riparian zones; 4) stream channel conditions; 5) water quality; 6) hydrology; 7) lakes and other freshwater habitats; 8) nearshore and estuarine habitats; and 9) exotic and opportunistic species.

The status of existing data and information varies considerably between factors. In some cases, extensive work has been done. In others, data may exist but there may be insufficient information to make connections to salmon populations. In other situations, there may be little or no information. Such data gaps are listed in Tables 24 and 25 near the end of the document.

Access to Spawning and Rearing Habitat

Anadromous fish that travel from Puget Sound upriver to spawn begin a maturation process geared to culminate when they reach their spawning habitat. Barriers to access take many forms. This section focuses primarily on culverts and other structures such as the Granite Falls fishway. The following section on floodplain connectivity discusses the impact that dikes and levees have had on blocking access to side channel habitats. Alterations in water quality may also form barriers to fish. Impacts from alterations in temperature, turbidity, low dissolved oxygen, and salinity are discussed later in this document.

Culverts

Unhindered fish passage at stream crossings is an important consideration in the engineering of the extensive road network throughout the Stillaguamish watershed. Improperly selected and placed culverts can block adult and juvenile fish migration, adversely affecting fish populations. Some culverts are passable at certain flows and unpassable at others. Some, because of their location, are detrimental to some species but not others. Culverts more negatively impact salmonids (such as coho, steelhead, and cutthroat) which depend on smaller tributary streams for spawning, rearing and migration than species (such as pink and chum) which mainly rely on larger stream channels. An estimated 37 % of the summer and 21 % of the winter coho smolt production loss in tributary habitats has resulted from blocking culverts (Pess et al., in press). These losses have not been quantified for other species.

There are least four culvert inventory projects in the Stillaguamish watershed designed to identify and prioritize culvert blockages throughout the basin (Map 5). In 1995 and 1996, the Stillaguamish and Tulalip Tribes' conducted an inventory of over 500 culverts in the watershed (Tulalip Tribes and Stillaguamish Tribe 1995). The inventory was oriented to coho habitat, however other species will also benefit. The high priority culverts are being replaced as funds become available. Approximately 15 culverts have been repaired to date, resulting in 25,000 m of restored stream and wetland habitat. Upstream and downstream monitoring of spawning adults and juvenile fish populations occurs for all culvert replacements. Table 6 is a prioritized culvert replacement list for the most significant coho blockage problems that remain to be completed (Pess et al. 1998).

Table 6. Prioritized culvert replacement list (Pess et al. 1998).

Stream	Blocked Habitat (m)	Potential Smolts	Smolts/meter	Cost ($1000)	Cost/smolt ($)
Rock Creek	3,477.00	890.00	0.26	10.00	11.24
Koonz Creek-2	2,867.00	471.00	0.16	6.50	13.80
Porter Creek-2	1,807.00	325.00	0.18	6.00	18.46
Little French	2,240.00	462.00	0.21	15.00	32.47
Jim Creek Trib-335	2,341.00	398.00	0.17	20.00	50.25
Trafton-1	1,255.00	395.00	0.31	20.00	50.63
Koonz Creek-1	3,450.00	816.00	0.24	45.00	55.15
Trafton-2	1,506.00	277.00	0.18	20.00	72.20
Jim Creek Trib-333(1)	1,527.00	171.00	0.11	15.00	87.72
Jim Creek Trib-334	662.00	161.00	0.24	20.00	124.22
Fortson Creek	1,272.00	180.00	0.14	25.00	138.89
Jim Creek Trib-337(3)	609.00	66.00	0.11	10.00	151.52
Cougar Creek	1,000.00	132.00	0.13	40.00	303.03
Little French	381.00	79.00	0.21	25.00	316.46
Total	24,394.00	4,823.00		277.50	1,426.03
Average	1,742.43	344.50	0.19	19.82	101.86

The Washington Department of Fish and Wildlife (WDFW) and Washington State Department of Transportation (WSDOT) also maintain an inventory of "problem" culverts in the Stillaguamish basin. The state barrier inventory pertains mainly to culverts associated with state highways and includes an assessment of the nature and passability of the culverts listed. The third culvert inventory is maintained by Snohomish County Surface Water Management (SWM) and includes culverts within the Stillaguamish Clean Water District. The culverts in this inventory have been located and mapped into a GIS system, but the passability characteristics remain to be evaluated. The US Forest Service (USFS) also has a culvert inventory but the data available for the Stillaguamish watershed is limited (Chang 1999).

Map 5 shows the culverts and other barriers contained within the tribal and state databases. The culverts in the County and Forest Service databases are not shown in Map 5 for lack of sufficient information. One problem that all culvert programs face is the lack of access to all lands in the watershed. Lack of access to private lands limits the biologists' ability to identify all blockages.

Tidegates

Tidegates are swinging gates located on the outside of a drainage conduit from a diked field that excludes saltwater at high tide and permits drainage at low tide. Tidegates, like culverts, can block fish passage. They can also trap organic debris that could contribute nutrients to the aquatic system. In some locations, the drainage ditches regulated by tidegates lack suitable habitat for salmonids. Tidegates remain to be inventoried for passability and the quality of the habitat impacted.

Diversions and Other Structures

The Stillaguamish is relatively unique among major Washington rivers in that there are no large hydroelectric or flood control dams within the watershed. This is a benefit to salmonids and other aquatic, riparian and floodplain species because where such structures exist they commonly lack adequate fish passage facilities. Also, the river's streamflow and flooding processes (while altered by other land uses) are not subject to a regulated flow regime dependent on human electrical or water supply needs. There are, however, two relatively small diversion structures in the watershed, the Cook Slough weir and the Granite Falls fishway, which pose some fish passage problems (Map 5).

Cook Slough Weir. A weir is like a dam in that its purpose is to stop and raise the water level, for the purpose of conducting it to another site. The Cook Slough weir is located about one-half mile downstream of the Interstate 5 bridge (Map 5). The Civilian Conservation Corps built the weir and 26 bank revetments in 1939. These projects were intended to reduce bank erosion and channel migration on the mainstem between Arlington and Hat's Slough, a distance of about 24 km. The 84-meter control weir was built at the mouth of Cook Slough to limit flow through the slough and through two cut-off channels (each about 274 m long). Subsequent to construction, most of the river's flow was channeled into North Slough. The Army Corps of Engineers is responsible for the weir's maintenance.

The ACOE modified the weir in 1991 to allow fish passage during low flows. However, in drought years, some salmon, especially pinks, have difficulty migrating through the structure. The weir and associated revetments have also altered the hydrology of the river system. These impacts include: 1) altered flow patterns; 2) straightening of the river; 3) isolation of the floodplain and sloughs; and 4) altered channel-forming processes (Collins 1997b). The feasibility of constructing a new fish ladder is being considered as part of the *Stillaguamish River Ecosystem Restoration General Investigation* (ACOE 1997).

Granite Falls Fishway. The Washington Department of Fisheries constructed the Granite Falls fishway in 1954 on the South Fork Stillaguamish (MBSNF 1995) (Map 5). The fishway was built to allow anadromous salmon access to spawning grounds above the natural falls. Chinook, coho, pink salmon and steelhead have gained access to the upper South Fork as a result. The fishway allows for fish access to the upper South Fork, but passage is still sometimes impeded. The large sediment load associated with the South Fork drainage contributes gravels that are deposited into the structure. The gravels are periodically removed by the WDFW. During summer low flows, especially in June and July, the fishway de-waters and occasionally strands fish.

The Granite Fall fishway has contributed to coho and steelhead production in the Stillaguamish watershed. However, this type of structure might not be built today in light of contemporary environmental regulations and more scientific understanding about the ecological impacts of introducing exotic (or native) species into habitats from which they were originally excluded. Providing access to areas that were not historically accessible to chinook and other salmon in the past may have harmed the aquatic ecosystem upstream of the falls. Resident bull trout may be one species that was negatively impacted by the construction of the fish ladder, as they do not compete well with other salmonids (MBSNF 1995). Their confinement to the upper headwater streams of the South Fork may have occurred as a result.

Splash Dams

Splash Dams were used in historic logging operations in the Stillaguamish watershed prior to the era of logging trucks and roads, and in areas were it was not economical to put in a logging railroad. They were used to transport logs from the upland harvest areas to the main river. Though no longer in use, splash dams have affected salmon in two ways. Initially the dams caused a temporary blockage to upstream migration of salmon and trout. The second impact was far more damaging and long-term. When the dams were breached, it resulted in severe destruction of the aquatic and riparian habitat.

Splash dams were made by building a log crib dam on a stream, and then filling the pool that formed behind it with logs. Once the pool was filled with logs, the dam was breached and the logs were flushed violently downstream to the mainstem river were they would be rafted together and transported to a mill. The legacy of splash dams remains to be seen in some stream channel segments in the Stillaguamish. Black Creek is one location where a splash dam is still in place. An interagency team of fish biologists has evaluated the structure. They subsequently decided to leave the dam in place.

Hydropower.

Historically, there were several small hydropower sites associated with early mining and logging development in the Stillaguamish watershed. At the present time, there are no major hydropower projects or dams on the Stillaguamish River with the exception of the weir mentioned above. There is one licensed household-sized hydroelectric project but it is located on a stream without trout or salmon.

Other Freshwater Blockages

There are other small structures like old mill ponds and farm pond weirs that may block access to upstream migration. may block access to smaller tributaries. Blockages on private lands remain to be inventoried.

Floodplain Connectivity

A floodplain is formed by and interconnected with its river, and includes the lowland bordering a stream or river that is usually dry but subject to periodic flooding. Floodplains are naturally complex landscapes containing habitats like sloughs, sidechannels, oxbows, lakes and wetlands that are important to fish and other aquatic and terrestrial organisms. The aquatic habitats in floodplains are particularly important to salmonids such as juvenile coho that use these areas for rearing and as refuge from large flow events. Large portions of the floodplains of many Washington rivers, including the Stillaguamish, have been converted to agricultural and urban uses, generally to the detriment of salmon. From a salmon's point of view, the floodplains of the Stillaguamish have been detrimentally impacted in at least three significant ways: 1) loss of access to side channel habitats; 2) loss of hydrologic connectivity between the floodplain and naturally-occurring peak flow events (which are important to creating a natural complexity of habitat types); and 3) loss and alteration of floodplain riparian habitats. This section focuses on the first issue.

As discussed previously, many beaver ponds, side channels and sloughs once used by salmon have been disconnected from the main river channel as a result of diking and other agricultural practices and bank revetments (Map 6). The slower water habitats provide important rearing areas for juvenile coho and other salmonids. Dikes were constructed along the banks of the Stillaguamish to prevent the river from overflowing into the floodplain during high water events. In tidally influenced areas, dikes were also constructed to convert estuary habitat into farmland. Revetments made of stone, concrete, or other materials, were used to prevent the riverbanks from eroding. Between 1933 and 1991, side channel slough habitat decreased by 31 % (Pess et al., in press). These losses are mainly a result of channel sloughs being cut off and the alteration of one former slough to a tributary now called Portage Creek (Collins 1997b). The rerouting of Portage Creek into a side channel slough occurred in the late 1800s. Map 7 shows the location of the river channel in 1933.

The side channels of the North and South Forks have been decreased by about one-third of their historic levels (Pess et al., in press). These losses are mainly due to filling, and can be attributed to the combined effects of bank revetment, agriculture and other land uses. The construction of the railroad grade along the south bank of the river, from Arlington to Darrington, and of State Route 530 also contributed to a loss of side channel habitat and limited the river's channel

migration zone. Riparian forests were typically harvested along with floodplain development projects.

The existing estimates of channel loss were made using historical aerial photos. Hence, they do not include all lost or existing side channels. Field verification is needed to more accurately inventory and quantify the amount of disconnected side channel habitats with potential for restoration.

Riparian Zone

The riparian zone consists of the transitional ecosystem between aquatic habitats (stream, lake, wetland, estuary) and upland forest habitats. It supports vegetation that may be influenced by fluctuating water tables. Riparian zones provide several ecological functions that are important to salmon. They contribute large woody debris that influences the hydrology of the stream channel. This, in turn, affects habitat types and quality. Shade is important to keeping water temperatures cool, and regulating sunlight and photosynthesis. Riparian vegetation also provides leaf material and other fine organic matter to the aquatic system that serves as food and nutrients for many organisms. The large trees lining stream channels provide structural support to the streambanks that helps to control sediment from entering the water. Riparian vegetation also plays a role in nutrient transformation and storage. This section discusses the loss of riparian forests. Impacts associated with large woody debris, pool habitat, and temperature are discussed later in this document.

Riparian Buffers

In the Pacific Northwest, the ecological integrity of a streamside riparian zone is managed through the maintenance of riparian buffers. For fish-bearing streams, the recommended buffer width ranges from: 25 to 100 ft (8 to 30 m) (Washington Department of Natural Resources (WDNR), to 100 to 250 ft (30 to 46 m)(WDFW), to 300 ft (91 m) (USFS) (Pollock 1998; Knutson and Naef 1997). Non fish-bearing streams typically receive protection with smaller buffers or no buffer at all, though there is ample scientific literature to support the importance of riparian buffers for numerous other species. From a watershed perspective, non-fish-bearing streams are also critical to the overall health of the watershed and the organisms they support.

An analysis of the historic and current riparian conditions of the Stillaguamish watershed was completed in 1998 (Pollock 1998). The historic information (described earlier) was obtained from the General Land Office surveys undertaken in the early 1870s prior to most logging activity, while the current conditions were evaluated from 1991 aerial photos. The riparian vegetation was classified by three characteristics: 1) tree size (large, medium, or small); 2) abundance of conifer and deciduous species (conifer, mixed, or deciduous); and 3) average forest density (dense or sparse). These characteristics were then used to classify the riparian forests (assuming a 100-ft (30 m) buffer on each side of the stream) by their ability to supply coniferous, large woody debris to the stream.

Map 8 depicts the general riparian condition by sub-basin based on the Pollock’s (1998) report and subsequent conversation with Pollock. Generally speaking, the headwaters of the South Fork and North Fork drainages are in the best condition and described as "Recovering." Sub-basins in the lower North Fork and north of the mainstem are generally described as being in a "Degraded" condition, while the remaining mainstem sub-basins are described as "Severely Degraded."

The sub-basins which are relatively large and in the best condition include: Upper South Fork, Upper Pilchuck, Upper North Fork, Robe Valley, Squire Creek, Gold Basin, Canyon Creek, Boulder Ridge, Burn Hill Area, and Higgins Ridge. Sub-basins with more than 70 % degraded riparian forests include: Arlington Area, Armstrong-Harvey Creek, Church Creek, Hell-Hazel, Hat Slough, Jackson Area, Jim Creek, Portage Creek, Stanwood City, Stillaguamish Floodplain, and Tributary 30. Of these sub-basins, Arlington Area, Church Creek, Hat Slough, Jackson Area, Portage Creek, Stanwood City, Stillaguamish Floodplain and Tributary 30 have more than 90 % riparian degradation. Riparian zones associated with agriculture and rural residential land use are the most severely degraded.

The current state of degradation for the anadromous zone of each sub-basin generally follows these trends. Only 11 % of the riparian forests are in an “intact” fully functional condition. The sub-basins with the most anadromous riparian forests (more than 100 km in length) and with most of these forests in a non-degraded condition include: Deer Creek, Upper South Fork, Canyon Creek, Robe Valley, Gold Basin, and Squire Creek. Sub-basins with more than 100 km of the anadromous stream segments bordered by a riparian forests which are generally in a degraded condition include: Stillaguamish Floodplain, Jim Creek, Higgins Ridge, Portage Creek, and Lower Pilchuck. One of the most significant conclusions is that, at best, only 41 % of the riparian forests bordering anadromous streams will be fully functioning (assuming no additional harvest) to provide large woody debris by the end of the 21st century, if left undisturbed (Pollock 1998). Generally speaking, the riparian forests within the boundaries of the Mt. Baker-Snoqualmie National Forest are in the best condition.

Channel Conditions

The stream channels of the Stillaguamish and its tributaries have been altered in several ways through natural and human causes. This section discusses changes in large woody debris, pool habitat, sediment supply, channel morphology, and gravel mining.

Large Woody Debris

Large woody debris comes from old trees and stumps that have fallen into the stream channel or eroded away during flood events. Old growth conifers are believed to provide the best type of woody habitat for salmon. Large trees are key to the natural process in which logjams are created. Alternately, streams lacking older, mature conifers along their riparian areas would be expected to have less large woody debris. The abundance and type of large woody debris in a stream is indicative of past and present recruitment rates of the riparian area. Sufficient large woody debris may be lacking due to a lack of riparian buffers in forest or agricultural areas.

Large flood events may flush out the large woody debris that is present. Wood debris may also be illegally removed from the gravel bars of stream channels to be sold or used for domestic purposes.

Large woody debris dissipates hydraulic energy within the stream and promotes localized scouring. This contributes to the formation of pool habitat for salmon. The wood also provides nutrients to the water and is a food source for other aquatic organisms. Stream segments that are deficient in large woody debris can lack habitat features suitable to rearing for coho and other salmonids (Miller and Somers 1989).

Recent reach-level (for stream segments between 50 and 3500 m) habitat data for stream channels throughout the Stillaguamish watershed have been collected by Pess et al. (in press) and Beechie and Sibley (1997). The wood pieces counted in this survey were at least 10 cm wide and 1 m long, and partially within the bankfull width. The lower Stillaguamish averages 15 pieces of wood per every 100 m, followed by the South Fork with 20 pieces per 100 m, and the North Fork with 24 pieces per 100 m, respectively (Table 7) (Pess et al., in press). The range of wood pieces per 100 m in each of these drainages followed a similar trend: lower Stillaguamish (7 to 23); South Fork (5 to 33); and North Fork (10 to 41). To put these numbers in perspective, old growth habitat typically provides between 0.4 and 1.5 piece of wood per meter (between 40 and 150 pieces per 100 m) (Pess 1999).

The discrepancy in large woody debris relates to the condition of the riparian zones. Stream channels in agricultural lands have much less wood debris than channels in forested and rural areas. The average and maximum number of pieces of wood per 100 m in agricultural stream channels is 70 % less than what is found in forested and rural residential lands.

Several tributaries in the lower South Fork have lost large woody debris due to high flows or timber harvest in riparian areas: both forks of Canyon Creek, Meadow Creek, upper Black Creek, upper Wiley Creek, upper Benson Creek, Hawthorn Creek, Rotary Creek, Hemple Creek, and Heather Creek (MBSNF 1996).

Pools

The presence of pools in stream channels is important to both juvenile and adult salmonids. Pools provide juvenile coho and other salmon important rearing habitat. Summer steelhead adults and other salmonids require deep holding pools and cool water when they return to the watershed in the hot summer months. The lack of deep holding pools is one factor that has been attributed to the decline of summer steelhead returning to Deer Creek.

The loss of pool area is associated with the removal and reduction of large wood debris, increases in sediment supply, and increased peak flows. Channel slope also influences the stability of the wood once it has entered the stream. Generally speaking, the spacing between pools in the Stillaguamish decreases with an increase in wood pieces and a decrease in channel slope (Pess et al., in press). The mainstem Stillaguamish has the highest average percent pool area (45 %) followed by the South Fork (35 %) and North Fork (28 %).

Table 7. Average percent pool area in the mainstem, North Fork and South Fork Stillaguamish river as a function of wood debris and channel slope (modified from Pess et al., in press).

		Wood Pieces Per 100 Meters		
Drainage	**Average Percent Pool Area**	**Range**	**Average**	**Channel Slope**
Mainstem	45	7 to 23	15	0.014
North Fork	28	10 to 41	24	0.026
South Fork	35	5 to 33	20	0.028

Sediment Supply

The *Stillaguamish Watershed Action Plan* (1990) rated sediment as one of the two most prevalent nonpoint source pollutants in the watershed, with the main contributors being: forest practices, agricultural practices, and development and urban runoff. Sedimentation problems have been a concern to resource managers in the Stillaguamish since at least the late 1950s (Washington Department of Fisheries (WDF) 1953). Sediment reduces inter-gravel water flow within the salmon redd, which limits life-sustaining dissolved oxygen and interrupts removal of metabolic waste. Sediment accumulations in the spawning gravel can also prevent fry from emerging from the gravel, entombing them in the streambed. Sediment can affect salmon in other ways as well. In a 1993 ecosystem assessment of National Forest lands, the lack of high quality pool habitat and increase in stream temperatures in the Stillaguamish were attributed to upstream landslide disturbance (MBSNF 1995). Landslides supply both coarse and fine sediment to pools.

Perkins and Collins (1997) inventoried a total of 1080 landslides in the Stillaguamish watershed for the period from the early 1940s to the early 1990s (Map 9). Some slides were shown to be active for several years. Fifty-eight percent (58 %) of the landslides occurred in the North Fork drainage, 38 % in the South Fork drainage, and 4 % in the mainstem drainage below the Forks (Table 8). Between 1978 and 1996, Collins (1997b) estimated an average annual transport of 340,000 tonnes/year in the North Fork, with a peak of 1.1 million tonnes/year in 1991. In that same study, the average annual sediment transport for the South Fork was 110,000 tonnes/year.

A total of 851 landslides delivered sediment to stream channels, and of these, at least 40 % delivered sediment directly to fish-bearing waters (Table 9). An additional 40 % also delivered sediment to the channel network. Sixty-one percent (61 %) of the 851 slides delivering sediment to streams occurred in the North Fork drainage, 36 % in the South Fork drainage, and 3 % in the mainstem drainage. The sub-basins accounting for most of the sediment delivered to stream channels include: Deer Creek, Upper North Fork, Higgens Ridge, Gold Basin, Canyon Creek, Boulder Ridge, Hell Hazel, Upper South Fork, and Jim Creek.

Landslides associated with human land uses are the primary source of sediment in the Stillaguamish. Seventy-five percent of the landslides in the watershed result from logging roads (22 %) or clearcuts (52 %), while 98 % of the volume of sediment is associated with these two

Table 8. Estimated volume of sediment delivered by sub-basin and time period (modified from Perkins and Collins 1997).

Drainages and Sub-basins			Dates of Aerial Photos					
	Not Determined	Chronic	1941-56	1962-70	1972-79	1983-89	1991-93	TOTAL
North Fork Stillaguamish								
Boulder Ridge	0	300	32,500	10,150	1,000	12,950	2,100	59,000
Deer Creek (partial)	181,142	0	2,173	167,220	68,818	1,700,111	na	2,119,464
Frailey Mountain	0	0	6,820	2,720	na	5,600	0	15,140
Grandview	0	0	3,400	500	na	0	0	3,900
Hell Hazel	27,000	0	5,800	7,400	5,200	3,270	2,200	50,870
Higgins Ridge (partial)	0	0	1,600	218,036	74,435	16,400	7,000	317,471
Squire Creek	0	0	24,220	1,720	na	0	0	25,940
Upper North Fork	0	0	na	23,559	36,458	522,779	na	582,795
TOTAL	208,142	300	76,513	431,305	185,911	2,261,110	11,300	3,174,580
		Chronic	**1948-55**	**1964-70**	**1972-79**	**1980-86**	**1991-92**	**TOTAL**
South Fork Stillaguamish								
Upper South Fork		3,420	15,140	15,065	2,600	18,205	17,770	72,200
Gold Basin		3,600	250,505	503,440	220,620	406,130	224,160	1,608,455
Robe Valley		0	na	2,700	6,270	7,530	2,300	18,800
Stillaguamish Canyon		1,000	1,400	5,070	100	1,700	100	9,370
Canyon Creek		3,600	67,970	117,510	11,984	25,070	54,688	280,822
Jim Creek		0	21,370	39,500	9,890	12,370	9,940	93,070
Burn Hill		0	1,260	3,220	na	740	7,930	13,150
TOTAL		11,620	357,645	686,505	251,464	471,745	316,888	2,095,867
			1941-56	**1960s***	**1970**	**1983**	**1991-95**	**TOTAL**
Mainstem Stillaguamish								
Lower Pilchuck			0	na	500	1,900	0	2,400
Upper Pilchuck			4,330	na	11,000	2,700	200	18,230
Floodplain			0	na	0	200	200	400
Tributary Thirty			4,600	na	13,800	0	4,600	23,000
TOTAL			8,930	na	25,300	4,800	5,000	44,030

Table 9. Landslide delivery by WDNR streamtype (modified from Perkins and Collins 1997).

	WDNR Stream Type											
	1+*	**1***	**2***	**3***	**4**	**5**	**4 or 5**	**Unknown Type**	**No Delivery**	**Delivery Uncertain**	**Total**	**Percent**
Drainage Basin												
Mainstem	2	4	0	2	17	3	0	0	15	0	**43**	**4**
North Fork	0	71	47	185	79	63	29	43	76	32	**625**	**58**
South Fork	16	11	24	69	49	57	2	79	99	6	**412**	**38**
Total	**18**	**86**	**71**	**256**	**145**	**123**	**31**	**122**	**190**	**38**	**1080**	**100**
* = Fish-bearing stream												

Table 10. Land use associations with landslides (Perkins and Collins 1997).

Land Use	Landslides	Percentage
Clearcut	484*	45
Old Clearcut (20-50 years)	70	6
Mature Forest	188	17
Partial Cut	5	0
Road or Railroad Grade	238**	22
Agriculture (uphill from slide)	1	0
Alpine	39	4
Mining (inferred but uncertain)	6	1
Other undisturbed	2	0
Unknown	47	4
Total	1,080	100

* Includes 47 landslides in a mature forest with a nearby clearcut uphill.

** Includes 13 landslides that occurred in a mature forest with a nearby road uphill.

sources (Collins 1997b; Perkins and Collins 1997) (Table 10). (The occurrence of landslides in areas undisturbed by human activities is estimated to be between 21 % and 26 %.)

In an analysis of the lower South Fork, the Forest Service found that when road density increases, an increase in road failures due to high surface runoff results (MBSNF 1996). All of the sub-basins in this area had road densities exceeding this threshold except for Bear Creek and Wiley Creek. In the upper South Fork watershed, areas with high road densities include: the South Fork valley bottom, Mallardy Creek, Beaver Creek, and Coal Creek (MBSNF 1995).

Sediment released from a major landslide in Gold Basin in 1952 is believed to have caused a significant decline in pink salmon production in the South Fork up until the late 1980s when turbidity levels declined (Miller and Somers 1989). Similar events happened at Hazel in the late 1960s, negatively affecting salmon spawning and rearing on the North Fork (Miller and Somers 1989). The 1983 Deforest Creek landslide significantly decreased the available spawning and rearing habitat below the mouth of Deer Creek. Large sediment “waves,” generated by landslides, may influence spawning patterns of chinook (and other salmonids) for a decade or more (Pess and Benda 1994), and reduce the rearing capacity for steelhead (Collins et al. 1994). Sediment flux varies greatly with the seasons and streamflow, with the greatest transport (83% of the annual rate in the North Fork) occurring from November through February (Collins 1997b). More sediment is transported in November than for the time period from February through October.

Channel Morphology

The disconnection of meander bends and the installation of levees and riprap along the mainstem Stillaguamish have altered channel morphology. The harvest of riparian forests and increase in peak flows (discussed later in this document) have also contributed to these changes. Prior to the early 1930s, only 1 km of revetment had been installed in the mainstem channel, but between 1935 and 1941, bank revetments were common (Table 11).

Table 11. Kilometers of riprap bank revetment installed on the Stillaguamish river between the late 1930s and the early 1960s (modified from Collins 1997b).

Channel	Left Bank Revetments	Right Bank Revetments	Total
Mainstem	14.2	9.8	24.0
North Fork	7.9	6.0	13.9
South Fork	2.3	3.7	6.0

Between 1933 and 1991, the mainstem shortened from 37.9 km to 33.9 km, primarily in the vicinity of the Cook Slough-South Slough reach, and in the reach downstream of Arlington. The reach downstream of Arlington also shortened significantly. The active channel narrowed in all reaches from an average of 145 m to 101 m. These changes are most evident in the uppermost stream segment. The result is a 37 % loss (185 ha) of channel area in the mainstem between 1933 and 1991 (Collins 1997b).

The North Fork and South Fork (below Granite Falls) also narrowed between 1933 and 1991 (Collins 1997b). Four possible explanations have been offered: 1) the reclamation of gravel bars for agricultural, residential, and other uses; 2) the passage of two coarse sediment “waves” between 1969 and 1991 in the upper North Fork (Pess and Benda 1994); 3) an increase in peak flows in the North Fork (Collins 1997b); and 4) an increase in sediment from earlier riparian logging (Collins 1997b).

Many of the tributaries to the main channels have experienced widening. More than 75 % of the tributary segments that had experienced widening were associated with some landslide activity within or upstream of the segment. Just less than three-quarters were associated with logging activities in riparian areas within the previous 60 years. Forty percent (40 %) were associated with riparian logging within the previous 20 years. One in thirteen of the affected stream segments lacked an association with either.

In a review of 1964 and 1982 aerial photos, Forest Service personnel found evidence to indicate that significant channel downcutting had occurred in stream reaches throughout the South Fork above Granite Falls. Sediment deposition, associated with this impact, was noted along the lower and middle reaches of the South Fork (RM 34.1 to RM 46.8), Canyon Creek (RM 8.3 to RM 10.0), and south Fork Canyon Creek (RM 1.6 to RM 7.9) (MBSNF 1996). These changes were attributed to timber harvest and road construction between 1950 and 1980.

Gravel Mining

Over the past few decades, several mining operations have removed significant quantities of gravel from the Stillaguamish riverbed. Currently, there are only two companies (Stanwood

Redi-Mix and Smokey Point Concrete) operating in the lower mainstem, though there has been no significant mining activity in the past two years (Stevenson 1999). Salmon can be negatively impacted by mining activities when gravel is removed at a rate faster than it is deposited by the river (Collins 1997a). The streambed downstream of the mining site can be hardened, which can degrade spawning and rearing habitat and change the aquatic invertebrate community. Downstream gravel bars may be diminished for lack of new gravel that can lead to a loss of spawning habitat. Spawning gravels may be reduced in areas where mining activities expose bedrock or other solid substrates. The groundwater table may be lowered in a localized area which can reduce streamflows in the summer months or reduce groundwater recharge to off-channel habitat.

Vegetation removal, associated with gravel mining activities may also harm salmon. The elimination of shaded areas can contribute to an increase in water temperature. The complexity of habitats within the channel may be simplified as a result of the loss of large woody debris. There may be a loss of nutrients, decreasing stream productivity. Additionally, a change in local flows of sediment and water may lead to the degradation, reduction, or elimination of spawning and rearing habitat.

Between 1966 and 1991, the estimated average volume of sand and gravel removed from the mainstem Stillaguamish exceeded the estimated rate of deposition, particularly between 1986 and 1991 (Collins 1992, 1997b). The rate of mining increased from about 22,962 m^3/yr in 1962 to 45,924 m^3/yr in 1970, to 68,886 m^3/yr in 1980. Gravel mining peaked in 1989 at about 145,426 m^3/yr. A total of 1.6 million cubic meters of sand and gravel was removed from the river channel between 1962 and 1991, averaging about 53,578 m^3/yr. The estimated off-take averaged 41,332 m^3/yr between 1962 and 1985, and about 103,329 m^3/yr between 1986 and 1991. These figures do not include undocumented mining activities. For comparison, the rate of gravel deposition (in the absence of mining) was estimated to exceed 20,666 m^3/yr downstream of Interstate 5, and to exceed 28,320 m^3/yr upstream of the freeway, totaling over 48,986 m^3/yr (Collins 1997b). A permit is currently pending for an annual off-take of 49,751 m^3.

Water Quality

Maintaining good water quality is critical to protecting salmonids and other organisms in aquatic ecosystems. Natural environmental variations and the connections between many water quality parameters make it difficult to pinpoint a single specific factor that might be blamed for poor salmonid returns. Collectively though, these practices degrade the water and habitat upon which salmon and other living organisms depend. In the Stillaguamish watershed, the primary water quality problems for salmon include: fine sediment loads, high stream temperatures, low oxygen levels, and high total suspended solids. Toxic chemicals may also be a problem to fisheries resources. They often are associated with urban land uses. Water quality problems exist in both freshwater and marine habitats.

The Washington Department of Ecology (WDOE) has been monitoring water quality in the Stillaguamish since 1982. Violations of water quality standards for temperature, dissolved oxygen, fecal coliform and pH at the five ambient monitoring stations are shown in Table 12.

Table 12. Water quality violations detected by WDOE since 1982.

Station Location	Parameter	Total Samples	Violations	Percent Exceedences
Stillaguamish River at Silvana	Temp	84	5	6
	DO	84	0	0
	FC	80	7	9
	pH	80	3	4
South Fork Stillaguamish at Arlington	Temp	72	2	2
	DO	72	0	0
	FC	68	6	9
	pH	68	2	3
South Fork Stillaguamish near Granite Falls	Temp	12	0	0
	DO	12	0	0
	FC	11	1	9
	pH	12	0	0
North Fork Stillaguamish near Cicero	Temp	72	0	0
	DO	72	0	0
	FC	67	2	3
	pH	68	2	3
North Fork Stillaguamish near Darrington	Temp	12	0	0
	DO	12	0	0
	FC	11	1	9
	pH	12	0	0

The number of reported water quality violations in this watershed are increasing as evidenced by Washington State's growing number of "303(d)" listings in the Stillaguamish drainage (Map 10; Table 13). As defined by the federal Clean Water Act, a water body listed on the state's 303(d) list is not expected to attain water quality standards after implementation of technology-based pollution controls (WDOE 1997). Typical control measures include discharge permits for point sources and best management practices for nonpoint sources. The Washington Department of Ecology will eventually implement a Total Maximum Daily Load (TMDL), defined as the sum of all pollutant loads to a water body, for each stream or lake on the 303(d) list.

An ambient water quality monitoring program was initiated by the Stillaguamish Tribe in 1993. This and other monitoring efforts by the Tulalip Tribes, Snohomish County, and the WDOE have generated a database to help assess changes in water quality and quantity. A portion of the Stillaguamish basin water quality data is presented here to illuminate factors and trends contributing to degradation of water quality.

Nonpoint source pollution is a major cause of water quality pollution in the Stillaguamish. Nonpoint pollution comes from any dispersed land-based or water-based activity. The *Stillaguamish Watershed Action Plan* identified four major land uses contributing nonpoint

Table 13. Current and candidate 303(d) listings (WDOE 1998).

Tributary	Parameter
Mainstem	Fecal coliform, temperature, **dissolved oxygen**, **ammonia-N, arsenic, copper, lead, nickel**
Fish Creek	Fecal coliform
Harvey Creek	**Fecal coliform**
Jorgenson Slough (Church Creek)	Fecal coliform
Pilchuck Creek	**Dissolved oxygen, temperature**
Portage Creek	Dissoved oxygen, fecal coliform, turbidity
Old Stillaguamish River	Fecal coliform
North Fork	Fecal coliform, **temperature**,
Deer Creek	Temperature
Higgens Creek	Temperature
Little Deer Creek	Temperature
South Fork	Fecal coliform, pH, **dissolved oxygen**, Temperature
Jim Creek	**Fecal coliform**

Bold items are candidate (1998) listings.

source pollutants: agricultural practices, onsite sewage disposal, development and urban runoff, and forest practices (Snohomish County Surface Water Management 1990). In a 1989 water quality study of the Portage Creek sub-basin, nonpoint source pollutants were determined to be negatively impacting fish habitat in 49 % of the stream segments studied (Puget Sound Cooperative River Basin Team et al. 1990).

Freshwater

Temperature. High water temperature is another significant water quality problem in the Stillaguamish. Human-caused increases in stream temperature are believed to be most directly influenced by the removal of streamside vegetation and by channel widening (due to high sediment loads) (Miller and Somers 1989). High temperatures can result in areas where there is a loss of deep pools and where the stream has become shallow. Stream temperatures may also be elevated in areas with high volumes of nutrient-rich runoff from agricultural lands and other sources as a result of heat-generating bio-chemical reactions.

The optimal temperature range for salmon is 12-14^{0}C, with lower temperatures preferred for spawning. Lethal temperature levels for adults are in the range of 20-25 ^{0}C. High temperatures can influence the immune system of chinook making them more susceptible to pathogens. In several cases river temperatures have been implicated in increased mortality rates in adult chinook prior to spawning. Increased water temperatures may give non-native warmwater species (such as pumpkinseeds and largemouth bass) a competitive edge over native salmonids (Nelson et al. 1997). These species may compete for space and food resources with stream type chinook juveniles.

Temperature, measured by continuously recording temperature loggers, can record the daily fluctuations and the extent of time that temperatures are stressful to salmon. A temperature study conducted by the Stillaguamish Tribe, the Tulalip Tribes, and Snohomish County in 1996 showed that temperatures in the mainstem and select tributaries fell into stressful ranges during high percentages of the time (Table 16) (Thornburgh 1999).

Table 14. Percentage of the total time from June 1996 through September 1996 that temperatures were recorded at preferred, stressful and potential lethal ranges for salmonids (Thornburgh 1999).

Location	Preferred (< 13 degrees C)	Stressful (13 to 20 degrees C)	Potentially Lethal (> 20 degrees C)
Mainstem			
Mainstem at I-5	16	68	16
Portage Creek at Burn Road	78	22	0
Portage Creek at 212th Bridge	34	66	0
Church Creek at Jensen Road	43	57	0
Pilchuck Creek at mouth	13	77	10
North Fork			
North Fork at C-post Bridge	48	52	0
North Fork at Smokes farm	31	61	8

Data from the Stillaguamish Tribe's monthly water temperatures readings from June 1994 through September 1998 also indicate high temperature problems in several locations in the watershed (Table 15) (Klopfer 1999). High water temperatures have also been measured in the lower South Fork and lower Jim Creek (Tulalip Tribes 1989).

Dissolved Oxygen. Salmon eggs show moderate impairment at dissolved oxygen levels of 8 mg/l or less while adult salmon are moderately impaired at or below 5 mg/l. Monthly monitoring data from the Stillaguamish Tribe and SWM show that the dissolved oxygen concentrations in the mainstem Stillaguamish usually fell within the preferred ranges for salmon during the 1991 to 1998 survey period. Dissolved oxygen in the tributaries to the Stillaguamish River usually meet or exceed the standard of 8.0 mg/l. Monitoring in Pilchuck, Church, and Fish Creeks and Tributary 30 since 1991 by the Tulalip Tribes and Snohomish County shows few violations of the dissolved oxygen standard. However, dissolved oxygen in lower Portage Creek ranges from 4 to 6 mg/l during most of the summer.

Fecal Coliform. The presence of fecal coliform bacteria indicates that human and/or animal wastes are entering the river system. Fecal coliform, by itself, is not necessarily detrimental to fish. However, high levels of fecal coliform are generally associated with high concentrations of nutrients such as nitrate and phosphorus. High concentrations of nutrients can feed algae and

Table 15. Total number of days of water temperature readings measured on a monthly basis from June 1994 through September 1998 (Klopfer 1999).

Location	Preferred (< 13 degrees C)	Stressful (13 to 20 degrees C)	Potentially Lethal (> 20 degrees C)
Mainstem			
Mainstem at Arlington	0	1	1
Mainstem at Silvana	0	4	3
Pilchuck Creek at mouth	0	5	2
Portage Creek at Burn Rd.	5	10	0
North Fork			
Boulder River	7	3	0
Deer Creek at mouth	2	6	3
Montague Creek	3	9	0
North Fork at C-post Bridge	1	1	0
North Fork at Whitman Bridge	2	10	0
Squire Creek	9	4	0
Whitehorse Bridge (Swede Heaven)	4	10	0
South Fork			
Canyon Creek at Masonic Park	3	5	0
Jim Creek at mouth	1	0	1
South Fork at Jorden Road	5	6	3
South Fork at Twin Rivers Park	0	0	1

generate algal blooms, which in turn, can lead to a decrease in dissolved oxygen levels. The two major sources of fecal coliform in the Stillaguamish watershed are commercial and non-commercial farms and leaking or inadequate septic systems. The contribution from municipal sewage treatment plants is not fully understood. High fecal coliform are a problem in the mainstem, North Fork and South Fork, in several mainstem tributaries and sloughs, and in Jim Creek. Port Susan is in a restricted shellfish harvest area as a result of fecal coliform bacteria.

Conductivity. Conductivity measures dissolved ions in the water. High conductivity values can indicate the presence of groundwater springs that are important to fish production. Conductivity values in surface waters can also change from impacts due to urbanization. An increase in conductivity values can be an indicator of increased runoff from fertilizers, land clearing, deicing salts, and metals contained in road runoff. Snohomish County finds the lowest conductivities (around 50 umhos/cm) in the least developed watersheds and higher conductivities (from 100-200 umhos/cm) in areas with more commercial, residential, or agricultural development (Thornburgh 1999). From 1994 through 1998, Snohomish County found a statistically significant increase in conductivity in the mainstem Stillaguamish, with most of the increase occurring after 1996. The mean conductivity in the mainstem at Arlington was 41 from 1994 through 1996, and 54 from 1997 through 1998. In the mainstem at Marine Drive, the mean conductivity increased from 49 to 75 during the same time period. This increase in conductivity is an indicator of a general increase of land use impacts to water quality in the Stillaguamish.

Toxic chemicals. Since 1994, the Washington Department of Ecology has been measuring metals six times per year in the Stillaguamish and other select rivers in Puget Sound (Puget Sound Water Quality Action Team, 1998). Concentrations of mercury and copper in excess of state criteria have been detected in the Stillaguamish watershed during the course of this monitoring program. Sources of mercury are usually industrial. Copper is found in nature as a native metal and as a component of certain minerals (Thomas et al. 1997). Oxides and sulfates of copper are also used in pesticides, paints and wood preservatives. Traces of another toxic chemical (4-methylphenol) have also been detected at one site in the lower mainstem in a sediment sample collected by the Tulalip Tribes (Halpin 1992). This chemical is associated with woodwaste and treating facilities. The potential impact of these toxic chemicals to salmonids in the Stillaguamish has not been studied.

Role of Groundwater Recharge to Surface Water Bodies

Groundwater and surface water flows are inextricably linked, particularly in the late summer months, when precipitation is relatively low. Groundwater discharge to streams plays a particularly important role in maintaining streamflows for salmon at these times. However, this is the time of year when groundwater withdrawals for domestic and agricultural purposes have the most impact on base flows and when pollutants contributed by groundwater may be most damaging.

The US Geological Survey recently completed a regional groundwater study of western Snohomish County (Thomas et al. 1997). Generally speaking, the ground-water system in western Snohomish County has experienced no appreciable widespread contamination. However, localized small-scale impacts are unknown. Numerous groundwater wells north of Granite Falls have experienced severe arsenic contamination (WDOE 1994). Arsenic is ubiquitous in nature, and most forms are toxic to mammals (Thomas et al. 1997). The Stillaguamish Tribe has conducted some limited testing for arsenic in the South Fork; this data suggests that there is currently not a problem. The Stillaguamish watershed does not have an ambient monitoring program for groundwater to systematically evaluate potential impacts to surface waters (WDOE 1994).

Hydrology

Over thousands of years salmon have adapted to the natural, highly variable fluctuations in streamflow that characterize Puget Sound rivers. They have developed survival strategies to withstand floods during the fall, winter and spring, and low flows during the summer months. However, human land use activities have significantly altered these natural streamflow cycles. Clearcuts, roads, and sub/urbanization tend to increase peak flows and the "flashiness" of streams. The loss of wetland habitats can also contribute. Activities that impede the land's ability to absorb rainwater into underlying aquifers (through an increase in impervious surface area) may cause perennial streams to experience lower than normal flows or even dry up. Low flow situations may also be caused by excessive water diversions or groundwater withdrawal typically associated with agricultural and municipal land uses. Low flows have been partially attributed to increases in sedimentation in the Stillaguamish (Miller and Somers 1989).

Salmon Streamflow Study

A streamflow study to establish instream flows for several species of salmon was initiated in the Stillaguamish river in the early 1980s (Embrey 1987). Sponsored by the Stillaguamish Tribe and U. S. Geological Survey, the study evaluated selected sites on the mainstem, North and South Forks, and four tributary streams. The results were used to identify potential target streamflows for three life stages of coho, two life stages of summer chinook, one each for pink and chum salmon, and four of winter steelhead (Table 18). This study was not completed nor officially agreed upon for use in setting streamflows.

Table 16. Streamflow (cfs) study results for select salmonids in the Stillaguamish watershed (modified from Embry 1987).

Species	Life Stage	Mainstem	Pilchuck Cr.	North Fork	Squire Cr.	South Fork	Jim Cr.	Canyon Cr.
Chinook	Fry	600	50 to 170	150 to 400	50 to 170	70 to 300	50 to 170	50 to 170
	Adult (spawning)		170 to 750	500 to 1300	170 to 750	300 to 900	170 to 750	170 to 750
Coho	Fry		20 to 80	50 to 200	20 to 80	50	20 to 80	20 to 80
	Juvenile	400	35 to 130	50 to 200	35 to 130	50 to 100	35 to 130	35 to 130
	Adult (spawning)		90 to 350	500 to 700	90 to 350	140	90 to 350	90 to 350
Pink	Adult (spawning)	800	70 to 300	300 to 600	70 to 300	100 to 1200	70 to 300	70 to 300
Chum	Adult (spawning)			200 to 600	70 to 450	100	70 to 450	
Steelhead	Fry		20 to 70	50 to 140	20 to 70	45 to 1600	20 to 70	20 to 70
	Juvenile	1000	70 to 350	300 to 500	70 to 350	200 to 500	70 to 350	70 to 350
	Adult	2000	170 to 500	500 to 1170	170 to 500	300 to 900	170 to 500	170 to 500
	Adult (spawning)		130 to 400	800 to 900	130 to 400	250 to 1200	130 to 400	130 to 400

Peak Flows

Peak streamflows are commonly recorded on the west side of the North Cascades in late autumn and winter, typically from rain-on-snow events. More than one-third of the Stillaguamish basin is in the rain-on-snow area, between 305 and 914 m in elevation. Accordingly, the Stillaguamish watershed may be particularly sensitive to peak flows, even in a natural state, because much of the watershed is relatively low in elevation, and thus more subject to this phenomenon (Pess 1999).

Excessively high stream flows can be detrimental to salmon when they cause scouring to occur in gravel beds containing salmon eggs. Also, the scoured substrate may be redeposited over downstream salmon redds, smothering the eggs. Salmon species which spawn just prior to the late fall/winter flooding season (pinks, chum, and chinook) are most vulnerable to the effects of peak flow events. Winter coho rearing habitat can also be negatively affected by peak flows that flush out normally quiet waters (such as beaver ponds and small tributary streams). High flows can also flush large woody debris out of stream channels, as is the case in Canyon Creek (MBSNF 1996).

The Stillaguamish watershed naturally exhibits a decadel-scale fluctuation in peak flows indicative of regional-scale climatic patterns (Collins 1997b). However, streamflow measurements from the North Fork also show a systematic increase in peakflows, superimposed on the decadel-scale fluctuations. Because this trend is not found in the South Fork streamflow data, it suggests a relationship between land use activities more prevalent in the North Fork. Between 1928 and 1995, ten of the largest peak flows recorded by the North Fork gage occurred between 1980 and 1995. A “slight overall upward trend” in peakflows on Jim Creek (1938 to 1968 record) and Pilchuck Creek (1953 to 1989 record) was also measured (Collins 1997b).

Impervious surface. Impervious surface is a term commonly used by hydrologists to refer to hard surfaces (such as roads, rooftops, parking lots) that shed rather than absorb precipitation. Urban areas, clear-cuts and hardened turf areas produce conditions that impede the land’s ability to soak up rainwater. When this occurs, the increased volume of stormwater runoff often leads to more severe and more frequent flooding.

In urban King County, alterations in streamflow begin to appear when a drainage has as little as 3 % impervious surface (Booth and Jackson 1997). Using a satellite image, Snohomish County estimated that the city of Arlington had approximately 30 % impervious surface in 1992 (Thomas et al. 1997). This suggests that the surface hydrology of the local streams in this urbanizing area has already been significantly altered. No impervious estimates are available for other urban areas in the watershed. However, the University of Washington is in the process of completing a land cover map of Puget Sound that will include impervious surface estimates for the Stillaguamish (Booth 1999).

Low Flows

Low streamflows during the summer months are a natural condition for some streams. But for others, low flows occur as a result of human land use impacts, and are a major concern because of the negative effect to salmon and other aquatic life. Low streamflows typically occur from July through September because there is minimal precipitation during these months. In addition to the causes already discussed, the cumulative effect of groundwater withdrawals can also contribute to low flow conditions and loss of wetlands. Long-term declines in the water table, and in turn, discharge to streams, can occur when the amount of water withdrawn exceeds the system's ability to replenish itself.

When low flows occur in salmon-bearing streams they can cause fish to be stranded and limit or impede salmon migration. Low flows can also contribute to a decrease in rearing space, a decrease in dissolved oxygen, an increase in water temperature, and an increase in the concentration of pollutants, if present. The low summer flows also permit saline waters from the Sound to move further upstream than in historic times when summer flows were at least 5.7 m^3/s (ACOE 1997).

Summer low flows and high temperatures negatively impact adult chinook migration and adult holding pools, especially in the slower moving areas (sloughs) in the lower mainstem (WDFW and WWTIT 1994). During the spawning period, low flows were directly correlated to coho smolt yield in Church Creek (Nelson et al. 1997). Severe summer low flow conditions in 1987 resulted in a substantial reduction in coho smolt production in 1988 and a low return of adult coho in 1989. Other known low flow problem areas include: the North Fork (from Oso to Whitehorse), Pilchuck Creek, Harvey/Armstrong Creek, Tributary 30, Jim Creek, and the lower mainstem at the weir (ACOE 1997; Nelson 1999; Stevenson 1999).

Wetlands

Wetlands are critical to a properly functioning watershed. Wetlands provide several functions that directly impact salmonids: sediment storage, flood flow storage and desynchronization, temperature maintenance, nutrient removal and transformation, groundwater recharge, and refuge and rearing habitats. A wetland does not have to be directly connected to a stream to support these functions.

The Stillaguamish watershed hosts three wetland types, each of which may perform any or all of the above-mentioned functions. Riverine wetlands are contained within a stream's floodplain and are directly adjacent to the stream. Natural and human-induced conditions may disconnect salmon access to riverine wetlands under certain flow conditions. Depressional wetlands are located in low-lying areas that collect surface water runoff and precipitation. Topographical wetlands form where seeps and springs emerge at the base of slopes.

A recent wetland study by the Washington Department of Ecology estimated that the Stillaguamish watershed historically supported 11,795 ha of wetlands (Gersib 1997) (Map 11). The current total wetland area is estimated to be 2,537 ha, indicating that 78 % of historic wetlands have been impacted or lost. This study will help to identify and prioritize restorable wetlands (that have been degraded by draining, filling, diking, and timber harvest) for the purpose of improving salmon habitat.

Riverine wetlands between River Miles 20 and 36 on the main channel of the North Fork offer the best opportunities for restoring wetlands that will help to improve sedimentation and provide streamflow attenuation. Partially functioning wetlands in the Squire, Fortson, Hazel, and other sub-basins in this drainage also have high potential for restoration. Many of the wetlands in the upper South Fork drainage occur on federal land and are generally protected from future loss. Important tributary wetlands in this area are located in the Cranberry, Tiger and Big Four stream systems.

The lower South Fork and mainstem Stillaguamish have a large number of wetlands that have degraded by agricultural and urban land uses. The Portage Creek and Church Creek sub-basins are examples of stream systems that have experienced a large loss of functioning wetland area. The commercial development that has occurred in these areas prevents these wetlands from ever being restored. There are historic wetland sites that do offer promise for improving salmon habitat. The depressional wetlands that are found in the floodplain of the lower Stillaguamish are

important to maintaining groundwater flow to the river during low precipitation months. There are many riverine wetland sites that have been disconnected by historic flood control projects. These sites are important to streamflow attenuation and sediment storage, and provide important rearing and refuge areas for juvenile salmonids. An interdisciplinary team of local, state and federal scientists and engineers are evaluating potential restoration projects in this area.

Beaver Ponds

The broad, glacially carved valley through which the Stillaguamish flows contains many small streams ideally suited to beaver. Beaver ponds provide important rearing habitat for coho and other juvenile salmonids (Pollock and Pess 1998). Beaver ponds are used for summer rearing and for overwintering, with the latter use believed to be particularly important (Pess 1998). Stream systems with extensive beaver ponds and wetlands that are accessible to coho, have been recorded to have significantly higher smolt yields than other systems in the Stillaguamish (Nelson et al. 1997). These include Tiger, Fortson and McGovern Creeks. Fortson and Tiger Creeks accounted for 50 % to 75 % of the coho smolts trapped. Smolt yields from Tiger and Fortson Creeks accounted for 5.9 % of the total smolt production in the watershed. Over 90 % of the surface area in these creeks is comprised of lakes, beaver ponds and wetlands. Fortson and McGovern Creeks are also believed to provide important refugia for juvenile coho migrating from other areas in the watershed. Wetland complexes associated with Trout, Marsh and Hawthorn Creeks (all located in the lower South Fork) also provide high quality habitat important to fish production (MBSNF 1996).

Beaver pond habitat within the anadromous zone of the Stillaguamish watershed has been reduced by 81 % to 96 % from historic levels (Pollock and Pess 1998). The total estimated historic area of beaver ponds was between 2.37 km^2 to 11.84 km^2. It is now estimated to be 0.44 km^2. Most of the historic beaver pond loss is due to trapping, in combination with the conversion of forested streamside areas to agricultural (Pess et al., in press). Recreational trappers annually harvest between 200 and 300 beaver from the Stillaguamish watershed.

Lakes

Snohomish County Surface Water Management administers a volunteer lake-monitoring program in nine of the largest lower elevation lakes in the Stillaguamish. Seven of these lakes are in the mainstem or Port Susan drainages. The goal of the program is to identify long-term water quality trends and problems around lakes as they occur. The water quality data has helped the County to assess the natural and human-induced impacts on the aging (eutrophication) process of the lakes (Table 17). As nutrient and sediment levels increase a lake transitions from oligotrophic to mesotrophic to eutrophic status. Eutrophication is a natural process that can take hundreds or thousands of years to occur, but human induced impacts can greatly accelerate this process. Generally speaking, the eutrophication of lakes results in a change in the composition of the fish community. Salmonids and other species which require cool, clear, well oxygenated water are gradually replaced by warmwater species that are more tolerant of nutrient-rich low oxygen conditions (Wetzel 1983).

Lakes are affected by many land use activities. Poor water quality from leaky septic systems, motor boats, fertilizers, stormwater, and other sources can degrade these water bodies. A lack of or insufficient riparian buffers can lead to increases in water temperature. Shoreline habitat may be lost or degraded by the construction of docks, bulkheads and other facilities. Invasive exotic species may outcompete native vegetation used by fish. Some introduced fish may have the potential to hybridize with or outcompete native salmonids. There has been no systematic study of the role of lakes in providing salmonid habitat in the Stillaguamish watershed, but only a few are found in the anadromous zone.

Table 17. Trophic status of lakes monitored by Snohomish County Surface Water Management (Williams 1999).

Lake	Drains To	Via WRIA ID	Barrier	Area (ha)	Shore (km)	Vol. (af)	Max. Depth (m)	Bulkhead (Percent)	Status
Rowland	Port Susan	5.0457	IC	1.4			18.3		E
Howard	Lake Martha	5.0455	IC	10.5	1.4	790.0	15.2	50.0	M
Martha	Port Susan	5.0455	IC	25.1	2.9	2000.0	21.3	49.0	NA
Ki	Fish Creek	5.0048, 5.0047	IC	38.9	3.0	3300.0	21.3	71.0	O
Bryant	Armstrong Cr.	5.0129	IC	8.5	1.4	520.0	7.0		ME
Armstrong	Armstrong Cr.	5.0126	PC	12.1	1.8	450.0	7.3	36.0	ME
Sunday	Jackson Gulch	5.0061	IC	15.4	2.1	370.0	6.1	13.0	E
Riley	Jim Creek	5.0322	?	12.1		670.0	13.7	0.0	M
Spring	Unnamed	5.0355	PC	3.8					M

Trophic Status: E - eutrophic, ME - meso-eutrophic, M - mesotrophic, O - Oligotrophic

Bulkhead: Percent of homes with bulkhead on the shoreline

Barrier status of draining tributary: IC - impassable casade; PC - passable cascade

Nearshore and Estuarine Habitat

Nearshore habitats lie along the shoreline of marine areas, and include the strip of shallow water and land immediately adjacent to the shoreline (Broadhurst 1998). More specifically, nearshore habitats include "intertidal and shallow subtidal marine waters, unvegetated zones, rocky shores, sand- and mudflats, and eelgrass, kelp, and intertidal algal beds" (Lynn 1998). The Stillaguamish watershed, as defined by WRIA 5 boundaries, includes 35.4 km of marine shoreline (Broadhurst 1998). This is less than 1 % of the total nearshore habitat contained within the 19 watersheds of Puget Sound, and 2.2 % of the total nearshore habitat within the five watersheds defined to be within North Puget Sound (Nooksack, Skagit, Stillaguamish, Island, and San Juan).

Generally speaking, the nearshore habitat associated with the Stillaguamish is in considerably better condition than the urbanized nearshore areas of Puget Sound. Between 1990 and 1996, two Hydraulic Project Approvals (HPAs) were issued for bulkheads in the nearshore areas contained within this area (Broadhurst 1998). (An HPA is required for construction and other work that uses, diverts, obstructs or changes the natural flow or bed of fresh or salt waters.) Residential development is the primary threat to nearshore habitats in the Stillaguamish watershed. Some potentially destructive activities commonly associated with this residential land use include: shoreline armoring (bulkheads and seawalls), boat docks and piers, failing septic systems, fertilizers from lawns, and stormwater outfalls (Broadhurst 1998). The nearshore habitats associated with this watershed that are outside of the estuary appear to be in relatively good condition, however there are no protection measures in place to ensure that they stay that way (Murray 1998). Nearshore habitats could be protected through acquisition, public education, regulations, and zoning. The Washington Department of Natural Resources is in the process of inventorying the nearshore habitats of Puget Sound using remote sensing and geographic information systems (Mumford 1999). A more detailed inventory of forage fish spawning areas, shoreline development, vegetation, and geomorphic structures (such as feeder bluffs and barrier beaches) is warranted.

Salmonid Use of Nearshore Habitats

There are currently no data directly linking nearshore habitat destruction with a quantifiable loss of fisheries resources of Puget Sound (Thom and Shreffler 1994). The Washington Department of Fish and Wildlife conducts marine salmon surveys along the shoreline of north Puget Sound in select index areas, but these surveys are primarily oriented towards juvenile pink and chum salmon. All species of juvenile salmon use nearshore habitats in Puget Sound at either the fry and/or smolt life stages (PSWQA 1990; Levings and Thom 1994). Returning adult salmon also use nearshore habitats. In a distributional study of nearshore fish use in Puget Sound, chum salmon and coho salmon occurred exclusively in north Puget Sound study sites (Wingert and Miller 1979).

Bottom-dwelling. In a late 1970s nearshore fish survey, juvenile chum and pink salmon and adult chinook salmon were of the ten most common demersal (bottom-dwellng) species encountered in beach seines in the San Juan Island study sites, while juvenile and adult chinook salmon and juvenile sockeye salmon were of the ten most common species encountered in the eastern mainland sites of north Puget Sound (Miller et al. 1977). Gravel habitats supported the highest mean species richness, fish density, and standing crop. The mud/eelgrass, sand/eelgrass, and cobble habitats followed with respect to these variables. Outmigrating juvenile pink and chum salmon were observed in gravel habitats in North Sound in early summer. Juvenile chum were also found in sand/eelgrass habitats in early summer, with coho entering the habitat in late summer.

Shallow water. Juvenile chinook, chum and coho salmon were of the ten most common neritic (shallow water) species encountered by tow nets in the Miller et al. (1977) survey. Catches of neritic juvenile salmonids were consistently greater at the eastern North Sound study sites, than at the San Juan site. Out-migrating juvenile chinook salmon were found in the rocky/kelp habitat from late spring through early fall, in the sand/eelgrass habitat, and less commonly in the cobble habitat. Juvenile chum and coho salmon appeared in the gravel habitat in late spring through early fall. Juvenile chum and pink salmon were mostly encountered in early spring through July, while coho and chinook were encountered from mid- to late spring into early fall. Juvenile pink were found in the largest numbers in the shallow waters of north Puget Sound from June through August, particularly in the sand/eelgrass and mud/eelgrass habitats. Juvenile chum were present from May through August. Juvenile coho were found throughout the shallow waters of North Sound from April through October. Sockeye salmon were infrequently encountered in the shallow waters, probably because they migrate more quickly into deeper waters upon entering salt water. When they were found, it was usually only in northeastern Puget Sound from May through September.

Stillaguamish Estuary

As discussed previously in this document, the historic Stillaguamish estuary habitat has declined approximately 85 %. In more recent decades the estuary has been increasing in size, possibly as a result of upland sediment impacts. Between 1947 and 1974, the Stillaguamish delta increased from 50.5 km^2 in 1947 to 64.8 km^2 in 1974, a 28 % change (Thom and Hallum 1991). The types of habitat that have formed as a result of this accretion have not been inventoried or studied but they appear to be predominantly sand and mud flats which are of less value to salmon than the original salt marsh habitat.

Salmonid Use of Estuaries

Estuaries provide the habitat for juvenile salmon to make a physiological transition between freshwater and saltwater environments and for adult salmon to transition between saltwater and freshwater. They also export nutrients in the form of organic carbon, which are important to the invertebrates upon which salmon feed. Hence, they provide an important forage location (Simenstad et al. 1982). Estuaries also support vegetation that helps to shelter salmon from predators (Simenstad et al. 1982). The blind channels found in the salt marshes of estuaries provide critical rearing habitat for juveniles, particularly chum, chinook, and pink (Collins 1997b). Chum salmon normally migrate to the estuary shortly after emerging from spawning gravels, and adapt to elevated salinity quickly (Thom and Shreffler 1994). Hence, chum fry are adapted to use the middle and lower portions of the estuary. Most chinook fry rear in freshwater for several months before migrating to the estuary, and tend to rear for prolonged periods in the upstream edge of the estuary. Some distribution and abundance data are available for Skagit Bay immediately north of the Stillaguamish (Table 18) (Monaco et al. 1990).

Little specific information is available on salmonid use of the Stillaguamish estuary. During a tagging feasibility study, Kirby (1994) captured the largest number of chinook juveniles in Hat Slough near the mouth. Residence time at the north end of Port Susan (Triangle Cove) by juvenile chinook occurred from April through the end of May (Beauchamp et al. 1987).

These salinity preferences may be highly variable depending on freshwater inflow, wind, and tides. The placement of each species in a salinity zone was determined by where they where actually observed or captured. The abundance estimates are relative to other species found in that estuary. Table 19 displays the general timing and abundance of salmon using the Skagit estuary. Chum and chinook salmon are more abundant because they are estuarine-dependent. They rely on the detrital food web present in this habitat type and the survival benefits accrued by residency (Levings and Thom 1994). Juvenile pink, coho, and sockeye salmon have shorter residence times in estuaries; they tend to depend more on marine foreshores, including kelp beds.

Generalized estuary habitat correlations for the salmonids discussed in this report are presented in Table 20, as modified from the Estuarine Habitat Assessment Protocol developed by Shreffler and Thom (1993).

Table 18. Spatial distribution and relative abundance of salmonids in the Skagit Bay estuary (modified from Monaco et al. 1990).

		Salinity Zone		
Species	**Life Stage**	**Tidal Fresh**	**Mixing**	**Seawater**
Cutthroat trout	Adults	C	C	C
	Juveniles	C	C	C
Cutthroat trout (kelts)	Adults	C	C	C
	Juveniles	N	N	N
Summer steelhead	Adults	C	C	C
	Juveniles	C	C	C
Winter steelhead	Adults	C	C	C
	Juveniles	C	C	C
Coho salmon	Adults	A	A	A
	Juveniles	A	C	C
Fall chinook	Adults	A	A	A
	Juveniles	A	A	C
Spring chinook	Adults	A	A	A
	Juveniles	A	A	C
Chum	Adults	H	H	H
	Juveniles	H	H	H
Pink	Adults	H	A	A
	Juveniles	H	H	H
Sockeye	Adults	R	R	R
	Juveniles	R	R	R
H - Highly Abundant; A - Abundant; C - Common; R - Rare; N - Not Present				

Marine Water Quality

Stratification. Port Susan is one of several marine areas routinely sampled as part of the Washington Department of Ecology’s Marine Waters Monitoring Program (Puget Sound Water Quality Action Team, 1998). The habitat quality of marine waters are characterized by analyzing the stratification of the water column (the layering of the water according to temperature and salinity changes) and by measuring dissolved oxygen, turbidity, and the availability of sunlight below the water surface. Port Susan was found to be persistently stratified, mainly because it is a semi-enclosed area that is directly influenced by freshwater inflow. The bay also has exhibited dissolved oxygen concentrations below 5 mg/l. Biological stress typically occurs when dissolved oxygen concentrations fall below this threshold. When oxygen concentrations drop to 2 mg/l some organisms may perish. The potential impacts of saltwater stratification on salmonids in Port Susan have not been studied.

Table 19. General timing and relative abundance of salmonids in the Skagit Bay estuary (modified from Monaco et al. 1990).

		Month											
Species	**Life Stage**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Cutthroat trout	Adults	C	C					C	C	C	C	C	C
	Juveniles			C	C	C	C	C	C	C			
Cutthroat trout (kelts)	Adults			C	C	C	C						
	Juveniles	N	N	N	N	N	N	N	N	N	N	N	N
Summer steelhead	Adults				C	C	C	C	C	C	C	C	
	Juveniles			C	C	C	C	C					
Winter steelhead	Adults	C	C	C	C	C	C					C	C
	Juveniles			C	C	C	C	C					
Coho salmon	Adults	C											
	Juveniles							C	C	A	A	A	C
Fall chinook	Adults							C	A	A			
	Juveniles	C	C	C	A	A	A	C	C	C	C	C	C
Spring chinook	Adults			C	C	A	A	C	C				
	Juveniles	C	C	C	A	A	A	A	C	C	C	C	C
Chum	Adults								A	A	A	H	A
	Juveniles		C	A	H	H	A	C	C				
Pink	Adults							C	A	A	H	A	
	Juveniles		A	H	H	H	A						
Sockeye	Adults						R	R	R	R			
	Juveniles				R	R	R						

H - Highly Abundant; A - Abundant; C - Common; R - Rare; N - Not Present

Table 20. Estuary habitat use by salmonid species (modified from Shreffler and Thom 1993).

	Upland Freshwater---							**Open Saltwater**
Species	**Emergent Marsh**	**Mudflat**	**Sandflat**	**Gravel/Cobble**	**Eelgrass**	**Soft Substate**	**Hard Substrate**	**Water Column**
Chinook Salmon	X		X					X
Chum Salmon	X	X			X			X
Coho Salmon				X				X
Pink Salmon				X			X	
Steelhead								X
Dolly Varden				X				
Cutthroat Trout	X			X				

Fecal Coliform. Port Susan is classified as a restricted shellfish harvest area due to high fecal coliform bacteria from agricultural nonpoint source pollution and discharge from sewage treatment plants (Washington Department of Health 1997).

Temperature. High water temperatures have been recorded in the lower Stillaguamish estuary when low flow streamflows and high summer temperatures coincide. Flood tides bring heated marine waters from shallow mud flats back into the estuary increasing the likelihood of disease, smolt stress, and migration blockage. Water temperatures above 21 º C are frequent in this estuary.

These conclusions are based on data collected by temperature loggers placed at two sites in Hat Slough and at one control site near Kayak Point from May through September 1998. The Kayak Point site represented near open water surface temperature. The temperatures recorded at this station on July 23, 1998 ranged from 12.9 º C to 19.4 º C in an eight-hour period. The second logger was located in the mud flats of the west branch of Hat Slough which is currently the second largest discharge outlet for the Stillaguamish River. The temperature at this location for the same time period ranged between 19.9 º C and 30.9 º C. The third site was located in the south branch of the Hat Slough estuary area. Here the temperature ranged from 19.4 º C to 26.5 º C for the above-mentioned time.

Toxic Chemicals. At least one toxic chemical has been detected in the Stillaguamish marine waters. The WDOE has measured PCBs in the tissue of edible fish caught in Port Susan Bay (WDOE 1994). Out-migrating juvenile salmon have been found to accumulate detectable levels of chemical contaminants as they migrate through urban estuaries (Johnson et al. 1994), though the source of the PCBs in this case is unknown. Immune system dysfunction is one of the potential effects of toxic chemicals on juvenile salmonids.

Marine Mammals

In the North Pacific, 15 species of marine mammals reportedly eat salmon. Documentation of predation on salmon smolts and adults in rivers, estuaries and nearshore areas exist for several species including: harbor porpoise, stellar sea lion, California sea lion, and harbor seal. Killer whales also consume free-swimming adult salmon in these habitats (Fiscus 1980). California sea lions (*Zalophus californianus*) and Pacific harbor seals (*Phoca vitulina*) feed on seaward migrating salmonid smolts, juveniles, and adults, and can, in some situations, hinder the recovery of depressed salmon populations (NMFS 1997). Declines in other food sources, such as hake, could result in increased predation of salmonids by seals and sea lions. The current adult hake population in Port Susan is approximately 1/40th of its historic size (Killebrew 1999). There have been no studies concerning the impact of either of these two marine mammals on Stillaguamish salmonid stocks.

Harbor Seal. Pacific harbor seals are found year-round in Puget Sound. There are two separate stocks on the outer coast of Oregon and Washington and off of the coast of California. Harbor seals are the most abundant pinniped in Washington, and are found in virtually all types of nearshore habitats. Seals generally remain within a 25 to 50 km^2 area (NMFS 1997). Counts of the harbor seals occupying the inland waters of Washington State have increased at an annual rate of 7.7 % (Huber 1995). Hake and herring are the primary prey items, but the seals will also prey on many other species. Salmon are less important in their diet. Harbor seals in the Puget Sound area have been documented to prey upon pink, coho and chum salmon in the fall, steelhead in the winter, and chinook in the spring (Everitt et al. 1981). There are about 319 known haulout sites in Washington, including at the mouth of the Stillaguamish river. Large numbers are seen at Livingston Bay and the South Pass channel (Huber 1995).

California Sea Lion. Puget Sound's California sea lion population consists primarily of sub-adults and adult males that annually migrate north from their breeding grounds in southern California. Their northward migration peaks in December in Washington State, and most of the animals have left the Northwest by June. Their numbers are believed to be increasing in our inland waters. Major haulout sites include Port Gardner and Edmonds Marine Park in the vicinity of Everett, and Race Rocks in Juan de Fuca Strait. Salmon are one of many species preyed upon by sea lions. Scat samples collected at haulout sites at Everett and Shilshole Bay contained salmonids in 5 and 25 % of the samples, respectively (NMFS 1997). At the Ballard Locks, sea lions have been observed preying upon adult sockeye, coho, steelhead, and migrating juveniles. The staff at the WDFW Marblemount hatchery on the Skagit River have observed an increase in scarring (from sea lions) on returning spring chinook and steelhead in recent years.

Exotic and Opportunistic Species

The introduction of exotic plants and animals into the Puget Sound region poses a serious threat to the ecological integrity of this ecosystem, and potential impacts to the economic, social and public health conditions within our state. Because exotic species have few natural controls in their new habitat, they spread rapidly, outcompeting native plants and animals. When non-native species are successful in establishing reproducing communities they are often prone to outcompete native species, and they are often extremely difficult to completely eradicate.

Exotic Species in Freshwater Habitats

There have been no systematic inventories of exotic species in the freshwater aquatic or riparian habitats of the Stillaguamish, nor any studies on the impacts these species may be having on native ecosystems.

Non-native Fish. Many lakes in the Stillaguamish watershed have been stocked with non-native fish species and native species which may not have been originally present in the ecosystem (Miller and Somers 1989). Data on the stocking history of the watershed is available from the WDFW, but not in a form that was readily available for this report.

A partial fish stocking history recorded by the WDFW and USFS for the South Fork, and a few select lakes in the North Fork (MBSNF 1999), is shown in Table 21. Many lakes in the upper South Fork have been stocked since the 1960s with cutthroat, rainbow and brook trout (MBSNF 1995). Non-native rainbow hybrids and non-native brook trout have been observed in streams draining lakes that have been stocked with these species (MBSNF 1996). Bull trout do not compete well with non-native species. Their confinement to the upper headwaters of the South Fork Stillaguamish may have occurred subsequent to the construction of the Granite Falls fishway in 1954 (MBSNF 1995).

Table 21. Partial fish stocking history of lakes in the Stillaguamish watershed (modified from MBSNF 1996 and 1999).

Drainage	Lake	Species	Year (Number of Fish Stocked)
South Fork	Bandana	Rainbow	1940(?), 1971(300), 1986(200), 1995(200)
		Unknown	1962(5000), 1963(5000)
	Bear	Rainbow	1971(?), 1977(2000), 1980(1050), 1982(800), 1983(780), 1992(200), 1993(200), 1994(200)
		Cutthroat	1985(720), 1986(750), 1987(836), 1991(1500)
		Unknown	1962(10000), 1963(10000),
	Canyon	Rainbow	1947(?)
		Cutthroat	1967(?), 1971(1248), 1977(510), 1979(510)
	Clear	Rainbow	1979(200), 1981(300), 1985(800), 1991(450)
		Cutthroat	1980(400), 1990(50),
	Columbine	Rainbow	1940(?)
	Gold Basin Pond	Rainbow	1956(?)
		Unknown	1964(?)
	Heather	Cutthroat	1963(5000), 1977(2550), 1978(2500), 1983(2520), 1989(2300)
	Hemple	Rainbow	1969(?), 1973(294), 1977(300), 1980(300), 1985(300), 1988(900), 1991(360)
		Cutthroat	1980(748)
	Lake 22	Rainbow	1951(?), 1969(5250), 1972(3780), 1977(2000), 1983(2002), 1988(2000), 1992(2500)
		Unknown	1963(?)
	Noble	Rainbow	1940(?)
	Pinnacle	Rainbow	1982(600), 1983(346),
		Cutthroat	1976(650), 1977(600), 1985(480), 1986(350), 1987(418), 1991(480)
		E. Brook	1994(200)
	Saddle	Rainbow	1950(?)
North Fork	Mt. Bullon Lakes	Cutthroat	1954 (5000)
	Craig Lakes	Rainbow	1937 (?)
		Cutthroat	1954 (5000)
	Myrtle	Rainbow	1943 (14940), 1944 (6000)
		Cutthroat	1980 (6000)
		Cutthroat	1970 (1200-Tokul Creek), 1977 (396)
	Wheeler	Cutthroat	1944

Invasive exotic plants. At least two exotic plant species are known to be present in significant numbers in the floodplain and riparian areas of the Stillaguamish watershed: Japanese knotweed (*Polygonum cuspidatum*) and reed canarygrass (*Phalaris arundinacea*). A large infestation of the former is present along the riparian corridor of the lower North Fork. Reed canarygrass is found throughout the Stillaguamish. Exotic vegetation can also be a problem in lakes and wetlands by displacing native flora and fauna and creating unnatural nutrient conditions. Eurasian watermilfoil (*Myriophyllum spicatum*), Brazilian elodea (*Egeria densa*), and purple loosestrife (*Lythrum salicaria*) can seriously damage a lake's ecosystem by outcompeting the native underwater vegetation. The distribution of exotic aquatic plants in the lakes of the Stillaguamish watershed has not been systematically inventoried, but some information has been gathered through Snohomish County's volunteer lake program. Potential impact to salmonids is not known.

Exotic Species in Marine Habitats

Non-indigenous marine species considered to be priority species and worthy of immediate or continued management action include: zebra mussel (*Dreissena polymorpha*); Chinese mitten crab (*Eriocheir sinensis*); European green crab (*Carcinus maenas*); Eurasian watermilfoil (*Myriophyllum spicatum*); hydrilla (*Hydrilla verticillata*); Brazilian elodea (*Egeria densa*); parrotfeather (*Myriophyllum aquaticum*); purple loosestrife (*Lythrum salicaria*); saltcedar (*Tamarix ramosissma*); smooth cordgrass (*Spartina alterniflora*); and common cordgrass (*Spartina anglica*). Of the above species, the exotic cordgrasses probably pose the biggest current threat to the Stillaguamish estuary and salmonids.

Cordgrass. Cordgrass invasions eliminate native salt marsh vegetation, displace native plants and animals, and raise the elevation of the estuary substrate. The best known example of these impacts is found in southwest Washington's Willapa Bay. There, viable seed production is common, and *Spartina* is spreading exponentially (Thom and Hallum 1991). The transition of intertidal acreage in the Pacific Northwest from the native species assemblage to *Spartina*-dominated salt marsh is accompanied by two groups of displacement features. The first is the physical exclusion of species typically found in the intertidal region. These species include eelgrasses, Dungeness crab, clams, juvenile salmonids and fish species, and migratory waterfowl. The second displacement feature is the trapping of sediments by this grass. *Spartina* can capture up to 15.24 cm of new material annually. The eventual consequence of *Spartina* growing in estuarine environments is the removal of intertidal acreage to salt marsh at and above Mean Ordinary High Water. Another impact is an increase in the severity and frequency of flooding (Gohrman et al. 1997).

Spartina is reported to have been introduced to Puget Sound as early as 1960, and has been planted intentionally at many locations in Port Susan and Padilla Bay (Gohrman et al. 1997). Portions of the coastline in Port Susan were planted with *S. anglica* in 1961 for the purpose of converting tidelands to pasture area for foraging cattle (Elston 1997). From there, the invasive species spread north into Skagit Bay (Aberle B. 1990). *Spartina anglica* is the dominant species in Snohomish County, although a small amount of *S. alterniflora* is growing in the upper tidal reaches of saltmarshes and along dikes (Gohrman et al. 1997). There are extensive populations of *S. anglica* in Port Susan and South Skagit Bay posing a significant threat to juvenile salmonids (chinook, chum) which rely on estuary habitats for a significant part of their rearing life stage. *Spartina anglica* is a cross between the American variety, *S. alterniflora*, native to the East Coast of the United States, and *S. maritima*, a European species (Gorhman et al. 1997).

Snohomish County Noxious Weed Board, with the assistance of several other entities from Snohomish, Island and Skagit counties, initiated a *Spartina* eradication program in June 1996. By 1998, a total of 749 ha had been targeted for control (by mowing, spraying and clipping) in Port Susan alone (Gohrman 1998). The primary control areas include: Kayak Point to Warm Beach (less than 0.4 ha); Warm Beach (less than 0.8 ha after 2 years of control); Port Susan: Hat's Slough to South Pass (41 to 61 ha); Leque Island (less than 4 ha); South Pass (less than 4 ha); Stillaguamish River (2.8 ha 2.5 miles upstream next to Thomle Road); West Pass and Skagit Bay (over 121 ha); and Davis Slough (2 ha) (Gohrman 1999). About 3 years of control work are needed to eradicate *Spartina* from an area, but monitoring and control work are required annually after that to prevent re-infestations from occurring.

Atlantic Salmon

Atlantic salmon (*Salmo salar*) have been imported for fish farming into Washington and British Columbia since the 1980s (Elston 1997). There have been several accidental releases of the fish from aquaculture facilities in the region, and the fish have been seen in some Puget Sound rivers, including the Stillaguamish (Nelson 1999). There have also been deliberate introductions of Atlantic salmon in British Columbia and other locations, but none resulted in self-sustaining populations (Hendrick 1999). A primary threat that this species poses to native salmon is the potential for disease transmission.

Habitat Alterations favoring Opportunistic Species

Sometimes human-induced land use changes have the effect of causing the displacement of one species over another. In the urbanizing watersheds of King County, cutthroat trout tend to replace coho salmon and steelhead as the dominant salmonid species (Lucchetti and Fuerstenburg 1992). This type of interspecies competition may be negatively affecting coho production in some tributaries of the mainstem Stillaguamish where the impacts of urban development are beginning to appear. In Church and Fish Creeks, the large numbers of older age class cutthroat may be depressing coho production (Nelson et al. 1997). This is because cutthroat trout are less specific in their habitat needs and better able to tolerate more urbanized stream conditions.

ASSESSMENT OF HABITAT LIMITING FACTORS

In summary, there are many habitat limiting factors negatively affecting the productivity of salmon and their ecosystems in the Stillaguamish watershed. Some impacts were initiated more than a century ago, with the advent of agriculture and timber harvest activities. The loss of estuarine habitat, floodplain connectivity, riparian forests, beaver ponds, wetlands, and off-channel rearing areas fall into this category. Altered streamflows, increased sedimentation rates, and stream channel impacts are primarily byproducts of a dramatic increase in timber harvest activities over the past few decades throughout much of the upper watershed. The Stillaguamish is sensitive to upland forestry activities because the geology of the watershed makes it prone to erosion, and it is relatively low in elevation and naturally susceptible to flooding. Water quality impacts, such as increases in stream temperature and decreases in dissolved oxygen are also related to forestry activities in certain locations, but agriculture, and suburban and urban land uses contribute as well. Fecal coliform and nutrients from agriculture and residential areas likely contribute to a decrease in dissolved oxygen levels in the lower watershed. *Spartina* and other exotic species are relatively new in the watershed, and their impacts to salmonids are less well known, but they have the potential to become serious problems if control measures are not implemented while the populations are still manageable. The impacts from urbanization are less significant in the Stillaguamish than they are in other Puget Sound watersheds, but once the conversion to urban land uses has occurred, the losses to natural ecosystem functions are often irreversible.

Table 22 summarizes the habitat limiting factors by stream location. The information was derived from the: 1) Reach Assessment Tables compiled by the Restoration Subcommittee of the Stillaguamish Implementation Review Committee (SIRC); 2) published and unpublished sources used in this report; and 3) field observations made by the members of the Technical Advisory Group for this watershed.

The table includes streams where one or more of the following occur: 1) loss of access to habitat; 2) loss of side channels and other habitat within floodplains; 3) problems with spawning gravel; 4) insufficient large woody debris; 5) inadequate pool habitat; 6) channel armoring with revetments (riprap); 7) sediment problems; 8) insufficient riparian buffers; 9) high temperature or low dissolved oxygen; 10) high fecal coliform bacteria; 11) the presence of toxic substances; 12) problems with peak flows; 13) problems with low flows; 14) potential for beaver pond or wetland restoration (this category is under-represented); 15) a problem with invasive exotic species.

This table shows where field biologists have been and what they’ve seen or studied. It represents the known and documented locations of impacts. The absence of a stream on this list does not necessarily imply that the stream is in good health. Some streams may not be listed because they have not been visited. Others may show more impacts because they are easily accessible and have been the focus of more scientific study.

Table 22

		Limiting Factors														
Stream	WRIA ID	Access	Floodplain	Stream Channel Conditions					Riparian	Water Quality			Hydrology		Beaver Ponds	Exotics
			Connectivity	[Gravels	Wood	Pools	Riprap	Sediment]	Buffers	[Temp/DO	Fecal	Toxics]	[Peak flow	Low flow]	and Wetlands	
Stillaguamish River	5.0001		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Old Stillaguamish R.	5.0005		X			X		X		X	X					
West Pass	5.0006		X					X	X							X
S. Douglas Slough	5.0009	X	X					X	X	X						
Irvine Slough	5.0014		X					X	X							
Unnamed	5.0017	X							X							
Jorgenson Slough/Church	5.0018	X	X					X	X	X	X		X	X		
Unnamed	5.0020	X														
Freedom Creek	5.0021	X												X		
Woodland Creek	5.0023								X							
Miller Creek	5.0024		X						X						X	
Jackson Creek	5.0027	X		X		X		X						X		
Tributary 30	5.0030	X			X	X		X	X	X	X			X		
Unnamed	5.0031	X							X	X	X			X		
Unnamed	5.0032	X						X								
Cook/South Slough	5.0034	X	X		X	X		X	X							
Knutson Creek	5.0035	X		X					X							
Portage Creek	5.0036		X					X	X	X	X		X	X	X	
Fish Creek	5.0038	X						X		X	X					
Cougar Creek	5.0041	X														
Unnamed Creek	5.0050	X														
Pilchuck Creek	5.0062							X	X	X	X		X	X		
Unnamed	5.0064	X														
Unnamed	5.0078													X	X	
Tributary 80	5.0080				X						X				X	
March Creek	5.0122							X	X	X						
Armstrong Creek	5.0126	X						X	X	X			X	X		
Unnamed	5.0127	X														
Bryant Creek	5.0129								X						X	
Harvey Creek	5.0131							X	X		X		X	X		
N. Fork Stillaguamish	5.0135	X	X		X	X	X	X	X	X	X		X	X	X	X
Rock Creek	5.0141	X			X											
Unnamed	5.0144								X							
Unnamed	5.0145								X							
Unnamed	5.0146								X							
Unnamed	5.0147								X							
Unnamed	5.0148								X							

Table 22 Continued

Limiting Factors

Stream	WRIA ID	Access	Floodplain	Stream Channel Conditions					Riparian	Water Quality			Hydrology		Beaver Ponds	Exotics
			Connectivity	[Gravels	Wood	Pools	Riprap	Sediment]	Buffers	[Temp/DO	Fecal	Toxics]	[Peak flow	Low flow]	and Wetlands	
Unnamed	5.0149	X														
Unnamed	5.0150								X					X		
Unnamed	5.0151	X												X		
Unnamed	5.0152													X		
Unnamed	5.0168								X							
Unnamed	5.0169								X							
Unnamed	5.0170								X							
Hell Creek	5.0171							X	X							
Unnamed	5.0172								X					X		
Deer Creek	5.0173			X	X	X		X	X	X			X			
Rick Creek	5.0181							X	X							
Little Deer Creek	5.0187				X	X		X	X	X						
DeForest Creek	5.0196							X	X							
Higgens Creek	5.0199				X	X		X		X						
Unnamed	5.0213								X					X		
Brooks Creek	5.0215				X	X		X								
Unnamed	5.0216				X	X		X								
Montague Creek	5.0217					X		X	X	X						
Rollins Creek	5.0221				X				X							
Unnamed	5.0222								X							
Dicks Creek	5.0223				X				X							
Unnamed	5.0224				X											
Unnamed	5.0226				X											
Boulder River	5.0229							X	X	X						
Gerkman Creek	5.0235								X							
French Creek	5.0246			X	X	X			X							
Placid Creek	5.0251													X		
Little French Creek	5.0253	X			X	X			X							
Fortson Ponds	5.0254							X								
Segelsen Creek	5.0255				X				X							
Moose Creek	5.0257				X	X		X	X					X		
Unnamed	5.0258				X	X		X						X		
Unnamed	5.0259								X							
Squire Creek	5.0260							X		X					X	
Furland Creek	5.0261							X	X					X		
Ashton Creek	5.0262													X		
Snow Gulch Cr.	5.0263													X		

Table 22 Continued

		Limiting Factors														
Stream	WRIA ID	Access	Floodplain	Stream Channel Conditions					Riparian	Water Quality			Hydrology		Beaver Ponds	Exotics
			Connectivity	[Gravels	Wood	Pools	Riprap	Sediment]	Buffers	[Temp/DO	Fecal	Toxics]	[Peak flow	Low flow]	and Wetlands	
Unnamed	5.0319								X							
S. Fork Stillaguamish	5.0001	X	X	X	X	X	X	X	X	X	X		X	X		
Jim Creek	5.0322	X			X			X	X	X	X		X			
Israel Creek	5.0323	X														
Porter Creek	5.0330	X														
Unnamed	5.0333	X														
Unnamed	5.0334	X			X									X	X	
Unnamed	5.0335	X														
W. Fork Riley Creek	5.0337	X														
Lake Riley	5.0338	X														
Unnamed	5.0346	X														
Unnamed	5.0347	X							X						X	
Unnamed	5.0349	X		X	X				X							
Jordan Creek	5.0350			X	X				X							
Unnamed	5.0358	X		X					X							
Canyon Creek	5.0359	X			X	X		X		X				X		
Unnamed	5.0364													X		
Meadow Creek	5.0368				X											
Tupso Creek	5.0369							X								
Saddle Creek	5.0374							X								
Unnamed	5.0375							X								
Cranberry Creek	5.0390	X			X									X		
Rotary Creek	5.0392				X											
Hawthorn Creek	5.0393				X											
Triple Creek	5.0395	X														
Heather Creek	5.0398				X								X			
Benson Creek	5.0399				X			X								
Hemple Creek	5.0401				X											
Hemple Lake					X											
Black Creek	5.0402				X											
Wiley Creek	5.0406				X											
Long Creek	5.0409				X	X		X								
Boardman Creek	5.0410					X		X	X							
Mallardy Creek	5.0417					X		X								
Eldred Creek	5.0419			X												
Blackjack Creek	5.0420							X								
Unnamed	5.0422					X										

Table 22 Continued

		Limiting Factors														
Stream	**WRIA ID**	**Access**	**Floodplain**	**Stream Channel Conditions**					**Riparian**	**Water Quality**			**Hydrology**		**Beaver Ponds**	**Exotics**
			Connectivity	[Gravels	Wood	Pools	Riprap	Sediment]	Buffers	[Temp/DO	Fecal	Toxics]	[Peak flow	Low flow]	**and Wetlands**	
Marten Creek	5.0423				X	X										
Daz.Howie Creek	5.0425	X														
Marble Gulch Cr.	5.0426				X											
Deer Creek	5.0428					X		X								
Coal Creek	5.0430					X		X	X							
Unnamed	5.0433	X						X								
Beaver Creek	5.0434							X								
Perry Creek	5.0436					X		X								
Palmer Creek	5.0444													X		
Port Susan										X	X	X				X

Assessment Between Species

The habitat limiting factors discussed in this report differentially affect salmonids as a result of the differences in the timing and manifestation of their life history stages. Table 23 provides a relative ranking of the identified significant limiting factors based on available information and the professional judgement of TAG members. The table does not include sockeye, char or cutthroat because there is relatively little information available on these species in the Stillaguamish watershed.

Table 23. Comparative impacts of habitat limiting factors on select salmonids in the Stillaguamish watershed.

Limiting Factors	**Chinook**			**Coho**			**Pink**			**Chum**			**Wtr Stlhd**			**Smr Stlhd**		
	S/I	**R/M**	**AM**	**S/I**	**R/M**	**AM**	**S/I**	**R/M**	**AM**	**S/I**	**R/M**	**AM**	**S/I**	**R/M**	**AM**	**S/I**	**R/M**	**AM**
Loss of Access	L	H	M	H	H	H	L	L	L	L	L	L	H	H	H	H	H	H
Loss of Side Channels	H	H	H	H	H	H	H	M	H	H	M	H	H	H	H	H	H	H
Degraded Riparian Area	H	H	M	M	H	M	M	L	M	M	L	M	H	H	M	H	H	M
Insufficient LWD	NA	H	H	NA	H	H	NA	H	H	NA	H	H	NA	H	H	NA	H	H
Insufficient Pools	NA	H	H	NA	H	H	NA	M	H	NA	M	H	H	H	H	H	H	H
Bank Armoring (riprap)	H	H	H	M	H	H	H	M	H	H	M	H	H	H	H	H	H	H
High Sediment	H	H	M	H	M	M	H	L	M	H	L	M	H	H	M	H	H	M
Deficient Spawning Gravels	H	NA	NA	L	NA	NA	H	NA	NA	H	NA	NA	H	NA	NA	H	NA	NA
High Temperature/Low DO	M	H	M	L	L	M	L	L	M	L	L	L	L	H	L	L	H	M
Peak Flows	H	H	L	H	H	M	H	L	L	H	L	L	H	H	M	H	H	M
Low Flows	M	H	H	M	H	H	H	L	H	M	L	M	L	H	L	L	H	H
Loss of Beaver Ponds	L	M	L	NA	H	M	L	L	L	L	L	L	L	H	L	L	H	L
Loss of Wetlands	M	M	M	NA	H	M	L	L	L	M	L	L	L	H	L	L	H	L
Loss of Estuary Habitat	NA	H	M	NA	M	M	NA	H	M	NA	H	M	NA	M	M	NA	M	M
Invasive *Spartina*	NA	H	M	NA	M	M	NA	H	M	NA	H	M	NA	M	M	NA	M	M
Loss of Nearshore	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG

S/I - Spawning/Incubation; R/M - Rearing/Migration; AM - Adult Migration
H - High; M - Moderate; L - Low; NA - Not applicable; DG - Data gap

DATA GAPS

Data gaps are identified in this report for the purpose of guiding future inventory and research needs. Two sources of information were used to compile this information. The first source is a compilation of data and information needs that were described in the reports used to prepare this document. The Stillaguamish TAG ranked the relative importance of these data gaps into three categories: high, moderate, and low (Table 26).

Table 24. Ranked list of general data and information gaps for the Stillaguamish watershed.

Relative Priority	Data/Information Gap	Source
High	History of diking (and other hydromodifications) to rank restoration projects	Colliins 1997b
	Long-term changes to peak flows as a possible result of human causes*	Collins 1997b
	Compile road network surveys, road density, composition, hazard zonation*	WDOE 1994
	History and impacts of nearshore development	TAG
	Nearshore habitat inventory and use by anadromous and forage fish	TAG
	Inventory and analysis of sediment/salt marsh accretion in Port Susan	TAG
	Current impacts of fine sediment in chinook spawning and other select areas	TAG
	Basin-wide multi-species instream flow study and water rights assessment	TAG
	Compile existing basin-wide physical habitat survey information	TAG
	Prioritization of landslides for restoration efforts and hazard zonation maps	TAG
	Identify high-quality habitat for future protection/acquisition opportunities	TAG
	Distribution of salinity/salt wedge in the estuary	TAG
	Chinook production estimation	Nelson 1999
	Chinook limiting factors	Pess 1999
Moderate	Extent and impact of invasive exotic species in riparian/aquatic habitats	TAG
	Basin-wide nutrient budget	TAG
	Fecal coliform/nutrient sources in relation to DO concentrations for fish	TAG
Low	Use of lakes by coho (and other anadromous fish)	Nelson et al. 1997
	The effects of gravel mining on the river channel and habitat quality	Collins 1997b
	The effects of channel widening on habitat quality	Collins 1997b
	Data on pesticide use to study potential sources of sediment contamination	WDOE 1994
	Genetic analysis of Stillaguamish sockeye	TAG
	Juvenile salmon stomach analysis in estuary habitats	TAG
	Juvenile salmon residence study in estuary habitats	TAG
	Ambient groundwater monitoring in relation to surface water pollution	WDOE 1994
	Distribution of and use by searun cutthroat and bull trout	USFS 1992

*** These projects are linked**

The second source of data gaps is derived from the Reach Assessment Tables (July 1997 version) compiled by the Restoration Subcommittee of the Stillaguamish Implementation Review Committee (SIRC 1997) (Table 25). The SIRC was created in the early 1990s as an outgrowth of the Stillaguamish Watershed Action Plan (Snohomish County 1990), and has broad representation within the watershed. The data gaps developed by the SIRC are specific to select streams (and in many cases specific stream reaches) in the watershed.

Table 25. Data gaps compiled from the Stillaguamish reach assessment tables (SIRC 1997).

Stream Name	WRIA No.	Topic	Proposed Action
Lower Stillaguamish	5.0001	Fish Use/Populations	Life history dynamics and juvenile use patterns
		Habitat	Effects of Arlington urbanization
		Water Quality	Improve water quality monitoring program
Church Creek	5.0019	Fish Use/Populations	Interaction between coho and cutthroat
		Fish Use/Populations	Chum returns and spawning evaluation
		Hydrology	Identify illegal withdrawals
		Water Quality	Temperature and invertebrate monitoring
Pilchuck Creek	5.0062	Habitat	Impact of historic land uses on habitat/fish
		Habitat	Physical survey of coho habitat
		Water Quality	Invertebrate monitoring for water quality
Harvey/Armstrong	5.0126/5.0131	Fish Use/Populations	Steelhead distribution and use
		Habitat	Habitat surveys of instream conditions
		Habitat	Historic land use and fish information
		Habitat	Identify source of sand in the lower reaches
		Fish Passage	Identify fish barrier to Bryant Lake
Lower South Fork	5.0001	Fish Use/Populations	Winter chum usage
		Fish Use/Populations	Effects of fine sediment on pre-emergent fry survival
		Habitat	Update WDNR hydrology map, including fish barriers
		Habitat/Water Quality	Effects of suburbanization on habitat and water quality
		Water Quality	Water quality monitoring
Jim Creek	5.0322	Habitat	Salmon usage above RM 4.0
		Habitat	Conduct a watershed analysis
		Water Quality	Fecal coliform sources
Canyon Creek	5.0359	Fish Use/Populations	Presence of and use by spring chinook
		Habitat	Rate of recovery from logging impacts
		Land Use	Inventory of forest roads on private lands
Upper South Fork	5.0001	Fish Use/Populations	Contribution of 2-year coho smolts
		Habitat	Limiting factors analysis: food and nutrients
		Land Use	Forest road inventory
		Fish Passage	Splash dam inventory
		Water Quality	Temperature problems in Perry, Boardman, Canyon
North Fork	5.0135	Fish Use/Populations	Genetic analysis of sockeye and coho stocks
		Fish Use/Populations	Contribution of LWD from the riparian corridor
		Habitat	Baseline habitat conditions in urbanizing areas
		Habitat	Quantify pools
		Habitat	Limiting factors for chinook
		Habitat	Coho habitat and use in tributaries
		Habitat	Improve mapping of tributaries
		Hydrology	Source of low flow problems
		Land Use	Analysis of forest roads
		Land Use	Assess recreational use along middle tributaries
		Land Use	Land use impacts in lower tributaries
		Wetlands	Ground truth wetland data for storage, temperature, habitat
		Water Quality	Improve temperature monitoring
		Water Quality	Potential contaminants at Fortson Pond

BEST FUNCTIONING HABITAT IN NEED OF PROTECTION

Properly functioning habitat is the most cost-effective habitat to protect. The ability to restore degraded habitat back to its proper function is limited by our technical knowledge of the complex physical, chemical and biological processes operating within and between ecosystems.

Within the Stillaguamish watershed, the vast majority of the habitat has been impacted, at some level, by human activities. Habitats in need of protection within the basin are those areas that still retain a significant portion of their original habitat functions or possess a high potential for re-establishing properly functioning habitat.

The method used to identify sub-basins within the watershed that were functioning at a relatively high level is based on a matrix using existing habitat research. Five factors were used to evaluate each of the 27 sub-basins: (Table 26). These include the: 1) condition of the riparian area; 2) level of recent landslide activity; 3) condition of beaver habitat; 4) function, value, and relative area of wetland habitats; and 5) value for fish production.

Table 26. Relative habitat protection values for the sub-basins of the Stillaguamish watershed using five habitat criteria.

Sub-basin	Improving Riparian Condition	Reduced Landslide Activity	Current Beaver Habitat	Functional Wetland Condition	Current Fish Production	Total
Squire Creek	3	3	3	3	3	15
Armstrong	2	3	3	3	2	13
Lower Pilchuck	2	3	3	2	2	12
Upper South Fork	3	2	3	2	2	12
Robe Valley	3	2	3	2	1	11
Boulder Ridge	3	2	1	3	2	11
Ebey Hill	2	3	2	3	1	11
Portage Creek	1	3	1	3	2	10
Canyon Drainage	2	3	1	2	1	9
Jim Creek	2	1	3	2	2	10
Frailey Mountain	2	3	2	2	1	10
Grandview	2	3	2	1	2	10
Higgins Ridge	3	1	2	2	3	11
Church Creek	1	3	2	2	1	9
Hat Slough	1	3	1	2	2	9
Stanwood City	1	3	2	2	1	9
Stillaguamish Floodplain	1	3	2	2	1	9
Tributary 30	1	3	1	2	2	9
Upper Pilchuck	3	3	1	1	1	9
Gold Basin	3	1	1	2	2	9
Hell Hazel	2	2	1	2	2	9
Arlington Area	1	3	1	1	2	8
Burn Hill	3	2	2	1	1	9
Deer Creek	2	1	2	1	1	7
Jackson Area	1	3	1	1	1	7
Canyon Creek	3	1	1	2	2	9
Upper North Fork	3	1	1	1	1	7
						264

Each factor was ranked using a numeric value with (3) representing the highest valued habitat and (1) representing the lowest value/ functioning habitat. Scores were summed over the five factors and assigned one of three priority tiers for protection.

Tier I (scores12 to15) priority protection sub-basins included Squire Creek, Upper South Fork Stillaguamish, Lower Pilchuck and Harvey/Armstrong. These watersheds had the highest rankings for recovering or intact riparian forests (Pollack 1998), lower recent landslide activity (Collins 1997), higher levels of beaver habitat (Pollack and Pess1998), better potential wetland conditions (Gersib 1997) and higher fish production (Killebrew 1999).

Sub-basins scoring in the Tier II (scores of 10 to 11) and Tier III (scores less than10) categories had one or more habitat factors that were degraded which reduced the best functioning score. These sub-basins still provide specific critical habitat within the overall watershed.

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