SALMON AND STEELHEAD HABITAT LIMITING FACTORS

WATER RESOURCE INVENTORY AREA 11

WASHINGTON STATE
CONSERVATION COMMISSION

FINAL REPORT

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Special thanks to Mr. Ron McFarlane who was responsible for digitizing and producing the maps contained in this report.

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Several maps have been included with this report for your reference. The maps are appended to the report, either as a separate electronic file (for the electronic copy of this report) or separate printed section (for hard copy). The maps are included as a separate electronic file to enable the reader to utilize computer multi-tasking capabilities to simultaneously bring up the map and associated text. Below is a list of maps that are included in the WRIA 11 Map appendix/file:

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PURPOSE OF REPORT

The successful recovery of naturally spawning salmon populations depends upon directing actions simultaneously at harvest, hatcheries, habitat and hydro, the 4H's.

The 1998 and 1999 state legislative sessions produced a number of bills aimed at salmon recovery. Engrossed Substitute House Bill (ESHB) 2496 is a key piece of the 1998 Legislature's salmon recovery effort. While both habitat protection and restoration need to be a part of the state's overall salmon recovery strategy, the focus of ESHB 2496 is primarily directed at salmon habitat restoration.

ESHB 2496 in part:

- directed the Conservation Commission in consultation with local government and the tribes to invite private, federal, state, tribal and local government personnel with appropriate expertise to act as a technical advisory group (TAG);

- directed the TAG to identify limiting factors for salmonids to respond to the limiting factors relating to habitat pursuant to section 8 sub 2 of this act;

- defines limiting factors as "…conditions that limit the ability of habitat to fully sustain populations of salmon."

- defines salmon as all members of the family salmonidae which are capable of self-sustaining, natural production.

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

It is important to note that the responsibilities given to the Conservation Commission in ESHB 2496 do not constitute a full limiting factors analysis. The hatchery, hydro and harvest segments of identifying limiting factors are being dealt with in other forums.

SESSB 5595 is a key piece of the salmon recovery effort from the 1999 Legislature's 1st Special Session. This legislation reaffirmed the needs to complete a limiting factors report (as found in 2496) and among other items modified the definition of limiting factors to mean "… conditions that limit the ability of habitat to fully sustain populations of salmon ..." While striking out that portion of the definition found in ESHB 2496 dealing with barriers, degraded estuarine areas, riparian corridors, stream channels and wetlands. Removing those terms does not eliminate them from inclusion in the limiting factors report, rather it expands the scope of the report to include those elements for inclusion along with other pertinent elements specific to the WRIA in this report.

EXECUTIVE SUMMARY

The ancestral home of the Nisqually Indian Tribe, the Nisqually River Basin(Figure 1), Water Resource Inventory Area 11 (WRIA 11) was one of the earliest areas settled in the Puget Sound area by Euro-American immigrants. This basin was prized for its deep-water access to saltwater, large tracts of pristine old growth forests, native prairies, fertile river valley soils, and numerous species of wildlife and abundant runs of salmon. The Hudson Bay Company established Fort Nisqually, as a fur trading post, in 1833 near the mouth of the Nisqually River. Homesteads and settlements began appearing as early as the 1840's and the new arrivals initiated a series of actions to modify the landscape to fit their needs. In 1850, the US Congress passed the Donation Land Law encouraging the settlement of the Washington and Oregon Territory. A chronology of events that have impacted the Nisqually River Basin is shown in Table 1. The known distribution of anadromous salmon, steelhead, and coastal cutthroat can be found in Appendix A, Figures 1-6.

The diking of the estuary, which started in 1904, was largely completed during the late 1920's. These dikes continue to be largely in place and maintained today.

Two hydroelectric projects have been constructed in WRIA 11. The Yelm Hydroelectric Project, constructed in 1929, consists of a diversion dam located at River Mile (RM) 26.2, a canal that transports water to a powerhouse, located at RM 12.7, where the water is returned to the mainstem Nisqually River. The original dam was a log structure with a log energy dispersion apron. It is doubtful that this structure was passable to adult salmonids and a fish ladder was not constructed until after several years of operation. Anadromous fish were delayed in their upstream migration by the operation of this facility. Between 1930 and 1955 there were no fish screens on the canal entrance. This would have allowed juvenile salmonids to enter the canal where the only exit would have been through the powerhouse turbines. Between 1955 and 1968 this project effectively diverted all the water during periods of low flow from the mainstem Nisqually River through the canal. The facility has undergone extensive renovations and currently meets all fish passage and protection standards.

The LaGrande Hydroelectric Project began in 1910 with major renovation in 1942. There is considerable doubt that anadromous fish were able to migrate much further upstream of this project due to the natural presence of a barrier in LaGrande Canyon.

Minimum instream flows were not established for the Nisqually River until 1978. The hydroelectric projects in the Nisqually River are not intended to provide flood control but the Alder/LaGrande Project does provide some flood tempering as a part of standard operations. The operations of the hydroelectric projects do not provide a naturalized flow regime to the mainstem Nisqually River.

The salmonid resources of the Nisqually River Basin has been adversely impacted through a variety of land use practices. Commercial timber activities have increased sediment loads, reduced large woody debris input and recruitment potential, and altered precipitation run-off patterns. The conversion of pristine valley bottom lands and wetlands to agricultural purposes and now to rural residential and hobby farms has reduced the natural biological processes of these parcels necessary for the natural production of salmonids in the Nisqually River Basin.

The Nisqually River estuary, has lost approximately 30 percent of its historical intertidal and subtidal habitat. Of critical importance to the natural production of salmonids is the 54 percent loss in intertidal emergent marsh habitats. The mainstem Nisqually River is constrained by a system of revetments and levees in the lower 5.2 river miles, remnant flood control dikes in areas near McKenna and maintained dikes that protect the Yelm Diversion Canal between RM 21.8 to 26.4. These channel containment structures are shown in Appendix A (Figure A-8) inhibit lateral channel migration and have eliminated much of the spawning and rearing habitats that were once present. Additionally, there is some evidence that suggests off-channel rearing habitats have been reduced in the mainstem Nisqually River between 1965 and 1995. Currently, off-channel rearing habitats are virtually absent between river miles 10 and 25.

This report examines these process changes and their associated functional implications in the Nisqually River Basin. While the Nisqually River Estuary is thought by many to be pristine, there has been a significant loss of estuarine habitat and function. Much of the historical estuary is in public ownership and available for return to historic habitats. Portions of the mainstem Nisqually River corridor are in good condition and in these reaches preservation is the preferred alternative. The cost associated with preserving the remaining functioning habitats and attempting to restore portions of lost habitats will be substantial. Many of the biological functions historically present in the Nisqually River Basin can be partially of fully restored. This restoration will require fundamental changes in land use to restore self-sustaining populations of salmonids in this basin. While the Nisqually River Basin is faced with many critical issues, it is the opinion of the Technical Advisory Group that it is still capable of self-sustaining runs of naturally produced salmonids.

Figure 1– Nisqually River Basin (WRIA 11) Location Map

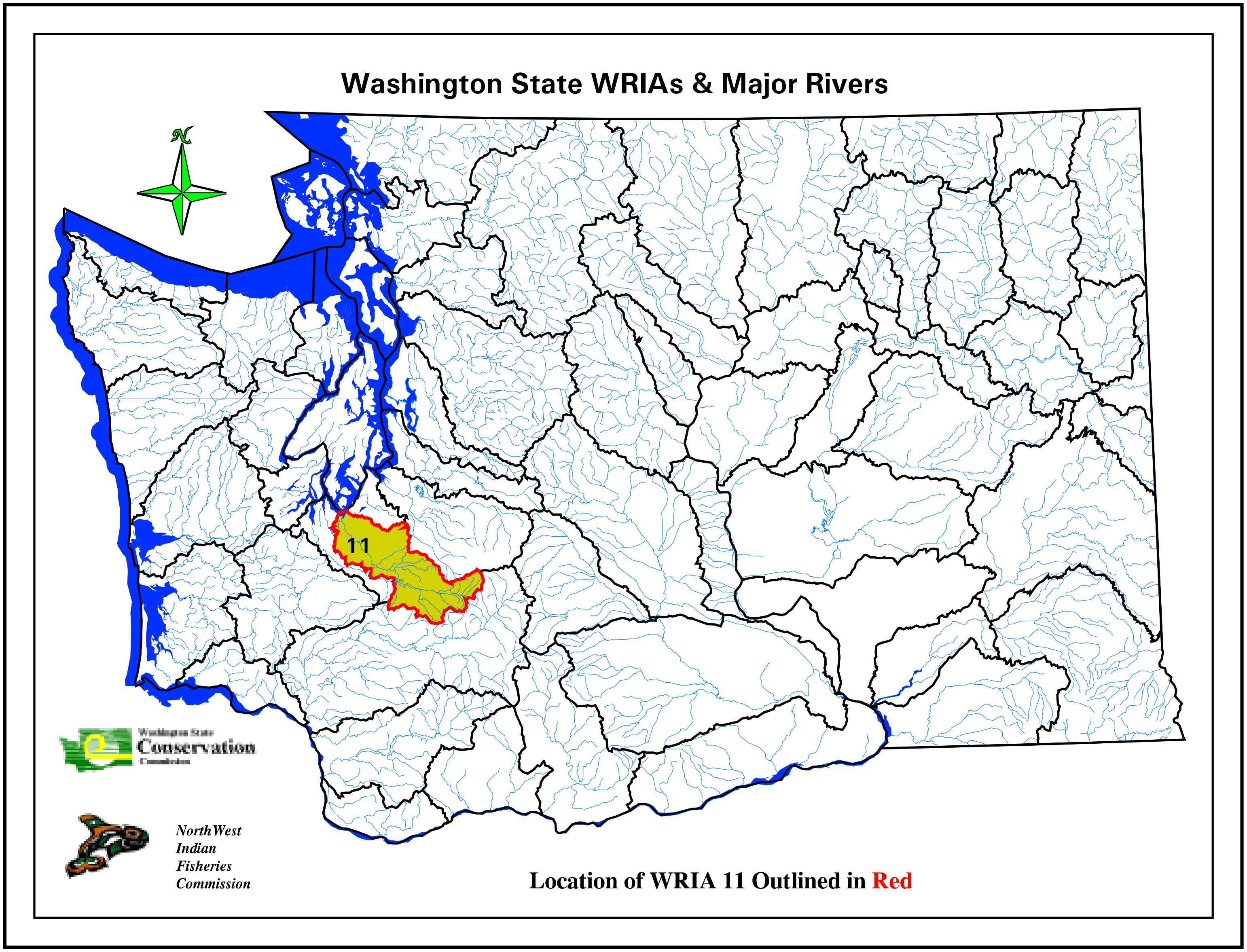


Table 1 : Nisqually River Basin Chronology of Major Events

Date	Event	Impact(s)
1792	First European description of the Nisqually River mouth	Initial description of attributes of area of Nisqually River
1833	Hudson Bay Co. selects site for Fort Nisqually	First Euro-American settlement in Nisqually River Basin
1845	Initial European settlers arrive in vicinity of McAllister Creek	Land clearing and farming begins
1850	Donation Land Claim Law	Encouraged settlement of Oregon and Wash.
1852	First ferry operated across Nisqually River	Transportation through the valley
1853	First railroad surveys conducted	First mapping attempts of historical habitat
1854	Medicine Creek Treaty signed	Large tracts of land are given up by the Nisqually Indian Tribe
1858	Laws permitting draining passed	Wetlands drainage begins.
1870	Irrigation of agricultural lands begins	Water withdrawals from surface waters
1889	Upper Ohop Creek diverted into Puyallup River	Loss of approximately 30% of flow in lower Ohop Creek
1899	Mt. Rainier National Park established	Headwaters of Nisqually River preserved.
1904	First dikes constructed on Nisqually River Delta	Tidal marshlands lost.
1910	LaGrande Hydroelectric Project constructed	Water flow regimes altered and interception of large woody debris
1912	Northern Pacific Railway constructs Point Defiance line	First mainline railroad bridge across Nisqually River
1929	Yelm Hydroelectric Project constructed	Significant adverse impacts to salmon runs occur.
1940's – 70's	Major logging activities in the upper watersheds	Logging road construction and impacts to riparian buffers and habitat
1965	Port of Tacoma announces annexation Of 1100 acres of Nisqually Delta for deepwater port	Plans opposed by local environmental groups
1971	U.S. Department of Interior designates 2756 acres of Nisqually Delta as a Natural Landmark	Preservation of Nisqually Delta
1974	The Brown Farm purchased by the Dept. Of Interior and designated a national Wildlife refuge	2818 acres of delta included as Nisqually National Wildlife Refuge
1978	Minimum flow regime ordered by FREC	Salmon transportation, incubation and rearing flows established for the central Nisqually River
1999	Puget Sound Chinook Listed as Threatened under the Endangered Species Act	Unknown

THE RELATIVE ROLE OF HABITAT IN HEALTHY POPULATIONS OF NATURAL SPAWNING SALMON

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

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

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

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

When adults return to spawn, they not only need adequate flows and water quality, but also unimpeded passage to their natal grounds. They need deep pools with vegetative cover and instream structures such as root wads for resting and shelter from predators. Successful spawning and incubation depend on sufficient gravel of the right size for that particular population, in addition to the constant need of adequate flows and water quality, all in unison at the necessary location.

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

Once the young fry emerge from the gravel nests, certain species such as chum, pink, and some chinook salmon quickly migrate downstream to the estuary. Other species, such as coho, steelhead, bull trout, cutthroat and chinook, will search for suitable rearing habitat within the side sloughs and channels, tributaries, and spring-fed "seep" areas, as well as the outer edges of the stream. These quiet-water side margin and off channel slough areas are vital for early juvenile habitat. The presence of woody debris and overhead cover aid in food and nutrient inputs as well as provide protection from predators. For most of these species, juveniles use this type of habitat in the spring.

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

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

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

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

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

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

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

In the Nisqually River, adult chum salmon (3 to 5 years old) have one major run type. These winter chum adults enter from late November through February and spawn from January through February. Chum salmon fry emerge from the nests in March and April, and quickly outmigrate to the estuary for rearing. In the estuary, juvenile chum salmon follow prey availability. Later as the food supply dwindles, chum move offshore and switch diets (Simenstad and Salo, 1982).

Chum and pink salmon have similar habitat needs such as unimpeded access to spawning habitat, a stable incubation environment, favorable downstream migration conditions (adequate flows in the spring), and because they rely heavily on the estuary for growth, good estuary habitat is essential.

Chinook salmon have three major run types in Washington State. Spring chinook are in their natal rivers throughout the calendar year. Spring chinook were historically present in the Nisqually River basin and would have entered into freshwater during as early as the late spring, typically peaking in April or May; however this run became extinct during the 1950's. Historically, they would have spawned from July through September and typically in the headwater areas where higher gradient habitat exists. Incubation continues throughout the autumn and winter and generally requires more time for the eggs to develop into fry because of the colder temperatures in the headwater areas. Fry would have begun to leave the gravel nests in February through early March. After a short rearing period in the shallow side margins and sloughs, Puget Sound and coastal spring chinook stocks juveniles begin to leave the rivers to the estuary throughout spring and into summer (August). The White River spring chinook stock, the closest remaining spring chinook stock to the Nisqually River, juveniles remain in the river for another year before leaving as yearlings. This is indicative of a wide variety of outmigration strategies used by spring chinook stocks.

Adult summer chinook are not present in the Nisqually River as a distinctive stock. Nisqually River fall chinook stocks range in spawn timing from late September through December. Juveniles incubate in the gravel until January through early March, and outmigrate to the estuaries occurs over a broad time period (January through August). While some emerging chinook salmon fry outmigrate quickly, most inhabit the shallow side margins and side sloughs for up to two months. Then, some gradually move into the faster water areas of the stream to rear, while others outmigrate to the estuary. Nisqually River fall chinook typically migrate within their first year of life, but a few stocks (Snohomish summer chinook, Snohomish fall chinook, upper Columbia summer chinook) have juveniles that remain in the river for an additional year, similar to many spring chinook (Marshall et al, 1995). There is some data that indicates a fall outmigrant component to Nisqually origin chinook (Tyler 1980). There are no data to indicate that there is a component of Nisqually River stock fall chinook juveniles that remain in freshwater for a full year after emerging from the gravel nests.

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

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

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

Sockeye salmon have a wide variety of life history patterns, including the landlocked populations of kokanee which never enter saltwater. The origin of adult sockeye observed spawning in the Nisqually River is not known. Three life history trajectories exist: (1) they are strays from outside the basin; (2) kokanee origin fish that have smolted and migrated from Alder Lake; and (3) a riverine form of sockeye. The first trajectory is thought to be the most likely. Adult sockeye are frequently observed in low numbers in the Nisqually River Basin.

Steelhead have one of the most complex life history patterns of any anadromous Pacific salmonid species (Shapovalov and Taft, 1954). In Washington, there are two major run types, winter and summer steelhead. Nisqually River winter steelhead adults begin river entry in a mature reproductive state in December and generally spawn from February through May.

Naturally produced juvenile steelhead can either migrate to sea or remain in freshwater as a resident rainbow trout. The vast majority of juvenile steelhead smolt and migrate to saltwater. Nisqually origin steelhead usually spend 1-3 years in freshwater, with the greatest proportion spending two years. Because of this, steelhead rely heavily on the freshwater habitat and are present in streams all year long.

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

Both resident and anadromous forms of coastal cutthroat are found in the Nisqually River Basin. These fish are found in most fish bearing waters of the Nisqually Basin from high elevation glacial fed streams downstream to the Nisqually Estuary. The aggressive and adaptive nature of these trout results in a self-reproducing population within the Nisqually River Basin. Coastal cutthroat trout are managed under a species complex scenario. This is at least in part due to multiple interacting life history trajectories.

Anadromous cutthroat trout have a freshwater life history similar to steelhead. Typically, anadromous cutthroat trout smolt at two years of age and migrate in the spring into the estuary and marine near-shore habitats. These anadromous cutthroat trout may move up rivers with daily tidal fluctuations to opportunistically feed. Their ability to physiologically handle transitions between salt water and freshwater during this life phase is unique to cutthroat. Remaining in the saltwater environment for two years, these fish again migrate into their natal stream to spawn. In the Nisqually River Basin, spawning typically occurs from January through June in small headwater streams. First time spawners typically deposit approximately 700 eggs into small gravels for incubation. Adults then return to nearshore habitats to rear again and have been known to spawn up to five times. The repeat spawners are critical to reproductive success of the species as they produce larger and more numerous eggs (Peoples 1988). These repeat spawners also provide for the exchange of genetic material between brood years.

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

The Nisqually River is home to several salmonid species, which together rely upon freshwater and estuary habitat the entire calendar year. As the habitat and salmon review indicated, there are complex interactions between different habitat components, between salmon and their habitat, and between different species of salmon.

DISTRIBUTION AND CONDITION OF STOCKS

HISTORIC CONDITIONS OF NATURALLY SPAWNING SALMONID POPULATIONS IN THE NISQUALLY RIVER BASIN

While runs of chinook (spring and fall stocks), pink, coho, chum salmon, winter steelhead and cutthroat trout were present in the Nisqually River system, there is no reliable historical source of information on salmonid species abundance in the Nisqually River Basin.

A single spring chinook stock was historically present in the Nisqually River basin (Smoker et al. 1952). The development of Alder Dam and Yelm Diversion hydroelectric projects on the mainstem Nisqually River are believed to have played a significant role in the extirpation of these fish (Smoker et al. 1952). Minimum flows in the mainstem Nisqually River, at both the diverted reach associated with the Yelm Diversion Project and upstream and downstream reaches, were not established when these projects were constructed and were identified by Phinney (1971) as detrimental to salmon passage. Screening of the Diversion Canal was non-existent from 1930 to 1955 and inadequate until 1999. By 1955, the Nisqually River origin spring chinook stock had become extinct. Currently, an occasional adult is observed which may be the result of strays from the outside WRIA 11attempting to recolonize the Nisqually River basin.

Since 1970, run sizes of fall chinook, coho, pink, chum and winter steelhead have been highly variable. Escapement trends for chum salmon has remained steady or trended upwards while coho have decreased significantly. Winter steelhead run sizes decreased throughout the 1990's and have not recovered (WDFW and WWTIT, 1994). Pink salmon populations have remained relatively stable (WDFW and WWTIT, 1994 (SASSI)). The naturally spawning fall chinook population in the Nisqually River is comprised of an unknown mixture of natural and hatchery origin fish. The magnitude of adult hatchery fish that contribute to the natural spawning population has not been determined. Because of hatchery origin fall chinook carcasses recovered during spawning ground surveys, there is the strong likelihood of genetic material exchange between natural and hatchery stocks. If adult hatchery strays have been included in present day escapements and SASSI escapement estimates, the current and SASSI status designations for this population could be overstated.

In a natural ecosystem, salmonids exhibit great variability with respect to the duration and types of habitats used for rearing. Juvenile chinook can spend anywhere from several days to a year in freshwater prior to migrating to the estuary (Healey 1991). These life histories or trajectories (in the terminology of Lichatowich and Mobrand 1995) vary most markedly with respect to timing and length of residency in the estuary.

Because of their recent Endangered Species Act listing as Threatened, the possible rearing trajectories of chinook salmon are discussed at this point in detail. Other species and stocks of Nisqually River origin salmonids have different rearing trajectories but a functioning freshwater and estuarine environment is important to the survival of all salmonid species and stocks of the Nisqually River basin.

Ocean type chinook are characterized by migrating from freshwater habitats into marine habitats during their first spring. Stream-type chinook typically migrate out of freshwater habitats into marine habitats in their second spring.

For ocean-type chinook, juvenile rearing is a transition in size and habitat use by which an individual grows from a newly emerged fry to an osmoregulating saltwater-tolerant juvenile without necessarily exhibiting a distinct smolt phase. Rearing occurs in one or more of the following habitat types: freshwater, estuarine, or marine shoreline. The different life history trajectories are expressed through the duration of use of these habitats. For migrating juvenile Puget Sound chinook this rearing phase is followed by a period of several months residence in the greater Puget Sound Estuary. All of these rearing trajectories, regardless of species, yield the same results, a fish of appropriate size that has successfully moved from freshwater existence to pelagic existence in Puget Sound, the Pacific Ocean and a returning mature adult salmon. Due to the importance of size, behavior, and physiology, this life history section presents discussions on feeding, growth, behavior and physiology to provide a context for the rearing trajectories described elsewhere in this report.

Immediately after emergence, ocean type chinook fry move to low velocity habitats, usually along stream margins before dispersing or migrating to rearing habitats in higher velocity water. This migration can taken them to relatively close freshwater habitats, the estuary (Congleton et al. 1981; Levy and Northcote 1981; 1982; Levings 1982; Hayman et al. 1996), or high salinity shoreline habitats (Healey 1991). In streams and tidal channels of estuaries, fry are located at the margins in low water velocities (Congleton et al. 1981; Healey 1991; Hayman et al. 1996).

Feeding and growth are functions of fish size and the habitat occupied. Insects dominate the diet of fry (<40 millimeters (mm)) whether the fish is rearing in a stream or in a tidal channel of an estuarine marsh (Dunford 1972; Levy and Northcote 1981; Meyer et al. 1981; Levings et al. 1995). The diet of fingerlings (55-70mm) is very dependent upon the habitat occupied. Fingerlings in freshwater feed on insects, while those in more saline areas feed on epibenthic crustaceans (Dunford 1972; Levy and Northcote 1981; Meyer et al. 1981; Levings et al. 1995), while taking insects opportunistically (Levings et al. 1995). In altered estuaries, the diet can be dominated by pelagic species such as calanoid copepods (Weitkamp and Schadt 1982). Growth is typically higher in estuarine habitats than in freshwater habitats (Healey 1991).

For ocean-type chinook, there is a convergence of rearing habitat needs as they reach a length of about 70 mm. At 70 mm juvenile chinook are physiologically capable of osmoregulating in full strength seawater (Clarke and Shelbourn 1985) and are large enough to feed on larger prey including larval and juvenile fish (Healey 1991). Ocean-type juvenile chinook that have been using estuarine or marine shoreline habitats will have typically migrated offshore at about this length.

Chinook residing within upstream freshwater habitats (or hatcheries) can be in excess of 70 mm when they reach the estuary. These fish are capable of moving offshore very soon after migrating from the river. In the Nisqually Reach, chinook longer than 70 mm have been captured along estuarine and marine shorelines, but they are likely facultative rather than obligate residents of these habitats relative to feeding and physiology. It is possible these fish are not behaviorally ready to leave the shoreline although they are morphologically and physiologically ready. A similar behavioral staging has been noted for coho salmon smolts in the lower Chehalis River (Moser et al. 1991). Individual growth rates of juvenile fish can be dependent upon a variety of factors such as dominant/submissive behaviors, wild vs. hatchery interactions, etc.

Chinook (>70) mm that reside in saltwater typically feed on pelagic prey of variable sizes including pelagic crustaceans, and juvenile fish (Healey 1991). These fish will also take smaller prey such as calanoids. Typically these large fish are no longer tied to either freshwater food webs (drifting chironomids) or detritus-based food webs (epibenthic zooplankton and crustaceans) of the estuary, but they will take these organisms opportunistically. Instead, they prefer the pelagic habitats and prey offered by the greater Puget Sound estuary.

In contrast, stream type chinook rearing occurs in freshwater habitats for one year or longer, dictated by their growth rate. This growth rate is often a function of water temperature and food supply.

Recently emerged chinook fry can tolerate high salinity as can newly emerged pink and chum fry (Wagner et al. 1969). However, chinook fry (< 40 mm) cope by tolerating elevated blood chloride levels, while pink and chum regulate blood chloride levels. Therefore, newly emerged chinook fry are not actually fully adapted to osmoregulate in seawater. Exposure to increasing salinity yields fry that regulate blood chloride levels sooner than if direct transfer to seawater occurs (Wagner et al. 1969). It is possible that some stocks of chinook fry are genetically adapted to regulate blood chloride levels in a manner similar to juvenile pink and chum salmon. The marine rearing chinook reported by Lister and Genoe (1970) are one possible example of this rearing trajectory.

The relationship of elevated blood chloride to fitness is unknown but would be expected to be adverse. Clarke et al. (1989) suggests that ocean-type chinook fry exploit estuarine habitat by seeking out lower salinity regions of the estuary, rather than through greater salinity tolerance. This may explain why fry (particularly those that are <45 mm) that rear in estuaries are typically concentrated in areas with very low salinity (<5 ppt), though high quality, habitats with high salinity, exist in adjacent areas. Older and larger chinook fry and fingerlings have greater tolerance to salt water than do younger and smaller fish (Taylor 1990). The growth rate is also important with faster growing fish at any length being more tolerant of higher salinities than slower growing fish (Wagner et al. 1969). The salinity tolerance benefit of rapid growth is more noticeable in smaller fish than in larger fish.

Once fingerlings achieve a length of 55-60 mm, salinity tolerance increases rapidly, and survival upon direct transfer to seawater is high (Wagner et al. 1969). By 65 mm chinook can fully osmoregulate and maintain blood chloride levels below a threshold of 170 meq/l (Wagner et al. 1969, Clarke and Shelbourn 1985, Clarke et al. 1989). Environmental factors, including but not limited to photoperiod and temperature, also influence seawater tolerance and other endocrine mediated changes involved in smoltification. Overall, increasing salinity tolerance creates a cascade of effects in response to both environmental and physiological events that support continued salinity resistance and growth (Wedemeyer 1980). The process of smoltification is a prerequisite for juvenile salmon to continue rapid growth after adapting to seawater (Wedemeyer 1980). Based on physiological studies, smoltification of ocean-type chinook appears to be complete at a length of 65-70mm.

The previous discussion is useful in understanding salmonid, and particularly, chinook utilization in the Nisqually Reach. Biological sampling efforts have been conducted in the Nisqually Reach over the last twenty years to determine the presence of juvenile salmonids. Fresh et al. (1979) first reported the presence 44 species of fish caught in surveys conducted in 1977 and 1978. During these surveys, juvenile chum, pink, coho and chinook salmon along with cutthroat and steelhead trout were captured. Adult coho, chum, chinook and steelhead were also captured during purse seine surveys conducted in 1977 (Fresh et al. 1979). Pearce (1982) reported on the temporal and spatial distribution and food habits of juvenile chum, chinook and coho salmon in the Nisqually estuary captured at 10 sites in the Nisqually estuary. In addition to the study target species, Pearce (1982) reports capturing cutthroat and steelhead trout and 11 other fish species. Cook-Tabor (1999) reported 94 species of fish from 30 families utilize the Nisqually estuary. This list includes 10 species of salmonids.

Overall, the sampling that has been conducted provides a partial picture of the timing and use of the Nisqually Reach by juvenile salmonids. General conclusions from these studies relative to chinook salmon include:

- Juvenile chinook are present in very low numbers in March, peak catches occur in late May or early June and were present through September when sampling ended. The timing of the peak is determined by releases from hatcheries.
- The progeny of naturally spawned chinook arrive in the estuary throughout this period at a variety of lengths.
- All shorelines are used.

Four rearing trajectories (Table 2) may occur in the Nisqually River for juvenile chinook as defined along the lines of Hayman et al. (1996), and are based on the timing of entrance to the estuary:

Emergent Fry: Emergent chinook fry migrate to estuarine rearing habitats immediately after emergence at a length of approximately 40 mm. This trajectory can include fry that rear in essentially freshwater habitats (typically marshes and tidal sloughs) (Hayman et. al 1996; Healey 1980; Levings et al. 1995) and to those that are rearing in moderate salinity (Levings et at. 1986; MacDonald et al. 1988). Of the two types, the freshwater rearing fry are more common.

The behavior, feeding habitats, and physiological state of emergent fry utilizing estuaries are very similar to chinook fry in freshwater. They are found in shallow water and at habitat margins, particularly tidal channels within salt marshes, and are closely associated with shorelines (Levy and Northcote 1981; Hayman et al. 1996). A high proportion of the diet of these emergent fry is composed of insects, although euryhaline species are also taken. These fry can tolerate salinity up to 15-20 ppt (Healey 1991). However, the bulk of the emergent fry occupy either low salinity habitats such as the marsh of the Fraser River (Levy and Northcote 1982) or low salinity strata of the water column (Healey 1991) which tends to be the surface waters.

This life history trajectory can be best understood as an adaptation for utilization of high quality estuarine rearing habitats that have few salmonid competitors. The use of these habitats are dictated either by density, where excess fry are displaced from upstream freshwater rearing habitats due to competition, or genetics.

Based on sampling efforts in the Nisqually Reach (Fresh 1979; Pearce 1982) no emergent fry are found in these waters. The lack of low catches may be due to sampling bias or fish physiological responses.

Fry/Fingerlings: For chinook, fry/fingerlings are fish that migrate to estuarine or marine shoreline habitats at a length of approximately 45 – 70 mm. These fish rear in the upstream habitats for a variable number of days or weeks prior to migrating downstream. They reach the estuary with much greater saltwater tolerance than do fry. Insects in the stream drift dominate chinook fry/fingerlings diets in upstream freshwater habitats. These fish may have limited territorial behavior and their downstream migration may involve a slow migration with continuous feeding. In the estuary, epibenthic zooplankton and crustaceans likely dominant diets, but these fish may also show an early shift to calanoid copepods (a pelagic species) if the latter are abundant relative to the former.

Fingerlings: Chinook fingerlings migrate to estuarine or marine shoreline habitats at a length of approximately 70 mm or more. This group includes naturally spawned and hatchery produced chinook. Prior to reaching this size, these fish exhibit territorial behavior dependent on the length of their time period of rearing in freshwater (Taylor 1990). Insects in the stream drift dominate diets in upstream freshwater habitats. This group likely undergoes smoltification comparable to coho, steelhead, or stream-type chinook while in freshwater. Based on their size it is reasonable to expect that they would have full osmoregulation capability when they reach the estuary.

The bulk of migration to the estuary occurs during May and early June and the duration of the peak of migration is narrow (Fresh et al. 1979; Pearce 1982). This observed pattern is determined primarily by the timing of hatchery fingerling releases in May that are spread out over several weeks. These fish arrive in all portions of the Nisqually Reach and are present on the estuarine shorelines, although the peaks of the runs differ slightly in each area.

Yearling chinook: These fish generally are the product of natural spawning in the Nisqually River or the result of hatchery releases from McAllister Creek hatchery. Yearling chinook are not believed to linger in estuarine and marine shoreline habitats.

Resident chinook: Resident chinook, sometimes referred to as blackmouth or feeder chinook are known to utilize the Nisqually Reach (Kerwin, J. pers. obs.) and have been collected from the Nisqually Reach (Fresh 1979). They were not included as a rearing trajectory for Nisqually River origin fish because of the likelihood that they are the result of delayed release hatchery programs located in McAllister Creek or from outside of WRIA 11.

Table 2: Nisqually River Basin Rearing Trajectories for Naturally Spawning and Hatchery Chinook in WRIA 11

Chinook Rearing Trajectory (1)	Abundance in the Nisqually Estuary (2)	Freshwater Rearing Duration (3)	Freshwater Rearing Season (4)	Estuarine Rearing Season (3)	Estuarine Rearing Season (4)	Bay Rearing Duration (3)	Bay Rearing Season (4)
Emergent Fry (< 40-45 mm)	Absent	Days	Late February thru March	Months	March to late May	Several weeks to months	May and June (5)
Fry/Fingerling (45-70 mm)	Present	Days to Months	Late February thru April	Several days to months	Early April to late May	Several weeks to months	May and June (5)
Fingerling (>70 mm)	Abundant	Months	Late February thru early June	Several days to two weeks	Late April to mid June	Several days to two weeks	May and June (5)
Yearling	Present	~14 months	Uncertain	Brief	----	----	----

(1) Defined based upon timing of entrance to estuary.
(2) Based on sampling conducted in Nisqually Reach estuary during the 1970's and 1980's.
(3) Individual residence
(4) Population residence
(5) Chinook may be present in small numbers through September.

CURRENT SALMONID POPULATION CONDITIONS IN THE NISQUALLY RIVER BASIN

The 1992 Washington State Salmon and Steelhead Inventory (SASSI) (WDFW and WWTIT, 1994) listed the stock status of Nisqually River fall chinook, chum, coho and pink salmon as unknown or healthy. Sockeye salmon were not identified as a stock present in this system but adult sockeye have been observed spawning in the mainstem. A summary of salmon and steelhead usage in major subbasins is presented in Table 3. The Nisqually River pink and chum salmon are defined as a native stock while coho and chinook are of a mixed native and hatchery origin. The National Marine Fisheries Service (NMFS) includes the fall chinook stock population in the Puget Sound Evolutionary Significant Unit (ESU) and has listed that ESU as Threatened under the Endangered Species Act. There have not been any observations of adult spring chinook spawning in this system. The stock status of Nisqually River fall chinook have been reviewed by NMFS and is still under active review. The stock status of Nisqually winter steelhead were listed as healthy in SASSI but recent population trends indicate that stock is depressed.

Table 3: Profiles of Nisqually River basin Salmon, Steelhead, Trout and Bull Trout Stocks as of December 1999.

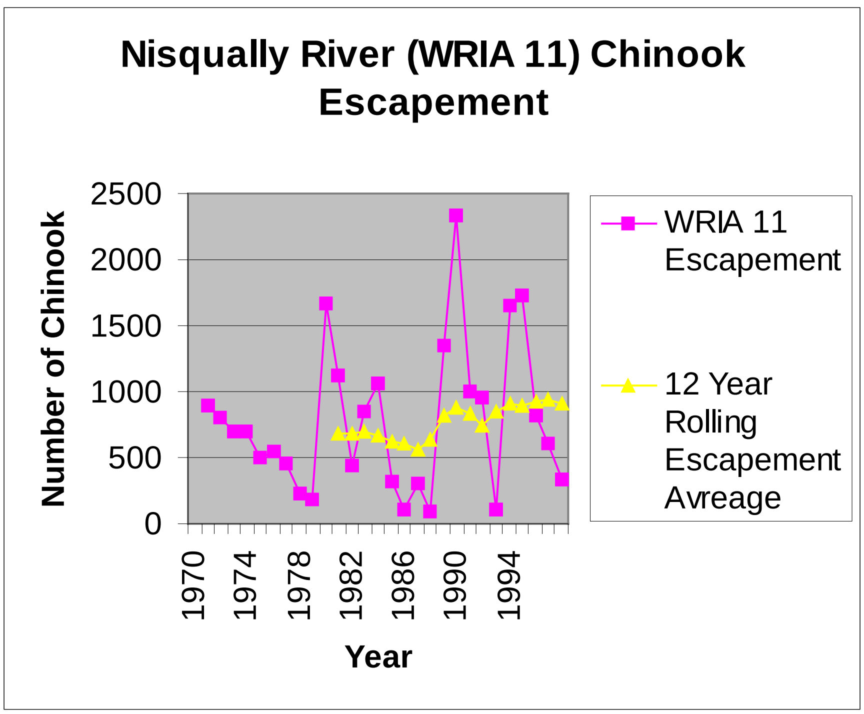
Stock	Major Subbasin(s)	Stock Status	Stock Origin	ESA Status
Nisqually River Fall Chinook	Nisqually River Mashel River	Unknown (1)	Mixed	Threatened
Nisqually River Winter Chum	Muck Creek Nisqually River	Healthy (1)	Native	Not Warranted
Nisqually River Coho	Nisqually River Mashel River Ohop Creek	Unknown	Mixed	Candidate
Nisqually River Pink	Nisqually River Ohop Creek Mashel River	Depressed (2)	Native	Not Warranted
Nisqually River Winter Steelhead	Nisqually River Muck Creek Mashel River	Depressed (2)	Native	Not Warranted
Nisqually River Sockeye	Nisqually River Basin	Unknown (3)	Unknown	Uncertain
Nisqually River Bull Trout	Nisqually River Basin	Unknown (4)	Native	Threatened
Nisqually River Coastal Cutthroat	Nisqually River and tributaries	Presumed Healthy	Native	Not Warranted

(1) Status from SASSI 1992
(2) Currently this status is considered depressed by WDFW and NT
(3) Species not managed, see narrative.
(4) One reported bull trout juvenile has been captured in the Nisqually River basin.

Chinook escapement for Nisqually River from 1970 to 1997 averaged 779 and ranged from 85 to 2332 during that time period. Between 1985 and 1996 the escapement of naturally spawning fish have varied substantially.

The naturally spawning fall chinook population in the Nisqually River basin is comprised of an unknown mixture of natural and hatchery origin fish. The magnitude of adult hatchery fish that contribute to the natural spawning population has not been determined. The spawning escapement estimates in Figure 2 and Table B-1 (Appendix B) include hatchery strays, a fact that leads to overestimation of the "wild" chinook run produced by naturally spawning parents. If large numbers of hatchery strays are included in SASSI (WDFW and WWTIT, 1994) escapement estimates, the SASSI status designation for this population could be changed to reflect that contribution.

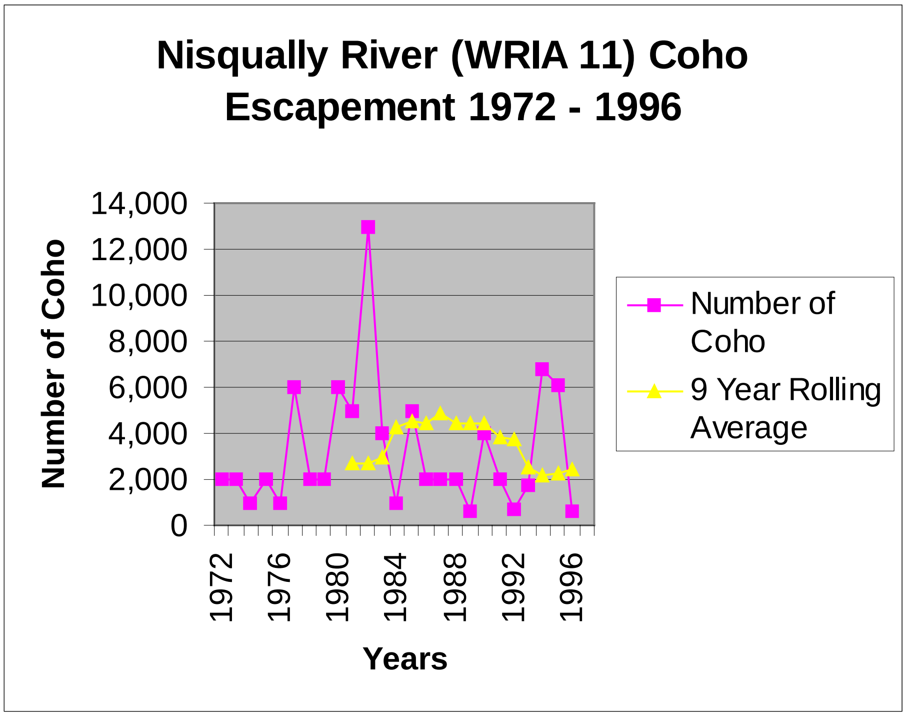
Figure 2 : WRIA 11 Chinook Escapement 1970 - 1997



Coho escapement for Nisqually River from 1972 to 1997 averaged 3,220 and ranged from 600 to 13,000 during that time period. Between 1985 and 1996 the escapement of naturally spawning fish have varied substantially.

The naturally spawning coho population in the Nisqually River basin is comprised of an unknown mixture of natural and hatchery origin fish. The magnitude of adult hatchery fish that contribute to the natural spawning population has not been determined. The spawning escapement estimates in Figure 3 and Table B-4 (Appendix B) include hatchery strays, a fact that leads to overestimation of the "wild" coho run produced by naturally spawning parents.   If large numbers of hatchery strays are included in SASSI escapement estimates, the SASSI status designation for this population could be changed to reflect that contribution.

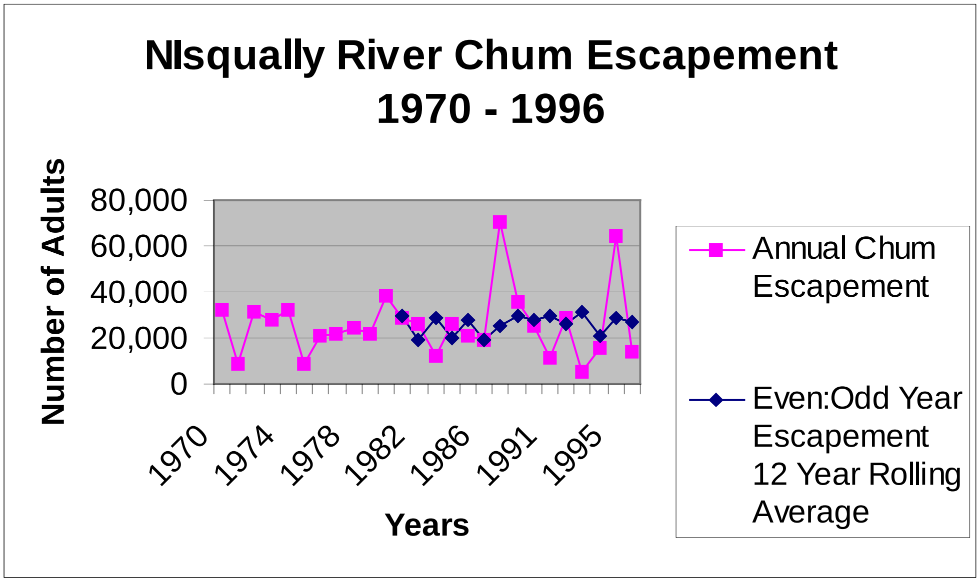
Figure 3: WRIA 11 Coho Escapement 1972 – 1996.



One winter chum stock for the Nisqually River was listed in SASSI. This chum stock is isolated from other Puget Sound chum stocks through geographic isolation and run timing. Additional genetic studies using electrophoresis have shown that this stock is distinct from both summer and fall timing chum stocks. Phelps et al (1995) separated chum stocks in Puget Sound based upon differences in major ancestral lineages (MAL's) and genetic diversity units (GDU's). The Nisqually River chum were identified as unique stock based on significant allele differences and the presence of a unique allele not observed in other collections. Nisqually River chum are considered native in origin.

Chum salmon escapement for the Nisqually River is depicted in Figure 4 and numerically in Table B-3 (Appendix B).

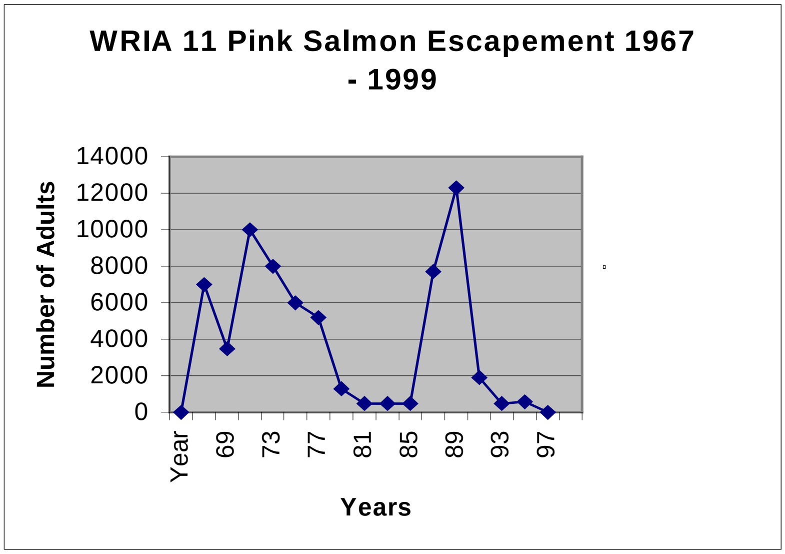
Figure 4 WRIA 11 Chum Escapement 1970 - 1996



Nisqually River pink salmon have been characterized as native and healthy (SASSI 1994). Currently, this stock is considered depressed by WDFW and the Nisqually Indian Tribe. This stock returns in odd numbered years only and is considered as native in origin. Population trends during the past five cycles (10 years) are not as optimistic. During the past thirty years Nisqually River pink salmon escapement has been highly variable ranging from an estimated low of 500 (1981, 1983, 1985) to 12,300 (1989). The trend for Nisqually River pink salmon escapement is shown in Figure 5 and numerically in Table B-2 (Appendix B)

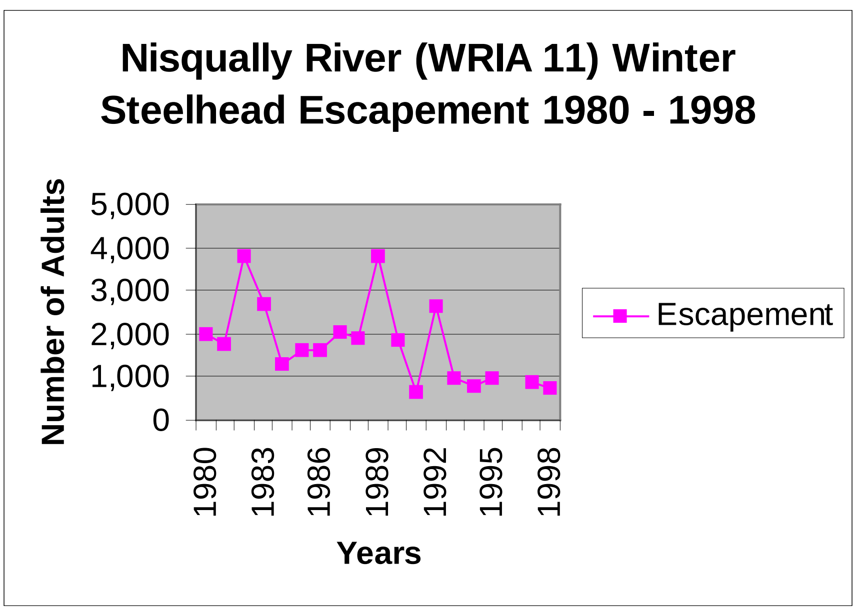
The Nisqually River winter steelhead stock has been characterized as native in origin and the status is depressed. Population trends in the early 1990's began a steady decrease similar to those of many other regional stream systems. However, while many of those systems have rebounded, or in some cases stabilized, the Nisqually winter steelhead population has continued to decline. No escapement data for Nisqually River winter steelhead is available prior to 1980. Escapement estimates are not available for 1996 due to poor water visibility conditions. Winter steelhead escapement to the Nisqually River is depicted in Figure 6 and numerically in Table B-5 (Appendix B).

Figure 5: WRIA 11 Pink Escapement 1967 – 1999



Note: No data is available for Pink salmon escapement for years 1997 or 1999.

Figure 6: WRIA 11 Winter Steelhead Escapement 1980 – 1998



The stock status for bull trout in the basin is unknown. Only limited data exists in the form of one reported juvenile bull trout caught by Nisqually Tribal biologists during mainstem river sampling in the 1980's (SaSI 1998).

Sockeye salmon are observed to spawn in the mainstem Nisqually River and Mashel River. Extensive sampling efforts in 1979 – 1980 at four locations in the mainstem Nisqually River did not record any observations of juvenile sockeye rearing in the freshwater environments of the Nisqually River (Tyler 1980). One juvenile sockeye was captured in estuarine surveys of the Nisqually Delta in 1979 (Fresh et al. 1979). The origin of this fish is unknown.

The reproductive success of this mainstem spawning sockeye is unknown. However, they would have significant rearing hurdles to overcome given the glacial origin of the Nisqually River, including the cold water temperatures and suspended sediments that would interfere with plankton production. Kokanee (landlocked sockeye) have been introduced into Alder Lake, a large hydroelectric water storage impoundment upstream of Alder Dam. This population reproduces naturally, primarily in the Little Nisqually River and East Creek and there are recorded hatchery releases in 1994, 1996 and 1997.

The adult sockeye observed spawning in the mainstem Nisqually River could be the result of these kokanee returning to their anadromous form and then returning to their natal system. However, water is not normally spilled by Alder Dam. The fish would also have to pass through the LaGrande Lake and Dam hydroelectric projects and mortality through the hydroelectric turbines and spilling would likely be significant.

The most likely hypothesis is that the sockeye adults are strays from other systems.

The population status of coastal cutthroat stocks is presumed healthy for the Nisqually River Basin. This is in part due to relative abundance in diverse habitats and multiple age classes present. This species is managed under a species complex scenario by WDFW. This is at least in part due to multiple interacting life history trajectories. Cutthroat trout are found in most fish bearing waters of the Nisqually River Basin from high mountain streams downstream to the Nisqually Estuary and Reach. Both resident and anadromous forms are found in the Nisqually River Basin.

The current known freshwater distribution of anadromous salmonids within the Nisqually River Basin and independent tributaries to Puget Sound in WRIA 11 is illustrated in Figures A-1 through A-6 (Appendix A). Figure A-7 (Appendix A) shows the known freshwater distribution for coastal cutthroat trout. Information for the known distribution was obtained from tribal, state, county and federal fishery professionals and published databases (SASSI, WDFW Spawning Ground Survey Database, and StreamNet, etc.). Individuals participating in the mapping of known distribution included: John Kerwin, Project Coordinator (Conservation Commission), George Walter (Nisqually Tribe), Dave Clouse (Ft. Lewis), Chuck Baranski (WDFW), John (Jay) Hunter (WDFW), and Jim Fraser (WDFW).

The current known freshwater distribution likely underestimates actual distribution because it does not include the historic or presumed distributions. The presumed distribution of salmonids is being addressed through efforts by the Northwest Indian Fish Commission, Salmon and Steelhead Habitat Inventory Project (SSHIAP). In many cases the smaller tributaries have not been surveyed. At times, private landowners may deny survey crews access to creeks. Some reaches of streams and rivers are not surveyed due to difficult access caused by natural terrain. Stream gradient break points are being digitized and a map illustrating the presumed distribution of salmonids should be available in 2000.

Currently, WRIA 11 stocks of both hatchery and naturally produced winter steelhead, yearling chinook and coho are returning in lower than expected numbers and this survival pattern is also being reflected in other WRIA's in southern Puget Sound. These fish all typically migrate from the freshwater as yearlings in the spring of their second year. Because of the regional nature of the poor survival of these stocks, concern was expressed by TAG members that the poor survival of these fish could be in the nearshore and/or south Puget Sound marine environment.

WATERSHED CONDITION

Salmon Habitats in the Nisqually River Basin

Water Resource Inventory Area (WRIA) 11 includes the Nisqually River which originates from the Nisqually Glacier on the southwest slopes of Mount Rainier (Figure 6) and three independent tributaries (McAllister Creek an unnamed creek and Red Salmon Creek) draining directly into Puget Sound. The Nisqually River flows northwesterly for approximately 72 miles before joining Puget Sound. The entire basin encompasses approximately 720 square miles and the principle drainage basin; the Nisqually River includes over 331 identified streams and 715 linear miles of river and stream channels (Williams 1975). The Nisqually River and its tributaries and the salmon stocks they support, are described in greater detail later in this report.

Salmonid habitat in the Nisqually River basin is controlled by basin-scale characteristics including water quality and quantity, sediment sources and associated transport, aggradation and deposition, nutrient supply, and hydromodifications. For purposes of this report, the Nisqually watershed has been divided into eleven subbasins. These subbasins are described below and the important habitat limiting factors for each are described in the next chapter of this report.

Annual average rainfall in the basin ranges from approximately 40 inches at the Olympia Airport to more than 140 inches in Mount Rainier National Park. Generally, sixty percent of this precipitation occurs in the fall and winter months (September thru March). Approximately sixty percent of the Nisqually basin lies at an elevation between 1,000 and 4,000 feet, an area where neither rain nor snow predominates. This topographical feature often leads to precipitation conditions that are capable of generating tremendous amounts of runoff. These flood events normally occur in the winter months and are followed by less severe spring runoffs generated by snowmelt.

Nisqually Estuary, Delta, Reach, Nearshore Environment and Nisqually River (RM 0.0 to RM 2.4)

The Nisqually Delta, formed by the Nisqually River, consists of broad mudflats and salt marsh. Bortleson (1980), using data from 1878, estimated that there were 6,360 acres of wetlands in the Nisqually Delta. Bortleson's classification criteria of habitat types are not consistent with that of the National Wetlands Inventory (NWI) that is currently in use. Using NWI criteria there are approximately 6,144 acres of wetlands in the Nisqually Delta. After allowing for differences in classification criteria, Table 1 compares current and historical acreage of habitat types in the Nisqually River Delta. The Nisqually Reach is that area where the Nisqually Delta and deeper waters of Puget Sound meet and includes those waters inside a line drawn from Johnson Point to Gordon Point, Anderson Island, Ketron Island and Drayton and Balch passages. The total surface area of the Nisqually Reach is approximately 76 square kilometers (Thom 1985).

The Nisqually nearshore environment includes those habitats outside of the Nisqually River delta but within the previously defined Nisqually Reach that are the interface between the terrestrial and marine environments. Even though some of these areas are within Water Resource Inventory Area (WRIA) 12 they are included in this discussion because of their influence to WRIA 11 (the Nisqually River Basin).

Independent Tributaries to Puget Sound

Two independent tributaries (McAllister and Red Salmon Creeks) are present in WRIA 11. Sequalitchew Creek is listed as being part of WRIA 12 (Williams 1975), but that decision is believed to be administrative in nature. Because of its importance to the WRIA 11 nearshore environment as input of freshwater it is included in both this report and the WRIA 12 report.

McAllister Creek supports natural runs of chinook, coho, chum, steelhead and anadromous (sea-run) cutthroat while Red Salmon Creek supports natural runs of coho, chum, steelhead and sea-run cutthroat. Both creeks and their tributaries originate from hillside springs and traverse through moderately timbered slopes immediately above the valley floor. Upon entering the valley they flow through agricultural lands with McAllister Creek entering the western edge of the Nisqually Reach while Red Salmon enters at the eastern edge through a distributary channel of the mainstem Nisqually River. Figures 1-5 in Appendix 1 show stream location and salmon distribution information. The largest spring in McAllister Creek has been developed by the City of Olympia to provide municipal drinking water to Olympia and neighboring communities.

The McAllister Creek stream channel is heavily armored and altered in the vicinity of Interstate 5 (RM 2.6) and localized armoring occurs where county and state roads cross the creek. Dikes exist in several local areas to afford property protection. These serve to limit lateral channel migration and off-channel rearing opportunities. The entire length of the mainstem creek and valley tributaries is subject to tidal influence.

The Sequalitchew Creek basin lies south of Tacoma between the communities of DuPont, Fort Lewis and Lakewood. The overflow from American Lake drains into Sequalitchew Lake, which has its own overflow outlet that forms the beginning of Sequalitchew Creek. Sequalitchew Lake is 80.9 acres in size (Wolcott 1973) and drains westerly through Hamer and Edmonds marshes before it descends from 200-foot elevation through a steep sided ravine and enters salt water in the vicinity of the DuPont Pier. The riparian habitat in the ravine primarily consists of second growth coniferous trees with blackberry vines along the streambank. Vegetation within the two swamps, both in excess of 100 acres, consist of natural rule weeds, cattails, devils club and aquatic weeds.

Sequalitchew Creek has very little natural estuary but the Nisqually Reach is immediately to the south and the importance of this creek is more as a source of freshwater input along this shoreline. The creek has historically supported runs of coho salmon up to approximately river mile (RM) 3.0 and chum salmon have been observed spawning in the lower 200 yards (Williams 1975).

Lower Nisqually River (RM 2.4 to RM 12.7)

For the purposes of this report the freshwater portions of the mainstem Nisqually River has been divided into three reaches. These reaches are:

- Lower Nisqually River – River Mile 2.4 to 12.7
- Middle Nisqually River – River Mile 12.7 to 26.2
- Upper Nisqually River – River Mile 26.2 to 42.5

The Lower Nisqually River is that portion of the Nisqually River from River Mile (RM) 2.4 to the City of Centralia's hydroelectric penstocks at RM 12.7 (Ames et al 1981). This reach serves as a transport corridor for all the anadromous salmonids in WRIA 11 and provides important spawning habitat for chum, coho, chinook and steelhead. Because of the glacial origin of the Nisqually River it is difficult to identify redds of anadromous fish that spawn in the fall. Steelhead redds are enumerated annually in this reach through aerial surveys conducted by the Nisqually Indian Tribe each spring.

Significant bank armoring is present in the lower portions of this reach along the left bank, near highway and railroad bridges. The Burlington Northern – Santa Fe Railroad grade limits the natural lateral channel migration in the area of RM 3.7. These have resulted in a reduction of lateral channel migration, available side channel rearing habitats and site specific riparian cover.

Upstream of RM 4.5 to RM 12.7, the mainstem Nisqually River meanders freely across the entire valley floor width. The river has several important wall-based side channels that are important for chum spawning and provide overwinter rearing habitat for coho and steelhead. Large numbers of chum have been observed spawning in the mainstem reaches. The riparian zone is largely forested with early, mid and late second stage seral conifers and hardwoods. Because of the freedom of the river to move laterally across the floodplain the riparian forests are in various stages of maturity throughout this reach. This reach of the mainstem Nisqually River represents the least impacted reach within that portion of the basin in the anadromous fish zone. Large woody debris (LWD) is present in large amounts throughout this reach.

Middle Nisqually River (RM 12.7 to RM 26.2)

This reach covers the mainstem Nisqually River from the City of Centralia owned and operated hydroelectric penstocks upstream to the Diversion Dam. It is been sometimes referred to as the Diversion Reach.

As in the Lower Nisqually River Reach, this reach serves as a transport corridor for all the anadromous salmonids in WRIA 11 and provides important spawning habitat for chum, coho, chinook and steelhead. Because of the glacial origin of the Nisqually River it is difficult to identify redds of anadromous fish that spawn in the fall. Steelhead, which typically spawn in the late winter and spring, redds are enumerated annually in this reach through aerial surveys conducted by the Nisqually Indian Tribe each spring.

This reach differs significantly from the lower Nisqually River. The majority of this reach from RM 12.7 to approximately RM 19.0 is contained within a shallow, narrow canyon and fairly steep gradient river channel bordered on each side by largely flat prairie habitats. Instream habitat can be characterized as deep pools with some boulder stretches and spawning gravel patch pockets. The presence of spawning gravel increases in the lower two miles of this section (EDT Workgroup, In Press). Riparian habitat varies considerably throughout this reach from what is considered late second seral stage to poor in the area of rural housing developments. Several flood control dikes are present in the vicinity of RM 21.8 along both sides of the river, along the Centralia Diversion Canal where it approaches the mainstem Nisqually River and in the vicinity of RM 26.2. These limit lateral channel migration reducing available off channel rearing opportunities.

The Centralia Hydroelectric Diversion Dam has a single, left bank, seven-pool fish ladder. The diversion canal intake structure fish screens were replaced in 1999 and meet current criteria for excluding fish from the canal.

Upper Nisqually River (RM 26.2 to RM 42.5)

This reach stretches from the Diversion Dam upstream to the City of Tacoma LaGrande Hydroelectric Dam.

As in the lower mainstem river reaches, this reach serves as a transport corridor for all the anadromous salmonids in WRIA 11 and provides important spawning habitat for chum, coho, chinook and steelhead. Because of the glacial origin of the Nisqually River it is difficult to identify redds of anadromous fish that spawn in the fall. Steelhead, which typically spawn in the late winter and spring, redds are enumerated annually in this reach through aerial surveys conducted by the Nisqually Indian Tribe.

Flood control dikes exist in the lower reaches along the left bank. These limit lateral channel migration and eliminate off-channel rearing and overwintering opportunities. There are single family residences, hobby farms and larger agricultural facilities in this reach that negatively impact riparian habitat quality particularly in the lower portions of this reach. In the middle portion of this reach the mainstem Nisqually River meanders freely across the valley floor width and off-channel rearing and overwintering habitats are present throughout. Four significant channel changes triggered by high flows have occurred since 1978. The largest of these was a landslide on a right bank in just downstream of the confluence of the Nisqually River and Ohop Creek that was estimated at approximately 200-300,000 cubic yards.

Riparian habitat consists of second growth coniferous and hardwood trees with some pockets of old growth conifers. These pockets of old growth trees are important in the recruitment of LWD into this section of the river.

Upstream of Ohop Creek, the mainstem Nisqually River is characterized by deep pools between narrow bedrock cliffs. The gradient of the river increases as one moves upstream and in spite of several actively eroding sand/gravel bluffs there are only limited areas of spawning size gravel. The few gravel pockets available assume a greater importance due to their relatively low number. The only channel constriction in this reach is an abandoned wood/log bridge that was part of a road system maintained by the Weyerhaeuser Company. This bridge is located just above the confluence of the Mashel and Nisqually Rivers and is being allowed to fall into the river.

Clear and Kalama Creeks

Clear and Kalama Creeks share similar origin, habitat and land use characteristics. Both creeks are wall-based spring fed systems that originate on Fort Lewis. Clear Creek lies entirely within the Fort Lewis Military Reservation (Ft. Lewis) and joins the Nisqually River at RM 6.1. Kalama Creek leaves Ft. Lewis and flows through the Nisqually Indian Reservation before entering a slough to the Nisqually River at RM 9.1.

Both creeks were historically utilized by coho and chum salmon, winter steelhead and searun cutthroat. Currently, the Nisqually Indian Tribe operates salmon hatcheries on each creek that primarily produce chinook and coho salmon. The Kalama Creek Hatchery began operation in 1979 and the Clear Creek Hatchery in 1990. Each facility has an adult salmon trap for returning broodstock collection that limits the upstream migration of salmonids.

The riparian habitat consists of second growth mid to late seral stage coniferous forests with some hardwoods. Only the lower 0.1 miles of the historical Clear Creek stream channel is available for salmonid utilization due to hatchery operations. The lower 0.5 miles of Kalama Creek and associated mainstem slough are available for natural rearing of anadromous salmonids.

Muck Creek

Muck Creek is the most significant tributary in the lower Nisqually River reach for anadromous salmonids. Located in southeast Pierce County, this creek system is comprised of 7 tributaries and over 50 miles of stream habitat. The creek and its tributaries take their origins from diverse springs that lie in the prairie area south and southeast of the City of Puyallup. The stream gradient is characteristic of prairie based systems, generally shallow with few moderate reaches primarily in its lower sections as it cuts through a canyon. Tributaries exhibit much the same characteristics as the mainstem. There are several marshes that the creek flows through in the flat prairies of Ft. Lewis and Pierce County.

The drainage has been moderately developed with rural residential homes, hobby farms, farms and pastureland. Portions of the subbasin face increasing pressure of urbanization as development pressures move south and east. Within the boundary of Fort Lewis the creek flows across training areas and along the edge of the artillery impact area.

The creek between RM 11 and its confluence with the Nisqually River, is predominantly within the boundary of Ft. Lewis. Only a 1.1 mile stretch in the vicinity of Roy is outside the Ft. Lewis Reservation boundary.

Chum salmon, winter steelhead and sea-run cutthroat are the primary species that utilize the Muck Creek subbasin.

Yelm, Murray and Unnamed Tributaries

These creeks are located in the middle reach of the Nisqually River basin downstream of the SR 507 bridge crossing. All take their origins from diverse seeps and springs in the prairie lands associated with this reach. Stream gradients are relatively flat and the systems generally are associated with wetlands.

In addition to Yelm and Murray creeks, there are several unnamed, or locally named, smaller creeks and wall-based springs that salmonids utilize which appear to be associated with leakage from the City of Centralia Hydroelectric Diversion Canal.

Stream gradients are relatively flat and require groundwater recharge prior to increases in surface flows. This flow pattern is similar to what is exhibited in Muck Creek. Salmonid utilization is primarily by chum salmon, winter steelhead and searun cutthroat trout. Because these creeks maintain stable surface water flows into early summer, they provide access for juvenile chinook and coho that may be important rearing and/or high flow refugia areas.

Intermittent flows occur upstream of RM 1.4 in Yelm Creek (Nisqually EDT Workgroup, In Press). These flows prevent upstream migration of salmonids. Anadromous access in Murray Creek is limited by naturally occurring low flows above RM 0.6. Young second growth hardwoods dominate the riparian zones in the lower reaches of both creeks.

Tanawx, Kreger, Horn, Toboton, Lackamas, and Powell Creeks

These creeks, all located downstream of Ohop Creek and upstream of the SR 507 bridge crossing take their origins from broad flat prairie areas in the Nisqually River basin. Stream gradients are relatively flat although some streams are locally incised immediately prior to their confluence with the Nisqually River. All are associated with wetland complexes and some are associated with lakes (e.g.: Tanwax, Kreger, Powell, and Toboton).

These drainages have been moderately developed with rural residential homes, hobby farms, commercial farms and pastureland. Portions of each subbasin face increasing pressure of urbanization as development pressures move east and southeast. Adverse water quality and quantity issues are associated with development of lands adjacent to these creeks.

Coho and chum salmon, along with steelhead and cutthroat trout utilize these creeks. There is the potential for chinook juveniles to utilize the lower reaches of these creeks as rearing areas or refugia from floods.

Ohop Creek

The Ohop Creek subbasin joins the Nisqually River at RM 37.3 and is the third largest anadromous fish accessible tributary in WRIA 11. The principal tributaries include Twenty-five Mile and Lynch creeks. The dominant hydrologic feature in this subbasin is Ohop Lake (RM 6.3).

Relatively dense residential development has occurred around Ohop Lake. The lower Ohop valley, downstream of Ohop Lake is currently in transition from commercial agricultural use (primarily dairy farms) to hobby farms and rural residential development. The lower valley reach is low gradient with no intact natural riparian zone. The lower 0.3 miles do exhibit some limited hardwood forests. Upstream of RM 0.3 to RM 4.5 the stream channel is channelized and bottom substrate is comprised of sands and silt. From RM 4.5 to RM 6.3 (Ohop Lake outlet) the stream emerges from the channelized lower reaches and gravels are present in the substrate. A log weir that may delay upstream migration of adult salmonids under certain flow conditions maintains Ohop Lake water levels.

The principle tributaries to Ohop Creek are Lynch Creek and Twenty-five Mile Creek. Lynch Creek, left bank tributary joins Ohop Creek at RM 6.2. The creek flows from commercially owned timberlands (Weyerhaeuser and Champion Pacific) and enters rural residential and hobby farm areas in the lower mile. Of particular note is that the Town of Eatonville stormwater collection system discharges into Lynch Creek. Anadromous fish are present from its confluence with Ohop Creek upstream to a natural impassable falls at RM 1.0. The gradient in this lower reach is relatively steep with only limited patches of spawning gravel.

The Twenty-five Mile Creek subbasin flows from commercial owned timberlands through an area of hobby farms and a recently abandoned clay mining operation before joining Ohop Creek at RM 9.9. A natural impassable barrier at RM 1.0 limits anadromous access.

Coho, chinook, and pink salmon, along with steelhead and coastal cutthroat trout utilize these creeks.

Mashel River

The Mashel subbasin is the largest tributary accessible to anadromous salmonids in WRIA 11. Draining an area of 83 square miles it joins the Nisqually River at RM 39.6. The Mashel River has over 20 miles of mainstem river plus another 67 miles of associated streams. The principle tributaries include Busy Wild and Beaver Creeks in the upper Mashel and the Little Mashel in the lower Mashel.

The Mashel River has its origins on the mountain slopes in southern Pierce County associated with Mt. Rainier. Flowing from commercially owned timberlands the upper reaches of the river are relatively steep gradient in a narrow canyon. A naturally occurring impassable falls is present at RM 15.4. Downstream of Busy Wild Creek, the Mashel River gradient is moderately steep and substrate is primarily cobble/small boulder with only small gravel pockets (Nisqually EDT Workgroup, In Press).

Busy Wild Creek lies entirely within commercial forest zones owned by the Washington Department of Natural Resources and Champion Pacific Timberlands. A naturally occurring impassable cascade at RM 5.0 limits anadromous fish migration. Outside of the lower two miles, the gradient is fairly steep and the channel confined within a narrow canyon. The creek flattens out in the lower two miles on to a broader hanging valley floor prior to entering a steep gradient canyon in the lowermost 0.5 mile.

Beaver Creek, left bank tributary, enters the Mashel River at RM 9.3. Only the lower 0.5 mile of this creek has historically been available for anadromous fish due to a natural impassable cascade at that point. A small fish ladder was installed in the early 1980's at this cascade but it is unknown if passage opportunities still exist. The creek lies entirely within commercial timberlands and flows from a series of wetlands across a broad valley before entering a narrow canyon at approximately RM 2.0. Downstream of RM 0.5 the creek gradient flattens out somewhat and the stream channel is comprised of boulders with small gravel patches.

Riparian cover throughout this basin consists of a mixture of hardwood and early- to mid-seral stage coniferous forests.

Flowing out of commercial timber production areas the Little Mashel River joins the Mashel River at RM 4.4. Numerous small hobby farms and rural residences predominate in the lower reaches. The riparian corridor consists of hardwoods and anadromous salmonid utilization is limited to the lower 0.8 miles due to a naturally occurring impassable waterfall at that point. The river channel is comprised of cobble/boulder type substrate with limited gravel patches.

Coho, chinook, and pink salmon, along with steelhead and cutthroat trout utilize the mainstem Mashel River while coho salmon, steelhead and cutthroat trout utilize the smaller tributaries.

HABITAT LIMITING FACTORS BY SUB-BASIN

In 1998 The Nisqually Indian Tribe commissioned an Ecosystem Diagnosis and Treatment Analysis report to evaluate the Nisqually River Basin (WRIA 11) habitat for chinook salmon and to identify constraints and opportunities for rebuilding chinook salmon stocks. That report, currently in its draft form (Nisqually EDT Work Group, In Press), is complementary to this report. Salmon, steelhead and coastal cutthroat trout distribution maps that are indicative of the known distribution are found in Appendix A of this report.

Nisqually Estuary, Delta, Reach, Nearshore Environment and Nisqually River (RM 0.0 to RM 2.4)

General

While regarded by some as relatively pristine, the Nisqually Delta has undergone extensive alteration in the last 100 years. Prior to 1850 the Nisqually Estuary ecosystem was characterized by interconnected and independent habitats dependent on one another to support the functioning ecosystem. The interaction of these habitats and their associated processes allowed for the natural flow of nutrients, energy and animal and plant species. A reduction in ecosystem size and complexity is associated with a reduction in function. The habitat loss, and reduction of connectivity of the remaining habitat, has reduced the productive capacity of the Nisqually Estuary to support juvenile and adult salmon.

Estuary and Floodplain Modifications

Habitat changes have occurred largely as the result of extensive diking along the mainstem river and estuary to convert valley bottomlands into agricultural use. The most recent analysis of these habitat alterations was done by Tanner (1999) who utilized GIS to examine the changes in different habitat types in the delta. Those results are presented below in Table 4.

Table 4 : Comparison of historical and current wetland acreages in the Nisqually Delta (Tanner 1999)

Habitat Type	Historical Acreage	Current Acreage	Percent Change
Estuarine Intertidal	6,207	5,016	- 19 %
Emergent Marsh	1,458	674	- 54 %
Palustrine Wetlands	152	1,082	+ 610 %
Riverine	46	46	0 %
Upland	1,296	1,512	+ 17 %

Through diking, the Nisqually River Delta has experienced a substantial reduction in estuarine wetland habitat and specifically that of intertidal emergent marsh habitat (-54 percent (Tanner 1999)). The Nisqually River estuary is an important rearing habitat for all seven species of salmon and anadromous trout of WRIA 11 origin and those that transit it from other WRIA's. A direct correlation between estuarine habitats lost and effect on natural production has not been completed but it would be expected to be adverse.

Of particular significance is the conversion of intertidal emergent marsh habitat to the freshwater-based wetlands that are found inside the diked areas north and south of the Nisqually River channel. Intertidal emergent marsh habitats are widely utilized by salmonids as they transition from freshwater to saltwater and are instrumental in their survival.

The diking first started in the late 19^{th} century and the ensuing actions fragmented some of the remaining estuarine habitats. Habitat alterations consisting of dikes with vertical or steeply sloping sides have lowered habitat value of the mainstem river. The historical migration routes of anadromous salmonids into off-channel distributary channels and sloughs have been reduced from historical levels. The dikes have also altered the saltwater intrusion and transition zones. Despite these modifications, the remaining habitats continue to support the biological resources associated with the historical functioning habitats.

The nearshore environment to the north of the Nisqually Delta was altered from its historical configuration when the Northern Pacific Railway Company constructed its Point Defiance line along the base of the bluff in 1912. Associated with this construction was the placement of large amounts if angular riprap to protect the line from erosion.

Based on shoreline surveys and aerial photo interpretation, it has been estimated that approximately 19,008 linear feet (3.6 miles) of riprap are present from the edge of the Nisqually Delta to Tatsolo Point. This represents 100% of the length of the shoreline. At least four gravel beaches have formed in this area (Kerwin pers. observ.). The above numbers likely underestimate the total impacts on habitat quality and quantity due to the steepening of the slope above MLLW. This reduces the surface area available for primary and benthic productivity and the shallow water habitat available as a refuge from predatory fish.

The protection of shorelines through bank hardening activities interrupts the natural process of wave and current erosion of bluffs and banklines in nearshore environment. This in turn interferes with natural processes of sediment recruitment. The use of shoreline protection methods also can alter substrate composition, increases slope, and natural successional processes of riparian plant communities. These changes have a negative impact to the quality of salmonid rearing habitat and adversely impact survival. The presence of larger substrate on steep slopes, typically supports reduced epibenthic assemblages compared to flatter habitats with finer substrate. Although vascular vegetation is precluded, hard substrate provides abundant attachment sites for macroalgae. Conversely, it also reduces the habitat available for shallow water avian predators of juvenile salmonids.

Channel Condition

The configuration of the mouth of the river is notable in that it discharges to the bay with two short distributaries separated by approximately one-half mile. The distance between the mouths of the distributaries is of interest in the distribution of freshwater to the estuary. This outlet configuration contrasts with the much wider separation between distributaries that occurs at the mouths of rivers with substantial deltas (e.g.; the Fraser, Skagit and Nooksack rivers) but is similar to that of the historic Puyallup River. Strong tidal currents carry the freshwater discharge in both directions across the Nisqually Reach daily. Because of the position of the Nisqually River mouth and distributaries, it is presumed that freshwater influence would be spread throughout the estuary.

In addition, the currently channelized lower reaches of the Nisqually River effects the saltwater wedge. Channelization has reduced the width of the river and since the freshwater lens is less dense and overlays the saltwaters, it can be hypothesized that the actual volume of the saltwater wedge that contributes to the saltwater transition zone has decreased. Additionally, within the tidally influenced zone, shallower sloping banks have been replaced by steeper banks comprised of rip rap that affords less surface area for benthic production and shallow water habitat for avoidance and escape from predatory fish, mammals and birds.

Sediments and Substrate

Nelson (1974) estimated the suspended sediments transported by the Nisqually River at Nisqually to be 105,000 tons annually. The vast bulk of this material is in the form of glacial flour and is deposited on the Nisqually Delta and into the deeper waters of the Nisqually Reach. A literature search did not reveal any published information suggesting adverse sediment issues that could impact salmonid survival in the Nisqually Estuary.

Riparian Condition

Attempts to reconstruct historic vegetation types in the Nisqually Delta are only marginally successful. Journal accounts, panoramic photographs and early survey maps lack specificity. Photographs taken at a close enough range to identify species lack location. Although it is not possible to reconstruct a detailed account of the composition of species present in the Nisqually Estuary, we assume that it possessed habitat types similar to that found in undisturbed areas of the delta. The historic plant communities were probably little different from current low- to intermediate-elevation plant communities found in present day marshes. Riparian habitat along the nearshore marine line has been extensively altered through the construction of the railroad mentioned previously in this report.

Water Quality

Water quality parameters necessary for salmonid production have been established and are widely accepted. When monitoring programs detect that those parameters have been exceeded they can be proposed for listing as impaired under current water quality law. Applicable laws include the Clean Water Act, Chapt. 90.48 RCW and Chapt. 173-201 WAC.

Every two years, the Washington Department of Ecology (WDOE) is required by the Federal Clean Water Act to identify waters in Washington State that do not meet minimum water quality standards. This list is known as the Section 303(d) list. The WDOE has noted limited numbers of excursions beyond water quality criteria at sampling stations in the Nisqually Reach/Drayton Passage for pH (1 excursion in 1997), dissolved oxygen (3 excursions between 1986 and 1990), fecal coliform (2 excursions in 1989 between 1990) and temperature (23 excursions between 1985 and 1991). The limited number of excursions for pH, dissolved oxygen and fecal coliform does not meet current WDOE criteria for including the Nisqually Reach in the Clean Water Act 303(d) list and the temperature excursions were a natural condition due to solar heating on the mud flats of the Nisqually Delta (WDOE 1999).

While there are elevated fecal coliform bacterial levels in the Nisqually Reach, the overall water quality is good and does not appear to be a significant issue in the Nisqually Delta.

Water Quantity

Water quantity within the Nisqually Delta is tidally influenced. Water within the area of the Nisqually Reach is replaced every 8 days (CH2M Hill 1978) and there are no reported concerns (WRIA 11 Technical Advisory Group).

Fish Usage

The most recent survey of fish utilization of the Nisqually River, estuary and reach was completed by Cook-Tabor in 1999. That survey found 94 species from 30 different families present in the WRIA 11. Ten species of salmonids were reported as observed or captured in the Nisqually River, estuary or reach (Table 5).

Table 5: Salmonids captured or observed in WRIA 11 (Source: Cook-Tabor)

Common Name	**Latin Name**	**Habitat**		
Cutthroat trout	*Oncorhynchus clarki*	F	E	M
Pink salmon	*O. gorbuscha*	F	E	M
Chum salmon	*O. keta*	F	E	M
Coho salmon	*O. kistuch*	F	E	M
Steelhead	*O. mykiss*	F	E	M
Sockeye	*O. nerka*	F	E	M
Chinook	*O. tshawytscha*	F	E	M
Mountain Whitefish	*Prosopium Williamsoni*	F		M
Bull trout	*Salvelinus confluentus*	F	E	M
Dolly varden	*S. malma*	F	E	M

F = Freshwater E = Estuarine M = Marine

Independent Tributaries to Puget Sound

McAllister Creek

Estuary

The McAllister Creek estuary (downstream of RM 2.5) lies at the western edge of the Nisqually River estuary and shares the same problems as identified previously for the Nisqually River Estuary.

Floodplain Modifications

McAllister Creek is the largest independent tributary in terms of freshwater flow to the Nisqually Estuary. Downstream of Interstate 5 (I-5) the creek is bordered by bluffs to the west and the Nisqually National Wildlife Refuge on the east. In the vicinity of I-5 the creek is confined between two hardened banks. Lateral movement is restricted until the creek turns away from I-5. Traversing along an area between the bluffs and the Nisqually National Wildlife Refuge, McAllister Creek is confined between those bluffs and dikes associated with the refuge lands. From approximately RM 2.5 to 3.0 the creek is confined within riprap armored dikes along both banks. Upstream of RM 3.0 the creek flows primarily though agricultural lands with localized bank protection in the vicinity of road crossings and streamfront houses. The floodplain suffers from localized confinement. Between RM 2.5 and 3.1 McAllister Creek has been relocated to accommodate highway construction.

Channel Conditions

Currently, bank stability is not a significant problem due to the stream's low gradient and minor influence of human, structural presence and associated disturbance. However, loss of old growth trees and replacement with second growth conifers and hardwood has reduced the natural, functional integrity of bank margins. The recruitment of large woody debris (LWD) is limited due to the poor condition of the riparian habitat. Much of the wood that does enter the channel is removed to provide passage for recreational boaters.

Sediments and Substrate

Because McAllister Creek has an extremely low gradient and the lack of pool forming LWD the sediments are largely composed of mud and fine sands with localized patches of gravels. These gravel patches are usually found in the vicinity of upwelling springs.

The saltwater wedge extends at least upstream to RM 3.8 (Wood, pers. comm. 1984) and the creek is tidally influenced upstream to RM 5.5.

Riparian Condition

Much of McAllister upstream of RM 2.5 is currently lacking in the coniferous riparian habitat that was present historically. This riparian habitat varies from second growth conifer to blackberry brambles. The existing dikes and revetments eliminate connection to adjacent lowlands eliminating beneficial estuarine habitats. The habitat, which remains, is comprised of disconnected areas that do not meet the properly functioning categories of the NMFS matrix of habitat pathways and indicators. The riparian area in its entirety can not be rated as functioning properly.

Water Quality

The sources of McAllister Creek are a series of springs with high quality groundwater. The City of Olympia has developed the largest of these springs as a domestic water source and that water is exported from the basin. Sources of fecal bacteria contamination occur from agricultural areas (e.g.: dairy lands) in areas between RM 3.1 to 6.0 (Whiley 1998). Water temperature from the springs is relatively constant at 10 C. and dissolved oxygen levels exceed 8 mg/L.

Water Quantity

The City of Olympia has a water right for 19.6 million gallons per day with an actual use generally less. This water is exported out of the basin.

Along the Hawks Prairie bluff are a diverse series of wall-based and in-channel springs that contribute to stream baseflows.

Little McAllister Creek, a tributary of McAllister Creek, is being adversely impacted by increased peak flows due to the urbanization of its watershed. The majority of the development in the upper watershed went in before current drainage standards were enacted. The upper ravine is rapidly eroding, sending fine material into the valley, covering salmonid spawning areas and filling in pools. The lower creek has been diked and there is a tide gate at the mouth that eliminates access at certain tide levels. Two regional stormwater facilities (Pacific Avenue Wetland and Mallard Pond) which will address the peak flow problem are scheduled for design and construction in 2000. A planned Phase II of this project, the Pacific Avenue Wetland, will double the storage volume of Phase I. Funding for Phase II has not been secured.

Red Salmon Creek

Estuary

Red Salmon Creek lies at the eastern edge of the Nisqually River estuary and is connected to the Nisqually River outflow through an eastern distributary of the mainstem Nisqually River. Red Salmon Creek shares the same problems as previously identified for the Nisqually River Estuary. The saltwater wedge penetrates at least up to RM 1.2. The extent of tidal influence extends above the same location (the Burlington Northern Railroad crossing) at RM 1.2.

Floodplain Modifications

Red Salmon Creek is a small independent tributary on the eastern edge of the Nisqually Delta. The creek originates from a series of diffuse springs and seeps in wetlands north of Interstate 5. From its origin, the creek flows westerly, through an area of low density residential houses, hobby farms and agricultural lands before flowing under the Burlington Northern railroad tracks and a small county road and then emptying into a distributary of the Nisqually Delta. The creek is channelized in the vicinity of these crossings and culverted under both.

Channel Condition

No specific data was identified relating to channel condition including the presence/absence of pools and LWD in Red Salmon Creek.

Sediments and Substrate

Gravel substrate condition is considered good in site-specific areas of the stream, particularly upstream of the Burlington Northern (BN) railroad crossing.

Riparian Condition

The riparian condition of the stream has been degraded throughout much of the length of Red Salmon Creek through removal of coniferous and deciduous trees. Encroachments into the riparian buffer by rural residential and hobby farms have adversely impacted this riparian buffer to function effectively. Those areas that remain forested consist of second growth deciduous hardwoods and LWD recruitment problems remain. Because of the small size of Red Salmon Creek and limited drainage area most medium sized pieces of wood would aid in pool forming processes.

Water Quality

No specific data were identified relating to water quality in Red Salmon Creek.

Water Quantity

No specific data were identified relating to water quantity in Red Salmon Creek.

Fish Usage

Fish passage does not appear to be a problem. Chum salmon adults have been observed spawning upstream of these culverts and steelhead juveniles have been captured upstream of the railroad crossing (Kerwin pers. observ.)

Sequalitchew Creek

Estuary

Sequalitchew Creek flows underneath the Burlington Northern – Santa Fe railroad tracks and directly into Puget Sound. Because of the stream gradient at the point of entry into Puget Sound there is very little estuary associated with this system. Rather its importance is as a freshwater input along the northern shoreline in the vicinity of the Nisqually Reach.

Floodplain Modifications

In the upper reaches the stream has been channelized. As the stream leaves Sequalitchew Lake it flows for approximately 0.5 miles through a channel before skirting Hamer Marsh and entering Edmonds Marsh. The creek then assumes a more natural channel before it passes through a large culvert under the railroad dike along the edge of Puget Sound. There is very little natural estuary present.

Channel Condition

The creek downstream of Sequalitchew Lake and upstream of Edmond Marsh is largely channelized in a ditch. This channelization limits the lateral movement of the creek within its natural floodplain.

Sediment and Substrate

No detailed studies have been completed on sediment quality within this basin. There is restricted opportunity for spawning in the lower reach due to limited gravel patches, but chum salmon have been observed spawning in the lower 200 feet (Williams 1975).

Riparian Habitat

The creek lies almost entirely within the boundary of Ft. Lewis and the old DuPont Powder property now owned by the Weyerhaeuser Company. This ownership pattern has afforded the creek a certain amount of riparian habitat protection. The riparian habitat consists of large second growth conifers, heavy stands of blackberries, brush and marshes that are densely covered with exotic reed canary grass.

Water Quantity

Sequalitchew Creek begins at the north end of Sequalitchew Lake where the Department of the Army currently has a pumping station referred to as Sequalitchew Springs. This pumping station is operated to supply irrigation, domestic and emergency water to areas of Ft. Lewis. Water withdrawal is greatest during summer months when baseflow into Sequalitchew Creek is lowest. From the lake source, and throughout its one-mile passage across Fort Lewis, Sequalitchew Creek is a low gradient and slow moving creek. An engineered drainage and diversion canal, located at the western end of the lake, diverts overflow from the creek into Puget Sound when the flow capacity of Sequalitchew Creek is exceeded. The weir is used to control the level of Sequalitchew Lake, which is necessary because of the small vertical separation between the springs and the lake. A backflow prevention weir accomplishes separation of lake water and the spring at the springs. When the lake rises above the level of the backflow prevention weir, lake-water flows into the springs, placing the water supply at risk. Fort Lewis prepared a lake-level management plan for Sequalitchew Lake in 1997. The objective of this management plan was to identify and recommend measures to minimize the risk of lake water intrusion into the springs. Since that time Fort Lewis Public Works has adopted the measures outlined in that plan.

Water Quality

Water quality issues (i.e.: temperature) in Sequalitchew Creek are directly linked to quantity of flow in this system. The beaver activity in Sequalitchew Creek and the stream gradient in the headwaters of the creek are the most important factors controlling lake level and consequently the volume and rate of water diverted over the outlet weir. The backwater conditions created by downstream beaver dams allow virtually no water to pass from the lake source to the creek. Without constantly clearing the stream channel, water continues to be held-up without flowing freely through Sequalitchew Creek.

Fish Usage

Sequalitchew Creek is listed by Williams (1975) in WRIA 12 but provides freshwater influence to the northeastern nearshore habitats of the WRIA 11. Adult chinook, coho and chum salmon destined for the Nisqually River and juvenile salmonids of an unknown species have been observed near the mouth of Sequalitchew Creek.

Lower Nisqually River Mainstem (RM 2.4 to RM 12.7)

General

The lowermost reaches of the Nisqually River from RM 0.0 to RM 2.4 are part of the estuarine environment and are covered under that section. Because of overlapping issues, we will include some of the habitat attributes associated with the mainstem Nisqually River dikes and levees in this section.

Floodplain Modifications and Channel Condition

The lower Nisqually River is that portion of the Nisqually River from RM 2.4 (Interstate 5 road crossing) to 12.7. The lateral movement of the Nisqually River within the natural floodplain is severely restricted in the lower 4.9 river miles by a dike and levee system constructed to provide a level of flood protection. The lower reaches of the Nisqually River are further confined and lateral channel migration opportunities eliminated by the Interstate 5 bridge and associated bank hardening. I-5 has only one bridge crossing across a confined channel. Nisqually River basin dikes and levees are shown in Figure A-8 (Appendix B).

The construction of dikes and levees in this reach has eliminated connections with side- and off-channel aquatic habitats. The maintenance of these structures has precluded the establishment of adequate riparian vegetation resulting in a decreased contribution of prey organisms to the river. Also, they have precluded the recruitment of small and large wood from areas most likely to contribute this material. Channelization and levees have also reduced river processes that form pools, side channels and other habitat features used by salmonids.

Extensive changes in the mainstem river channel and throughout the valley floor have reduced the rearing habitat available for the migrating and non-migrating salmonids. As previously discussed, emergent chinook fry would have been present in high numbers in the lower river and the distributaries. Water velocity refugia along the lower Nisqually River has been reduced by alteration of the shoreline, thereby decreasing the suitability of this area for all salmonids, including juvenile chinook. This reduction in flow reduces habitat quality and quantity by increasing water velocities, degrades habitat quality by increasing metabolic energy demands of juveniles attempting to maintain position and defend territories.

The loss of natural vegetation and wetlands in the Nisqually River basin has reduced the watershed's ability to store and process water in a manner to minimize flood event duration and peaks.

Sediments and Substrate

The Nisqually River's glacial source produces large volumes of pulsed sediment migrating through the mainstem Nisqually River. While no sediment quality and quantity studies are known to have been conducted specific to this reach, Nelson (1974) examined sediment transport and concluded that the Nisqually River near Nisqually carried 105,000 tons of sediment annually. The bulk of this material consisted of suspended sediments.

Visual observations by TAG members are consistent with what one would expect to find in this reach. The mainstem Nisqually River is subject to tidal influence upstream to RM 3.7 and the bottom is comprised of mud, silt and gravel. Between RM 3.7 and 4.9 the river bottom is generally small to medium sized gravels in a series of long glides with riffles. Upstream of RM 4.9 to 12.7 the river bottom has been influenced by a series of natural processes such as large amounts of LWD and lateral movement that has recruited small to medium sized gravels on riffles and bars with pools.

Riparian Condition

Riparian vegetation downstream of RM 2.4 is influenced by the diking system present along both banks the result being a non-functioning riparian system. From RM 2.4 to 4.9 the right bank riparian vegetation consists mainly of hardwoods with second growth conifers. The areas upstream of RM 4.9 to 12.7 are forested with hardwoods and second growth conifers. These areas are the source of much of the LWD present in the mainstem Nisqually River downstream of RM 12.7.

Water Quality

The Nisqually River's glacial source delivers large volumes of pulsed cold water to the mainstem Nisqually River. This is moderated by tributary inflow but the temperature of the mainstem river is driven by its source. Water temperatures are all within allowable limits in this reach of the river.

Fecal coliform bacteria have been detected in this reach and this reach is listed on the 1996 and 1998 Clean Water Act 303(d) list (WDOE Website.1999). Whiley et al (1998) concluded that based on their observations this section of the river should not be included on the 1998 303(d) list. These conclusions were based at least partially on the finding that while there were significant increases in fecal coliform bacterial levels in the lower 22 miles of the mainstem Nisqually River, the increases were within Washington State Water Quality Standards.

There are no known water quality parameters in this reach that would be considered impacting natural salmonid reproductive success.

Water Quantity

Water quantity (flow) in the mainstem Nisqually River is provided through flow agreements that are linked to the hydroelectric licenses for the Tacoma Power Alder/LaGrande Project and the City of Centralia Yelm Hydroelectric Project. These flows are discussed later in this chapter.

Middle Nisqually River Mainstem (RM 12.7 to RM 26.2)

General

This portion of the Nisqually River stretches from the point where water from the Centralia Powerhouse is routed back into the Nisqually River upstream to the Centralia Diversion Dam, the point at which water is diverted out of the mainstem Nisqually River. This reach is commonly referred to as the "McKenna Diversion".

Floodplain Modifications and Channel Condition

In the lower reaches of the McKenna Diversion, the Nisqually River meanders freely, confined only by naturally occurring geomorphic features and at points where crossed by bridges. There are localized remnants of abandoned dikes along the right bank in several places but they are no longer fully functional. Bank hardening features (riprap) remain in these locations but are in a state if disrepair. The floodplain is generally confined within a canyon but specific river reaches exhibit a wider area. Upstream of the State Highway 507 bridge lateral movement of the river channel is confined in places by abandoned flood control dikes on the right bank and the Diversion Canal on the left bank. This has resulted in a loss of habitat diversity through removal of off-channel rearing opportunities.

These dikes and bank-hardening features have continued to limit lateral channel migration in an area of the mainstem Nisqually River that is particularly lacking in off-channel rearing opportunities.

Substrate and Sediments

Sediment within this reach is gradient dependent with the lower gradient reaches having ample spawning gravel. Reaches in this section that are of higher gradients typically having cobbles and boulders with patches of gravel.

In the vicinity of the Centralia Diversion Dam there are several point bars that supply good spawning opportunities. Downstream of these point bars the stream channel consists of cobble and boulders with patches of spawning gravel. Those gravels present at the point bars in the vicinity of the Diversion Dam are transported through the reach and deposited in lower reaches of the Nisqually River mainstem.

Riparian Habitat

Riparian habitats are typically second growth hardwoods with limited numbers of second growth conifers. Land owned by Ft. Lewis typically has riparian habitat that is considered good and provides a source of LWD. Upstream of Ft. Lewis, encroachments by stream-side developments, consist of single family homes, rural residential houses, housing developments, agricultural and hobby farms. Where these developments have encroached on the river there is some destruction of riparian habitat through tree removal.

An inventory of LWD in this reach of the river was not located during the course of this project. The reach is considered generally deficient in LWD and given the river gradient, individual key pieces will have a difficult time in anchoring. Except on Ft. Lewis, LWD recruitment is limited by the condition of the riparian habitats in this reach and those upstream.

Water Quality

The Nisqually River's glacial source delivers large volumes of pulsed cold water to the mainstem Nisqually River. This is moderated by tributary inflow but the temperature of the mainstem river is driven by its source. Water temperatures are all within allowable limits in this reach of the river.

The water quality in the mainstem Nisqually River is characterized by periods of clear water and periods of glacial melt that cause the water to turn murky gray. The principle source of sediments are glaciers on Mt. Rainier that begin to melt in late spring and contribute finely ground sediments (glacial flour) to the river. Typically the Nisqually River upstream of Alder Lake is clear during November through April or May. Turbidity increases in June, peaks in August and decreases through December. All reaches of the mainstem Nisqually River downstream of the Alder/LaGrande Hydroelectric Project remain clear usually from March through mid-August (FERC 1994). Turbidity increases beginning in mid-August and dramatically peaks in December before decreasing rapidly in January and is usually clear in April.

It is not known what impact this shift in turbidity may have to primary productivity in the mainstem Nisqually River or to the natural production of salmonids in the Nisqually River.

Water Quantity

Water quantity in this reach is driven by the amount of water released by the hydroelectric projects operated by the city of Tacoma at LaGrande and the city of Centralia at the Diversion Dam. Historically, these projects operated independently with no coordination. In 1978, Tacoma was required to comply with an interim minimum instream flow regime that was amended in 1985 (Table 6) that became part of the permanent operating requirements of both projects in 1993.

Table 6: Minimum instream flow regime for Nisqually River (Grossman 1993)

Date	Mainstem flow (cfs)*	Bypass Flow (cfs)**
10/1 - 12/15	700	550
12/16 – 5/31	900	600
6/1 – 7/31	750	500
8/1 – 9/30	575	370

* Mainstem flow is defined as the minimum flow to be released by the Tacoma Nisqually Hydroelectric Project as measured at the Centralia Diversion Dam.

** Bypass flow is defined as the minimum flow that must be allowed to pass the Centralia Diversion Dam as measured at McKenna.

There are operational circumstances where mainstem river flows in the bypass reach may increase beyond the flow regime depicted in Table 6. If the Centralia Diversion Dam project was not taking its allotted water and bypassing through the diverted reach during chinook spawning, and then went back into operation, a portion of the chinook redds in the bypass reach could be desiccated.

Upper Nisqually River Mainstem (RM 26.2 to RM 42.5)

This reach of the Nisqually River stretches from the point where water is diverted from the mainstem Nisqually River by the Centralia Diversion Dam upstream to Tacoma's LaGrande Dam. Additionally, many of the most significant salmon producing tributaries join the mainstem Nisqually River in this reach.

Floodplain Modifications

Land use in areas along the mainstem Nisqually River downstream of confluence with Ohop Creek (RM 37.3) is primarily a mixture of deciduous hardwood and coniferous forests, single family residences, hobby farms, large and small agricultural based farms. Flood control dikes just upstream of the Diversion Dam along the right bank serve to eliminate the lateral movement of the channel and off-channel refugia and rearing opportunities. Bank hardening at the Diversion Dam also limits lateral channel migration. The presence of land features that suggest cut-off oxbows are present in the lower reaches. Once upstream of the flood control dikes, the channel is allowed to migrate freely across a broad valley. Upstream of Ohop Creek the mainstem Nisqually River gradient increases as it enters a narrower valley floor and ultimately a steep walled canyon in the vicinity of the confluence with the Mashel River.

Channel Condition

Since 1978 there have been at least four significant channel changes in this reach. All of these channel changes have been triggered by flood events. These changes are likely to be natural in origin, have shortened this reach by approximately one (1) mile, and have added four (4) backwater sloughs and in part caused a significant landslide. This landslide located on the left bank of the Nisqually River just downstream of the confluence with Ohop Creek was estimated at 200,000 (Cupp In Press) to 300,000 (EDT Workgroup In Progress) cubic yards in size.

Sediments and Substrate

The river gradient varies considerably though this reach. In the lower section of this reach the river gradient is low to moderate with the stream channel comprised of gravel bars, cobble and boulders. Upstream of the confluence with Ohop Creek, the gradient steepens and less evidence of gravel is present until it enters the canyon immediately upstream of the Mashel River where the gradient is steep and the river bottom is comprised of large and medium sized boulders with only a few patches of gravel.

The dams serve to effectively intercept bedload movement from reaches upstream and recruitment into downstream reaches. The Alder/LaGrande hydroelectric projects intercept both fine and coarse sediments from upper mainstem river reaches. Suspended sediments, primarily consisting of glacial flour, are transported downstream through the mainstem river system and into the Nisqually Reach. Studies conducted by Tacoma Power (Tacoma Public Utilities 1996) indicate that gravel size is coarser between the LaGrande Powerhouse and the confluence of the Nisqually and Mashel rivers than what would naturally be expected if the project was not in place. This result is consistent with what one would expect of a river reach that has its historical coarse sediment supply eliminated. It is not known if the reach has attained a state of equilibrium or if additional channel incision will occur. In an effort to address a portion of this impact, Tacoma Power is currently embarking on a three year gravel augmentation test project. No results of this project are available at this time.

Somewhat ameliorating the interception of gravels from the Nisqually River upstream of the hydroelectric projects are land use practices associated in the Mashel River. The

Mashel River drains an area of approximately 83.5 square miles mostly from steep sloped hills between 1000 and 4000 feet in elevation. The forests in these hills have been extensively commercially logged in the previous 50 years and woody debris removed from the Mashel River. Whiley et al (1997) found the highest levels of sediment load for water years 1994 and 1995 to originate from the Mashel River subbasin. Sediments, of all types, are transported out of the Mashel River subbasin at a higher than natural rate and deposited into the mainstem Nisqually River. Smith (1997) concluded that the Mashel River provided some compensation for the reduction of sediments recruited into the mainstem by the Alder/LaGrande hydroelectric projects but the Nisqually River could have lower than natural levels of sediments downstream from the dams. As the Mashel River transitions back to a river system that captures sediments there could be areas immediately downstream of its confluence with the mainstem Nisqually River that suffer from gravel availability.

Riparian Habitat

The riparian area is comprised primarily of second growth deciduous trees with smaller numbers of conifers. Inside the canyon, upstream of the confluence with the Mashel River is the only section of old growth forest along the mainstem Nisqually River Basin. These trees are all within the walls of a steep canyon that has afforded them protection from commercial timber harvest and riparian habitat is considered good in this section.

Water Quality and Quantity

Water quality and quantity in the mainstem Nisqually River have been discussed previously in this document.

Fish Usage

This reach is utilized by chinook, coho, pink, and chum salmon along with steelhead and coastal cutthroat trout. The fish ladder at the Centralia Diversion Dam has not been evaluated to determine if it causes a significant delay to upstream migration of adult and juvenile salmonids.

Nisqually River Mainstem Upstream of LaGrande and Alder Dams (RM 42.5 to Headwaters).

General

Since anadromous fish migration is limited to areas downstream of LaGrande Dam the TAG felt that the greatest influence this river reach has on anadromous fish is flow, sediment and LWD related. Those issues are discussed below.

Sediments and Substrate

Sediment and bedload movement in this reach of the Nisqually River basin is influenced by land use practices (i.e.: commercial timber harvest, residential development, etc.). No problems were identified concerning sediment transport into the Alder Reservoir.

Riparian Habitat

The riparian habitat varies from severely impacted around Alder Lake to pristine inside the boundaries of Mt. Rainier National Park. Commercial logging activities and rural residential housing have encroached on much of the area around Alder Lake. Downstream, the smaller LaGrande Lake has a virtually intact riparian habitat at least in part due to its placement inside a narrow canyon with steep sides that are unsuitable for development.

While no quantitative data were available for the amount of LWD in the mainstem upstream of Alder Lake, observations by TAG members indicate large amounts of conifers and hardwoods in both the mainstem Nisqually River and Mineral Creek. Because of the steep, high energy canyons of the mainstem Nisqually River inundated in LaGrande Lake and downstream of LaGrande Dam it is unclear how much LWD would have successfully recruited into downstream mainstem stream reaches. It is assumed that some recruitment of LWD would have occurred as portions of large pieces would have passed successfully through these reaches.

Water Quality

No water quality problems were identified in this reach of the Nisqually River.

Water Quantity

The primary source of water in the Nisqually River to the Alder/LaGrande Hydroelectric Project is rainfall, snowmelt and glacial melt. The river experiences seasonal flow fluctuations with high flows corresponding to snowmelt in April, May and June and high flows associated with rain in November through February. There are occasional high flows associated with rapid glacier melting (*jokulhlaups)* in the late summer.

The Alder/LaGrande Hydroelectric Project is operated to capture annual snowmelt runoff in Alder Lake. The Alder Lake is operated at 30 to 50 feet below full pool beginning in October or November with sporadic filling and dropping that follows winter storms. Refill usually begins in April or May.

The flood of record for the Nisqually River is the February 1996 event that had an estimated discharge of 39,500 cubic feet per second as measured just downstream of the LaGrande Powerhouse (USGS Gage #12086500) (USGS 1998).

The issue of minimum instream flows (MIF) was discussed previously in the Middle Nisqually River Mainstem section.

Fish Usage

LaGrande Dam is the current upstream limit to anadromous fish use in the mainstem Nisqually River. Upstream of LaGrande Dam, in LaGrande Lake, is a naturally occurring steep-walled canyon of the mainstem Nisqually River. It is believed that this canyon has a natural falls or cascades that likely would have been a velocity barrier to anadromous salmonids at most flows. Investigations conducted by the Nisqually Tribe in the 1980's were inconclusive in locating this geologic feature and determining if it was indeed a barrier to anadromous fish migration. These investigations were dropped as a part of the settlement between Tacoma and the Nisqually Indian Tribe.

Clear and Kalama Creeks

General

Clear and Kalama Creeks share similar origin, habitat and land use characteristics. Both creeks are wall-based spring fed systems that originate on Fort Lewis. Clear Creek lies entirely within Ft. Lewis and the historic boundaries of the Nisqually Indian Reservation boundaries and joins the Nisqually River at RM 6.1. The mainstem of Clear Creek was historically approximately 1.1 miles in length. Kalama Creek leaves Ft. Lewis and flows through the Nisqually Indian Reservation before entering a slough to the Nisqually River at RM 9.1. Kalama Creek, including all three forks, is approximately 1.5 miles in length. The Nisqually Tribe utilizes water from both creeks for intensive hatchery rearing of anadromous salmonids.

The Nisqually Hatchery at Clear Creek is operated by the Nisqually Indian Tribe, producing juvenile coho and fall chinook salmon for on- and off-station releases. A barrier to anadromous fish migration occurs at RM 0.1 and all fish entering the adult trap at this barrier are incorporated into hatchery production or killed. This trap is operated to capture adult chinook and coho and closed during the remaining portions of the year to exclude trapping of non-target fish species. There is no natural production of anadromous salmonids upstream of this barrier. The use of water for the hatchery water supply eliminates the streams natural connectivity to its historical floodplain.

Kalama Creek consists of two main forks and is the location of the Nisqually Tribal Fish Hatchery. The hatchery is operated by the Nisqually Indian Tribe and primarily produces chinook and coho salmon. A barrier to anadromous fish migration occurs at approximately RM 0.5 and all salmon entering the adult trap at this barrier are incorporated into hatchery production or killed. The trap is operated in a similar manner to that of the Clear Creek hatchery trap mentioned above. The downstream slough and lower 0.5 miles of Kalama Creek are available for natural salmon rearing.

Floodplain Modification

Clear Creek has been modified to accommodate the operation requirements of the hatchery. The creek has been impounded behind a series of levees and small water intake structures for hatchery operations. Because the origin of the creek is a series of wall-based springs and upwelling springs in the creek bottom it was historically not subject to dramatic flow increases that would have resulted in stream course changes. Rather, the input of LWD and beaver dams would have been the principle processes responsible for channel changes.

Kalama Creek has three small hatchery water intake systems that result in small local impoundments. The reach of the creek accessible to anadromous fish is unconfined by anthropogenic influences.

Sediment and Substrate

Historically both streams were low gradient streams with patches of gravel primarily in the vicinity of upwelling springs and eroding banks. Currently, all water flow is utilized for hatchery production. These gravels provided excellent chum and coho spawning habitat.

Riparian Habitat

The old second growth conifers and hardwoods present in the riparian zone of Clear Creek were removed when the hatchery was constructed. The riparian habitat in the Kalama Creek area consists primarily of hardwoods and second growth conifers.

Water Quality

In both creeks, water quality is considered excellent with an average temperature of 10.5 C.

Water Quantity

During the 1970's and early 1980's, water flows are quickly responsive to rainfall with changes noted within 24 hours after local significant rainfall events. Currently, these flows are much more stable and do not exhibit the same responsiveness to precipitation. One hypothesis is that the aquifer feeding these springs is much more stable today.

Flows in Clear Creek range upward of 20 cfs in the winter and low flows are about 5 cfs. Streamflow to the Clear Creek Hatchery is augmented with well water from five wells.

Kalama Creek flows remain more constant and are in the 5 cfs range. A well associated with a portion of the Kalama Creek project augments creek flow during the spring rearing season.

Muck Creek and Associated Tributaries

General

The Muck Creek subbasin is the most significant tributary in the lower Nisqually River reach for the natural production of anadromous salmonids. Typically, it supports over 25% of the natural chum production of WRIA 11 (Walter 1986) and up to several hundred steelhead spawn naturally in this subbasin.

The Muck Creek subbasin consists of Muck Creek and two larger tributaries, Lacamas and South Creeks along with other named and unnamed short feeder streams (i.e.: Exeter Springs) that contribute flow and natural production opportunities. The lower 7.0 miles of Muck Creek are within the boundaries of Ft Lewis and have natural intact functioning riparian habitats.

With a drainage basin of approximately 92 square miles, Muck Creek has its origins in a diffuse series of springs, seeps, and groundwater (that upwells in the stream bottom) throughout the prairie lands of eastern Pierce County. The lands in this drainage have until recently been a mixture of agricultural and pasture/prairie areas with low density rural housing. However, development pressures from the Interstate 5 and State Route 7 corridors have been extending into this area and increasingly housing developments are being constructed. This trend has been controlled to some extent through zoning changes by Pierce County under the Growth Management Act. Much of the subbasin is zoned rural with only one (1) housing unit per five (5) acres. While most of these areas are outside the geographic range of anadromous salmonids in this subbasin, they do contribute to water quality and quantity in the anadromous fish zone.

Floodplain Modifications

There are localized encroachments that limit lateral stream channel migration in the vicinity of road crossings.

Channel Condition

The presence of invasive reed-canary grasses have the most dramatic adverse impact to channel condition in this subbasin. This issue is discussed immediately below.

Riparian Habitat

All of these streams travel across the broad natural prairies that historically and currently do not have riparian habitats typical of the more forested streams found in western Washington. These prairie streams have local second growth coniferous and hardwood forested riparian habitats interspersed with open prairies consisting of native grasses and blackberry patches that border the streams.

Many reaches of Muck Creek exhibit monotypic stands of invasive reed-canary grass that effectively degrade the ability of the riparian habitat to function effectively. These areas of reed-canary grasses pose a limiting factor for salmonid production through loss of access, spawning and rearing opportunities. Those areas need further identification so that effective corrective measures can be taken to restore a functioning riparian habitat.

Water Quality

Water quality is currently considered good with no parameters identified as exceeding Washington State Water Quality Standards.

Water Quantity

Water quantities are determined by seasonal rainfall patterns and groundwater recharge. Walter (1986) stated that this subbasin is relatively free of flash flooding, scouring and excessive turbidity. While no citation is associated with this statement it is consistent with the free draining characteristics of the soil types found in the subbasin.

Muck Creek does experience natural intermittent flows during seasonal low flow periods. This limits year round coho and steelhead rearing opportunities. However, steelhead parr have been observed actively migrating out of Muck Creek during the spring when flows are decreasing. It is theorized they complete their rearing elsewhere in the Nisqually River basin. Lacamas Creek does not experience the same intermittent flows as Muck Creek and provides suitable year-round rearing opportunities for coho, steelhead and cutthroat. The marsh habitats associated with the middle reaches of Muck Creek and the reaches of Muck Creek that remain watered may also serve as refugia for coho and steelhead juveniles.

The streamflow pattern within Muck Creek is the principle factor regulating salmonid usage. At its confluence with the Nisqually River, Muck Creek flows do not begin as expected with seasonal precipitation patterns. Rather they typically do not increase until groundwater recharge has occurred, generally in the first two weeks in December.

Fish Usage

Because of the natural lack of adult transport flows during fall and early winter there is no utilization of this system by chinook or pink salmon and only limited utilization by coho. Chum salmon, winter steelhead and searun cutthroat make extensive use of this subbasin.

There are no known anthropogenic barriers to salmon migration but a scientifically based barrier survey has not been conducted in this subbasin.

Yelm, Murray, Horn and Other Mid-Reach Tributaries

General

These creeks are located in the middle reach of the Nisqually River basin downstream of the Centralia Diversion Dam. In addition to the named creeks there are several locally named small seeps, creeks and wall-based springs located along both banks of the mainstem Nisqually River.

A series of small unnamed wall-based springs surface along the left bank of the Nisqually River between RM 20 to 21 (J. Fraser pers comm 1999). Their origin seems to be linked to leakage from the Centralia Hydroelectric Diversion Canal (Diversion Canal). These springs provide limited opportunities for juvenile rearing and refugia from high winter flows. Coho and chum salmon have been observed spawning in the lower reaches of some of these small streams (J. Fraser pers comm 1999).

The Yelm Ditch shown in Williams (1975) no longer carries water (G.Walter pers comm., 1999).

Yelm Creek

General

Yelm Creek is approximately 9.1 miles in length (Williams 1975) with a drainage area of approximately 20 square miles (Nisqually EDT Work Group In Press). Land use within the drainage basin is comprised of rural residential, hobby farms and commercial agricultural. In recent years, this subbasin has been under increasing pressure of development as agricultural lands are converted to rural residential and hobby farms.

Floodplain Modifications

There are localized road encroachments throughout the drainage of this creek. They were not believed to be a limiting factor by the TAG.

Channel Conditions

Intermittent water flow occurs regularly upstream of RM 1.4. A groundwater study conducted in 1949-50 documented this loss to the aquifer through the porosity of the stream channel and attributed it to a naturally occurring event during months of low precipitation. Channel conditions have been adversely impacted through the removal of LWD and potentially by water withdrawals (Nisqually EDT Workgroup, In Press).

Sediments and Substrate

No data was obtained to evaluate sediment and substrate conditions Yelm Creek.

Riparian Condition

Riparian habitats have been adversely impacted as stream-side developments encroached on the creek channel and the rate of these development activities have increased in recent years. Yelm Creek flows downstream out of Yelm Prairie where the riparian habitat was naturally grasses and smaller brush. The lower 1.2 river miles enter an area that historically would have exhibited a riparian habitat of coniferous trees. This riparian habitat in this stream reach currently habitat consists of deciduous hardwoods and the recruitment of LWD has been greatly diminished or lost.

Water Quantity and Water Quality

Yelm Creek flows across a relatively flat prairie with stream gradients being moderate to low. A significant source of water to lower creek is Crystal Springs, which joins Yelm Creek at RM 1.4. Crystal Springs provides a relatively constant source of cool, 51 F., groundwater to the lower section. Upstream of RM 1.4 streamflows are often intermittent.

The Recessional Outwash Aquifer is the closest to the surface aquifer and believed to be a contributory source for baseflow of Yelm Creek and Crystal Springs. This aquifer represents the saturated portion of Vashon recessional outwash deposits. Immediately below this aquifer is the Advance Outwash Aquifer that occurs at a depth of 70 to 100 feet below surface elevation. Erickson (1998) found elevated levels of nitrates in this aquifer. The preferred groundwater flowpath in the studied area was toward Crystal Springs.

Potable water to these developments, as previously mentioned, and the City of Yelm is supplied through groundwater withdrawals and to a lesser scale by small unregulated wells (<5000 gallons per day). The cumulative impacts of these withdrawals is thought to impact baseflows in Yelm Creek and pose a limiting factor to natural salmonid production in this subbasin.

There are a number of studies being initiated by the Washington Department of Ecology and others to more closely examine groundwater issues in this subbasin.

Murray Creek

General

Murray Creek is approximately 12.2 miles in length (Williams 1975) with a drainage area of approximately 20 square miles (Nisqually EDT Work Group In Press). Land use within the drainage basin is comprised of rural residential, hobby farms and commercial agricultural. In recent years, this subbasin has been under increasing pressure of gravel mining operations and development as agricultural lands are converted to rural residential and hobby farms.

Floodplain Modifications

There are several road crossings in this system that locally influence the floodplain but they were not believed to be a limiting factor.

Channel Condition

During the 1990's the lower 0.5 river miles have experienced increases in sediment deposition and aggradation. Associated with this is an increase in the channel migration of this reach of the creek (Nisqually EDT Workgroup, In Press). No source for sediments for these increases has been identified.

A separate, but related and recent issue concerns a commercial gravel mining operation along Murray Creek that experienced a hydraulic induced slope failure in December 1996. This failure released an estimated 2.4 million cubic feet of impounded pit/lake water and 302 cubic yards of cobble, gravel and fine sediments into wetlands of Murray Creek (Keller 1998). There has been local concern expressed about this commercial gravel mining operation intercepting some springs and in turn adversely impacting baseflow in the lower reaches of Murray Creek.

Riparian Condition

The creek has its origin in the expansive wetlands roughly bordered by McKenna Road on the south, the railroad line on the west, Hawk Peterson Road to the east and 288th Street S. on the north. This large wetland occupies a large flat portion of southeastern Pierce County and is thought to be the origin for Brighton and Horn Creeks.

The lower reaches of the creek are forested primarily with young second growth hardwoods.

Water Quality

The origins of the creek are from a large prairie area in southern Pierce County. Land use in this area is comprised primarily of a mixed agricultural and rural residential housing. Because of the low flows in this creek there is an unverified concern that water quality (temperature) may be of concern.

Water Quantity

Summer low flows usually cause intermittent flows between RM 0.6 to 1.0 and a blockage caused by those conditions at approximately RM 0.5 limits upstream anadromous access.

Potable water to the previously mentioned new developments is supplied in part through groundwater withdrawals by small unregulated wells (<5000 gallons per day). It is believed that these withdrawals adversely impact stream baseflows.

Fish Usage

Anadromous fish access in Murray Creek is limited at times by beaver dams in the lower stream reaches and the low flow conditions previously mentioned. Anadromous fish access is limited by the natural low flow barrier at RM 0.5.

Horn Creek

General

Horn Creek drains an area of approximately 15 square miles that is used for rural residential, hobby farms and commercial agricultural purposes. In recent years, this subbasin has been under increasing pressure of development as agricultural lands are converted to rural residential and hobby farms.

Floodplain Modifications

Williams (1975) showed that the Harts Lake (outlet) Creek flowed into the Nisqually River upstream of Horn Creek. In 1976, the Harts Lake Creek changed course and now flows into Horn Creek at approximately RM 0.4. Harts Lake Creek suffers from water withdrawal during the summer months which decreases the amount of water available during low flow periods. Williams (1975) indicated the presence of a natural cascade in the vicinity of Harts Lake Valley Road (Hagedorn Road) that defined the upper extent of anadromous fish migration. This barrier was a concrete weir removed later in the 1970's (Walter pers. comm.).

Throughout Brighton, Horn, Yelm, Murray and the unnamed creeks there are numerous streambed encroachments at old railroad grade, state, and county and private road crossings. On Horn Creek these crossings are upstream of the fish ladder and further investigations need to be conducted to identify any passage problems.

Riparian Condition

The stream banks of Harts Lake and Horn Creeks are stable, with no obvious evidence of erosion or bank failures. Their riparian habitats are typical moderate aged hardwoods with some second growth conifers.

There have not been any formal investigations or analysis of riparian habitat in these subbasins but observations of the riparian habitat by Nisqually TAG members indicates that this habitat has a wide variation. For Harts Lake Creek the riparian habitat is generally considered poor while good for Horn Creek. The lower reaches of Horn Creek have considerable amounts of LWD primarily through the contribution of active beaver colonies.

Substrate

Downstream of RM 0.4 the stream gradient is flat with a large amount of fine sediments.

Water Quantity

Potable water to new residential housing developments is supplied through groundwater withdrawals primarily by small, unregulated wells (<5000 gallons per day). It is unknown what impacts these water withdrawals have on stream baseflows but concern was expressed by some TAG members.

Water Quality

Water quality in all of these creeks is suspected to be adversely influenced by the large commercial agricultural use and hobby farms in their drainages. Harts Lake appears on the WDOE 1998 303(d) list for total phosphorus. Whiley (1999 In Progress) examined a number of the lakes in these subbasins and found their waters to have elevated levels of total phosphorus and eutrophic.

Fish Access

A waterfall at RM 1.0 created by old concrete and boulders served as a barrier to upstream migration for anadromous fish. A fish ladder was installed in 1997 at these falls and may improve upstream migration. Searun cutthroat trout have been observed at the confluence of Horn Creek and the Nisqually River (Kerwin pers. observ.). Fall chinook, coho and chum salmon have been observed spawning in the lower reaches of Horn Creek.

Miscellaneous Tributaries

General

In the vicinity of RM 20 – 21 there are a series of diffuse wall-based springs located along the left bank of the Nisqually River. All are relatively short in length (< 0.25 mile) but in their aggregate contribute to rearing opportunities for chum, coho, steelhead and potentially chinook. There are reports of juvenile coho and chum rearing in several of these short channels (Fraser, pers. comm.).

The springs do not appear in William (1975) but have been reported by professional biologist (Fraser, pers. comm) familiar with the area.

The wall-based springs have small drainage areas and land use in the vicinity of the springs is rural residential. The origin of the springs is believed to be leakage from the Yelm Hydroelectric Diversion Canal.

Floodplain Modifications

There exists a concrete dam and weir on the outlet structure to Schorno Springs (a left bank tributary in the vicinity of RM 22.25). This structure backs the spring water up and creates a pond that adversely impacts water quality through water temperature elevation.

Riparian Condition

The riparian conditions around these springs consist of mixtures of early second growth conifers and hardwoods. The riparian conditions are stable, with no obvious evidence of erosion or bank failures.

Water Quantity

Water quantity has not been assessed.

Water Quality

Water quality has not been assessed.

Tanwax, Kreger, Lackamas, Toboton and Powell Creeks

General

Collectively, these creeks are referred to as the "lake creeks" because many of them have their headwaters, at and/or flow through lakes. They all drain from similar land form features into a geographically identified reach of the mainstem Nisqually River. These subbasins are all located upstream of the Centralia Diversion Dam and downstream of the confluence of the Nisqually River and Ohop Creek. As a group they share many of the same physical habitat features, biological species and associated problems.

Tanwax Creek

General

The largest of these creeks is Tanwax Creek with a drainage basin of approximately 26 square miles and 13.3 miles in length. The headwaters of this subbasin are Tanwax, Byron and Whitman lakes with a total surface area of 209.4 acres (Wolcott 1973). The lakes associated with this creek receive relatively intense public recreational fishing pressure and recreational boating activity. Tanwax Creek enters the Nisqually River at RM 30.8.

Tanwax Lake

In Tanwax Lake there are self-sustaining populations of several exotic warmwater species (yellow perch, large-mouth bass, bluegill, etc.). These fish have been introduced illegally through individual efforts. While WDFW does operate a warmwater fish management program, they have never attempted to establish and maintain warmwater fish in Tanwax Lake. Since there are no barriers to downstream migration these warmwater species can move out of the Tanwax Lake, and other lakes in this basin, into the lower stream reaches where anadromous salmonids are present. While the mainstem Nisqually River, with its cold glacial origin, would present an inhospitable environment to the natural reproduction of these fish, warmer tributary and side-channel waters important to salmonids could prove to be environments for opportunistic warmwater species.

Many of these species are predatory and their impact to native salmonids within these lakes, streams and sidechannels is unknown but is expected to be adverse.

Floodplain Modifications

There are reaches of the creek that have been channelized and/or relocated and structures associated with road crossings encroach on the floodplain. Upstream of RM 6.5 riparian habitat is generally poor due to the effects of these past channelization activities. Downstream of RM 6.5 there exist several areas of wetlands that have been invaded by reed-canary grass, which locally reduces the effectiveness of the riparian zone. However, between these wetlands there are several reaches of second growth conifers and hardwoods.

Substrate and Sediments

Tanwax Creek, downstream of Tanwax Lake, is low-gradient stream typical of valley floors. In places the creek is incised as it cuts through fine sediment layers. There are areas of streambank erosion that contribute additional fines to this system. Most of these fines are ultimately deposited into downstream wetlands where channel aggradation causes lateral channel migration and anadromous fish access problems during some years.

An inventory of mass wasting sites identified through aerial photo interpretation and aerial survey was conducted by Cupp (In Press). The vast majority of failures were not associated with any land use activities. Most of the remaining failures were associated with road construction and occasionally timber harvest.

The largest number of slides appeared on the 1965-66 aerial photos with only a few instances of new slides in the 1978 and 1989 photos. There were no new slides identified in the 1993, 1995 or 1996 photo sets. This suggests that the drainage is in a state of recovery. The overall risk to natural fish production caused by mass failures is probably low in this basin.

Fine sediment load is high with deposition occurring in downstream wetlands. Historical agricultural activities are believed to be partially culpable. The stream does cut through several fine-sediment layers and bank erosion is common in the lower reaches. This later action contributes fine sediments to downstream reaches (Nisqually EDT Workgroup, In Progress).

Riparian Condition

Tanwax Lake is densely lined with single family houses used year-round or for recreational purposes. Recreational boaters have removed large quantities of LWD and impacts caused by development have further reduced the function of the riparian zone. Docks and overwater structures also serve as cover for predatory species and alter the behavior of salmonids. Additionally, overwater structures (i.e.: docks) are believed to influence the behavior of some anadromous species. The impact(s) of these structures in Tanwax Lake requires additional investigation.

Land use within the floodplain has traditionally been agricultural based with the adjoining hillsides being commercial timberland. Both are gradually being converted into rural residences and hobby farms.

Water Quantity

Low flow problems associated with water withdrawals are an annual problem and have been identified as a limiting factor in this creek (Nisqually EDT Workgroup, In Progress).

Water Quality

These low flows and summertime lake temperatures exacerbate water quality. Stream water temperatures often exceed state water quality standards during summer and early fall low flow periods.

Water temperatures exceed state water quality standards during summer low flow periods (G. Walter pers. comm. 1999) but the creek itself has not been identified for inclusion on EPA 303(d) list. The expansive open water wetlands are believed to partially contribute to the high water temperatures (Nisqually EDT Workgroup, In Progress).

Fish Usage

No anthropogenic barriers are known to exist in this subbasin but beaver dams have hindered anadromous fish access.

Kreger Creek

Kreger Creek enters the Nisqually River at approximately RM 34 and is a small right bank tributary originating from Silver Lake. Williams (1975) indicated the presence of an impassable cascade at RM 0.1. Recent field investigations indicate that this barrier no longer exists (Walter, pers. comm.) and the upper extent of anadromous fish utilization is limited by beaver dams in the wetland complex at approximately RM 1.1. Kreger Creek is similar to Tanwax Creek in geographic location, type of origin and land use. It also shares similar riparian, sediment, water quality and quantity issues.

Lackamas Creek

General

Lackamas Creek, a small left bank tributary in the vicinity of RM 28.8, is similar to both Tanwax and Kreger Creeks in geographic location, type of origin and land use. The creek is approximately 3.0 miles in length and drains from rural residential and agricultural area of the Bald Hills.

Sediment and Substrate

The stream has degraded sediment conditions that are believed to be caused by encroachments on the riparian buffer zone by agricultural practices (in the headwaters) and rural residential development (Nisqually EDT Workgroup. In Progress).

Riparian Condition

Riparian habitat consists mainly of second and third growth hardwoods that have reduced potential for LWD recruitment.

Water Quality

The water quality in this subbasin has not been assessed.

Water Quantity

The creek experiences intermittent flows in the upper reaches during most summers. The exact cause of these low flows is not completely understood. Water from springs in the lower 1.0 miles augments base flow.

Fish Usage

Stream gradient is low throughout the system and anadromous fish access is occasionally blocked by beaver dam construction. There are no known anthropogenic barriers in this system within the anadromous fish reaches.

Toboton Creek

General

A tributary of Lackamas Creek, the Toboton Creek subbasin is approximately 5.6 square miles (Denman 1998) in size draining an area of the Bald Hills that is rapidly converting from historical commercial timber use to rural residential and hobby farms.

The majority of timber harvest in this subbasin was completed during the 1940's. A harvest of second growth timber occurred during the 1960's and 1970's. The greatest impact of these harvests was apparent in the reduction and recruitment of LWD into the creek channel. Denman (1998) found Toboton to have low densities of LWD. In small streams such as Toboton Creek a single functional piece of LWD can have tremendous influence to the channel morphology and subsequently the ability of the stream to optimally produce anadromous and resident salmonids.

Riparian Condition

The riparian habitat consists of second growth hardwoods with encroachment into the floodplain and riparian buffer by residential and agricultural development. These activities further serve to exacerbate the LWD problems in this subbasin.

Substrate and Sediment

With approximately 31.9 miles of road in the subbasin it has one of the highest road densities of subbasins in this geographic area of the mid-Nisqually River Basin. While this subbasin has a relatively high road density, the existing roads are generally older ones that are more stable and not generating sediment loads that are of concern (Denman 1998).

Water Quantity

The headwaters of Toboton Creek are Clear Lake, a residential and recreational oriented lake with populations of rainbow and cutthroat trout. The creek has documented adequate annual flows in the lower two river miles from the natural introduction of spring water at that point. Upstream of RM 2.0 the flow is often intermittent during summer low flow months. High water temperatures often occur upstream of RM 2.0 that exceed state water quality standards (Nisqually EDT Workgroup. In Progress).

Water Quality

Water quality has not been thoroughly assessed.

Fish Usage

In the lower 1.0 miles up to 200 adult coho salmon have been observed spawning annually. Resident an/or anadromous cutthroat trout can be found in this stream, even in areas that do not have current surficial connection to the Nisqually River. This stream may also support small numbers of chum and steelhead.

Powell Creek

General

A left bank tributary at RM 31.9 to the Nisqually River, Powell Creek has a drainage area of approximately 12.5 square miles (Denman 1998) in size draining from an area of the Bald Hills that are generally managed for commercial timber harvests. Within the subbasin there are areas of rural residential development and hobby farms.

Riparian Condition

The majority of initial timber harvest in this subbasin was completed during the 1940's followed by a harvest of second growth timber during the 1960's and 1970's. During both harvests any streamside buffers were not retained along Powell Creek or its numerous small tributaries. The greatest long-term impact of these harvests was apparent in the reduction and recruitment of LWD into the creek channel. Denman (1998) found Powell Creek to have low densities of LWD. In small streams such as Powell Creek a single functional piece of LWD can have tremendous influence to the channel morphology.

The riparian habitat consists of second growth hardwoods with encroachment into the floodplain and riparian buffer by residential and agricultural development. These activities further serve to exacerbate the LWD problems in this subbasin.

Substrate and Sediment

With approximately 67.6 miles of road in the subbasin it has one of the highest road densities of subbasins in this geographic area of the mid-Nisqually River Basin. While this subbasin has a relatively high road density, the existing roads are generally older ones that are more stable and not generating sediment loads that are of concern. Road delivered sediment was only 10 percent over background sediment loads (Denman 1998).

An inventory of mass wasting sites identified through aerial photo interpretation and aerial survey was conducted by Cupp (In Press). The vast majority of failures were not associated with any land use activities. Most of the remaining failures were associated with road construction and occasionally timber harvest.

The largest number of slides appeared on the 1965-66 aerial photos with only a few instances of new slides in the 1978 and 1989 photos. There were no new slides identified in the 1993, 1995 or 1996 photo sets. This suggests that the drainage is in a state of recovery. The overall risk to natural fish production caused by mass failures is probably low in this basin.

Riparian Condition

The lower reaches of Powell Creek are located on the Nisqually River floodplain and consist of a forested wetland. Cupp (In Press) as a part of a watershed analysis determined that 59 percent of the riparian area length examined of the Powell Creek subbasin to have an inadequate riparian recruitment potential. In that same analysis, a combined high and moderate value for LWD recruitment potential was determined to be of 41 percent for short term and 99 percent for long term. Thus, LWD appears to be of short-term concern but has potential for long term recovery.

Existing shade levels are generally above required values (Cupp, In Press) and were not a limiting factor.

The lower 0.3 river miles of Powell Creek is through a Class 1 floodplain wetland of the Nisqually River. Powell Creek is the primary supplier of water flow in this wetland complex.

Water Quality

Water quality in Powell Creek has not been thoroughly assessed. Cupp (In Press) monitored stream temperatures in three locations between June 29 and September 17, 1997. One station, at RM 0.4, consistently exceeded Stream Type "A" water quality standards while the other two were substantially below that criteria.

Water Quantity

Elbow Lake contributes additional stream flows at approximately RM 0.8 but there is no documented evidence anadromous salmon usage of its outlet stream.

During summertime, flows upstream of RM 2.0 are intermittent. Flows in the lower two river miles originate from a series of springs in the vicinity of RM 2.0. Salmon fry are mentioned to occur in the springs at this point of the creek (Nisqually EDT Workgroup. In Progress).

The over allocation of water from Powell Creek and consequent summer low flows was considered a limiting factor by Walter (1986). However the actual water use as compared to water rights remains largely unknown.

Fish Usage

A natural impassable barrier at approximately RM 2.2 limits the upstream migration of anadromous salmonids. Williams (1975) indicated an impassable cascade at approximately RM 1.2 and 1.35. These barriers were most likely the presence of beaver dams contained within a large wetland in this area. These beaver dams have also been known to limit upstream migration of anadromous salmonids depending upon their state of repair and flows. There are reports of a locally maintained screen at the confluence of the outlet stream of Elbow Lake and Powell Creek. This screen, when in place, would effectively limit anadromous fish access into outlet stream of Elbow Lake.

Ohop Creek and Its' Tributaries

General

The Ohop Creek subbasin consists of Ohop Creek proper and the tributaries Twentyfive Mile, Lynch and Berg Creeks. Combined, these creeks have a drainage area of approximately 44 square miles. They differ from the creeks discussed previously in both the size of the subbasin and the geographic origin. While those creeks have their origins from an elevation of about 1000 feet, Ohop and its tributaries have their origins from elevations up to 3700 feet. Ohop Creek enters the Nisqually River at RM 37.3.

Floodplain Modifications and Channel Condition

One of the most significant disturbances, and unique to this subbasin in the Nisqually River Basin, occurred in 1889. At that time, early settlers diverted a portion of Ohop Creek northward into Kapowsin Lake and the Puyallup River Basin (WRIA 10) in an effort to afford lower Ohop Valley some protection from flooding. This effort resulted in approximately 30 percent of the flow being diverted into the Puyallup River Basin.

This event was described by Hlavin (1954) in the following passage:

> "The pioneers were at first harassed by the floods in the valley as each time there was a little rain the valley would be under water. Torger Peterson found that on the divide between Lake Ohop and Lake Kapowsin it was just as easy for the water to run into Lake Kapowsin and down the Puyallup as it was to run down the Ohop Valley. In 1889 he obtained permission from the St. Paul Company and Judge Wickersham, who claimed 80 acres, to turn the main Ohop Creek into Lake Kapowsin and all the settlers in the valley from the Nisqually River to Lake Kapowsin, 22 of them, turned out and helped with the work".

The disconnection of this portion of the stream and its habitat forming processes are obvious but the ramifications to anadromous fish production are poorly understood. Certainly, base and peak flows are diminished along with sediment transport. These would have been responsible for channel forming processes and channel complexity which are currently decreased. Additionally, opportunities for summer rearing would have lost for coho, steelhead and cutthroat trout.

Ohop Creek, downstream of Ohop Lake, has also been significantly altered and instream habitat simplified by ditching associated with agricultural activities. This channelization, started by the Works Progress Administration in 1934, was intended to facilitate the growing use of the valley for agricultural purposes. During that project, the stream was essentially transformed to a water conveyance ditch with all lateral movement eliminated. Hlavin (1954) provides a descriptive account of work done in the 1930's:

> "A long line of debris, from numerous log jambs and ancient beaver dams marked the course of a gas shovel along Ohop Creek which was widened, straightened and deepened by WPA workmen as a means of drainage and flood control in Ohop Valley".

This channelization of Ohop Creek resulted in little or no off-channel rearing opportunities, meanders and the riparian area have been eliminated. The presence of LWD is considered poor to non-existent in this section.

Ohop Creek, upstream of RM 8.8 has also been channelized. During the dry season, the majority of the flow into Ohop Lake is from Twentyfive Mile Creek. The water source for Ohop Creek, upstream of the confluence with Twentyfive Mile Creek (RM 9.9) is mainly groundwater provided through diverse springs and seeps. Remnant stream channels can be observed in 1965 Washington Department of Natural Resource aerial photos in the upper reaches of Ohop Creek and are probably from pre-diversion time periods.

Ohop Creek flows through Ohop Lake between RM 6.3 and 8.6 (Ames 1981). Wolcott (1973), lists Ohop Lake as being 2.25 miles in length with a surface area of 235.6 acres. The lake is a popular recreational boating lake with the lakeshore lined by recreational and residential housing. Significant populations of warmwater fish species (yellow perch, large-mouth bass, bluegill, etc.) are self-sustaining within Ohop Lake. The impacts of these predatory fish to anadromous salmonids have been discussed previously.

A portion of the City of Eatonville's Urban Growth Area boundary extends into the Ohop Creek subbasin. The present and future urban growth pressures are a potential threat to Lynch Creek and Ohop Creek for the 1.5 river miles downstream of Ohop Lake.

Sediment and Substrate

The stream gradient of Ohop Creek is low and sediment loads are high through the entire lower subbasin due to bank erosion and from tributaries. All identified spawning locations within Ohop Creek had mean fine sediment loads above 17 percent (Whiley 1997). Levels this high are above acceptable criteria and suggest poor intergravel spawning survival and success. In those stream reaches where sediment loads exceed 17 percent they represent a limiting factor affecting natural salmon reproduction.

In the Ohop Valley, landslides are exclusive to shallow rapid failures. Cupp et al (In Press) determined that both the Lower Ohop valley and Ohop Creek subbasins have significantly higher risk toward mass wasting. However, they are not very active in terms of mass wasting and do not appear to pose an immediate threat.

Riparian Condition

The riparian area of the lower 0.25 stream miles of Ohop Creek is forested with second growth hardwoods. Upstream of RM 0.25 to RM 4.5 the stream is channelized, low gradient and flows through agricultural lands with a non-functioning riparian zone. There is almost no hardwood or coniferous trees present in this reach. From RM 4.5 to 6.2 the creek flows through a narrow corridor of hardwood trees, exhibits localized channelization and has limited small wood inputs that aid in channel and pool forming processes resulting in pools and riffles.

Timber harvest has played an important part in the land use of Ohop, Lynch and Twentyfive Mile Creeks. Most of the initial harvest was completed prior to 1941, much of it utilizing a railroad constructed through the east side of Ohop Valley. This railroad was constructed using extensive fills for crossing tributary stream channels and given the construction techniques employed at that time is believed to have contributed large volumes of sediments to streams. The railroad grade also serves to limit the lateral movement of stream channels at localized sites. While the rails have been removed, the railroad grade continues to exist and the impacts to channel morphology are still present.

Commercial managed forest lands account for approximately 64 percent of the Ohop Creek subbasin (Cupp, In Press). The Ohop Valley floor, until recently, was used for agricultural purposes but has been converting to rural residential and hobby farms.

A Level II Watershed Analysis Assessment (Cupp, In Press) for riparian habitat function has been conducted on the Ohop Creek basin. Included in this report is an assessment of historic riparian conditions to identify areas that provide naturally low-levels of LWD and/or shade. Through the utilization of early cadastral survey notes, historical accounts, and early aerial photography, an assessment of historic conditions was made. Large portions of the riparian areas, both historically and at present, are located within or adjacent to wetland areas.

As a part of this analysis, approximately 470 miles of stream-side and 40 miles of lake-side riparian areas were evaluated as part of this analysis. Large woody debris recruitment hazard calls were determined based on current recruitment potential, channel sensitivity, and current in-stream LWD loading. Current instream LWD loading was rated as poor ("off-target") (Cupp, In Press) for Ohop Creek and its tributaries.

Existing shade conditions were evaluated (Cupp, In Press) for Ohop Creek and its tributaries. Existing shade levels are generally above target values in the sub-basins where forest management is the dominant land-use (Lynch Creek, Berg Creek, and Twentyfive Mile Creek). Low existing shade levels in the remainder of the Ohop Creek sub-basins are generally a result of agricultural land practices and the influence of wetlands (Cupp, In Press).

An inventory of mass wasting sites identified through aerial photo interpretation and aerial survey was conducted by Cupp (In Press). The vast majority of failures were not associated with any land use activities. Most of the remaining failures were associated with road construction and occasionally timber harvest. The largest number of slides appeared on the 1965-66 aerial photos with only a few instances of new slides in the 1978 and 1989 photos. There were no new slides identified in the 1993 and 1995 photo sets and one new slide in the 1996 set. This suggests that the drainage is in a state of recovery. The overall risk to natural fish production caused by mass failures is probably low in this basin.

The Pierce County Conservation District (1994) found that 25 percent of the evaluated farm sites in the Ohop Valley reported uncontrolled stream access by farm animals (primarily dairy herds). Nineteen percent reported "heavy use" less than 20 feet from surface waters. These poor riparian area land use practices, combined with the fine grains naturally found in the soils, have resulted in direct sediment delivery into Ohop Creek.

Water Quality

Stream water temperatures within Ohop Creek downstream of Ohop Lake are driven by the outflow of Ohop Lake. These temperatures exceeded state water quality standards during 1993 and 1994 (Whiley 1997). For a short distance, cool water from Lynch Creek partially tempers Ohop Creek water temperatures.

Low dissolved oxygen levels have also been observed in Ohop Creek at sites monitored downstream of RM 6.0. While not within a lethal range some measured levels are considered stressful to juvenile salmonids.

Degraded water quality characterized by elevated levels of total phosphorus, and ammonia were identified in Ohop Creek downstream of RM 6.0. Additionally, water quality in Ohop Lake is degraded because of high levels of total phosphorus. These levels impair salmon rearing habitat for chinook, coho, steelhead and coastal cutthroat trout. Ohop Lake was listed on the EPA 1996 303(d) list and is proposed for the 1998 list.

Whiley (1997) found elevated levels of total phosphorus and ammonia, low dissolved oxygen and high temperatures flowing out of Ohop Lake. Stream water temperatures exceeded 18 C for 70 days in 1993 (Whiley 1997) and chronically exceeded in 1994 (incomplete record). Ohop Creek is on the 1998 Clean Water Act 303(d) list for exceeded state water quality standards for fecal coliform and total phosphorus. Additionally, low dissolved oxygen levels were observed in 1995 and 1996 at the outlet to Ohop Lake (Whiley 1997). Whiley concluded that the source of elevated ammonia concentrations in Ohop Creek below RM 6.0 was Ohop Lake. All of the above water quality parameters serve to limit natural production of salmonids within this reach of Ohop Creek.

Water Quantity

The over allocation of water from Ohop Creek and consequent summer low flows was considered a limiting factor by Walter (1986). However the actual instantaneous water use as compared to water rights remains largely unknown and requires additional clarification.

Fish Usage

The lake surface elevation of Ohop Lake is artificially maintained by a low wooden weir. While the weir does not eliminate the upstream migration of adult anadromous salmonids it is unknown if it causes migration delays. The height of this structure was determined through litigation and court order.

Ohop Creek is utilized by coho, chinook, and pink salmon along with steelhead and cutthroat trout.

Lynch Creek

General

Lynch Creek is a left bank tributary of Ohop Creek at RM 6.2, downstream of Ohop Lake, whose headwaters occur from a ridge at approximately 3000 feet in elevation. The lowest reaches flow through rural residential and are currently in Eatonville's Uniform Growth Management Act boundary, but the majority of the creek lies within commercial forest lands. The lower portion of Lynch Creek was subjected to timber harvest that was completed in the 1950's and 1960's. Subsequent timber harvests have extended further east and deeper into the subbasin on steeper ground in the higher elevations.

Floodplain Modifications

Changes in channel width of Lynch Creek have been detected between aerial photographs taken between 1965 to 1990. These channel width changes may be attributed to timber harvest (Cupp, In Press). The length of channel affected is approximately 3.0 miles.

Sediments and Substrate

Within the alluvial fill deposits of Lynch Creek, large amounts of gravel are stored that provide an important input into lower Ohop Creek. This sediment delivery is vital to the more significant spawning areas of Ohop Creek (Cupp, In Press).

The relatively high transport capacity of Lynch Creek quickly moves coarse and fine sediments into downstream reaches. The amount, and degree, to which coarse sediments are retained would be influenced by the presence, abundance and effectiveness of LWD. However, LWD is limited and often found atop boulders in the upper stream reaches.

Lynch Creek also receives the discharge of approximately 50 percent of the Town of Eatonville's stormwater collection system. This line was constructed in 1943 and consists of a single 36 inch diameter line. Chandler (1993) estimated that the portion of Eatonville's stormwater collection system draining into Lynch Creek produces approximately 10 to 19 tons/year of sediments. This amount contributes to the approximately 17 percent over background amounts of sediments Lynch Creek transports annually (Denman 1998).

Riparian Condition

Localized encroachment by rural residential homes occurs in the lower reaches of Lynch Creek. Outside of this area, the streamside riparian area is comprised of second growth hardwoods and is considered fair. LWD is sparse in the lower reaches of Lynch Creek.

Water Quality

No significant water quality problems were identified in Lynch Creek during sampling conducted from 1994 - 95 (Whiley 1997).

Water Quantity

Much of the upper reaches of the stream channel is entrenched into very coarse material and boulders that generally armor the streambanks. Increased discharges generally results in an increase in flow width and stream height without additional channel incision or bank erosion (Cupp, In Press). In the lower reaches the banks are effectively protected by stream adjacent forest and/or wetland shrubs. In these reaches peak flows spread across the wetlands.

No significant water quantity problems were identified in Lynch Creek during sampling conducted from 1994 - 95 (Whiley 1997).

Fish Usage

A naturally occurring impassable velocity barrier (cascade) occurs at RM 1.0 that limits upstream migration of salmonids. Lynch Creek is utilized by coho salmon along with steelhead and cutthroat trout. Chinook juveniles may utilize the lower reaches for juvenile rearing.

Twentyfive Mile Creek

General

Twentyfive Mile Creek is a left bank tributary whose confluence with Ohop Creek is upstream of Ohop Lake at approximately 9.9 (Williams 1975). A naturally occurring impassable falls at RM 1.0 limits the upstream migration of anadromous salmonids.

Floodplain Modifications

The upper reaches of Twentyfive Mile Creek have numerous wetlands and during the dry season represents approximately 50 percent of the flow in upper Ohop Creek. Land use within the lower portion of this creek is hobby farms, rural residential and commercial timber production. The upper reaches of the Twentyfive Mile Creek subbasin are entirely within commercial timber production.

Channel gradient within the lower 1.0 miles rarely exceeds 2 percent, although short stretches of up to 4 percent do occur. The channel is essentially unconfined with areas of good spawning gravel apparent on riffle reaches.

Riparian Conditions

The riparian conditions of Twentyfive Mile Creek vary significantly and are based on historical and current land management practices. Encroachments by rural residential and hobby farms have caused localized adverse impacts in the lower 0.3 miles. Upstream of RM 0.3 the riparian area lies largely within commercial timber lands and functions well. In these reaches the riparian habitat is comprised of second growth hardwoods with limited numbers of conifers. LWD is present outside of the anadromous fish zone and recruitment of upstream pieces into downstream reaches occurs.

Sediments and Substrate

Sediment inputs from this creek are potentially significant. Data from the Nisqually Indian Tribe (Whiley 1997) indicates percent mean fines of 19 and 18 percent in 1993 and 1994 respectively. This exceeds the 17 percent level and sediments can only be considered poor at the locations sampled. A combination of fine grained soils present in the headwaters, and alluvial/lacustrine soils present in the central portions of the subbasin are thought to be the dominant sources of fine sediments transported in the subbasin (Denman 1997). Land management practices in this subbasin are thought to exacerbate soil movement in site specific areas and contribute to sediment levels approximately 26 percent over background levels (Denman 1997).

A unique, and potentially significant problem, is the presence of a recently abandoned commercial clay mining operation at RM 0.5 in this subbasin. This mine was in operation from 1906 to 1994 and removed clay from open pits for adjacent brick manufacture. Debris from the manufacture of bricks can be found in the vicinity of the plant. Riparian vegetation has colonized the streambanks in the vicinity of the plant and provided some bank stability. However, debris from the manufacturing process in the form of discarded broken bricks continues to enter the stream through erosion of the toe of the discard slope.

Stormwater drainage from the plant and open pits is through detention ponds in the direction of Twentyfive Mile Creek. Drainage from springs that surface on the property is channeled through a pipe to Twentyfive Mile Creek. The later discharge has caused an erosion gully that may contribute additional sediments into the lower reaches of Twentyfive Mile Creek.

Water Quality

Macroinvertebrate fauna characteristics in Twentyfive Mile Creek exhibited a high level of taxa richness and diversity (Whiley 1997). These characteristics are indicative of good water quality present in this subbasin.

Whiley et al (1997) also expressed concerns over elevated levels of fine sediments in the vicinity of coho salmon spawning habitat. Denman (1998) also found elevated levels but below what is considered needed to assign a moderate or high risk rating.

Water Quantity

No specific concerns about water quantity were expressed by TAG members. Metzler (In Press) did not identify peak flows as an issue.

Fish Usage

Coho salmon utilize the lower reaches of Twentyfive Mile Creek. Coastal cutthroat trout are know to inhabit waters upstream of the barrier but the actual extent of their distribution is unknown.

Mashel River and Associated Tributaries

General

Draining an area of approximately 83.5 square miles (Williams 1975), land use within the Mashel River subbasin is primarily commercial timberland (96 percent) with smaller amounts of rural residential, private small timberlands and the city of Eatonville (Table 7). Most of the drainage is forested with second and third growth deciduous hardwoods and conifers.

A Level II Watershed Analysis (Cupp, In Press) has been completed for the Mashel River Watershed Administrative Unit (WAU) and is in press at the time of this report. That analysis addressed the following five input factors:

- Coarse sediment
- Fine sediment
- Large woody debris
- Water
- Solar radiation

Any changes in the amount or timing of these variables were evaluated for their potential to affect the public resources of fish (WAC 222-22-010). Portions of that report are cited in the text below.

Table 7: Land use within the Mashel River (Source: Whiley et al. 1997)

Location	Drainage Area (miles sq.)	Land Use	Percent of Basin
Mashel River @ RM 3.2	81	Agricultural Urban Forestry	3 1 96
Mashel River @ RM 6.0	54	Forestry	100
Little Mashel River	23	Agricultural Forestry	10 90
Beaver Creek.	9	Forestry	100
Busy Wild Ck	15	Forestry	100
Mashel River @ RM 14.5	18	Forestry	100

Current fall chinook usage is concentrated in the lower four miles while steelhead are known to occur throughout the subbasin. Coho and pink salmon also utilize this subbasin to a lesser degree. Coastal cutthroat trout are found throughout the subbasin in both the anadromous and non-anadromous fish zones. The mainstem Mashel River is accessible to anadromous salmonids up to RM 15.4 where a naturally occurring waterfall blocks access.

There is little data documenting coho utilization in the basin. Spawning ground surveys for coho have been sporadic and those that have been conducted show little evidence of strong coho salmon runs within the Mashel River Basin in the past 20 years. Even less is known about the adult and juvenile usage by coho in the upper basin. The Mashel River below Eatonville is the known coho primary spawning habitat. This is probably more a function of accessibility for survey crews than indicative of biological usage.

The Mashel River Basin supports a wild, native winter-run of steelhead trout. Little is known about the usage of the system by steelhead, but adults have been observed spawning in upstream reaches of the mainstem Mashel River.

Pink salmon adults have been observed only in the lower reaches of the Mashel River.

The following is a summary of the principal habitat concerns identified in the Mashel River.

Channel Conditions

For its lower 3.2 river miles, the Mashel River freely migrates laterally but is confined naturally within a narrow canyon. The river emerges from the canyon at approximately RM 3.2 and up to RM 6.0. The Town of Eatonville is located between RM 5.1 and RM 6.0 where the river is rip rapped and channelized. Upstream of RM 6.6 the Mashel River enters timberlands managed for commercial forestry and the channel migrates freely across another narrow canyon floor.

Numerous unstable banks and areas of mass wasting are found upstream of RM 6.6. Substrate upstream of RM 6.6 is primarily cobble and small boulder with patches of spawning gravels. Deep scour pools, primarily associated with large rock boulders are found upstream to RM 15.4. The substrate composition is consistent with the high stream flows that follow storm events and rain-on-snow events that typify this subbasin. Most of the LWD historically present in this subbasin was removed as a part of previous logging practices during the 1950's, 60's and early 70's. This has resulted in a lack of habitat diversity for juvenile rearing and a limiting factor to natural salmon production in this basin.

Downstream of RM 15.4 the channel is naturally confined in a steep-walled canyon to RM 6.6 with a moderately steep gradient. Between RM 6.6 and RM 3.2 the floodplain opens up, the stream gradient flattens somewhat and is characterized as moderate. Some natural braiding occurs within this section. At RM 3.2 the river enters another steep-walled canyon with a moderate to moderately-steep gradient.

Dramatic channel changes occurred as little as 20 years ago throughout the Mashel River Basin. These changes continue to influence the physical processes of the channel seen today. Large amounts of fine and coarse sediments have been delivered to the lower portion of the basin from mass wasting events in the upper watershed. The fine sediments were transported through and out of the system while the coarse sediments were deposited into the lower gradient reaches. The river continues to rework these deposits today. Consequently, a lack of roughness elements and a poorly-sorted mix of fine sediment, gravel, cobble and some boulders characterize many of the mainstem reaches. The pools are often shallow and infrequent, with LWD and small wood playing a relatively minor role. Although fine sediment is prevalent throughout the basin, the classic pool filling and sediment pillows are not prevalent due to the limited depth of many pools. Instead, fine sediment is often distributed throughout a reach.

Current levels of large woody debris are, in general, low throughout the basin. These levels are the result of removal of the recruitment trees along the stream corridor during the 1950's, 60's and 70's. Exacerbating those timber harvest practices was the in-channel removal of LWD common during the same time period combined with floods and catastrophic channel scouring events.

Cupp (In Press) concluded that significant channel widening was observed within lower Busywild Creek and South Fork Mashel River during the late 1960's and early 1970's. The cause of this channel widening probably stemmed from a combination of peak and debris flows. With the exception of a recent debris flow on the South Fork Mashel River, the gradual narrowing of the stream channel has occurred in both sub-basins since 1978. Significant channel widening occurred in the early 1980's within the upper Busywild Creek while less dramatic widening within the lower reaches of the Upper Mashel subbasin was observed between 1955 and 1965. Currently, most of the basin has been in a stage of "recovery" where stream channels narrow and associated riparian growth increases. No large scale channel changes were noted for the other subbasins, though ponds associated with beaver dams on Beaver Creek disappeared between 1955 and 1965. The construction of ditches along portions of Midway Creek likely occurred prior to 1955.

Within the Mashel River Basin there are 402 wetlands covering 3,367 acres (Cupp, In Press). A wetland in the middle reach of Beaver Creek is 341 acres in size, and is the single largest wetland in the Mashel basin. A 555 acre wetland complex divided by roadways extends along Midway Creek. Most of the Midway Creek wetland complex is utilized for agricultural purposes.

Sediments and Substrate

Patches of spawning gravels are found throughout the lower 3.2 river miles but the dominant substrate is comprised of small boulders and cobble. At the mouth of the Mashel River, mean fine sediment levels of 15 percent in 1993 and 12 percent in 1994 were recorded (Whiley 1997). This level of fines would moderately impact incubation success. Sediment criteria standards found in a review of several guidance documents all indicated percent fines should not exceed 11%.

In the Mashel Watershed Analysis, Cupp et al (In Press) determined that there was an increase in the frequency of mass wasting caused by roads and timber harvest which in turn has adversely impacted the channel and habitat conditions in the Mashel River subbasin. The increases of landslides has increased the sediment supply to streams, primarily in the upper watershed and the inner gorge of the Middle and Lower Mashel. Additionally, the reduced area of mature timber has reduced the recruitment of large woody debris from landslides. The frequency of pools is likely to have been reduced from historical levels due to the increases in number of landslides and volume of sediments along with a dearth of LWD that is important to the pool forming processes.

Shallow-rapid landslides characterized by events such as debris avalanches, debris flows, and quarry spoil failures accounted for 86 percent of the landslides in the Upper Mashel River, South Fork Mashel River, and Upper Busywild Creek subbasins. In the past 60 years, most of these debris flows have been associated with logging road construction practices such as road fills and sidecast at the stream crossings.

Deep-seated landslides, characterized by events such as slump-earthflows and bedrock landslides accounted for 14 percent of the landslides in the Mashel River WAU.

Debris avalanches are common in the steeper (greater than 40 percent slopes as identified on USGS 7.5-minute topographic quadrangles) topography associated with the upper watershed composed of volcaniclastic and sedimentary rocks and also in the inner gorges of Busywild Creek, the upper Mashel River, and the South Fork Mashel River. Debris avalanches and small slumps are also found on the steep valley walls of the mainstem Mashel River.

Debris flows initiated in this subbasin have sometimes run into Type 3 channel segments where debris scour destroys an entire year class of redds and degrades channel conditions for years. After a debris flow, the channels are typically left without pools and without functional woody debris and with a reduced shade level due to disturbance of streamside vegetation. Following a debris flow, it takes years for pool habitat to reform and stream banks to revegetate.

In that same analysis, Cupp et al (In Press) found that the increased sediment load also had widened stream channels, which causes a reduction in shade levels and the depth of water flow in the summer. Both of these impacts adversely effect the survival of fish, (i.e.: coho, cutthroat and steelhead) that rear in the affected reaches during those low flow periods. Locations of debris flows into fish-bearing reaches were identified by Cupp et al (In Press). Debris flows limit the natural production of salmonids by scouring channel reaches and further degrading stream channel conditions. A summary of these events is depicted in Table 8.

Table 8: Mass wasting summary by forest management practices in the Mashel River Basin (Cupp, In Press).

Activity	Small Sporadic Deep-Seated Failure	Large Persistent Deep-Seated Failure	Debris Avalanche	Debris Flow	Total
Clear Cut 0 to 10 years		1	55	27	83
Clear Cut 10 to 40 years		12	53	10	75
Partial Cut					0
Road	2	8	50	11	71
Stream Crossing			52	21	73
Landing					0
Other Forest Practices	1		4	1	6
Wildfire					0
Mature Forest	1	25	26	18	70
Non-Forest Land Use		3	6		9
Totals	4	49	246	88	387

The removal of timber on the steep valley walls has eliminated an important natural source of LWD delivered when these slopes inevitably fail. Due to increased sediment inputs from these failures and from the upper watershed, LWD is especially important for forming pools in segments. The removal of timber in this area can be linked to a decrease in pool frequency and a decrease in rearing and refuge habitat and decrease in natural production of salmonids (Cupp et al, In Press).

Cupp et al (In Press) identified historic road construction and timber harvest activities within and adjacent to certain wetlands within the Mashel River basin. These activities have imported and/or remobilized sediment within some of the wetlands. The saturated soils of these wetlands has led to occurrences of overland flow, and the transportation of fine sediment to streams.

The road systems (Table 9) of the Upper Mashel, South Fork Mashel, and Upper Busywild subbasins were demonstrated to increase the delivery of fine sediments to streams (Cupp et al. In Press, Whiley 1997). The increases in sediment delivery were attributed to high connectivity of the road system to channels (Cupp In Press). The primary reasons for this connectivity is believed to be the lack of relief culverts draining the interior ditches to unchanneled hillslopes and the creation of outside berms on the roads due to grading and maintenance practices.

Table 9: Mashel WAU Analysis Road data (Source: Cupp)

Subbasin	Basin Area miles square	Road Length miles	Road Density miles/mile square	Road Length Surveyed miles	Road Length Surveyed percent
Beaver Creek	12	44.1	3.7	15.2	35
Little Mashel River	15	42.1	2.8	24.0	57
Lower Busy Wild Creek	7	25.3	3.8	8.8	35
Lower Mashel River	12	129.2	10.9	28.1	22
Middle Mashel River	8	43.4	5.6	15.0	35
Midway Creek	8	51.7	6.9	9.6	19
South Fork Mashel River	8	46.3	5.6	11.4	25
Upper Busy Wild Creek	9	61.3	7.1	15.8	26
Upper Mashel River	7	60.1	8.9	23.8	40
Total	**84**	**503**	**6.0**	**152**	**30**

The Watershed Analysis Manual provides for two thresholds of concern for road sediment delivery: (1) a moderate level of concern at a 50 percent increase in sediment production over background hillslope erosion and (2) a high level of concern at a 100 percent increase. The road systems in three subbasins, Upper Mashel River, South Fork Mashel River, and Upper Busywild Creek, exceed the 100 percent threshold (Table 10). A quantitative impact to natural salmonid production was unavailable for this report but it is expected to be adverse to spawning success and juvenile rearing.

Riparian Conditions

Riparian stands in the Mashel River basin reflect the conditions of the upland forests. The majority (70 percent) of the Mashel Watershed Administrative Unit (WAU) riparian stands are in a young (<40 years old) age class. Riparian stands in the upper portion of the WAU (Upper Busy Wild Creek, South Fork Mashel River, and Upper Mashel River) do not contain any riparian vegetation large enough to be considered mature (40-120 years old). The only area containing riparian vegetation with a majority of the trees greater than 20 inches dbh is on the lower mainstem of the Mashel River. Nearly half (44 percent) of the riparian stands in the WAU are conifer-dominated, 33 percent are mixed, and 23 percent are deciduous-dominated.

Table 10: Percent increase in surface erosion inputs over estimated soil creep inputs by subbasin in the Mashel WAU

Sub-basin	Soil Creep	Road-Related Surface Erosion	Percent Increase
	tons	tons	
Beaver Creek	292	112	38
Little Mashel	239	29	12
Lower Busy Wild	60	36	60
Lower Mashel	123	11	9
Middle Mashel	236	66	28
Midway Creek	239	25	10
South Fork Mashel River	70	557	800
Upper Busy Wild	88	315	358
Upper Mashel	183	420	229
Total	**1,530**	**1,571**	**97**

The vast majority of stream channels in the Mashel River basin are bordered by riparian vegetation of insufficient size to supply adequate recruitment of LWD. Currently, the riparian vegetation along the entire length of the mainstem Mashel River is generally too small to be stable and functional as an individual piece within the channel. Riparian areas in the Upper Busy Wild and South Fork Mashel sub-basins are completely dominated by small trees (<12 inches dbh) due to timber harvest in the past 20 years Cupp et al (In Press). Recent debris flows have disturbed riparian areas in the South Fork and Upper Mashel sub-basins.

In the Mashel Watershed Analysis, Cupp et al (In Press), used Standard Methodology for Conducting Watershed Analysis, Version 2.1 (Washington Forest Practices Board 1994), and identified only a limited shade hazard within the basin (primarily in the Lower and Middle Mashel, Little Mashel, and Midway Creek subbasins). However, results of stream temperature monitoring in 1993 and 1994 (Whiley 1997) indicated Washington

State Class A water quality standards were often exceeded throughout the basin. For this basin, target shade levels identified in the Standard Methodologies manual do not appear to be effective in preventing stream temperatures from exceeding state water quality standards. Consequently, all fish bearing and contributing Type 4 streams were identified as shade hazards (Cupp. In Press).

Single and multiple large pieces of functional wood are generally scarce throughout streams of the basin. LWD is not the primary habitat-forming factor in all areas, however in many areas, the lack of effective in-channel debris, combined with debris torrents and continued downstream sediment routing, is believed to be responsible for the simplified habitat conditions present throughout the basin. Channel aggradation and the reduction of bed particle size has occurred in some stream reaches. In some areas, the combination of lack of wood and undercut bank habitat limits the stream's effectiveness to serve as overwinter habitat for salmonids.

Water Quantity

Water quantity is of concern in the diversion reach in the vicinity of Eatonville's sewage treatment plant. Also, fall low flows may inhibit the migration of adult chinook into the Mashel River upstream of the diverted reach. It is unclear if these flows are the result of naturally occurring seasonal flow patterns, the result of a porous stream channel bed, the diversion of water, influenced by land use or a combination of all these issues.

An analysis of land use impacts on hydrology within the Mashel River basin suggested the following (Source: Cupp In Press):

- Modeling results suggest that all subbasins have a low hazard to peak flow increases.

- Snowpack probably is not a significant contributor to runoff during winter storms at lower elevations (Lower and Middle Mashel, Little Mashel, and Midway subbasins.

- Significant channel disturbance was observed along many segments within the watershed. While a series of peak flows during this time may have contributed to the disturbance, the extent to which these peaks were influenced by management remains unknown. The timing of these peaks coincides with a period of high resource sensitivity (due to recent logging in riparian areas, removal of LWD from streams, etc.).

- Most subbasins had projected increases in peak flows of 14 to 20% for fully clear cut conditions. While peak flow increases for current conditions are generally less than 10%, extensive clear cuts from past timber harvesting could have led to significant short term increases in peak flows in the past. It would follow that the potential for future land use activities to result in higher rain-on-snow generated peak flows exists.

- The extent to which roads are increasing the magnitude of peak flows is unknown. However, field observations in the Upper Mashel, Upper Busywild, and South Fork Mashel subbasins identified subsurface flow interception by ditches as well as a high degree of connectivity between the road and channel networks. This suggests that the extensive road network may have an effect on the timing and magnitude of peak flows.

- The combination of an extensive road ditch network which is highly connected to stream channels with frequent conversion of coniferous to hardwood-dominated riparian stands within the Upper Mashel, South Fork Mashel and Upper Busywild subbasins may be resulting in lower than normal base flows.

Water Quality

Water quality in the Mashel River is generally considered good with site specific areas of concern. Water temperatures recorded by Whiley (1997) conducted during 1994 showed elevated temperatures from RM 5.2 to RM 0.6. Temperatures were recorded as high as 26 C. (RM 5.2) and 24 C (RM 0.6). The heating of water in this section of the river is believed to be a function of anthropogenic changes, solar heating, loss of riparian vegetation, river substrate, stream width and gradient.

The Town of Eatonville operates a point source for nutrients in the form of a secondary treatment sewage plant that discharges into the Mashel River at RM 5.4. Water for the operation of this plant is removed at RM 5.7 and the reach between these points can be rather shallow. As previously noted, flows in this reach may cause delays in upstream migration of adult salmonids dependent on the water year. The treatment plant appears to be the source of elevated levels of total phosphorus within the Mashel River. It is unknown if the operation of this facility is adversely impacting salmonids. Other water quality parameters (pH, total ammonia, nitrite-nitrate) measured by Whiley (1997) in the vicinity of the wastewater treatment plant are within state water quality standards.

Cupp (In Press) identified three potential limiting factors (total phosphorus, excessive algae growth and low dissolved oxygen levels) to natural salmonid production in this subbasin. Concentrations of total phosphorus increase in the Little Mashel River associated with storm events (Whiley 1997) and appear linked to total suspended solids in the water column. These sediment bound phosphorus concentrations are likely the result of non-point source inputs potentially associated with agricultural activities in the upper subbasin. Total phosphorus and nitrogen loading from the Eatonville wastewater treatment plant to the lower reaches of the mainstem Mashel River and sediment loading from historical forestry activities to the middle reaches of the mainstem Mashel River are potentially impacting salmonid natural production. The presence of elevated concentrations of phosphorus and nitrogen compounds, particularly in a soluble form, can lead to excessive algae growth during the growing season. Algae in excessive numbers can then lead to wide variation in dissolved oxygen concentrations; supersaturated oxygen levels during periods of photosynthesis and depletion during periods of respiration. This potential impact has not been observed at the monitoring locations. Dissolved oxygen levels measured at the lower river station (Mashel 3.2) in the early morning hours remained elevated and not significantly different from oxygen levels observed in the Mashel River at monitoring stations located above these influences. The identification of the total phosphorus and nitrogen loading associated with the operation of the Eatonville Wastewater Treatment plant as a concern (Cupp In Press) is in conflict with conclusions reached during the same time period by Whiley (1997).

Water temperatures within the Little Mashel River are cooler than the Mashel River during summer low flows and tend to temper the higher temperatures of the Mashel River at their confluence.

Fish Usage

The Mashel River subbasin is a significant subbasin for fall chinook and coho salmon along with steelhead trout production. The known salmonid utilization of this basin is depicted on maps in Appendix B, Figures B-1 through B-6.

Little Mashel River

General

The Little Mashel River joins the Mashel River at approximately RM 4.4. A naturally occurring waterfall at RM 0.8 limits anadromous salmonid migration in the Little Mashel River. Land use within the lower reaches of the basin consists of rural residential, hobby farms, commercial timber and agriculture. The upper reaches are managed for commercial timber production

The basin lies within an elevation between 700 and 4000 feet. Streamflows rise rapidly following storm events and rain-on-snow events typical of basins located at this elevation range.

Floodplain Modifications

Metzler (In Press) examined aerial photos of the Little Mashel River subbasin and determined that there were not any channel changes associated with catastrophic events. In the 1955 aerial photos, approximately 3,000 feet of channel in one stream segment had numerous beaver dams and pond complexes. By 1965, the ponds were gone and channel width had decreased by about 25%.

There are localized channel alterations in the vicinities of road crossings but these are not believed to adversely impact salmon production.

Channel Condition

The Little Mashel River represents approximately 18% of the total acreage of the Mashel River WAU yet only approximately 0.8 miles of the Little Mashel River are accessible to salmonids. The channel is composed mostly of cobbles and boulders with patches of spawning sized gravels. Sediments are recruited from bank erosion, agricultural activities and logging roads in the headwater reaches. The stream lies at an elevation where rain-on-snow events are common and the rapid flow increases caused by this precipitation pattern tends to quickly transport smaller gravels out of the system.

Riparian Condition

The riparian corridor is largely intact and consists of second growth deciduous hardwoods. Only in the vicinity local road crossings are there adverse impacts to the riparian habitat.

Sediment and Substrate

The vast majority of the Little Mashel River streambed is comprised of small boulders and cobbles with the notable exception of the plunge pool tailwaters where a large gravel bar is present. Stream gradient is moderate to steep. There are localized areas of channelization and bank armoring in the vicinity of county road crossings.

Sediment within the subbasin is believed to occur from bank erosion, agricultural activities and logging roads (Cupp, In Press; Nisqually EDT Workgroup In Progress).

Water Quality

Water temperatures within the Little Mashel River are cooler than the Mashel River during summer low flows and tend to temper the higher temperatures of the Mashel River at their confluence. Concentrations of total phosphorus increase in the Little Mashel River associated with storm events (Whiley 1997) and appear linked to total suspended solids in the water column. These sediment bound phosphorus concentrations are likely the result of non-point source inputs potentially associated with agricultural activities in the middle reaches of this subbasin.

Whiley et al (1997) found the Little Mashel River to have the highest total abundance of macroinvertebrates in the Mashel River subbasin. However, there was little diversity of species and the samples were dominated by a single taxa (Simulium sp.) While stream temperature data suggested that the Little Mashel River remains relatively cool during summer months, macroinvertebrate taxa associated with colder waters were present only in low numbers. Also, no wood associated taxa were captured in the samples. This suggests the system lacks wood in the form of small and/or large wood debris.

Water Quantity

As previously mentioned, the flows in this subbasin tend to rise and fall quickly based on precipitation patterns. Summer flows can be quite low and this impacts water quality.

Fish Usage

Coastal cutthroat trout are found throughout the subbasin and coho and chinook have been observed below the falls at RM 0.8.

Beaver Creek

General

Beaver Creek is a small left bank tributary that enters the Mashel River at RM 10.4. An impassable cascade at RM 0.5 limits upstream migration of anadromous salmonids. An attempt to ladder this cascade was made in the mid-1980's but there is no evaluation of whether this project was or continues to be successful.

Floodplain Condition

Beaver Creek meanders freely within its floodplain with only minor confinement at road crossings. The lower 0.5 miles of the creek have a moderate to steep gradient as it passes through a confined small canyon. Even with the extensive wetland complexes in the upper reaches the creek is typical of many western Washington streams with similar gradients in that its flows respond quickly to storm events.

Sediment and Substrate

The predominant substrate in the lower 0.5 mile section is cobble with boulder outcrops and small patches of spawning gravel. Upstream, the wetland complexes act as sediment traps for quantities of coarse and fine sediments as they settle out in these lower gradient reaches.

Riparian Condition

The creek lies entirely within lands managed for commercial forest production and the riparian habitat consists entirely of second growth conifers and hardwoods. The headwaters are a series of extensive wetlands and beaver dam complexes (abandoned and active) that support extensive populations of naturally reproducing coastal cutthroat trout. The discussion of riparian habitats in the Mashel River portion is applicable to this subbasin.

Water Quality

No water quality problems in Beaver Creek were identified.

Water Quantity

The stream lies at an elevation where rain-on-snow events are common and the rapid flow increases caused by this precipitation pattern tends to quickly transport smaller gravels out of the system. Summer flows can be quite low.

Fish Usage

Coastal cutthroat trout are present throughout the subbasin, and are quite numerous in the large wetland complexes located throughout the middle reaches of this stream. Coho are known to utilize the lower reaches.

Busy Wild Creek

Channel Condition

The lower 0.5 mile of the creek has a moderately steep gradient before entering a broad valley where the gradient becomes low. Upstream of RM 2.5 the gradient increases again and the channel is confined from lateral movement by a narrow canyon before reaching an impassable cascade at approximately RM 5.0 (Williams 1975) limits upstream migration of anadromous salmonids.

There are several mass wasting sites in the upper reaches of Busy Wild Creek that contribute sediment to lower reaches and inhibit lateral movement (Nisqually EDT Workgroup. In Progress) of the creek.

Sediment and Substrate

Substrate in the steeper reaches of Busy Wild Creek are typically small boulder and cobble with only limited patches of gravel suitable for spawning. In the more moderate and low gradient reaches sediments from upstream mass wasting problems are deposited which degrades the already limited spawning habitat.

Riparian Condition

Busy Wild Creek is a left bank tributary to the Mashel River at RM 14.5.
The creek lies entirely within lands managed for commercial forest production and the riparian habitat consists entirely of second growth hardwoods and smaller numbers of conifers.

Water Quantity and Quality

Typical of many western Washington streams with similar elevations and gradients, the water flow in Busy Wild Creek responds quickly to storm events. Macroinvertebrate sampling data shows an absence of long lived taxa (Whiley 1997) that may be the result of scour and substrate sorting caused by high flows. The creek does not have extensive wetlands in the upper reaches that would serve as water reserves and low stream flows during summer months serve to limit salmonid rearing habitats. Summer water temperatures are known to exceed state water quality standards (Whiley 1997).

Fish Usage

Many localized reaches on Busywild Creek provide the water conditions required for coho spawning and rearing if side channels and wood concentrations are allowed to become re-established. Currently, utilization is primarily limited to low numbers of coho salmon and cutthroat trout.

ASSESSMENT OF HABITAT LIMITING FACTORS

Recommendations by Prioritized Habitat Factor

This chapter presents habitat limiting factors conclusions by factor type. The occurrence and severity of habitat impacts varies between subbasins within the Nisqually River Basin (WRIA 11) and between reaches within an individual subbasin. Combined, however, these impacts significantly reduce the salmonid production potential of the streams in WRIA 11.

Perhaps the most extensive habitat alterations may have occurred post World War II, with rapid development and the availability of heavy equipment. The availability of heavy equipment provided the capability to alter the configuration of the stream channels and floodplains, and to reconfigure upland areas and build roads into previously marginally accessible areas. The ability to build logging roads deep into the Cascade Mountains and on steep slopes resulted in rapid logging of the headwater areas.

Current habitat condition was also adversely impacted through well-intended actions to restore habitat, such as removal of log jams to ensure fish passage, that are now known to have been detrimental to habitat quality and diversity. This chapter provides an opportunity to examine each of the key habitat elements and identify common themes across subbasins in the WRIA 11.

Through the construction of roads and timber harvest in upper watershed, areas once forested have seen increased rates of mass wasting and sediment deposition in streams. In many areas, the conversion of lands in floodplains to agricultural and rural development has resulted in floodplain constriction and channelization, increased sedimentation of stream gravels, increased stormwater runoff, loss of LWD and instream pools, and the loss of the habitat functions provided by riparian buffers.

Surface and groundwater withdrawals in WRIA 11 tributaries for irrigation and domestic use substantially reduce the availability of instream flow during adult salmon upstream migration and spawning. This in turn results in salmon spawning redds being constructed in channel areas that are extremely susceptible to sediment scour and deposition. The increase in impervious surfaces associated with various land uses increases the frequency and magnitude of stormwater runoff, and decreases the infiltration of precipitation to groundwater. All of these factors combine to compromise the productive capacity of stream habitat. Productivity potential is further compromised by the reduction of adult salmonids that have returned to some streams in recent years, whose carcasses provide a component of the freshwater nutrient base that serves as the foundation of the food web for juvenile salmonids and other stream associated plants, fish and wildlife.

There is often significant variability in the status of specific habitat elements between different reaches of the stream. In the Habitat Limiting Factors by Subbasin chapter of this report, reach-specific information is provided for streams, where available. Table 11 provides representative habitat condition ratings (Good, Fair, Poor) by stream for each, identifies the source for those ratings (e.g.: best professional judgement, written analysis, etc.) of the identified habitat elements in the previous chapter of this report. A comparison of Salmonid Habitat Condition Rating Standards and preferred choice used to identify the habitat condition ratings are included for reference in Appendix D. These ratings are based on the average habitat condition for the various reaches of a stream. Table 11 also provides information on the relative reliability of the source of the information that led to the habitat condition rating. These ratings are based on quantitative studies, published reports, and the professional judgement of TAG members. Action recommendations to address the identified habitat limiting factors are included in the next chapter of this document.

Table 11 also identifies those streams/habitat elements for which insufficient information was available to make a habitat condition assessment. These are noted in the table as Data Gaps (DG). Information presented in this section is limited to those streams where studies or observations have been made and limiting factors identified. The lack of mention of a particular stream in this discussion likely reflects that no information was available. However, the habitat element may be of concern if observations or investigations were to be made. The absence of a stream in Table 11 does not necessarily imply that the stream is in good health. Others may show more impacts because they are easily accessible and have been the focus of more extensive scientific study.

Most acquisition and restoration projects will likely be targeted at specific streams and stream reaches but it is important to understand each stream in the broader context of the entire Nisqually River Basin. The major habitat factors that are presented in this chapter include:

- access to spawning and rearing habitats
- riparian condition
- floodplain condition
- substrate and sediment
- water quality
- water quantity
- lakes (where applicable)
- estuarine (where applicable)

Access to Spawning and Rearing Habitats

There are a number of natural landscape features that serve to limit salmonid production at various life stages. These features include stream channel gradient (velocity barriers), and other landscape characteristics (channel constrictions, beaver dams, etc.). Streamflow can affect whether certain physical features are barriers. As an example, a cascade impassable at low flow may be passable at a higher flow. The reverse of this situation may also occur. Additionally, each salmon species has its own unique swimming characteristics and while chum salmon may be blocked at a certain flow, coho salmon may be able to pass the same point at the same flow. Each site must be examined and reviewed in terms of species and life stage impacted. This chapter focuses on anthropogenic caused factors that limit natural salmonid productivity.

In addition to natural barriers, the construction of road crossings, dams, and fish screens all have created fish passage barriers that serve to restrict or prevent juvenile and adult salmon from gaining access to historically accessible habitats. The most obvious of these barriers are dams and water diversions that prevent fish passage. However, in recent years it has become evident that we have created barriers that prevent juvenile salmonids from accessing rearing habitats. Poorly designed and/or installed culverts in streams have impacted the ability of salmon adults and juveniles to access historically productive reaches of streams. In estuaries, dikes and levees have eliminated access to sloughs and tidal marshes previously utilized by salmon for rearing and transition to saltwater.

Dams and Diversions

Two hydroelectric projects are located on the Nisqually River. The city of Tacoma’s Nisqually Project, which was started in 1910 and expanded in 1942, is located at the upper extent of the current distribution of anadromous salmonids. The City of Centralia’s Yelm Project was constructed in 1929, expanded in 1955 and extensively renovated in the 1980’s and 1990’s.

The Nisqually Project consists of two adjacent hydroelectric dams on the mainstem Nisqually River. The LaGrande Dam is the defining feature as it is the upstream barrier to anadromous fish distribution in the Nisqually River. Upstream of LaGrande Dam is the Alder Dam with Alder Lake behind it. Alder Lake effectively intercepts all salmon spawning sized gravels and LWD from the upper Nisqually River basin.

During the 1996 Federal Energy Regulatory Commission (FREC) relicensing process for these facilities, studies were conducted that indicated riverbed substrates downstream of the LaGrande Powerhouse to the Mashel River confluence had coarsened as a result of project operations. Tacoma is presently in the second year of a three year gravel augmentation pilot study. This study is in partial response to those findings with the intent to define if gravels placed in this section will provide the desired benefits.

In general, the flow regime necessary for the support of salmon and their habitat in the Nisqually River involves more than maintenance of seasonal "floors" or "ceilings". As noted by Spence et. al. (1996):

> "... although over shorter time scales high- or low-flow events may temporarily reduce salmonid numbers, dynamic flows are needed to perform essential functions important in the long-term persistence of salmonid populations. The specific flow requirements of salmonids vary with species, life history stage, and time of year. Local populations of salmon have evolved behavioral and physical characteristics that allow them to survive the flow regimes encountered during

> each phase of their development. Protection of salmonid habitats requires streamflows to fluctuate within the natural range of flows for the give location and season."

This statement, contained in a NMFS-USFWS publication, sums up the normative flow concept as it applies to conservation of salmon habitat. Natural abundance and diversity of salmonids (and other aquatic species) interlock with and depend on analogous natural characteristics of water flow regimes involving magnitudes, seasonal patterns, and random variation. Hydrologists have utilized flood frequency, means, maxima, minima and other statistics to describe flow regimes for many decades. More recently a systematic approach to biologically relevant flow statistics was presented by Richter et al, (1996) and Poff (1997) catalogued 32 flow parameters (so-called Indicators of Hydrologic Alteration (IHA)) related to ecosystem function tailored for comparative flow regime analysis. Richter, Baumgartner, and Braun (1997) presented a scheme for managing regulated stream flow by limiting the discrepancies between frequency distributions of natural and altered IHA parameters.

Conservation biologists and hydrologists are beginning to apply these concepts to salmon producing rivers in the Pacific Northwest. Hartley (personal communication, 1999) has applied IHA statistics and concepts to estimate alterations of the water flow regime in the middle Green River (WRIA 9) caused by the construction of Howard Hanson Dam and the diversion of water by Tacoma.

The Alder/LaGrande Hydroelectric Project does not have the flood control responsibilities that the Howard Hanson Dam Flood Control Project does, the former may exert many similar influences through the reduction of peak flood flows, increases in the duration of reduced peak flows, and alterations of fall and spring flows by water storage activities. A similar river flow analysis has not occurred for the Nisqually River.

The impacts of high flows (floods) on channel forming processes is significant. Floods provide the energy for natural lateral channel migration and creation of new off-channel habitats. Washington Department of Natural Resource aerial photographs from the years 1965 and 1970 were examined and compared against 1995 aerial photographs. The year 1965 was the oldest photographs available but the file was not complete. In those areas of the Nisqually River where 1965 photographs were not available, photographs from the next oldest set (1970) were used. Off-channel rearing habitats were identified and distances were estimated using a map wheel and a comparison of these distances by location (river mile) are shown in Figures 7 and 8. A significant landslide in the vicinity of RM 37 occurred in 1990. This event supplied between 200,000 and 300,000 cubic yards of gravels, sand and finer sediments and contributed to increases in mainstem channel width (Cupp In Press).

The distances of off-channel rearing habitats in the Nisqually River mainstem have been reduced between 1965/70 and 1995. However, in terms of geologic forming processes, this is a short time period. Confounding this observation is the flood of record in the Nisqually River that occurred in 1996. That event may have significantly altered off-channel rearing habitats. Unfortunately, aerial photographs since that flood are not yet available. More confidence could be placed in this pattern of decreased off-channel rearing habitats if older aerial photographs and photographs since 1996 were available. It is significant to note the almost total absence of off-channel rearing habitat opportunities between Nisqually River mainstem river miles 10 and 26.

Additionally, Alder Dam currently intercepts LWD and there are no operational provisions to pass this material downstream. Cupp (In Press) found that very little LWD was observed to play a role in formation and stabilization of channel morphology in reaches of the Nisqually River mainstem downstream of LaGrande Dam to at least RM 40.9. Limited accumulations of wood are distributed along the channel well beyond the bankfull channel area. LWD that does contribute to pool formation is primarily isolated pieces or small groups, along the channel margins. LWD was not observed to provide sediment trapping or sorting functions, although it may contribute to bar stabilization near the mouth of the Mashel River. Flood flows in this reach are typically capable of redistributing debris in this segment to downstream reaches. A change in LWD input would not be expected to change the frequency or abundance of primary pool habitat. In this reach, pools are formed largely by bedform and boulder clusters while LWD more serves to enhance overwinter and spring cover and velocity refuge margin habitat, important for all juvenile salmonid species rearing in these areas during those time periods.

Downstream of RM 40.9 to approximately RM 36.5 (below the confluence of the Nisqually River and Ohop Creek) concentrations of LWD were relatively scarce (Cupp, In Press). A high proportion of the LWD observed in this mainstem reach is stored on terraces and cobble bars, presumably the result of high flows. Locally, only small sized conifers are available for recruitment and are thought to be of insufficient size and quantity to supply this reach with suitable LWD.

LWD could be added to this reach through spill over the projects and/or trucking around the projects and placed into the mainstem.

The Yelm Hydroelectric Project is located approximately 14 miles downstream of the LaGrande Dam Project. The Yelm project diverts water out of the mainstem Nisqually River through a diversion canal for approximately 13.6 river miles prior to returning the water to the mainstem Nisqually River. The project has undergone renovations to the fish screens in 1999 and currently meets state screening standards.

Impassable Culverts

There is only one identified impassable culvert to anadromous fish in the Nisqually River Basin (G. Walter pers comm.). The WDFW culvert database only lists four impassable culverts in WRIA 11. All of these culverts are located outside the anadromous fish zone. A comprehensive inventory of culverts on private and county roads that are impassable to resident fish species has not been initiated.

Riparian Condition, Floodplain Condition, Sediment and Substrate Condition

The construction of road systems for the express purpose of commercial timber harvest in upper watershed forested areas have increased the rate of mass wasting and sedimentation to streams. The conversion of lands from historical uses to agriculture and development in the lower watershed have resulted in the channelization and constriction of the Nisqually River and many of its tributaries floodplains and their channelization. These land use changes have brought about localized increases in the sedimentation of stream gravels, increased stormwater runoff, loss of LWD and instream pools, loss of necessary streamside shade, loss of the habitat functions provided by riparian buffers. There has been recent developments of scientific evidence that illustrate the importance on nutrient recycling to ecosystems through salmon carcasses. It is these carcasses and the nutrients they bring back to the basin that provide the marine nutrient base that serves as the foundation of the food web for juvenile salmonids and other stream associated fish and wildlife.

There exist several reaches of the mainstem Nisqually River and some tributaries where dikes and levees have been constructed. These structures were generally built in an effort to protect property from flood water and are shown in Figure A-8 (Appendix A).

<u>Water Quality, Water Quantity and Lakes</u>

The withdrawals of surface and groundwater for irrigation, domestic, and industrial use substantially reduce the availability of instream baseflows during adult salmon upstream migration (particularly chinook salmon) and spawning, and potentially result in spawning redds being constructed in channel areas that are extremely susceptible to sediment scour and deposition. They also decrease summer low flows that reduce rearing areas for fish residing year-round in these streams. The increase in impervious surfaces associated with various land uses increases the frequency and magnitude of stormwater runoff, and decreases the infiltration of precipitation to groundwater. All of these factors combine to compromise the productive capacity of stream habitat.

Many of the middle river tributaries flow through or originate from lakes that have been converted from historical nursery areas to recreational oriented purposes. The introduction of several exotic fish species that are predatory have an unknown but presumed adverse impact to naturally produced salmonids. These fish are capable of migrating out of lakes and into the stream and river environments where they could opportunistically prey upon naturally produced salmonids. Multiple age classes of large mouth bass have been observed rearing in upper and lower river side-channels and sloughs.

Associated with the conversion of lake shorelines to recreational and principle houses has come water quality degradation in the form of increases in total phosphorus. This in turn has led to increased water quality degradation through algae blooms, higher stream-water temperatures, and lower dissolved oxygen levels which further degrade the habitat.

Estuarine

The construction of levees along both sides of the lower mainstem Nisqually River have reduced the estuary by approximately 30 percent. This has caused a substantial shift in habitats from the historical presence of marine oriented marshes to freshwater wetlands located behind the dikes. Off-channel acclimation opportunities and the distributary channels of the historical estuary have been largely eliminated.

However, given the public ownership of much of these lands there is probably the largest opportunity for conversion back to historical ecological uses of any lands within the basin. This conversion would result in significant benefits to all anadromous salmon species and especially chinook and chum salmon. It would also be expected that salmon from other WRIA's would benefit from this conversion.

General

There is often significant variability of habitats between different reaches of the stream. For that reason a stream reach or subbasin may have more than one factors listed. In the Habitat Limiting Factors by Sub-Basin chapter of this report, reach-specific information was provided for streams, where available. Table 11 provides representative habitat condition ratings (Good, Fair, Poor) by stream/subbasin for each of the identified habitat elements in the previous chapter of this report. Where available, information from published reports (i.e.: watershed analysis, technical reports, etc.) were used. In the absence of published reports the best professional judgement of Nisqually River Technical Advisory Group members was used. That information is also provided.

The Salmonid Habitat Condition Rating Standards used to identify the habitat condition ratings are included for reference in Appendix D. These ratings are based on the average habitat condition for the various reaches of a stream. Action recommendations to address the identified habitat limiting factors are included in the next chapter.

Table 11 also identifies those streams/habitat elements for which insufficient information was available to make a habitat condition assessment. These are noted in the table as Data Gaps (DG). The absence of a stream in Table 11 does not necessarily imply that the stream is in good health. Some streams may not be listed because they have not been visited, or no information is available. Others may show more impacts because they are easily accessible and have been the focus of more extensive scientific study.

Table 11: Identified habitat limiting factors in WRIA 11

Subbasin/ Stream Name	WRIA Stream Index Number	Fish Passage	Floodplain Connectivity	Bank Stability	LWD	Pools	Side Channel Habitat	Substrate Fines	Riparian	Water Quality	Water Quantity	Sediment Contamination	Lakes	Estuarine
Nisqually Nearshore		NA	NA	P (2)	P (2)	NA	NA	P (1)	P (1,2)	G (1)	G (1)	NA	NA	NA
Nisqually Delta		NA	F (1,2)	NA	P (1,2)	NA	P (1)	NA	P (1)	G (1)	G (1)	G (1)	NA	---
Independent Tributaries														
McAllister Creek	11.0324	G (1,2)	P (1)	F (2)	P (2)	F (2)	P (1,2)	F (2)	P (1,2)	G (1,2)	F (1,2)	F (2)	NA	P (1)
Red Salmon Creek	11.0001	G (1,2)	F (1,2)	F (2)	P (2)	F (2)	P (2)	F (2)	F (2)	G (2)	G (2)	F (2)	NA	P (2)
Sequalitchew Creek	12.0019	F,1,2	G (1,2)	G (2)	P (2)	G (2)	G (2)	F (2)	F (2)	F (1,2)	F (2)	F (2)	F (2)	P (2)
Lower Nisqually River														
Lower Nisqually River														
Mainstem	11.0008	G (1)	F (1,2)	F (1,2)	G (2)	G (1,2)	G,F,P (1,2)	G (2)	G,P (1,2)	G (1,2)	G (1,2)	G (2)	NA	P (1,2)
Clear Creek		P (1,2)	P (1,2)	G (2)	P (2)	NA	P (2)	P (2)	P (2)	G (1,2)	G (1,2)	F (2)	NA	NA
Kalama Creek		P (2)	P (2)	G (2)	P (2)	F (2)	P (2)	F (2)	G (2)	G (2)	G (2)	F (2)	NA	NA
Muck Creek	11.0018	G (2)	G (2)	G (2)	F (2)	G (2)	G (2)	G (2)	G (2)	F (2)	F (2)	G (2)	F (2)	NA
Lacamas Creek	11.0022	G (2)	G (2)	G (2)	F (2)	DG	G (2)	G (2)	G (2)	G (2)	G (2)	G (2)	NA	NA
South Creek	11.0028	G (2)	G (2)	G (2)	F (2)	DG	G (2)	G (2)	G (2)	G (2)	G (2)	G (2)	NA	NA
Exeter Springs	11.0019	G (2)	G (2)	G (2)	NA	DG	G (2)	G (2)	F (2)	G (2)	G (2)	G (2)	NA	NA
Johnson Marsh	11.0027	G (2)	G (2)	G (2)	NA	DG	G (2)	F (2)	F (2)	G (2)	G (2)	G (2)	NA	NA
Middle Nisqually River														
Middle Nisqually River														
Mainstem	11.0008	G (1,2)	F (1,2)	G (1,2)	F (2)	G (2)	F (2)	UC	F (2)	G (2)	G (1,2)	G (2)	NA	NA
Thompson Creek	11.0041	G (2)	F (2)	F (2)	P (2)	F (2)	F (2)	UC	DG	G (2)	F (2)	UC	NA	NA
Yelm Creek	11.0043	G (1,2)	G (2)	G (2)	P (2)	F (2)	F (2)	UC	P (1,2)	F (2)	G (2)	UC	NA	NA
Murray Creek	11.0005	G (2)	G (2)	F (2)	P (2)	P (2)	F (2)	UC	F (1,2)	G (2)	F (2)	P (1,2)	NA	NA
Horn Creek	11.0059	G (1,2)	G (1,2)	G (2)	P (2)	P (2)	P (2)	UC	P (2)	F (2)	F (2)	F (2)	NA	NA
Harts Lake Outlet Creek	11.006	P (1,2)	P (1,2)	F (2)	P (2)	P (2)	P (2)	UC	P (2)	F (2)	F (2)	F (2)	P(1,2)	NA
L.B. Unnamed Springs														
RM 20-21		G (2)	G (2)	G (2)	P (2)	F (2)	NA	DG	F (2)	G (2)	G (2)	UC	NA	NA

Table 11: Identified habitat limiting factors in WRIA 11 (continued)

Subbasin/ Stream Name	WRIA Stream Index Number	Fish Passage	Floodplain Connectivity	Bank Stability	LWD	Pools	Side Channel Habitat	Substrate Fines	Riparian	Water Quality	Water Quantity	Sediment Contamination	Lakes	Estuarine
Upper Nisqually River														
Upper Nisqually River														
Mainstem	11.0008	**G (1,2)**	**G (1,2)**	**G (1,2)**	**P (1,2)**	**G (1,2)**	**G (1,2)**	**G (1,2)**	**G (1,2)**	**G (1)**	**G (1,2)**	**G (1,2)**	**G (1,2)**	**NA**
Lackamas Creek	11.0063	**F (1,2)**	**F (2)**	**F (2)**	**P (2)**	**F (2)**	**F (2)**	**UC**	**P (2)**	**F (2)**	**F (2)**	**UC**	**NA**	**NA**
Toboton Creek	11.0065	**F (2)**	**F (2)**	**F (2)**	**P (2)**	**F (2)**	**F (2)**	**UC**	**P (2)**	**DG**	**F (2)**	**UC**	**NA**	**NA**
Tanwax Creek	11.0067	**F (1,2)**	**F (1,2)**	**F (1,2)**	**P (1,2)**	**F (1,2)**	**F (1,2)**	**F(1,2)**	**F(1,2)**	**F,P (1,2)**	**F (1,2)**	**F (1,2)**	**P (1,2)**	**NA**
Powell Creek	11.0076	**F (1,2)**	**F (1,2)**	**F (1,2)**	**P (1)**	**F (1,2)**	**F (1,2)**	**F(1)**	**P (1)**	**G (1,2)**	**P (1)**	**UC**	**P (1,2)**	**NA**
Kreger Lake Outlet Creek	11.0081	**F (2)**	**F (2)**	**F (2)**	**P (2)**	**P (2)**	**P (2)**	**P (2)**	**P (2)**	**P (2)**	**P (1,2)**	**UC**	**P (1,2)**	**NA**
Ohop Creek	11.0086	**G (1,2)**	**P (1,2)**	**P (1,2)**	**P (1,2)**	**P (1,2)**	**P (1,2)**	**P (1)**	**P (1,2)**	**P (1,2)**	**F (1)**	**P (1,2)**	**P (1,2)**	**NA**
Lynch Creek	11.0088	**G (1,2)**	**F (1,2)**	**G (1,2)**	**P (1,2)**	**P (1,2)**	**P (1,2)**	**F (1,2)**	**F (1,2)**	**F (1,2)**	**F (1,2)**	**F (1,2)**	**NA**	**NA**
Twenty-five Mile Creek	11.0095	**G (1,2)**	**F (1,2)**	**G (1,2)**	**P (1,2)**	**P (1,2)**	**P (1,2)**	**P (1,2)**	**F (1,2)**	**G (1,2)**	**G (1,2)**	**F (1,2)**	**NA**	**NA**
Mashel River	11.0101	**F (1,2)**	**G (1,2)**	**F (1,2)**	**P (1,2)**	**P (1,2)**	**F (1,2)**	**F (1,2)**	**F (1,2)**	**G,F (1,2)**	**G,F (1,2)**	**G (1,2)**	**NA**	**NA**
Little Mashel River	11.0102	**G (1,2)**	**G (1,2)**	**G (1,2)**	**P (1,2)**	**P (1,2)**	**F (1,2)**	**F (1,2)**	**G,F (1,2)**	**F (1,2)**	**G (1,2)**	**G (2)**	**NA**	**NA**
Beaver Creek	11.0111	**G (1,2)**	**G (1,2)**	**G (1,2)**	**P (1,2)**	**F (1,2)**	**G (1,2)**	**G (1,2)**	**G (1,2)**	**G (1,2)**	**G (1,2)**	**G (2)**	**NA**	**NA**
Busy Wild Creek	11.0114	**F (1,2)**	**G (1,2)**	**F (1,2)**	**P (1,2)**	**F (1,2)**	**G (1,2)**	**F (1,2)**	**F (1,2)**	**G (1,2)**	**G (1,2)**	**G (1,2)**	**NA**	**NA**
	NOTE: Habitat ratings may not reflect site specific issues that require corrective actions.													
F =	**Average habitat condition considered to be fair for the listed subbasin**													
P =	**Average habitat condition considered to be poor for the listed subbasin**													
G =	**Average habitat condition considered to be good for the listed subbasin**													
1 =	**Quantitative studies or published reports documenting habitat limiting factor.**													
2 =	**Professional judgement of TAG members.**													
DG =	**Data Gap**													
UC =	**Unverified**	**Concern**												

Figure 7: A comparison of off-channel habitat estimated lengths between RM's 0.0 and 25.8 in the Nisqually River between 1965/70 and 1995.

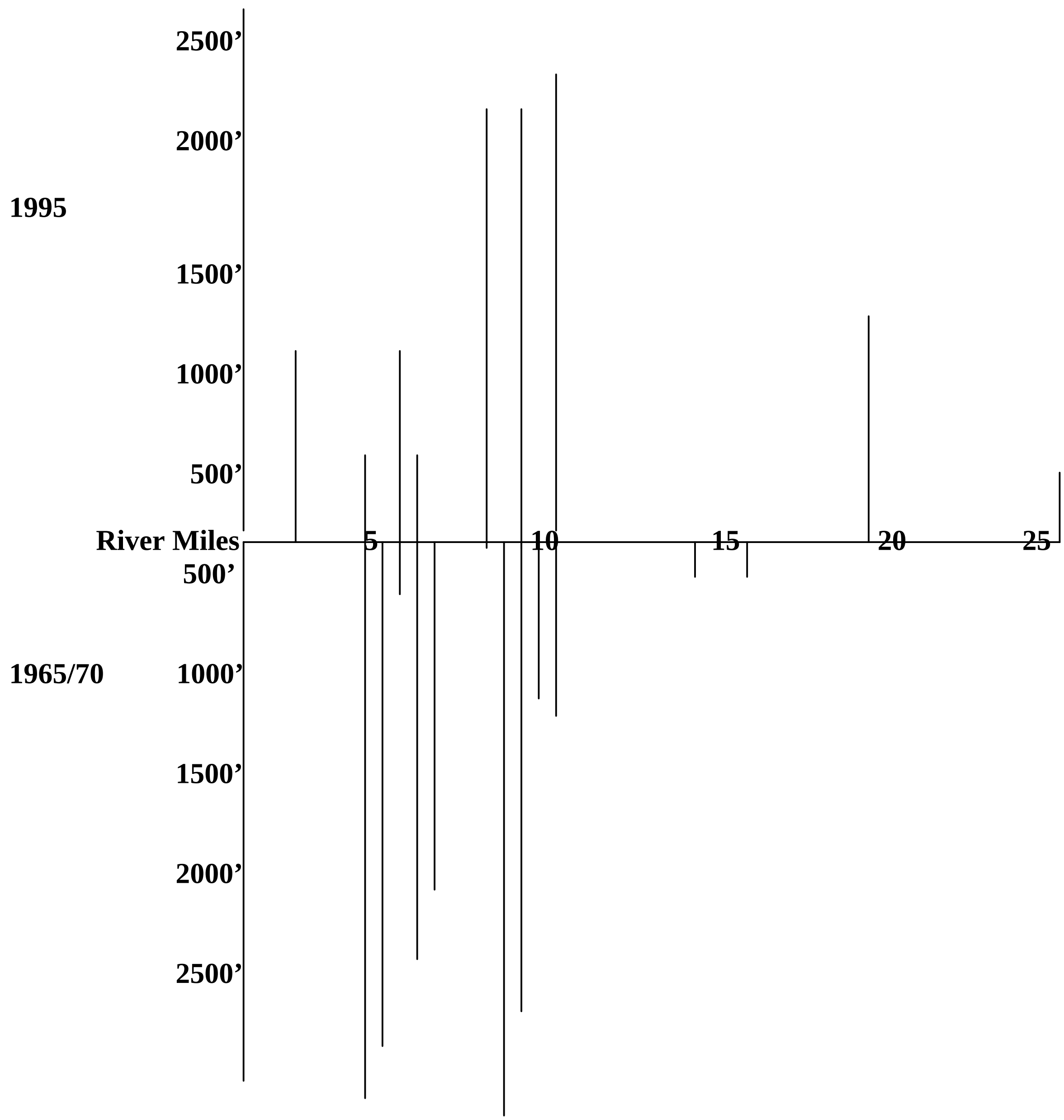
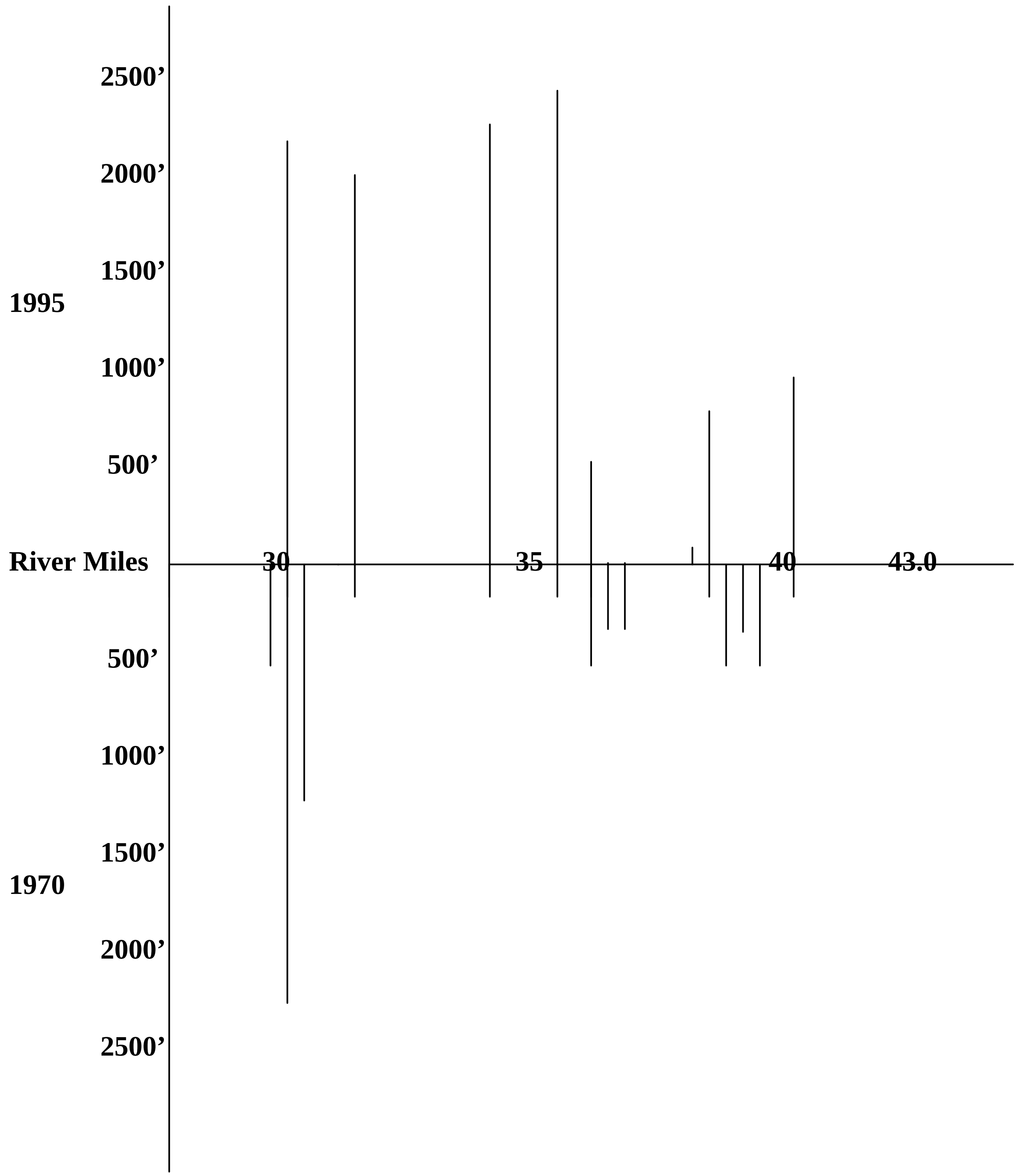


Figure 8: A comparison of off-channel habitat estimated lengths between RM's 29.9 and 42.5 in the Nisqually River between 1970 and 1995.



HABITATS IN NEED OF PROTECTION

Action Recommendations

The purpose of this action plan is to provide guidance toward the goals of restoring functioning natural habitats in the Nisqually River Basin. It is the intent of these recommendations to contribute to the recovery and de-listing of Puget Sound fall chinook and to provide benefits to other species of salmonids. Some of these action recommendations are the result of the Technical Advisory Group (TAG) recommendations and others were adopted by the TAG from the Nisqually River Ecosystem Diagnosis and Treatment Analysis (Nisqually River EDT Workgroup, In Press).

I. Habitat Protection and Enhancement Actions

A. Protection of critical areas from future degradation

Objective: ***Acquisition of key properties and/or development rights****.*

Justification: It is acknowledged that specific habitat conditions in the Nisqually Basin have become degraded from historical functions. The acquisition of certain properties and/or development rights is necessary to prevent further degradation, and to allow for active (as well as passive) restoration. The acquisition of certain key properties is necessary where development is incompatible with protection of aquatic systems. A management plan for properties that are acquired should be developed.

Action Items:

Action: Acquisition and protection of non-public estuary properties.

Action: Acquisition of property or development rights for riparian habitats along the Nisqually River mainstem. Initial efforts should focus resources in the areas of the middle Nisqually River mainstem. Such efforts could be in the form of conservation easements, tax incentives, acquisition or other suitable measures.

Action: Encourage the early completion of property acquisition of the lower 3.2 miles of the Mashel River mainstem and the lower 1 mile of Ohop Creek which is currently being considered for purchase by the Washington State Park system. Ensure that the management plans for these properties provide adequate protection for natural biological and physical processes to occur.

Action: Acquisition of development rights of certain properties along tributary streams. The focus of this effort should be the Mashel sub-basin (within the Lower Mashel and the Little Mashel stream reaches), the Ohop Creek sub-basin (Ohop Creek, Ohop Lake, and the downstream portions of the Lynch Creek and Twentyfive Mile Creek - including the former Clay City mining operation), and the downstream portions of the Prairie Creeks (those portions of the creeks closest to the mainstem Nisqually River).

Action: Acquisition and protection of identified wetlands that have a significant influence on stream conditions.

Monitoring:

Implementation (actions): 1) Monitor to insure compliance with agreements (i.e.: conservation easements, development rights, etc.).

Effectiveness (objectives): 1) Develop criteria to evaluate if critical functions are being successfully protected.

Validation (goals): 1) Evaluate trends in physical and biological processes of acquired and protected areas over time.

Objective: ***Secure commitments for permanent protection of publicly-owned properties.***

Justification: Many areas key to the success of the natural production of salmonids are currently in public ownership. Permanent protection of these properties is necessary to prevent further degradation, and to allow for active (as well as passive) restoration.

Action Items:

Action: Secure from the US Department of Defense (USDOD)/Ft. Lewis permanent protection commitment for right-bank areas of the Nisqually River currently owned and managed by Ft.

Action: Secure from Tacoma Public Utilities (TPU), Tacoma Power, and City of Centralia permanent protection commitments for specific Nisqually River mainstem reaches.

Action: Secure from the City of Olympia, Public Works Department, permanent protection commitments for the headwaters of McAllister Creek.

Monitoring:

Implementation (actions): 1) Monitor to ensure compliance with agreements (i.e.: conservation easements, development rights, etc.).

Effectiveness (objectives): 1) Develop criteria to evaluate if critical functions are being successfully protected.

Validation (goals): 1) Evaluate trends in physical and biological processes of acquired and protected areas over time.

Objective: ***Secure commitment for permanent protection of tribally-owned properties***

Justification: Much of the lower mainstem Nisqually River is in Nisqually Tribal or Nisqually Tribal member ownership. Permanent protection of this area is necessary to prevent degradation, and to allow for active (as well as passive) restoration.

Action Items:

Action: Secure Nisqually Indian Tribe permanent protection commitment of the lands over which the Tribe has jurisdiction.

Monitoring:

Implementation (actions): 1) Monitor to insure compliance with agreements (i.e.: conservation easements, development rights, etc.).

Effectiveness (objectives): 1) Develop criteria to evaluate if critical functions are being successfully protected.

Validation (goals): 1) Evaluate trends in physical and biological processes of acquired and protected areas over time.

Objective: ***Secure land use regulations against incompatible uses.***

Justification: Effective land use regulations are one of the methods necessary to prevent further habitat degradation, and to allow for active and passive restoration.

Action Items:

Action: Secure permanent protection through county ordinances against further development of stream corridor in all reaches. In conjunction with local governments develop critical area ordinances to protect critical habitats from degradation.

Action: Secure permanent forest zone designation for all current commercial forest lands in and upstream of the Middle Mashel, Upper Mashel, Busywild, Little Mashel River, Lynch Creek, Twentyfive Mile Creek, Lackamas, Toboton, and Powell rivers and creeks.

Action: Secure permanent protection through City of Eatonville regulations against further development of the Mashel River corridor in the Eatonville area.

Action: Secure permanent protection through county and city regulations (i.e.: Critical Area Ordinances, drainage ordinances, etc.) against development levels in upland areas that will adversely affect aquatic conditions.

Action: Secure permanent water quality protection through the basin-wide adoption of an anti-degradation policy for water quality.

Monitoring:

Implementation (actions): 1) Monitor to insure compliance with agreements

Effectiveness (objectives): 1) Develop criteria to evaluate if critical functions are being successfully protected.

Validation (goals): 1) Evaluate trends in physical and biological processes of acquired and protected areas over time.

Objective: ***Support non-regulatory education/outreach actions to encourage habitat protection.***

Justification: Non-regulatory education/outreach actions are necessary to prevent further degradation, and to allow for active and passive restoration opportunities.

Action Items:

Action: Support local sub-watershed groups (e.g., the Muck Creek Watershed Council) in their efforts at public outreach leading to habitat protection/enhancement. Support activities will include technical assistance and information sharing

Action: Support the Nisqually River Council, local sub-watershed groups, and agencies to develop and implement an educational/public outreach program that communicates value of habitat protection and enhancement to Nisqually River Basin residents, visitors, communities, and businesses.

Monitoring:

Implementation (actions): 1) Monitor to insure compliance with agreements

Effectiveness (objectives): 1) Develop criteria to evaluate if critical functions are being successfully protected.

Validation (goals): 1) Evaluate trends in physical and biological processes of acquired and protected areas over time.

B. Studies Needed to Support Actions

Objective: ***Refine our understanding of the potential for improvement of the estuarine environment.***

Justification: The Nisqually estuary is critical to all life stage trajectories experienced by Nisqually Basin fall chinook. This report indicates that the estuarine reach is degraded for several survival attributes affecting several life stages. Fundamental to all restoration action plans is an understanding of the extent of the degradation (how much, in what specific areas), and the range of specific opportunities for enhancement.

Action Item:

Action: Identify and prioritize key habitat and habitat diversity problems and restoration opportunities in estuary area (include assessment of desirable vegetation characteristics and channel/flow patterns).

Action: Use the results of the above action to support the implementation schedule of habitat action items.

Monitoring:

Implementation (actions): 1) Develop study plans to monitor recolonization of restored habitats.

Effectiveness (objectives): 1) Develop criteria to evaluate if critical functions are being successfully protected.

Validation (goals): 1) Evaluate trends in physical and biological processes of restored areas over time.

Objective: ***Comprehensive Reach-Specific Restoration Plans.***

Justification: The lower Ohop Creek and the lower Mashel River reaches were identified as a highest priority in need of restoration within the Nisqually River basin for fall chinook. Although the restoration opportunities are apparent (restoration of a functional channel configuration, riparian/wetland vegetation planting), several constraints to implementation remain. Consequently, both reaches were identified as requiring comprehensive planning studies.

Action Item:

Action: Develop a comprehensive Lower Ohop Restoration Plan. Elements of the plan will include: 1) identifying all current landowners in the Lower Ohop valley and those willing to allow restoration plans to be developed; 2) assembling relevant site information needed to develop a stream corridor and wetland restoration plan; and 3) development of restoration designs for specific areas within the reach that will address restoration of the streams natural process to become re-established (i.e.: lateral channel migration, off-channel rearing opportunities, channel configuration, native plant communities, in-stream structures, etc.) including cost estimates, long-term maintenance needs, and monitoring recommendations.

Action: Develop a comprehensive Eatonville Restoration Plan. Elements of the plan will include 1) working with public and private landowners to identify areas for which restoration plans can be developed, 2) assembling relevant site information needed to develop a stream corridor restoration plan, and 3) development of restoration designs for specific areas within the reach that will address the re-establishment of natural river processes (i.e.: channel configuration, native plant communities, dike removal or dike setback opportunities, restoration of summertime streamflow in de-watered section, in-stream structures, etc.) and cost estimates; long-term maintenance needs, and monitoring recommendations.

Monitoring:

Implementation (actions): 1) Monitor to insure compliance with agreements

Effectiveness (objectives): 1) Develop criteria to evaluate if critical functions are being successfully restored.

Validation (goals): 1) Evaluate trends in physical and biological processes of acquired and protected areas over time.

Objective: ***Develop a Riparian Conditions Inventory for the Nisqually River Basin.***

Justification: Information on current riparian condition is needed to guide protection/enhancement actions. Riparian assessments are currently available for approximately half of the anadromous portion of the Nisqually River Basin (Bohle et al. 1996; Cupp et al. In press), but no detailed information is available for the remainder of the Nisqually River Basin. A database of current riparian conditions is also needed as a baseline to monitor future protection /enhancement actions.

Action Item:

Action: Assemble all available riparian condition information (i.e., Bohle et al. 1996; Cupp et al. In press) into a geographic information system (GIS).

Action: Acquire aerial photographs of riparian areas in the basin. Photos will be used to implement the following action item, and will serve as a record of current conditions.

Action: As an initial step, assess current riparian conditions for the remainder of the anadromous portion of the Basin using modified version of the Washington DNR Watershed Analysis Methodology (WFPB, 1997) or techniques similar to those in Kuzis et al. (1999). Expand this assessment into all identified fish-bearing streams.

Monitoring:

Implementation (actions): 1) This is a database activity and the acquisition of the described materials is necessary

Effectiveness (objectives): NA

Validation (goals): 1) Evaluate trends in physical and biological processes of acquired and protected areas over time.

Objective: ***Evaluate land use impacts on streamflows.***

Justification: The degradation of stream baseflows are suspected to be a result of certain land uses in the Nisqually River Basin. Results from the Mashel Watershed Analysis (Bohle et al. 1996) indicate that forest-harvest related rain-on-snow effects probably do not have a significant impact on wintertime peak flows in the Mashel sub-basin, however, increased drainage efficiency (i.e., conversion of sub-surface flow paths to surface flow paths) due to the logging road system in the headwaters may have an effect on the timing and magnitude of wintertime peak flows. Possible future scenarios include increases in urbanization that may, in the future, result in increased peak flows in some areas (by an increase in impervious surfaces), and decreased base flows (by increased water consumption, aquifer depletion, loss of storage capability). An evaluation of these possible impacts is needed to guide future actions.

Action Item:

Action: Evaluate the extent of forest-management-related activities on peak- and base-flows. Use state-of-the-art techniques to evaluate management-related effects on streamflows in the headwater areas of the Mashel, Little Mashel, Lynch Creek and Twentyfive Mile Creek sub-basins. New techniques (e.g., Bowling and Lettenmaier, 1997) have become available since completion of the Mashel Watershed Analysis to asses the impacts of forest roads and vegetation changes on streamflow. These techniques should be used to evaluate the effects of past practices, and to help guide future practices, for the area.

Action: Evaluate the potential impacts of future urbanization on peak- and base-flows using state-of-the-art modeling techniques.

Action: Evaluate the extent of current surface and groundwater use in the Nisqually River Basin. Actions will include compiling and mapping locations of water rights, minimum instream flows, federal reserved rights, and reviewing the current status of water use.

Action: Evaluate potential impacts of well-withdrawals from the aquifer on summertime stream flows following the methodology of Ross & Associates (1998) or some other suitable protocol.

Action: Evaluate potential positive impacts of increased base flow in McAllister Creek from the City of Olympia, shifting its water withdrawal from the headwater springs to an up-gradient deep aquifer well field.

Monitoring:

Some monitoring activities will be required to implement this objective, including 1) the development of stream-flow monitoring sites to verify and refine the results of modeling efforts; 2) maintain existing USGS stream gages in the Mashel River and Ohop Creek along with new gages as deemed necessary; 3) develop an approach to evaluate any modeled changes in streamflow on the habitat of the sensitive life stages; 4) develop methods that quantify improvements in forest road drainage systems; and 5) compare baseline conditions with post-implementation conditions at multi-year intervals following project completion.

C. Action Items Intended to Address Loss of Key Habitat

Objective: ***Increase quantity and diversity of key habitat for estuarine life stages.***

Justification: Increasing the quantity of key habitat is expected to improve salmonid abundance in these reaches. Actions are expected to provide benefits for all salmonid species but greater benefits for chinook and chum salmon are expected (Healey, 1982).

Action Items:

Action: Restore former estuarine habitat, including reconnection to marine and fresh waters, along the right-bank portion of the estuary (Braget Farm).

Action: Work with USFWS personnel to develop and implement a plan to restore connectivity of estuarine habitat in the Nisqually NWR.

Objective: ***Increase quantity and diversity of key habitat for freshwater life stages.***

Justification: Increasing the quantity of key habitat is expected to improve salmonid abundance in these reaches. Actions in mainstem are expected to benefit all species whereas tributary actions will provide greater benefits to steelhead, coho, and chum salmon.

Action: Enhance degraded riparian areas through passive restoration (i.e., small stands of suitable species that simply need time to grow), reforestation of non-forested sites, stand-improvement for sites with marginal recruitment potential, or conversion of unsuitable sites (e.g., hardwood-dominated sites) to more desirable stands. Riparian enhancement along the mainstem Nisqually River will occur primarily in the areas near McKenna and Wilcox Farm. Enhancement sites in tributary areas will be selected using riparian-stand, riparian shade, stream temperature, and channel-responsiveness information from the Mashel Watershed Analysis (Bohle et al. 1996), the Ohop/ Tanwax/Powell Watershed Analysis (Metzler et al. In press), and from the assessment outlined under Objective 1.2.3 above.

Action: Create off-channel rearing habitats where feasible. Initial efforts should be focused along reaches of the mainstem Nisqually River, the mainstem Mashel River and Ohop Creek.

Action: Mitigate (to the extent practical) the negative effects of the diking and development in the former floodplain in the areas along the lower Nisqually River, McKenna and Wilcox Farms reaches. An effort should be made to explore mitigation possibilities in conjunction with local landowners and agencies.

Action: Develop and implement a long-term plan to restore natural channel configuration of the Nisqually River in the estuary (including McAllister and Red Salmon Creeks) and the lower Nisqually River reach.

Action: Investigate the potential to transport logs recruited from above the Alder/LaGrande dams to downstream areas to supplement LWD recruitment to mainstem reaches. Transportation could be through spill and/or trucking.

Action: Investigate the placement of in-stream large wood (either key pieces or aggregations) in the mainstem Nisqually River and side channels

Action: Develop and implement a plan for in-channel placement of LWD in responsive tributary channel reaches. Enhancement sites will be selected using channel responsiveness information from the Mashel Watershed Analysis (Bohle et al. 1996), the Ohop/Tanwax/ Powell Watershed Analysis (Metzler et al. in press), and from the assessment outlined under Objective 1.2.3 above.

Action: Work to reduce the impacts of existing residential development on former floodplain lands along the Nisqually River (in addition to direct benefits to riparian function this will also eliminate the need for future diking). Initial efforts should be the McKenna and Wilcox Farm reaches of the mainstem Nisqually River.

Action: Develop and implement a long-term plan to restore the lateral river meander belt and to reestablish connections with side channels for off-channel rearing opportunities along the Nisqually mainstem. Focus of actions should be the McKenna Reach and Wilcox Farm reaches.

Action: Implement the wetland restoration recommendations for degraded wetlands in the Mashel River basin identified in Sargent and Salminen (1996). Initial efforts should be on wetlands that are connected with anadromous fish-bearing streams and that have the ability to provide key habitat. Subsequent efforts should include wetlands identified as critical in the non-anadromous fish zone.

Action: Study the role of beaver dams in providing key habitat in tributaries and side channels of the Nisqually River. Develop a Nisqually River Basin wide management policy on beaver-dam removal; develop policy that weighs benefits of removal for anadromous fish passage versus loss of key habitats associated with removal of dams for other species.

Action: Logging road construction in the Mashel River basin has been identified as contributing to adverse sediment input into this basin. Develop a comprehensive plan for opportunities for road decommissioning and restoration.

Action: Investigate the role of a naturalized flow regime in the mainstem Nisqually River and the impacts of such a flow regime to the channel forming processes.

Action: Investigate the effectiveness of the fish ladder at the Centralia Diversion Dam. While meeting current criteria, salmonid passage at the ladder has not been evaluated to determine if it causes delays of upstream adult and juvenile salmonid migration or increases in spawning below the dam.

Monitoring:

Implementation (actions): 1) Monitor to determine that restoration plans are implemented.

Effectiveness (objectives): 1) Develop methods that quantify key habitat and habitat diversity; compare baseline conditions with post-implementation conditions at multi-year intervals following completion of. 2) Monitor development of riparian conditions (species composition, density, and shading) in restored areas (use information from watershed analyses (Bohle et al. 1996; Cupp et al. In press) and from the assessment outlined under Objective 1.2.3 above as baseline for monitoring). 3) Monitor the trends in stream water temperatures, account for all factors affecting temperature (see Mashel Watershed Analysis (1996) for techniques of stream temperature analysis). 4) Evaluate success of the pilot restoration project implemented for a portion of the Braget Farm in 1995; use information in developing future estuary restoration plans.

Validation (goals): 1) Evaluate trends in fish usage of protected/restored areas over time. 2) Ensure that fish are not being trapped and killed. 3) Evaluate adequate passage at the Centralia Diversion Dam.

GLOSSARY

Adaptive management: Monitoring or assessing the progress toward meeting objectives and incorporating what is learned into future management plans.

Adfluvial: Life history strategy in which adult fish spawn and juveniles subsequently rear in streams but migrate to lakes for feeding as subadults and adults. Compare fluvial.

Aggradation: The geologic process of filling and raising the level of the streambed or floodplain by deposition of material eroded and transported from other areas.

Anadromous fish: Species that are hatched in freshwater mature in saltwater, and return to freshwater to spawn.

Aquifer: Water-bearing rock formation or other subsurface layer.

Basin: The area of land that drains water, sediment and dissolved materials to a common point along a stream channel.

Basin flow: Portion of stream discharge derived from such natural storage sources as groundwater, large lakes, and swamps but does not include direct runoff or flow from stream regulation, water diversion, or other human activities.

Bioengineering: Combining structural, biological, and ecological concepts to construct living structures for erosion, sediment, or flood control.

Biological Diversity (biodiversity): Variety and variability among living organisms and the ecological complexes in which they occur; encompasses different ecosystems, species, and genes.

Biotic Integrity: Capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region; a system's ability to generate and maintain adaptive biotic elements through natural evolutionary processes.

Biological oxygen demand: Amount of dissolved oxygen required by decomposition of organic matter.

Braided stream: Stream that forms an interlacing network of branching and recombining channels separated by branch islands or channel bars.

Buffer: An area of intact vegetation maintained between human activities and a particular natural feature, such as a stream. The buffer reduces potential negative impacts by providing an area around the feature that is unaffected by this activity.

Carrying capacity: Maximum average number or biomass of organisms that can be sustained in a habitat over the long term. Usually refers to a particular species, but can be applied to more than one.

Channelization: Straightening the meanders of a river; often accompanied by placing riprap or concrete along banks to stabilize the system.

Channelized stream: A stream that has been straightened, runs through pipes or revetments, or is otherwise artificially altered from its natural, meandering course.

Channel Stability: Tendency of a stream channel to remain within its existing location and alignment.

Check dams: Series of small dams placed in gullies or small streams in an effort to control erosion. Commonly built during the 1900s.

Confluence: Joining.

Connectivity: Unbroken linkages in a landscape, typified by streams and riparian areas.

Critical Stock: A stock of fish experiencing production levels that are so low that permanent damage to the stock is likely or has already occurred.

Depressed Stock: A stock of fish whose production is below expected levels based on available habitat and natural variations in survival levels, but above the level where permanent damage to the stock is likely.

Debris torrent: Rapid movements of material, including sediment and woody debris, within a stream channel. Debris torrents frequently begin as debris slides on adjacent hillslopes.

Degradation: The lowering of the streambed or widening of the stream channel by erosion. The breakdown and removal of soil, rock and organic debris.

Deposition: The settlement of material out of the water column and onto the streambed.

Distributaries: Divergent channels of a stream occurring in a delta or estuary.

Diversity: Variation that occurs in plant and animal taxa (i.e., species composition), habitats, or ecosystems. See *species richness.*

Ecological restoration: Involves replacing lost or damaged biological elements (populations, species) and reestablishing ecological processes (dispersal, succession) at historical rates.

Ecosystem: Biological community together with the chemical and physical environment with which it interacts.

Ecosystem management: Management that integrates ecological relationships with sociopolitical values toward the general goal of protecting or returning ecosystem integrity over the long term.

Endangered Species Act: A 1973 Act of Congress that mandated that endangered and threatened species of fish, wildlife and plants be protected and restored.

Endangered Species: Means any species which is in endanger of extinction throughout all or a significant portion of its range other than a species of the Class Insecta as determined by the Secretary to constitute a pest whose protection under would provide an overwhelming and overriding risk to man.

Escapement: Those fish that have survived all fisheries and will make up a spawning population.

Estuarine: A partly enclosed coastal body of water that has free connection to open sea, and within which seawater is measurably diluted by fresh river water.

Eutrophic: Water body rich in dissolved nutrients, photosynthetically productive, and often deficient in oxygen during warm periods. Compare *oligotrophic.*

Evolutionary Significant Unit (ESU): A definition of a species used by National Marine Fisheries Service (NMFS) in administering the Endangered Species Act. An ESU is a population (or group of populations) that is reproductively isolated from other conspecific population units, and (2) represents an important component in the evolutionary legacy of the species.

Extirpation: The elimination of a species from a particular local area.

Flood: An abrupt increase in water discharge.

Floodplain: Lowland areas that are periodically inundated by the lateral overflow of streams or rivers.

Flow regime: Characteristics of stream discharge over time. Natural flow regime is the regime that occurred historically.

Fluvial: Pertaining to streams or rivers; also, organisms that migrate between main rivers and tributaries. Compare *adfluvial*.

Gabion: Wire basket filled with stones, used to stabilize streambanks, control erosion, and divert stream flow.

Genetic Diversity Unit (GDU) is defined as: A group of genetically similar stocks that is genetically distinct from other such groups. The stocks typically exhibit similar life histories and occupy ecologically, geographically and geologically similar habitats. A GDU may consist of a single stock.

Geomorphology: Study of the form and origins of surface features of the Earth.

Glides: Stream habitat having a slow, relatively shallow run of water with little or no surface turbulence.

Healthy Stock: A stock of fish experiencing production levels consistent with its available habitat and within the natural variations in survival for the stock.
Hydrograph: Chart of water levels over time.

Hydrology: Study of the properties, distribution, and effects of water on the Earth's surface, subsurface, and atmosphere.

Intermittent stream: Stream that has interrupted flow or does not flow continuously. Compare *perennial stream*.

Intraspecific interactions: Interactions within a species.

Large Woody Debris (LWD): Large woody material that has fallen to the ground or into a stream. An important part of the structural diversity of streams. LWD is also referenced to as "coarse woody debris" (CWD). Either term usually refers to pieces at least 20 inches (51 cm) in diameter.

Limiting Factor: Single factor that limits a system or population from reaching its highest potential.

Macroinvertebrates: Invertebrates large enough to be seen with the naked eye (e.g., most aquatic insects, snails, and amphipods).

Mass failure: Movement of aggregates of soil, rock and vegetation down slope in response to gravity.

Native: Occurring naturally in a habitat or region; not introduced by humans.

Non-Point Source Pollution: Polluted runoff from sources that cannot be defined as discrete points, such as areas of timber harvesting, surface mining, agriculture, and livestock grazing.

Parr: Young trout or salmon actively feeding in freshwater; usually refers to young anadromous salmonids before they migrate to the sea. See *smolt*.

Plunge pool: Basin scoured out by vertically falling water.

Rain-on-snow events: The rapid melting of snow as a result of rainfall and warming ambient air temperatures. The combined effect of rainfall and snow melt can cause high overland stream flows resulting in severe hillslope and channel erosion.

Rearing habitat: Areas required for the successful survival to adulthood by young animals.

Recovery: The return of an ecosystem to a defined condition after a disturbance.

Redds: Nests made in gravel (particularly by salmonids); consisting of a depression that is created and the covered.
Resident fish: Fish species that complete their entire life cycle in freshwater.

Riffle: Stream habitat having a broken or choppy surface (white water), moderate or swift current, and shallow depth.

Riparian: Type of wetland transition zone between aquatic habitats and upland areas. Typically, lush vegetation along a stream or river.

Riprap: Large rocks, broken concrete, or other structure used to stabilize streambanks and other slopes.

Rootwad: Exposed root system of an uprooted or washed-out tree.

SASSI: Salmon and Steelhead Stock Inventory.

SSHIAP: A salmon, steelhead, habitat inventory and assessment program directed by the Northwest Indian Fisheries Commission.

Salmonid: Fish of the family salmonidae, including salmon, trout chars, and bull trout.

Salmon: Includes all species of the family Salmonid

Sediment: Material carried in suspension by water, which will eventually settle to the bottom.

Sedimentation: The process of sediment being carried and deposited in water.

Side channel: A portion of an active channel that does not carry the bulk of stream flow. Side channels may carry water only during high flows, but are still considered part of the total active channel.

Sinuosity: Degree to which a stream channel curves or meanders laterally across the land surface.

Slope stability: The degree to which a slope resists the downward pull of gravity.

Smolt: Juvenile salmon migrating seaward; a young anadromous trout, salmon, or char undergoing physiological changes that will allow it to change from life in freshwater to life in the sea. The smolt state follows the parr state. See *parr*.

Stock: Group of fish that is genetically self-sustaining and isolated geographically or temporally during reproduction. Generally, a local population of fish. More specifically, a local population – especially that of salmon, steelhead (rainbow trout), or other anadromous fish – that originates from specific watersheds as juveniles and generally returns to its birth streams to spawn as adults.

Stream order: A classification system for streams based on the number of tributaries it has. The smallest unbranched tributary in a watershed is designated order 1. A stream formed by the confluence of 2 order 1 streams is designated as order 2. A stream formed by the confluence of 2 order 2 streams is designated order 3, and so on.

Stream reach: Section of a stream between two points.

Stream types:

Type 1: All waters within their ordinary high-water mark as inventoried in "Shorelines of the State".

Type 2: All waters not classified as Type 1, with 20 feet or more between each bank's ordinary high water mark. Type 2 waters have high use and are important from a water quality standpoint for domestic water supplies, public recreation, or fish and wildlife uses.

Type 3: Waters that have 5 or more feet between each bank's ordinary high water mark, and which have a moderate to slight use and are more moderately important from a water quality standpoint for domestic use, public recreation and fish and wildlife habitat.

Type 4: Waters that have 2 or more feet between each bank's ordinary high water mark. Their significance lies in their influence on water quality of larger water types downstream. Type 4 streams may be perennial or intermittent.

Type 5: All other waters, in natural water courses, including streams with or without a well-defined channel, areas of perennial or intermittent seepage, and natural sinks. Drainage ways having a short period of spring runoff are also considered to be Type 5.

Sub Watershed: One of the smaller watersheds that combine to form a larger watershed.

Thalweg: Portion of a stream or river with deepest water and greatest flow.

Watershed: Entire area that contributes both surface and underground water to a particular lake or river.

Watershed rehabilitation: Used primarily to indicate improvement of watershed condition or certain habitats within the watershed. Compare *watershed restoration*.

Watershed restoration: Reestablishing the structure and function of an ecosystem, including its natural diversity; a comprehensive, long-term program to return watershed health, riparian ecosystems, and fish habitats to a close approximation of their condition prior to human disturbance.

Watershed-scale approach: Consideration of the entire watershed in a project or plan.

Weir: Device across a stream to divert fish into a trap or to raise the water level or divert its flow. Also a notch or depression in a dam or other water barrier through which the flow of water is measured or regulated.

Wild Stock: A stock that is sustained by natural spawning and rearing in the natural habitat regardless.

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APPENDIX A

KNOWN FRESHWATER DISTRIBUTION of SALMONIDS in WRIA 11

Figure A-1

WRIA 11 Known Chinook Freshwater Distribution in the Nisqually River Basin

(This map can be found in the electronic file attached)

Figure A-2

WRIA 11 Known Coho Freshwater Distribution in the Nisqually River Basin

(This map can be found in the electronic file attached)

Figure A-3

WRIA 11 Known Pink Freshwater Distribution in the Nisqually River Basin

(This map can be found in the electronic file attached)

Figure A-4

WRIA 11 Known Chum Salmon Freshwater Distribution in the Nisqually River Basin

(This map can be found in the electronic file attached)

Figure A-5

WRIA 11 Known Steelhead Trout Freshwater Distribution in the Nisqually River Basin

(This map can be found in the electronic file attached)

Figure A-6

WRIA 11 Known Sockeye Salmon Freshwater Distribution in the Nisqually River Basin

(This map can be found in the electronic file attached)

Figure A-7

WRIA 11 Known Coastal Cutthroat Trout Freshwater Distribution in the Nisqually River Basin

(This map can be found in the electronic file attached)

Figure A-8

Dikes and Levees of the Nisqually River Basin (WRIA 11)

(This map can be found in the electronic file attached)

APPENDIX B

Nisqually River Basin, WRIA 11, Salmon Escapement Estimates

Figure B- 1: WRIA 11 Chinook Salmon

Year	Escapement
1970	900
1971	800
1972	700
1973	700
1974	500
1975	550
1976	450
1977	220
1978	178
1979	1,665
1980	1,124
1981	439
1982	848
1983	1,066
1984	313
1985	112
1986	302
1987	85
1988	1,342
1989	2,332
1990	994
1991	953
1992	102
1993	1,655
1994	1,730
1995	817
1996	606
1997	340

Figure B- 2: WRIA 11 Pink Salmon Escapement Estimates 1967 - 1997

Year	Escapement
1967	7,000
1969	3,500
1971	10,000
1973	8,000
1975	6,000
1977	5,200
1979	1,300
1981	500
1983	500
1985	500
1987	7,700
1989	12,300
1991	1,900
1993	500
1995	579
1997	No Data
1999	In Progress

1. 1995 Escapement estimate is from limited field surveys
2. No data gathered in 1997

Figure B- 3: WRIA 11 Chum Salmon

Year	Escapement
1970	32,500
1971	8,500
1972	31,500
1973	27,500
1974	32,114
1975	8,942
1976	21,012
1977	21,726
1978	23,979
1979	21,720
1980	38,083
1981	28,914
1982	25,773
1983	12,171
1984	25,949
1985	21,195
1986	18,986
1987	70,002
1988	35,893
1990	25,213
1991	11,288
1992	28,325
1993	5,282
1994	15,501
1995	64,065
1996	14,106

Figure B- 4: WRIA 11 Coho Salmon

Year	Escapement
1972	2,000
1973	2,000
1974	1,000
1975	2,000
1976	1,000
1977	6,000
1978	2,000
1979	2,000
1980	6,000
1981	5,000
1982	13,000
1983	4,000
1984	1,000
1985	5,000
1986	2,000
1987	2,000
1988	2,000
1989	600
1990	4,000
1991	2,000
1992	700
1993	1,700
1994	6,800
1995	6,100
1996	600
1997	Nd

Figure B- 5: WRIA 11 Winter Steelhead

Year	Escapement
1980	1,972
1981	1,782
1982	3,809
1983	2,705
1984	1,304
1985	1,599
1986	1,620
1987	2,022
1988	1,916
1989	3,817
1990	1,853
1991	642
1992	2,618
1993	993
1994	794
1995	976
1996	No Data *
1997	882
1998	721

* No data available due to poor water visibility

APPENDIX C

Table C- 1: Off Channel Habitat Estimated Lengths from Washington Department of Natural Resources 1995 Aerial Photographs in the Mainstem Nisqually River.

River Mile	Distance (feet)
3.8	1100
5.2	500
6.0	1100
7.5	500
8.0	2100
9.0	2200
10.0	2200
19.0	1300
25.8	500
27.7	600
28.8	400
30.3	2000
32.4	1900
34.5	2100
35.5	2200
36.2	500
36.5	350
36.6	300
37.3	150
37.6	600
40.2	1000
Total	23,600

Table C- 2: Off Channel Habitat Estimated Lengths from Washington Department of Natural Resources 1965/70 Aerial Photographs in the Mainstem Nisqually River.

River Mile	Distance (feet)
6.0	3600
7.5	2700
7.6	400
7.6	2300
8.0	1900
9.0	4000
9.2	2500
9.4	1000
10.0	1200
14.5	300
15.9	300
27	4400
28.8	2000
30.0	500
30.3	2250
30.4	1250
36.2	1100
38.8	500
39.0	300
39.2	600
Total	33,100

APPENDIX D

Salmonid Habitat Condition Rating Standards for Identifying Limiting Factors

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

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

Table D-1: Source documents for Habitat Conditions Ratings

Code	Document	Organization
Hood Canal	Hood Canal/Eastern Strait of Juan de Fuca Summer Chum Habitat Recovery Plan, Final Draft (1999)	Point No Point Treaty Council, Skokomish Tribe, Port Gamble S'Klallam Tribe, Jamestown S'Klallam Tribe, and Washington Department of Fish and Wildlife
ManTech	An Ecosystem Approach to Salmonid Conservation, vol. 1 (1995)	ManTech Environmental Research Services for the National Marine Fisheries Service, the US Environmental Protection Agency, and the US Fish and Wildlife Service
NMFS	Coastal Salmon Conservation: Working Guidance for Comprehensive Salmon Restoration Initiatives on the Pacific Coast (1996)	National Marine Fisheries Service
PHS	Priority Habitat Management Recommendations: Riparian (1995)	Washington Department of Fish and Wildlife
Skagit	Skagit Watershed Council Habitat Protection and Restoration Strategy (1998)	Skagit Watershed Council
WSA	Watershed Analysis Manual, v4.0 (1997)	Washington Forest Practices Board
WSP	Wild Salmonid Policy (1997)	Washington Department of Fish and Wildlife

The ratings adopted by the WCC are presented in Table D-2. These ratings are not intended to be used as thresholds for regulatory purposes, but as a coarse screen to identify the most significant limiting factors in a WRIA. They also will hopefully provide a level a consistency between WRIAs that allows habitat conditions to be compared across the state. However, for many habitat factors, there may not be sufficient data available to use a rating standard or there may be data on habitat parameters where no rating standard is provided. For these factors, the professional judgment of the TAG should be used to assign the appropriate ratings. A set of narrative standards will be developed to provide guidance in this situation.

In some cases there may be local conditions that warrant deviation from the rating standards presented here. This is acceptable as long as the justification and a description of the procedures that were followed are clearly documented in the limiting factors report. Habitat condition ratings specific to streams draining east of the Cascade crest were included where they could be found, but for many parameters they were not. Additional rating standards will be included as they become available.

Table D-2: Washington Conservation Commission Salmonid Habitat Condition Ratings

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
Access and Passage						
Artificial Barriers	% known/potential habitat blocked by artificial barriers	All	>20%	10-20%	<10%	WCC
Floodplains						
Floodplain Connectivity	Stream length with lost connectivity due to incision, roads, dikes, flood protection, or other	<1% gradient, with floodplain	>50%	10-50%	<10%	WCC
Loss of Floodplain Habitat	Lost wetted area	<1% gradient, with floodplain	>66%	33-66%	<33%	WCC
Channel Conditions						
Fine Sediment	Fines < 0.85 mm in spawning gravel	All – Westside	>17%	11-17%	≤11%	WSP/WSA/NMFS/Hood Canal

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
	Fines < 0.85 mm in spawning gravel	All – Eastside	>20%	11-20%	≤11%	NMFS
Large Woody Debris	pieces/m channel length	≤4% gradient, <15 m wide (Westside only)	<0.2	0.2-0.4	>0.4	Hood Canal/Skagit
	or use Watershed Analysis piece and key piece standards listed below when data are available					
	pieces/channel width	<20 m wide	<1	1-2	2-4	WSP/WSA
	key pieces/channel width*	<10 m wide (Westside only)	<0.15	0.15-0.30	>0.30	WSP/WSA
	key pieces/channel width*	10-20 m wide (Westside only)	<0.20	0.20-0.50	>0.50	WSP/WSA
	* Minimum size to qualify as a key piece:	BFW (m) 0-5 6-10 11-15 16-20	Diameter (m) 0.4 0.55 0.65 0.7	Length (m) 8 10 18 24		
Percent Pool	% pool, by surface area	<2% gradient, <15 m wide	<40%	40-55%	>55%	WSP/WSA
	% pool, by surface area	2-5% gradient, <15 m wide	<30%	30-40%	>40%	WSP/WSA

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
	% pool, by surface area	>5% gradient, <15 m wide	<20%	20-30%	>30%	WSP/WSA
	% pool, by surface area	>15 m	<35%	35-50%	>50%	Hood Canal
Pool Frequency	channel widths per pool	<15 m	>4	2-4	<2	WSP/WSA
	channel widths per pool	>15 m	-	-	chann width / pools/ mile / cw/ pool 50’ 26 4.1 75’ 23 3.1 100’ 18 2.9	NMFS
Pool Quality	pools >1 m deep with good cover and cool water	All	No deep pools and inadequate cover or temperature, major reduction of pool volume by sediment	Few deep pools or inadequate cover or temperature, moderate reduction of pool volume by sediment	Sufficient deep pools	NMFS/WSP/WSA
Streambank Stability	% of banks not actively eroding	All	<80% stable	80-90% stable	>90% stable	NMFS/WSP
Sediment Input						
Sediment Supply	$m^3/km^2/yr$	All	> 100 or exceeds natural rate*	-	< 100 or does not exceed natural rate*	Skagit
	* Note: this rate is highly variable in natural conditions					

Habitat Factor	**Parameter/Unit**	**Channel Type**	**Poor**	**Fair**	**Good**	**Source**
Mass Wasting		All	Significant increase over natural levels for mass wasting events that deliver to stream	-	No increase over natural levels for mass wasting events that deliver to stream	WSA
Road Density	mi/mi^2	All	>3 with many valley bottom roads	2-3 with some valley bottom roads	<2 with no valley bottom roads	NMFS
	or use results from Watershed Analysis where available					
Riparian Zones						
Riparian Condition	• riparian buffer width (measured out horizontally from the channel migration zone on each side of the stream) • riparian composition	Type 1-3 and untyped salmonid streams >5' wide	<75' or <50% of site potential tree height (whichever is greater) or • Dominated by hardwoods, shrubs, or non-native species	• 75'-150' or 50-100% of site potential tree height (whichever is greater) AND • Dominated by conifers or a mix of conifers and hardwoods of any age (or hardwoods where they were dominant historically).	• >150' or site potential tree height (whichever is greater) AND • Dominated by mature conifers (or hardwoods where they were dominant historically)	WCC/WSP

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
	• buffer width • riparian composition	Type 4 and untyped perennial streams <5' wide	<50' with same composition as above	50'-100' with same composition as above	>100' with same composition as above	WCC/WSP
	• buffer width • riparian composition	Type 5 and all other untyped streams	<25' with same composition as above	25'-50' with same composition as above	>50' with same composition as above	WCC/WSP
Water Quality						
Temperature	degrees Celsius	All	>15.6° C (spawning) >17.8° C (migration and rearing)	14-15.6° C (spawning) 14-17.8° C (migration and rearing)	10-14° C	NMFS
Dissolved Oxygen	mg/L	All	<6	6-8	>8	ManTech
Hydrology						
Flow	hydrologic maturity	All	<60% of watershed with forest stands aged 25 years or more	-	>60% of watershed with forest stands aged 25 years or more	WSP/Hood Canal
		or use results from Watershed Analysis where available				
	% impervious surface	Lowland basins	>10%	3-10%	≤3%	Skagit

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