Habitat Limiting Factors and Reconnaissance Assessment Report

Volume II

Green/Duwamish and Central Puget Sound Watersheds

(Water Resource Inventory Area 9 and Vashon Island)

December 2000

KING COUNTY

Washington State Conservation Commission

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3. TRIBUTARY CONDITIONS

SALMONID HABITATS IN THE TRIBUTARIES OF THE GREEN/DUWAMISH RIVER BASIN, WRIA 9 DIRECT DRAINAGES TO PUGET SOUND AND VASHON ISLAND

GENERAL OVERVIEW

Many of the tributaries of the Green/Duwamish River are among some of the most hydrologically altered streams in the Puget Sound ecoregion. The tributaries of the lower Green/Duwamish River exist in heavily urbanized locale and are subjected to the adverse habitat impacts that accompany this setting. These streams and their subbasins generally have high levels of impervious surfaces, altered hydrologic regimes, loss of floodplain connectivity, poor riparian conditions and water quality problems. As one moves upstream into the middle reaches of the watershed, the habitat conditions of the tributary streams show some improvement and the land use becomes a mix of residential, agricultural and forestry. Tributaries in the middle reach still do not meet many of the criteria necessary for properly functioning habitats important for salmonid survival. Upstream of the Tacoma Headworks Dam, the tributary streams are almost exclusively in lands utilized for commercial forestry and recreation. While the habitat around these streams is generally better than downstream, it has problems typically associated with commercial forestry and damage to habitat forming processes are less permanent.

In this chapter, the tributaries of the Green/Duwamish watershed (WRIA 9) and Vashon Island (a portion of WRIA 15) are subdivided into important streams as follows:

- Longfellow Creek Subbasin (chapter 3.1);
- Hamm Creek Subbasin (chapter 3.2);
- Spring Brook Creek Subbasin (chapter 3.3);
- Mill Creek and Mullen Slough Subbasin (chapter 3.4);
- East Hill Tributaries Subbasin (chapter 3.5);
- Middle Green River Tributaries Subbasin (chapter 3.6);
- Soos Creek Subbasin (chapter 3.7);
- Newaukum Creek Subbasin (chapter 3.8);
- Coal and Deep Creek(s) Subbasin (chapter 3.9);
- Upper Green River and Sunday Creek Subbasin (chapter 3.10);
- Lester WAU Subbasin (3.11)
- Puget Sound Creeks (chapter 3.12); and
- Vashon and Maury Island Creeks (chapter 3.13).

There are numerous additional tributary streams not covered in this assessment. Generally these streams do not have anadromous fish access or have very limited amounts of access. However, the absence of these creeks in this report should not be interpreted as diminishing their importance, rather the lack of information that was located during the course of this investigation.

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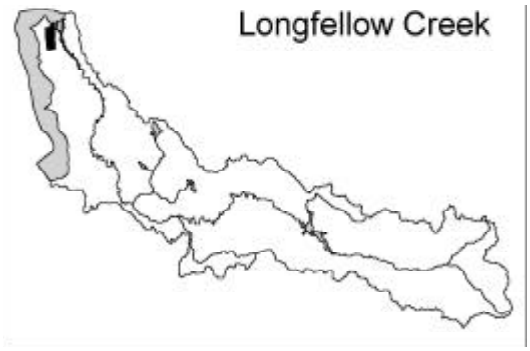
3.1. LONGFELLOW CREEK SUBBASIN (09.0359)



PHYSICAL DESCRIPTION

SUBBASIN

The basin is comprised of one distinct physical setting that was defined by the retreat of glaciers about 13,500 years ago. This retreat left a series of physical features that were shaped by the grinding action, which today are best described as depressions or hollows.

The Longfellow Creek Subbasin, is located in West Seattle's Delridge and Westwood Neighborhoods, entirely within the boundaries of the City of Seattle. Because the subbasin lies within a heavily urbanized area the borders are best defined geographically by using street names. Longfellow Creek subbasin is that area between SW Roxbury Street at the Seattle City limits to the south; between 13th Avenue SW and 21st Avenue SW on the east; 35th Avenue SW on the west (with an extension out to 41st Avenue SW in the northern portion of the subbasin); and north to SW Spokane Street and the industrialized area under the West Seattle Freeway to the north. Generally flowing from the south to the north, Longfellow Creek does not flow directly into the Duwamish River but rather into the West Waterway (also referred to as the West Duwamish Waterway. Longfellow Creek appears to fall under the category of "tributary to the Duwamish River" as defined by the boundaries used for the Duwamish River in 173-201A WAC, WQ Standards for surface waters in WA).

STREAM COURSE AND MORPHOLOGY

Longfellow Creek flows from an area of approximately 2,685 acres and was calculated as approximately 1.45 miles in length (Williams 1975) and more recently 4.2 miles long (J. Starstead, pers comm.).

The historical headwaters are located at a natural wetland and peat bog in what today is Roxhill Park. Even today, portions of Roxhill Park have been reported to be so wet that they are unusable for recreational activities. Seattle Parks is currently undertaking a project to reestablish this historic headwaters site through daylighting of the creek (which is now in a stormdrain beneath the site) and re-creation of the peat-based bog (which was filled many years ago). This project has the potential for improving water quality and stabilizing flows entering Longfellow Creek at

its historic headwaters. After leaving Roxhill Park, the creek travels north in pipes beneath the Westwood Village Shopping Center, which when constructed, was built on driven piles due to unstable soils. The upper 4,900 feet of Longfellow Creek is fully contained in pipes of various sizes. Today, approximately one third of the creek length lies within enclosed pipes and travels under developed urban areas including shopping centers, houses and roads.

The creek initially appears above ground at a Seattle Department of Parks and Recreation (Parks) open space site in the vicinity of 24th and 25th Avenues Southwest and north of Southwest Thistle Street. After leaving this location, the creek meanders through multi-family residential property before entering the 5-acre SW Webster Street Water Detention facility. This detention facility was recently modified in 1999, to improve operational efficiency during small and large storms and improve wetland habitat inside the facility. The creek exits the detention facility through a 60-inch by-pass pipe that runs along the back of K-Mart and reconnects with open channel at SW Myrtle Street.

Longfellow Creek meanders a considerable distance between private property, the West Seattle Golf Course, and a four-block Seattle Parks open space site, prior to entering a pipe at Southwest Andover Street and traveling beneath yet another parking lot. In the vicinity of Southwest Spokane Street, the Longfellow Creek pipe connects with another pipe carrying stormwater and the combined flow discharges into the West Duwamish Waterway.

Longfellow Creek has two small, unnamed tributaries, both of which were not identified in Williams (1975). Both tributaries are on the left bank and the largest is located in the West Seattle Golf Course. The tributaries are believed to be too small for anadromous fish use, but the lower reaches, particularly of the tributary in the golf course, may be important refugia for overwintering salmonids from high flows (MacIntosh, 1990).

Information concerning the amount of total effective impervious surfaces within this basin was not located during the course of this investigation. However, given the heavy urbanization and residential development it is assumed to be quite high.

SALMONID USE

The known freshwater distribution of anadromous salmonids and the presumed distribution of coho and steelhead are depicted in the report Appendix. This presumed distribution uses a stream gradient of $\geq$12 percent as the point which steelhead and coho are presumed to be present. Historically, Longfellow Creek was thought to contain populations of coho salmon, cutthroat trout and steelhead trout (MacIntosh 1990). Williams (1975) indicated that the stream might contain coho salmon. The WDFW Spawning Ground Survey Database (1999) does not contain any indication of adult salmonid observations in Longfellow Creek for any species. Prior to the middle 1990's there was the rare report of an adult salmonid observed (Dick Lunt, 1990, personal communication reported to B. MacIntosh) and the creek was not believed to support a self-sustaining population of any salmonid species.

MacIntosh (1990) observed coho smolts and juvenile coho rearing in portions of Longfellow Creek. In 1999, Seattle Public Utilities (SPU) conducted spawning surveys on Longfellow Creek. These surveys indicated the presence of sixty (60) adult coho salmon. During 1998, SPU

staff observed forty-four (44) adult coho salmon carcasses stranded along the banks of lower Longfellow Creek. *The Riparian Zone*, a local citizen newsletter about events of Longfellow Creek basin, also reported adult salmon sightings by local neighbors in both the Fall of 1995 (approximately 20 coho), and reported anecdotal accounts from December 1993 and 1994, of 13, and 2 adult coho, respectively.

In addition, juvenile rainbow trout and coho salmon were captured during electrofishing surveys in 1999, from the mouth up to SW Graham, and up to SW Oregon streets, respectively (Washington Trout, In Preparation). It is not known if the creek supports a self-sustaining population of coho salmon, because it is not known if the adult coho returning to the creek originate from hatchery strays, hatchery releases, or are being produced by the system ((b) (6) , pers. comm.).

Numerous groups have released coho salmon fry into Longfellow Creek for several years. Coho smolts and juvenile coho have been observed rearing in portions of Longfellow Creek (MacIntosh 1990; Washington Trout, In Preparation). To date there have not been any verifiable adult salmonid returns linked to these programs due to lack of a monitoring program.

FACTORS OF DECLINE

FISH PASSAGE

There are several known and potential barriers in this system. Some are located in pipelines, such as the lower 3,161 feet, and likely occur when maintenance has not removed debris. A list of known and potential culverts is shown in table LONG 1.

LONG 1: Longfellow Creek Known and Potential Barriers to Anadromous Salmonids

Location	Known	Potential	Brief Description
Downstream of Andover St.		X	Debris in pipe could be a barrier
Culvert under Genesee St.		X	Culvert with a 45 degree bend
Culvert under 12th Fairway, W. Seattle Golf Course		X	Long, narrow culvert with 2.5 percent gradient
Golf Course falls	X		Constructed waterfall, cats as upper limit for anadromous fish
South end of W. Seattle Golf Course	X		Perched (2') culvert
Culverts at Willow Street	X		Perched culverts 3-4 feet above streambed.
Culvert under K-Mart parking lot	X		Velocity barrier and may represent upper limit accessible to fish
Miscellaneous debris barriers	X	X	Require annual maintenance through streamwalks.

LAND USE

The percent of impervious surfaces in the Longfellow Creek subbasin are approximately 45 percent in the upper part of the basin, 35 percent in the middle part of the basin, 50 percent in the lower part of the basin (Longfellow Creek Watershed Characterization Background Report, 1992).

RIPARIAN CONDITION

MacIntosh (1990) examined the riparian habitat of Longfellow Creek as a part of the Puget Sound River Basin Team. She divided the creek into segments, working from downstream to upstream, and provided narrative descriptions of each segment. These same segments were used as a basis for a habitat evaluation in the Longfellow Creek Habitat Restoration Master Plan, January 1999. The information below is attributed to MacIntosh et al unless otherwise noted.

Segment 1. The lower 3,161 feet is completely contained within a culvert. The Port of Seattle installed "skylights" in 1998, in an attempt to improve fish passage and has committed to outfall and pipe hydraulics improvements at some time in the future. There has not been any monitoring program in place to determine the effectiveness of these "skylights". Because this stream segment is entirely within pipes there is no effective riparian habitat. Land use within this reach is predominantly scattered residential and industrial.

Segment 2. This segment lies between the culvert intake at Andover Street and Genessee Street. The four-block open space between SW Yancy and SW Genesee Streets has been purchased as Seattle Parks open space. Land use within this reach is predominantly scattered residential and industrial. This segment ranked as a high priority in the Master Plan, based on minimal obstacles to salmon; reasonable habitat potential; and, high public visibility and accessibility.

There is no quantifiable data for canopy coverage or age but the riparian habitat was considered "fair to good" in the lower portions of this reach and "lacking" in the upper portions. There were several unvegetated eroding stream banks observed in this reach in 1990. Site restoration work is currently underway here, and instream and upland improvements are scheduled for completion in 2001.

Segment 3. The majority of this reach is located within a wooded ravine in the West Seattle golf course, and includes that portion of open channel from SW Genesee Street to the confluence of unnamed tributary in golf course. Two major obstructions prevent salmon access to relatively good habitat upstream. Public access is now limited. In the lower portions of this reach there is some canopy present but it is generally considered "lacking". Upstream of the lower 150 feet the canopy quality improves. Golfers searching for "missing" golf balls have cut numerous trails into the riparian corridor and contribute to its degradation.

Segment 4. This segment consists of a small left bank tributary that drains from a steep ravine believed to originate from a brushy wetland area to the west. Numerous small slides have occurred in the upper portion of the tributary channel. This area probably accounts for a significant proportion of the observed suspended sediment load in the main channel. Here too, golfers searching for "missing" golf balls have cut numerous trails into the riparian corridor and contribute to its degradation.

Segment 5. This reach extends from the confluence of the left bank tributary upstream to SW Brandon Street and winds through a wooded ravine. The overhead canopy was considered "dense" except in the vicinity of the several golf course walkways across the creek. Recurrent bank failure problems exist in this reach and one channel obstruction is present.

Segment 6. This reach extends from SW Brandon Street upstream to the location of the stormwater bypass segment enters the mainstem of Longfellow Creek. Numerous trails and pathways have effectively eliminated much of the riparian vegetative zone. The overhead canopy was termed “dense”. The upper portions of this reach have a riparian zone termed “brushy” with only minimal overhead canopy present.

Segment 6. This reach extends from SW Brandon Street upstream to the outlet of the stormwater bypass channel north of SW Findlay Street. MacIntosh indicated that numerous trails and pathways have effectively eliminated much of the riparian vegetative zone. The overhead canopy is termed “dense”. The upper portions of this reach have a riparian zone termed “brushy” with only minimal overhead canopy present.

Segment 7. This reach includes open channel from the bypass channel outlet to SW Juneau Street (bypass channel starts at SW Juneau Street). The reach is characterized by a highly modified stream bank that has been channelized and armored, and flanked on both sides by private property. . A corresponding amount of limited canopy and overhanging vegetation is present.

Segment 8. This reach stretches from SW Juneau Street upstream to SW Graham Street and has a “dense” canopy present throughout most of its length. There are local areas where no canopy is present. Himalayan blackberries and reed-canary grass are present in areas with minimal or no canopy.

Segment 9. This reach extends between SW Graham Street to SW Willow Street and flows primarily through a residential area in the lower portion and a park-like area in the upper section. Canopy was termed “adequate” in the upper section.

Segment 10. Flowing between SW Willow Street and SW Myrtle Street, this section had stream associated vegetation that was dense and brushy.

Segment 11. This segment is comprised of a piped channel from SW Myrtle Street to the SW Webster Street Detention Basin, and an open channel from the detention basin to SW Holden Street. Most of the segment is piped, with modest trout habitat potential within the open channel portion. Rock grade control structures located in the stream channel upstream of the detention basin are two feet high, and impede passage by all anadromous and resident fish species. Seeps from hillside behind K-Mart may contribute fine sediments to bypass pipe. Streambank erosion was observed along channel upstream of the detention basin.

Segment 12. This reach extends between SW Holden and SW Thistle Streets, and contains modest trout habitat potential. Most of the segment is on private land, with the exception of a small open space parcel, contiguous with Chief Sealth High School. The creek is highly visible to local apartment dwellers, and there is little to no riparian buffer in this reach as high-density housing is constructed in some cases to the stream’s edge. Open space next to high school has been recently improved with trails and native vegetation in recognition that this “headwater” reach is important to downstream segments.

In conclusion, the riparian habitat of Longfellow Creek suffers from many of the ailments associated with urbanization including in many reaches dominated by non-native plant species,

lack of suitable buffer width or functioning buffer and can only be considered to be "Not Properly Functioning."

LARGE WOODY DEBRIS

There has been no quantification of LWD in Longfellow Creek, but visual stream surveys by MacIntosh (1990) indicate that LWD is quite limited. This is probably due to inadequate recruitment potential from the degraded riparian zone.

MacIntosh (1990) specifically noted the need for additional instream structure and wood placement. Seattle Public Utilities began adding LWD to Longfellow Creek in 1999, particularly to the stream reach between Andover and Genesee streets, where most of the adult coho were recorded during spawning surveys in 1999 (WA Trout, In Preparation). Although LWD is limiting in Longfellow Creek, it has been placed in critical reaches over the last couple of years, and may not be a major limiting factor compared to stormwater runoff. Specific stream channel and riparian improvement projects identified by the Longfellow Creek Master Plan are intended to improve fish passage and access to significant habitat areas, and enhance available salmonid habitat via a combination of in-stream and riparian habitat diversity and channel stabilization

HYDROLOGY

MacIntosh (1990) suggested that the high quantity and degraded quality of stormwater was detrimental to salmonid production. Davis et al (1992) also concluded that the adverse effects of increased volumes of stormwater flows and decreased volumes of low flows were a result of urbanization in the subbasin. The Longfellow Creek Wastewater Management Committee identified the issues associated with high stormwater flows and increased urban runoff as principle problems facing the creek (Davis 1992a).

This problem persists, at least in part, due to the City of Seattle Comprehensive Drainage Plan adopted in 1989 that states that Longfellow Creek will remain the principle conduit for stormwater for the drainage basin. One solution to this problem is to control the flow rate and treatment of stormwater to the creek.

Very few flow measurements have been taken in Longfellow Creek, and no hydrograph has been established for the creek. Flow was measured in 1976 at 2.5 cubic feet per second (cfs) at SW Webster Street and SW Andover (City of Seattle 1977). Flow measurements taken in 1990 at SW Adams Street averaged 1.15 cfs (Davis et al. 1990). It is unclear if the dates of both measurements were similar, but both were attributed to possible low flow measurements. It is believed that impervious surfaces increased in the intervening 14 years. Increases in impervious surfaces results in less infiltration and are associated with a decrease in low flows, and an increase in the magnitude, duration, and frequency of storm events (Booth, 1991).

Longfellow Creek is the natural drainage conveyance for a watershed of approximately 2,685 acres. Today, Longfellow Creek receives surface water from natural areas in addition to stormwater runoff from streets, paved areas such as parking lots, and run-off from a series of constructed ditches. Some of these ditches are lined with impervious materials while others have placed rocks or vegetation. Collectively, these all channel stormwater into Longfellow Creek.

Approximately 45 percent (1,208 acres) of the subbasin is served by combined sewers. The remainder collects surface water in ditches and pipes and delivers it directly to the creek. Sewers and storm drains were separated along SW Roxbury, SW Webster, and through most of the lower watershed by the late 1970's. Drainage improvements in the early 1980's included: separation of sewers and storm drains, the construction of a 26-acre foot capacity detention basin at SW Webster Street, and installation of four combined sewer overflow holding tanks (10 yr-storm event capacity). A by-pass was constructed between SW Juneau and SW Findlay in 1989 to relieve a channel constriction and associated flooding.

HYDROMODIFICATION

Longfellow Creek, as is the case with many streams in urbanized settings, has undergone a long history of extensive floodplain modifications. The City of Seattle calculates the length of Longfellow Creek as 20,630 feet long (Joe Starstead, pers. comm., calculated from GIS measurements) and with two left bank unnamed tributaries each contributing approximately 1,300 and 270 additional linear feet there is approximately 22,200 total linear feet of creek length (Joe Starstead, SPU, personal communication, calculated from GIS measurements). Approximately 8,200 (36.1%) linear feet of Longfellow Creek lie entirely within pipelines and another 1,034 (4.7%) linear feet under road crossings (Joe Starstead, SPU, pers. comm., calculated from GIS measurements). There are also numerous sections that are channelized, between bank hardening features such as rock gabions, poured concrete walls, large placed rocks and stacked broken slabs of concrete. The channelization of this creek has caused a simplification of channel complexity, increased water velocities, loss of pools for juvenile rearing and adult and juvenile holding, loss of spawning habitat, loss of side channels, loss of any significant wood recruitment and loss of connectivity with its historic floodplain.

The length of these areas was not available for this report but based on professional observations (MacIntosh 1990) it is expected to be significant.

While there has not been an exhaustive inventory of floodplain modifications there is sufficient data (MacIntosh 1990, Davis 1992a, Davis 1992b) to indicate extensive modifications have occurred". MacIntosh (1990) did conclude that despite urbanization, the subbasin still contained some usable fish habitat. This information, in combination with the presence of juvenile rainbow and coho found during the1999 electrofishing surveys (WA Trout, In Preparation, Taylor & Associates, 1999) suggests that there are reaches within Longfellow Creek that possess some capacity to support juvenile salmonid rearing. However because of the extensive amount and nature of the modifications to the floodplain it should be rated as severely impaired and "Not Properly Functioning."

OFF CHANNEL HABITAT

The ability of Longfellow Creek to form off-channel habitats has been eliminated in approximately the 40 percent of the creek where it is within pipelines. Other portions of Longfellow Creek are channelized between bank hardening structures that limit lateral movement that is necessary to form many off-channel habitats.

FLOODPLAIN CONNECTIVITY

The extent and form of channelization within Longfellow Creek has greatly interfered with this system's capacity to connect to its historic floodplain. Additionally, as in many urban streams, increases in streamflow have caused the creek to incise in many places, further impacting floodplain connectivity.

WATER QUALITY

Longfellow Creek is designated as a Class A stream by WDFW and WDOE. While Longfellow Creek does not directly flow into the Duwamish-Green River, it is considered a tributary to the Duwamish River, which is designated as a Class B surface water (Chapter 173-201A WAC). However, water quality is only currently listed as degraded for fecal coliform violations on the EPA 303(d) list for 1998. Table LONG 2 illustrates the Environmental Protection Agency 303(d) 1998 list for Longfellow Creek.

LONG 2: Environmental Protection Agency, Clean Water Act 303(d) 1998 List for Longfellow Creek

Sampling Location (RM)	Parameter
LFC 24	Fecal Coliforms
RM 1.1	Fecal Coliforms
RM 0.5	Fecal Coliforms
LFC 1	Fecal Coliforms
LFC 3	Fecal Coliforms

While fecal coliform violations are a human health threat, they are not necessarily a threat to natural salmonid life history stages. However, they may be an indicator of overall stream health and because of the multiple excursions beyond acceptable limits provide cause for concern. Fecal coliform counts were noted to exceed acceptable limits when samples were taken during both low flows and storm events (Goldberg et al 1992, Minton 1998). They also noted increased levels of Total Suspended Solids (TSS) and turbidity during storm events and metal concentrations increased as TSS increased.

A more suitable indicator of overall stream health is the presence, diversity and population of benthic invertebrates. MacIntosh (1990) and Goldberg (1992) both indicate an overall lack of benthic invertebrates that is indicative of overall stream degradation. Healthy populations and species diversity of aquatic invertebrates have not been found in Longfellow Creek (Davis et al 1992, Goldberg 1992). This may be due to a combination of factors including high storm flows, low base flows, degraded water quality and/or degraded habitat conditions.

During water quality sampling conducted prior to 1992, Longfellow Creek exceeded state water quality criteria for fecal coliforms, turbidity, lead, copper, zinc and dissolved oxygen. The levels of total lead, copper, and zinc exceeded both acute and chronic criteria more than 50 percent of the time during storm flows but not during low flows.

Longfellow Creek Data Review and Segment Ranking Technical Memorandum, September 1998, reviewed the water quality data contained in the *Longfellow Creek Background Characterization Report* (City of Seattle 1992) and in the draft *Review of Water and Sediment*

Quality Data for Longfellow Creek (Resource Planning Associates 1998). In addition, this technical memorandum reviewed water quality data provided by Seattle Public Utilities (SPU). The monitoring data provided by SPU are summarized in LONG 3 below.

LONG 3: Longfellow Creek Water Quality Sampling Locations				
Station ID	**Location**	**Sampling Period**	**No. of Baseflow Samples[1]**	**No. of Storm Samples[1]**
C370	Longfellow Creek at Yancy Street	3/93-12/97	46	11
LFC3	Longfellow Creek at Adams Street	11/79-7/90	49	12
LFCP23	Storm drain pipe discharging to Longfellow Creek near Edmunds Street	3/90-7/90	0	6
J370	Longfellow Creek at Brandon Street	12/92-12/97	46	12
LFC24	Longfellow Creek at Findlay Street	11/87-6/90	2	19
LFCP25	Storm drain pipe discharging to Longfellow Creek near Myrtle Street	3/90-7/90	2	13
Sta91	Longfellow Creek at Graham Street	12/95-4/97	0	8
LFC1	Longfellow Creek upstream of Webster Basin	5/89-7/90	5	8
Note: Baseflow and storm samples identified in *Review of Water and Sediment Quality Data for Longfellow Creek* (Resource Planning Associates 1998).				

Evaluation of this data was confined to sampling results collected since January 1990. Key findings, related to descriptive statistics (e.g., median, mean, maximum, minimum) for each constituent of potential concern, and compared with current state water quality criteria for Class A waters, are summarized as follows:

- Fecal coliform densities often exceeded the state criteria during storm events. Fecal coliform is a human health concern but not a major aquatic life concern. Domestic pets and geese are believed to be the most likely sources of fecal coliform in stormwater runoff. Combined sewer overflow at SW Henderson Street and SW Orchard Street are also potential sources. Fecal coliform densities were occasionally high in baseflow samples, which may indicate leaking sanitary lines or cross-connections to the storm drain system.

- Overall water quality was fair for aquatic life. Under baseflow conditions, the creek generally met the water quality criteria for aquatic life protection. However, samples collected during storm runoff occasionally exceeded the criteria for copper, pH, and temperature.

- Dissolved oxygen (DO) did not meet the state criteria on two occasions. However, DO has not been measured at night or just prior to first light, when aquatic plant respiration tends to reduce DO levels. Water temperature exceeded the state criteria on a few occasions during the months of July and August.

- Total suspended solids and turbidity were often elevated during storm events.

- Nitrate-nitrogen was often elevated. Total phosphorus concentrations were within the typical range for urban streams. The lack of DO problems suggests that nutrient enrichment has not had a major impact on the creek.

- Samples collected from the two storm pipelines generally contained higher pollutant concentrations than the in-stream stations.

- There was little difference in water quality among the creek stations. Water quality in the upper, middle, and lower reaches was similar. This spatial pattern indicates that there are no major point sources (or distinct non-point source areas) affecting the creek between monitoring stations.

Table 4-5 in the Longfellow Creek Data Review and Segment Ranking Technical Memorandum, summarizes the results of the water quality evaluation for each segment. Potential areas within each segment are noted in the table. (Attach).

SEDIMENT CONDITION

MacIntosh (1990) noted numerous areas where the streambed was sand, mud and/or compacted gravels. Some of these reaches were in areas that were on top of gabion bottoms. Rock gabions and/or cyclone fencing have been placed over the stream banks and streambed between Nevada and Genesee streets, which would limit access to spawning gravels in this reach (MacIntosh, 1990, WA Trout, In Preparation). High amounts of fine sediments were also present in several reaches.

Eroding stream banks were noted throughout the creek by MacIntosh (1990) and are one source of the sediment problems noted previously.

Although not surveyed, the apparent limited availability of suitable amounts and quality of spawning gravels may be a limiting factor to the natural production of salmonids in this stream. Erosion of streambanks and fine sediment input by stormwater contributes to the poor quality of those gravels that are present.

NON-NATIVE SPECIES

ANIMALS

No information was obtained to indicate the presence of non-native aquatic animal species.

PLANTS

Non-native plant species found in the subbasin include numerous ornamental species associated with plantings by private and public landowners. Examples include mountain ash (*Sorbus spp.*), blue beech (*Carpinus spp.*), butterfly bush (*Buddleia spp.*), cherry laurel *Laurocreasus officenalis*), dogwoods (*Cornus spp.*), and non-native rhododendrons (*Rhododendron spp.*). Exotic species of plants more closely associated with riparian and aquatic environments include: scotch broom (*Cytisus scoparius*), reed canarygrass (*Phalaris arundinacea*) which is abundant throughout this subbasin and Himalayan blackberry.

Non-native animal and/or plant species do not appear to currently be a limiting factor to natural salmonid production.

KEY FINDINGS AND IDENTIFIED HABITAT-LIMITING FACTORS

- Naturally producing anadromous salmonids may be absent from this subbasin, possibly since 1939. In recent years adult coho have been observed and recent electrofishing surveys indicate the presence of rainbow trout.
- The creek suffers from extensive channelization
- Water quality in Longfellow Creek is a significant adverse issue impacting anadromous fish success.
- Hydrologic regime has been severely altered along with system's ability to support salmonids
- Instream structures are needed to produce channel complexity for successful salmonid production.
- Known and potential anthropogenic barriers limit access to spawning and rearing habitat.
- The quality and quantity of gravels in the stream may be limiting anadromous and resident salmonid spawning success and potentially juvenile rearing.
- Although no quantifiable storm-flow information was available, it was the professional judgement of the TAG that flood flows due to increased impervious surfaces would serve to adversely limit any successful egg incubation.
- There are only limited amounts of off-channel habitat suitable for juvenile salmonid rearing and holding.

DATA GAPS

- Fish passage barriers have not been comprehensively assessed for the subbasin.
- Information regarding existing riparian conditions and functions for supporting salmon habitat is limited.
- There is no LWD inventory for the subbasin..
- Aquatic invertebrate populations should be monitored and the cause of lack of diversity and presence should be determined and addressed.
- Present fish use information of the system is not comprehensive.

- The state of the stream channel condition is unknown.
- Flow data is scarce or non-existent. Hydrologic analysis designed to assess the potential for salmon restoration is essential.
- The impacts of water quality to salmonid productivity have not been documented.

RECOMMENDED EARLY ACTIONS

- A comprehensive baseline habitat survey including elements that address the above referenced data gaps should be initiated to shape a subbasin-wide, ecosystem-based, stream rehabilitation strategy. The strategy should be used to direct the type and timing of rehabilitation activities to maximize resource potential and promote efficient expenditures.

LIST OF TABLES

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3.2 HAMM CREEK SUBBASIN

PHYSICAL DESCRIPTION

SUBBASIN

Located immediately south of the Seattle City limits, locally named Hamm Creek (09.0002) is a small left-bank tributary to the Duwamish River. Draining an area of approximately 1,408 acres, the Hamm Creek subbasin is composed of four unofficially named perennial tributaries:

- South Fork;
- Middle Fork,
- Lost Fork; and
- North Fork.

STREAM COURSE MORPHOLOGY

The North, South and Middle Forks have their origins from a diverse series of groundwater seeps and springs that surface in roadside ditches in the hills west of the Duwamish River. These then drop through ravines along the western bluff line of the Duwamish River onto the valley floor. Historically, the lands downstream of this point were thought to have been a series of wetlands with largely undefined stream channels that connected to the Duwamish River.

The Middle Fork and North Fork join near S. 96th Street west of State Highway 99. When flows in these forks exceed the five-year interval storm event, they overflow into the Lost Fork. The Lost Fork originates from a diverse series of seeps and springs on the valley floor. The South Fork joins the combined three forks via a culvert at S. 95th Street. Hamm Creek then flows about 200 feet to the confluence with the Duwamish River at RM 4.95.

SALMONID USE

The known freshwater distribution of anadromous salmonids is depicted in the report Appendix. Hamm Creek historically was believed to contain populations of coho salmon, cutthroat trout and steelhead trout.

Currently, only the South Fork is thought to contain significant numbers of anadromous salmonids. At least one salmonid was reported observed in the spring-fed area of 96th Street ditch that is connected to the South Fork via culvert under Highway 99 ((b) (6), pers. comm.). During July, 2000, 322 cutthroat trout juveniles and 222 coho juveniles were estimated to have been removed from an approximately 400-meter reach in the area of construction downstream of Highway 99 near RM 0.3 (D. Eastman 2000, King County unpublished summary of Hamm Creek fish removal). Coho adults have been observed spawning in the South Fork up to RM 0.7. Coho and cutthroat juveniles were captured during 1998 project fish relocation near RM 0.5 and observed up to RM 1.0 ((b) (6), pers. comm.) Coastal cutthroat have been located in the

upper reaches of Middle and North Forks and throughout the upper and lower reaches of the South Fork.

Some marginal salmonid habitat potential exists in the upper reaches of the North, Middle and South Forks above the valley floor.

FACTORS OF DECLINE

FISH PASSAGE

Fish passage into the Middle, North and Lost forks is partially obstructed at the perched outfall into the Duwamish River. The outfall is located within a reach of the Duwamish River that is subject to tidal influence, and adult and juvenile salmonids can only enter the system when the tide reaches approximately +6.5 feet ((b) (6) pers. comm.). The lower 190 feet of this stream is fully contained in a 6-foot-diameter pipe, which may also inhibit salmonid migration. While the gradient is relatively flat (approximately 1 percent), the lack of suitable holding areas and darkness may inhibit some upstream salmonid migration.

The South Fork converges with the other three forks via a 6-foot corrugated culvert. This culvert is integrated into the toe of a riprapped bank within the Duwamish Yacht Club boat basin. It is perched above the river at low tides.

A fish and wildlife restoration project was completed on the South Fork in 2000. A root complex forming at the channel nick point at RM .7 was creating a migration barrier in 1997 (Nelson, 1997).A new, fish-friendly outlet to the Duwamish River was constructed that should allow unrestricted salmonid access.

RIPARIAN CONDITION

The lower 190 feet of the South, Middle, North and Lost Forks is encased within a 190-foot-long, 6-foot-diameter pipe. Moving upstream, the pipe opens into a 60-foot-long stream reach of channel that is between buildings and paved surfaces. This channel has a less than 1 percent gradient, is roughly 8 feet deep, and has a bank width of 10 feet.

At approximately RM 0.1 the combined Middle, North and Lost Forks are again within a culvert until they reach the State Route (SR) 99 cloverleaf. It then emerges into a 225-foot-long trapezoidal channel where riparian vegetation consists of deciduous trees, Himalayan blackberry, reed canarygrass and nightshade. Upstream of the SR 99 cloverleaf, the creek traverses through a 50-foot-long open channel before it enters a 450-foot-long straight channel lined with Himalayan blackberries. At the upper end of this reach the creek enters a 1,010-foot-long culvert until it reaches the confluence of the North and Middle Forks.

The North Fork is completely encased in a culvert that is approximately 2,175 feet long that emerges in the vicinity of the west side of SR 509. At this point the North Fork ascends a steep ravine with riparian habitat consisting of immature deciduous trees, Himalayan blackberry, stink and red current.

The Middle Fork, upstream from the confluence with the North Fork, is encased within a 825-foot-long culvert. It then emerges in a reed- and canarygrass-lined 300-foot-long ditch that is fed by surface drainage through smaller culverts from the Rasmussen Wire Rope facility. Upstream of this point, the stream travels alternatively through reed- canarygrass-lined roadside ditches and culverts until it ascends the bluff via a 750-foot-long ravine where riparian habitat consists of deciduous trees and Himalayan blackberries.

The area of the South Fork enhancement project from Highway 99 to the Duwamish (RM 0.0 -0.5) will be revegetated with a variety of native plants including fresh and salt water emergents, shrubs and trees. In the Point Rediscovery reach (about RM 0.5 to 0.6), the adjacent stream corridor is dominated by red alder and Himalayan blackberry with some big leaf maple, recent small red cedar plantings, indian plum, horsetails, snowberry and ivy. Upstream of Des Moines Way at RM 0.6 to RM 0.7, the one- to two-percent-gradient stream enters a 600-foot-wide ravine. The ravine provides a good vegetative buffer from the top-of-slope residential development. Large deciduous trees (big leaf maple, alder and cottonwood) with some sporadic large conifers (red cedar and douglas fir) provide the canopy. The understory is composed of vine maple, salmon berry, ferns, blackberry, ivy, nettles, skunk cabbage, sedge and devils club. From RM 0.7 to 1.1, the ravine narrows to 200 - 500 feet but still provides a significant buffer from residences and a golf course. In this reach, the one- to three-percent-gradient stream flow diminishes by about one third, and the channel is devoid of pools (as was the adjacent lower reach). Landslides are apparent through this reach and the vegetation is similar to the previous but much more dense, especially near the flowing channel. A landslide has formed a large pond (in 1997 it was 120 feet long x 40 feet wide x 3 -6 feet deep) at RM 1.0. In 1997, this slide material was considered a significant risk to downstream habitat because of the potential that it could remobilize and create a dam break event (Nelson, 1997).

LARGE WOODY DEBRIS

LWD is virtually absent in all Hamm Creek tributaries. Given the state of riparian zone, any near-term natural recruitment is precluded.

HYDROLOGY

The changes in the flow regime of all forks of Hamm Creek have been extensively altered by a variety of anthropogenic impacts. These include increases in impervious surfaces associated with industrial development and urbanization, channelization and piping, dredging, and removal of wetlands, riparian vegetation and LWD. All of the forks of Hamm Creek exhibit flows typical of lowland western Washington streams in urbanized settings. Stream flows increase quickly to rainfall events and decrease quickly upon the cessation of rainfall. Some of the reaches that are not confined in pipelines show evidence of stormwater impacts, such as the lower mile of the Middle Fork where streambed incision and channel widening has been observed (King County 1995a).

The Rainier Golf and County Club diverts water from the South Fork Hamm Creek out of a ditch into two ornamental ponds. A pump house located adjacent to the lower of these two ponds then supplies water to an ornamental concrete-lined pond on a golf course fairway.

Flows were measured at 1.3 cfs on January 11, 1996 and 1.5 cfs on May 21, 1997 (King County 1995a).

SEDIMENT CONDITION

Long reaches of all forks are contained in pipes and culverts, and many of the stream reaches outside the pipes are in highly channelized ditches. This is particularly true of the reaches that are on the valley floor. The low gradient of all forks once they reach the valley floor has resulted in the accumulation of large quantities of fine gravels, sands and silts which dominate the substrate (King County 1994, King County 1995a). In locations where moderate or larger gravels are located, they are cemented with considerable amounts of fines. The lack of suitable spawning gravels is a habitat-limiting factor to natural salmonid production.

WATER QUALITY

Stream flows in all forks of Hamm Creek have exhibited evidence of water quality degradation typical of streams in urbanized settings during storm events. Metals such as zinc, copper, and lead have been measured at high concentrations during these storm events. In addition to the high metal concentrations, high concentrations of total suspended solids and total petroleum hydrocarbons (TPH) have been measured at sampling locations throughout the streams with only minor exceptions (King County 1994, King County 1995a).

Elevated pH with values up to 8.72, sampled during base flow conditions, have been attributed to runoff from a cement kiln dust pile located in the vicinity of South 96th Street and 10th Avenue South (King County 1994).

During mid 1997, a fish kill occurred from the flushing of chlorinated water from the local water purveyor pipeline into the South Fork Hamm Creek near Des Moines Way.

LAND USE

Land use within the basin is dominated by residential and commercial/industrial uses. Open space is typically occupied by public right-of-ways (i.e.: Seattle City Light transmission lines) or golf course property. There are some mixed deciduous/coniferous second growth forests, especially in the bluffs that the tributaries transect. Table Hamm-2 shows land use acreage and percent of basin occupied by these land uses.

Table Hamm-2: Land Use in Hamm Creek (Source: King County 1994).

Residential	Commercial/Industrial	Open Space
850 acres (61%)	242 acres (17%)	316 acres (22%)

The percent of effective impervious surface was not located during the course of this investigation. But because in excess of 88 percent of the land was in either residential or commercial/industrial use as determined in 1994, it is expected that the percent of impervious surfaces in this basin is quite high.

NON-NATIVE SPECIES

ANIMALS

There are no known non-native aquatic animal species in Hamm Creek.

PLANTS

There are numerous plant species associated with ornamental plantings throughout all of the forks. Thickets of reed canarygrass, ivy, Himalayan blackberry, and bittersweet nightshade dominate numerous stream reaches (King County 1994). The thicket in these reaches serves to constrict stream channel flow and present a lack of channel complexity and habitat necessary for salmonid production.

HYDROMODIFICATION

As detailed previously in this chapter, the stream channels of all forks of Hamm Creek have been extensively modified (table Hamm-2) from historic uses. The insufficient amounts of stream associated structure and the habitats it would create that are necessary for support of various life phases of salmonids effectively limits their natural production.

Table 1: Hamm Creek (09.0002) Stream Channel Types and Distances* (Source: King County 1995a).

Stream Name	Piped (feet)	Confined Ditch (feet)	Otherwise Modified (feet)	Unmodified (feet)
Mainstem of Middle, North & Lost Forks	1,925	785	0	0
South Fork	770	1,350	1,470	3,885
Middle Fork	825	1,160	2,500	750
North Fork	2,875	0	500	0
Lost Fork	1,800	300	0	0

* Distances are approximate.

OFF CHANNEL HABITAT

Several South Fork Hamm Creek stream enhancement efforts have occurred recently. An off-channel wetland-pond and stream channel enhancement project at “Point Rediscovery” has been constructed in 1996 and 1998 between Highway 99 and Des Moines Memorial Drive (about RM .5) at the old Rainier Vista treatment plant site.

FLOODPLAIN CONNECTIVITY

Many of the stream reaches have been disconnected from the floodplain and tightlined or channelized by development. Low-gradient riffles and shallow pools dominate the lower reaches of all forks that might have been utilized by salmonids for natural production.

The condition of the channels of all of the forks of Hamm Creek limit natural salmonid production.

KEY FINDINGS AND IDENTIFIED HABITAT-LIMITING FACTORS

- Naturally producing anadromous salmonids may be absent from most of this subbasin. Presently, only the lower 0.7 of South Fork Hamm Creek contains any potential spawning habitat for anadromous salmon for the subbasin.

- There is utilization by coho salmon of only the South Fork Hamm Creek.

- All forks of Hamm Creek suffer from an particularly severe system of piping and channelization.

- A combination of stream sediment load, stream channel characteristics, and high flows during storm events adversely impact anadromous fish success.

- Water quality in the lower stream reaches is particularly degraded by metals, TSS and TPH.

- Outside of the bluff-associated ravines, the riparian habitat (where present) is composed of numerous non-native plant communities.

- The stream channels generally lack complexity due to the lack of LWD, vertical channel migration, and bank armoring. Instream structures are needed to produce channel complexity for successful salmonid production.

- The quality and quantity of gravels in the stream limits anadromous and resident salmonid spawning potential juvenile rearing success.

- There are only limited amounts of off-channel habitat suitable for juvenile salmonid rearing and holding.

- Access to the Middle and North Forks is limited by the outlet into the Duwamish River and the amount of piping present throughout these streams.

- While the percent of effective impervious surfaces in these streams was not found as a part of this investigation, the amount and type of land use in this subbasin indicates that the percent would quite high.

EARLY ACTION RECOMMENDATIONS

- The water quality, sediment regime, and hydrology of this subbasin has been severely degraded and could undermine stream enhancement efforts A thorough, scientific evaluation of the production potential of this system for a naturally sustaining stock of salmonids should be conducted prior to further resource expenditure.

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Table Hamm-1: Hamm Creek (09.0002) Stream Channel Types and Distances* (Source: King County 1995a).

Table Hamm-2: Land Use in Hamm Creek (Source: King County 1994).

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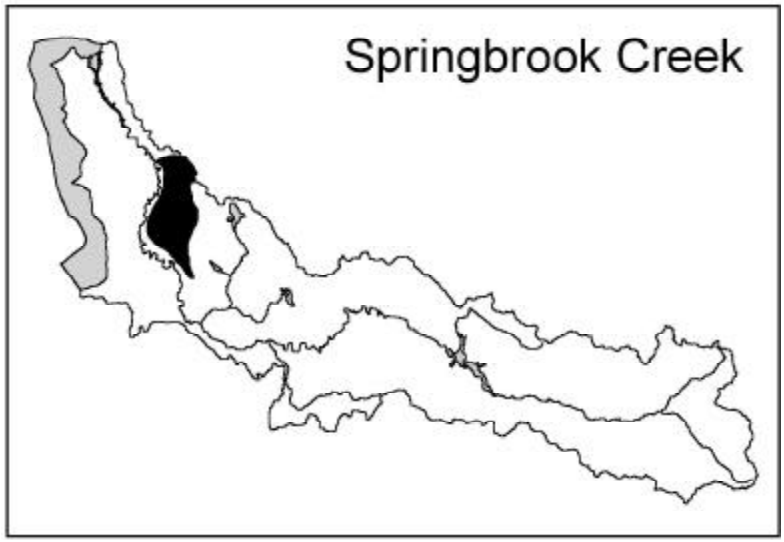
3.3 SPRINGBROOK CREEK SUBBASIN



PHYSICAL DESCRIPTION

SUBBASIN

Springbrook Creek (09.0005) Subbasin is located east of the mainstem Green River, in and around the cities of Kent and Renton. The Springbrook Creek subbasin enters the mainstem Green River via the Black River at RM 11.0. With an estimated mainstem stream length of 12.0 miles, and approximately 19.1 miles of tributary streams and 3.8 miles of drainage ditches (Williams 1975), it is the largest subbasin in the lower Green River Basin. Springbrook Creek subbasin drains an area of about 15,763 acres

The basin is comprised of two distinct physical settings. In the eastern half of the subbasin, rolling hills rise to elevations of about 525 feet above the valley floor. In this area, the origins of stream courses are often not well defined. Slopes in the subbasin range from near 0 to 70 percent. One significant lake is present (Panther Lake) along with several smaller ponds and wetlands. Creeks originating from these upland sources drop abruptly through sharply defined steep canyons to the valley floor where stream gradients flatten quickly. Typically, these canyons are short, with high gradients and generally not accessible to anadromous salmonids

A unique feature to this subbasin in the Black River Pump Station, the details of which will be covered in the Hydromodification section of this chapter. Except where indicated by specific citations, the following descriptions of the Springbrook Subbasin comes from a comprehensive fisheries assessment of the Mill, Garrison and Springbrook Creek system conducted by Harza (1995).

STREAM COURSE AND MORPHOLOGY

Instream potential fish habitats include approximately 5.8 miles within Springbrook Creek, 6.65 miles in Mill Creek, and 5.2 miles in Garrison Creek. The specific habitat types are summarized in table Springbrook-1.

TABLE SPRINGBROOK-1: SUMMARY OF VARIOUS HABITAT TYPES IN THE SPRINGBROOK CREEK SUBBASIN

Habitat Type	Springbrook Creek		Mill Creek		GARRISON CREEK	
	Length (ft)	Percent	Length (ft)	Percent	Length (ft)	Percent
All Potential Fish Habitat	30,645	100	35,096	100.0	27,456	100.0
Steps	40	< 1	0.5	<1	0	0
Pools	54	<1	627	2	40	<1
Riffles	4,174	13	7,555	22	1,420	5
Glides	0	0	886	3	225	1
Low Gradient Glides	25,304	83	26,023	74	14,488	53
Habitats Not Delineated	1,073	4	0	0	11,283	41
Source: Harza 1995						

The western half of the subbasin lies on the valley floor and stream gradients are virtually flat. Mill and Garrison Creeks are the primary tributaries. Both have their origins in the eastern foothills before dropping quickly through the respective steep ravines. The stream labeled by Harza (1995) as the Valley Floor Fork Garrison Creek was depicted by Williams (1975) as Springbrook Creek. In this report we will use the Williams (1975) descriptor and numbering system (09.xxxx). The Garrison Creek subbasin consists of the three forks: North Fork (09.0023), Middle Fork (09.0022) and South Fork (09.0025), and an unnamed tributary to the South Fork (09.0024).

SALMONID USE

The known freshwater distribution of anadromous salmonids is depicted in the report Appendix. Coho salmon, cutthroat trout, and winter steelhead adults have been observed spawning in Springbrook Creek and its tributaries (WDFW Spawning Ground Survey Database., (b) (6) pers. comm.). Juvenile hatchery origin coho salmon have also been released routinely in upper reaches of several tributary streams. Adult chinook have been observed entering the Black River (R. Malcom pers. comm.) and attempting to spawn near the SW 27th Street culvert during the fall of 1997 (P. Schnieder pers. comm.). It is hypothesized that they are exploring this system, but once they enter the Black River via the fish ladder at the Black River pump station there is no mechanism for them to exit.

Juvenile coho, winter steelhead, and cutthroat have been captured at numerous locations throughout the subbasin. (Williams 1975, Harza 1995, (b) (6) pers. comm., (b) (6) pers. comm.). Approximately 17.9 stream miles of potential fish habitat exist within the Springbrook Creek subbasin. Of this amount, approximately 17.2 miles is believed to be accessible to anadromous salmonids (Harza 1995).

FACTORS OF DECLINE

FISH PASSAGE

The most significant fish passage barrier in this system is the presence of the Black River Pump Station. In 1958, the Black River Dam (an earth-filled dam) was completed on the Black River approximately 1,000 feet upstream of its confluence with the Green River. The purpose of this structure was to control outflows from the Black River and prevent flows on the Green River from backing up into the Black River/Springbrook Creek floodplain during floods. Six 48-inch diameter culverts extended through the dam and were fitted with flapgates. In 1972, the U.S. Soil Conservation Service (SCS) (renamed the Natural Resources Conservation Service) replaced the dam with the current Black River Pumping Station (BRPS), to provide a means of releasing flood flows from the Black River/Springbrook Creek system when the Green River is at high stage. The BRPS is currently operated and maintained by King County Surface Water Management.

During flood periods on the Green River, the pumping station acts as a dam, preventing floods from backwatering into the Black River and the wide valley floor of the lower Springbrook Creek subbasin. Water levels downstream of the pumping station range from –4.0 to +21.5 feet MSL, depending on tidal conditions and the water level of the Green River. Water surface elevations upstream of the pumping station are normally held in the range of 0.0 to 2.0 feet, but can reach as high as 13.0 feet. The pumping station consists of a series of eight pumps, and can pass flows of up to 2,945 cfs. Two large pumps with a capacity of approximately 1,028 cfs are also present, but have not yet been used.

The BRPS represents a barrier to upstream passage of salmonids. In addition, the ability to control the water surface elevations upstream of the BRPS often results in situation where the downstream water surface is higher than the upstream water surface. In order to pass upstream and downstream migrating salmonids around the structure, a unique fish passage system has been constructed and is in operation. A combination of a fish ladder and fishway chute is used for upstream passage. Fish migrating downstream are diverted around the pumps using an air-lift pump to raise the fish to the downstream water levels. The general layout of the BRPS and fish passage facilities is illustrated by Figure Pass-11.

UPSTREAM PASSAGE

Upstream passage facilities are located on the south side (left bank) of the pumping station, and consist of a combination fish ladder and fishway chute (Figure Pass-12). The main components of the upstream fish passage facility are a water supply pump, denil fish ladder, a false attraction weir, and a fish way chute. Fish enter the denil fish ladder, swim up and over the false weir and are then returned to the river upstream of the project via the fishway chute.

The denil ladder extends from the downstream pool on the south side of the BRPS approximately 60 feet horizontally and 14 feet vertically to a resting pool below the false weir. From the resting pool, fish enter the second portion of the ladder that extends 25 feet horizontally and seven feet vertically to the top resting pool. The velocity of the 5 cfs flow directed through the ladder is approximately 2.5 to 3.0 feet per second. This velocity is well within the normal range for this

type of ladder and is suitable for adult salmon (Bell 1986). However, these velocities are at the upper limit of sustained swimming speeds for juvenile fish (Bell 1986), and thus likely prevent upstream migration of juvenile fish.

From the top resting pool, fish pass over the false weir and down the fishway chute. The fishway chute drops from approximate elevation 16.0 feet to 2.0 feet, creating a potential vertical drop of 2.0 feet at the end of the chute when the upstream water surface is held at 0.0. The 60 foot long chute is an open channel for the first 10 feet, a closed pipe for 25 feet and ends in an open channel for the final 25 feet. The inside of the chute is coated with vinyl to protect fish from abrasion. Two 30-degree angles in the closed section are used to align the chute parallel to the forebay south (left bank) wingwall.

The upstream passage facility is normally operated from mid-September through 31 January of each year. Before 1993, the upstream passage facility was usually operated 24 hours per day, Monday through Friday. Since 1993, the upstream passage facility has been operated about 24 hours per day, seven days per week, during the seasonal window. The operational window likely precludes the upstream migration of some adult resident and anadromous cutthroat trout and anadromous steelhead.

The species composition of fish migrating upstream was assessed in 1994 by trapping adult fish in a net pen installed in the forebay of the BRPS, immediately below the outflow of the fishway chute (Harza 1995). A total of 229 coho salmon and 14 chinook were trapped between 17 September and 9 December (Harza 1995). Fair coho spawning habitat was noted in some reaches, although the streambed appeared to be unstable and flow levels may have been insufficient for successful spawning (Harza 1995). The facility is not equipped to handle downstream migrating adult steelhead (kelts) or chinook. Adult steelhead and chinook that move upstream past the BRPS cannot exit the Springbrook Creek subbasin, and once there are believed to experience high levels of stress or be killed outright prior to successful spawning (Harza 1995).

DOWNSTREAM PASSAGE

The downstream passage facilities provide a means of transporting juvenile salmonids migrating towards the ocean around the BRPS. The downstream fish passage facility consists of entrance fish ports and associated piping, an air lift system, deaeration tank and transport pipe (Figure Pass-13). Fish travelling through the system enter the downstream passage facility through the fish ports on the upstream side of the dam. The fish are then transported to the air lift system and into the deaeration tank. Fish exit the deaeration tank via a bypass pipe that delivers them to the pool downstream of the dam.

The entrance ports to the system are located at elevation +2.0 and –2.0 on the south wingwall (left bank) and are adjacent to the fish screens for the pumps on the south half of the structure on the south side of the BRPS (Figure Pass-13). The airlift pumps draw flow into the transport pipes, attracting fish to the entrance ports. Fish travelling downstream move across the screens and into the ports. Except for the two large pumps, fish are prevented from entering the pumps by galvanized 0.25-inch mesh screens. To date the large, unscreened pumps have not been used during the late winter or spring (April to June). A visual inspection of the screens in March 2000

provided some concerns that the screens may not meet current screening criteria. The facility was not designed to meet salmonid swimming approach velocities that are now required of facilities under construction.

After entering the fish ports, the fish descend a vertical fiberglass pipe to elevation –17.0 feet, and are then directed towards the airlift through a horizontal collection pipe. As the horizontal pipe passes into the airlift chamber, it turns vertically 90 degrees and descends to elevation –39.0 feet. At this point, the fish go through two more 90 degree elbows, then enter the airlift pump. Air added at –39.0 feet displaces water at the base of the vertical column, lifting the fish to +13.0 feet and into the deaeration tank.

The dimensions of the five-foot deep deaeration tank are 9.5 feet x 9.5 feet. The entrance to the 18-inch diameter fiberglass downstream transport pipe is located at the west end of the tank. This pipe transports fish approximately 108 feet horizontally to the fishway exit. The exit invert pipe is at 10.0 feet elevation, which can vary in height above the receiving water; normally, the drop is approximately 6 feet from the pipe to the receiving water. There is the potential for drops to reach 14 feet under low flow circumstances.

The downstream passage facility is operated from early April to mid-June each year, for approximately eight hours per day, Monday through Friday. Fish attempting to move downstream outside of that operational window are either prevented from exiting the Springbrook Creek subbasin, or must pass through the unscreened large pumps (if operational). Juvenile chinook emerge and begin moving downstream in the middle Green River system and Soos Creek as early as February (J. Kerwin pers obs., Jeanes and Hilgert 2000; Hilgert and Jeanes 1999), thus early downstream migrants may be prevented from exiting the Springbrook Creek subbasin.

The known anadromous fish barriers are summarized in table Springbrook-2. This table likely underestimates the number and types of barriers to anadromous and resident fish because a comprehensive fish barrier assessment has not been initiated for this subbasin.

Table Springbrook-2: Springbrook Creek Subbasin Fish Passage Barriers

Creek Name/Number	**Barrier Type**	**Location**
Springbrook/09.0005	Water quality	Lower reaches
Mill Creek/09.0015	Water quality	Lower reaches
Mill Creek/09.0015	Culvert (unverified concern)	Earthworks Park Detention Pond
Springbrook/09.0005	Culvert	At Talbot Road
S.F. Springbrook/09.0024	Concrete pad & weir	At Talbot Road
Springbrook/09.0005	Diversion	Springbrook trout farm
Springbrook/09.0005	Culverts choked with brush & aquatic vegetation	Throughout creek
M.F. Garrison/09.0022	Braided channel/wetland	Between 212th & 218th
N.F. Garrison/09.0023	Culvert	212th Way

There exists a barrier in the North Fork Garrison Creek at the South 212th Street road crossing. This culvert has a wide concrete chute which is thought to have been designed to distribute flow energy. There is at least a 3.5 foot drop immediately below this chute with no plunge pool present.

The Unnamed tributary (09.0020) Harza (1995) refers to this tributary as Springbrook Creek) has a 2-½-foot step with no plunge pool immediately east of the SR 167 crossing. While not believed to be a blockage to adult salmonids it could prevent instream movement of juvenile salmonids. Between the SR 167 crossing and Talbot Road the creek flows through a private trout farm. These ponds present a migrating barrier for anadromous salmonids for both 09.0020 and a tributary 09.0021.

Several sections of Springbrook Creek are so choked with invasive reed canarygrass and vegetation that they serve as partial barriers. The Springbrook Trout Farm serves as a barrier, under most streamflow situations, to anadromous fish upstream migration. If the bypass reach is dewatered then it would also serve as a barrier to downstream migration. Upstream of the trout farm, Springbrook Creek flows through a 30-foot culvert that is sloped at approximately 100 percent in the vicinity of Talbot Road. On the South Fork Springbrook Creek there is a concrete pad and notched weir that likely is a barrier to upstream and downstream migrating anadromous and resident fish.

Water quality may serve to act as a barrier to anadromous migrating fish in the lower reaches of Mill and Springbrook Creeks.

A culvert in the North Fork Garrison Creek was believed to be impassable in 1993 (Harza 1995). Additionally, those same investigators thought the highly braided channel in the middle Fork Garrison Creek that traversed the wetlands between 212th Way and South 218th Streets may be impassable.

RIPARIAN CONDITION

The riparian habitats in this subbasin range from bare banks to remnant coniferous forest fragments.

In Springbrook Creek, the Black River Pump Station creates a slackwater pond of approximately 3 surface acres. The actual surface acreage is dependent on specific water surface elevations. Riparian vegetation around this pond consists of willow species (*Salix sp.*), Pacific dogwood (*Cornus nuttallii*), cattails (*Typha latifolia*), reed canarygrass (*Phalaris arundinacea*) and red alder (*Alnus rubra*).

As the creek moves upstream out of the inundation reach, the riparian habitat changes slightly to a mixture of red alder, willow species, Himalayan blackberry and sedges (*Carex spp.*) along with some ornamental trees. Conifers are almost exclusively absent and in those areas where shade was absent reed canary grass is abundant. From the 16th Street crossing upstream to the confluence with Mill Creek, Springbrook Creek resembles a drainage ditch with reed canary grass the dominant vegetation with only token numbers of black cottonwood, willow and alder present. Ribbonleaf pondweed (*Potamogeton epihydrous*) was also identified in this reach.

Construction practices observed in the basin in the 1990s indicated vegetation removal to the water's edge.

From the confluence of Mill Creek upstream to the State Route 167 highway crossing the stream more closely resembles a drainage ditch. Reed canarygrass is the dominant riparian vegetation.

Sloughing of the streambank was common in places. From the State Route 167 highway crossing upstream to Talbot Road the stream lost its drainage ditch appearance but still did not have a function riparian zone. A right bank tributary stream at RM 5.2 (09.0020) upstream of the Talbot Road crossing enters an area protected by the City of Renton for municipal water supply. An unnamed tributary (09.0020) flows from a gabion water control structure while the south fork (09.0021) flows from a small reservoir. Harza (1995) labeled these tributaries as north and south forks of Springbrook Creek.

Springbrook Creek continues mostly parallel and adjacent to State Route 167 with reed canarygrass and Himalayan blackberry bushes the dominant riparian habitat. Again, the creek more resembles a drainage ditch used for water conveyance. Red alder was found sporadically throughout this reach with very little instream structure. During the 1993 Harza survey, there were instances of vehicles parked adjacent to the waters edge preventing the establishment of any vegetation.

In summary, riparian habitat within this creek meets the NMFS criteria of not properly functioning and is a limiting factor to natural salmonid production.

In Mill Creek, from its confluence with Springbrook upstream past the West Valley Highway to the East Novac Valley Road, the dominant riparian vegetation was reed-canary grass with minor amounts of red alder and black cottonwood (*Populus trichocarpa*). At some places in this reach, dredging of the creek has created vertical banks and other areas have contoured banks with approximately 4:1 slopes. In many segments, this reach resembles a drainage ditch. Very few riparian trees or shrubs were observed during a habitat survey in 1993.

Mill Creek flows within 5 feet of an apartment complex in the Kent City limits. The primary riparian vegetation consisted of reed canarygrass and a few black cottonwoods. Considerable instream garbage is a problem in the reach near Memorial Park in Kent. It is approximately this point (RM 8.5) that the historic Springbrook Creek as shown in Williams (1975) was diverted into Mill Creek. Because of that diversion we will continue to label this stream as Mill Creek.

Mill Creek flows through the Earthworks Parks Detention Pond (EPDP), a water detention structure that lacks trees, and shrubs. Additional trees were planted in 1994 in an effort to provide riparian habitat. Upstream of the EPDP the character of the stream changes as it enters a forested ravine dominated with red alder and bigleaf maples. Black cottonwood, Douglas fir and western red cedar are also present.

Upstream of the EPDP, the character of the creek changes dramatically as it enters a forested ravine with predominantly red alder and bigleaf maples. There are also black cottonwood, Douglas fir and western red cedar present along with an understory of salmonberry and vine maple. This creek has its origins at an ornamental pond before moving downstream through an open swale upstream of 274th Street.

Garrison Creek is a right bank tributary that enters Springbrook Creek at RM 6.25 and is comprised of three forks (North (09.0023), Middle (09.0022) and South (09.0024)). The South Fork Garrison Creek has one tributary (09.0025) that is accessible to anadromous salmonids.

The lower reaches of Garrison Creek are typical of a drainage ditch with riparian vegetation comprised predominantly of reed canarygrass and Himalayan blackberry plants. Sporadic red alder trees were present during the 1993 Harza survey. Woody vegetation is generally absent in the riparian zone throughout the lower reaches downstream of 88th Avenue South. Upstream of State Route (SR) 167, the Middle Fork Garrison Creek (09.0022) riparian habitat changes slightly as more red alders and Himalayan blackberries are present. The habitat survey conducted by Harza (1995) indicates the presence of a wetland upstream of SR 167. This wetland has a riparian habitat consisting of black cottonwood, red alder, bigleaf maple, pacific willow (*Salix lasiandra*), pacific dogwood (*Cornus nuttallii*), Himalayan blackberry and willow species. An understory of sedge, rush and bulrush species is also present.

Upstream in the reach from SE 218th Street to the confluence of the South Fork there have been several attempts at streambank restoration, including planting of non-native deciduous trees. Investigators involved in the Harza (1995) survey thought most of the attempts to be ineffective at that time.

The creek flows from the foothills through a relatively short steep gradient ravine vegetated with older bigleaf maple, red alder, black cottonwood, Douglas fir and western hemlock. Streamside canopy cover was estimated at 90 percent in 1993.

The North Fork Garrison Creek (09.0023) has a riparian vegetation zone consisting of red alder and bigleaf maple with an understory of salmonberry and blue elderberry (*Sambucus cerulea*). Streamside shade was estimated at 80 percent.

The South Fork Garrison Creek (09.0024) and an unnamed tributary (09.0025) share a high gradient shot ravine with a riparian zone vegetated by older bigleaf maple, red alder, black cottonwood, Douglas fir and western hemlock. Streamside shade in these tributaries was estimated at near 100 percent.

LARGE WOODY DEBRIS

In Springbrook Creek, the area parallel and adjacent to State Route 167 the instream substrate consists exclusively of silts and contains no LWD.

Once Mill Creek enters the forested ravine upstream of the EPDP, LWD is present in this upper reach but has not been inventoried or measured. This LWD is believed to have been deciduous tree in origin and less than 50 years old. However, it is responsible for adding channel complexity, creating pools and sorting of sands and gravels. LWD is absent from the area near EPD as well as the lower reaches of the creek.

LWD is present in Garrison Creek, upstream of the confluence with the South Fork Garrison Creek and is thought to help sort sediments. In the South Fork Garrison Creek, upstream in the reach from SE 218th Street to the confluence of the South Fork, LWD (conifer logs) and boulder clusters is present due to streambank restoration projects. LWD is present in the North Fork Garrison Creek upstream from its mouth but has not been inventoried or measured.

HYDROLOGY

Springbrook Creek flow has an annual yield of about 40 cfs.

Bortz (1981) concluded that the most serious condition existing in these streams was the extreme volumes of water associated with storm events. Harza (1995) reported that water quantity responded quickly after each storm event. Hydrographs indicated that the creek stage decreased after the conclusion of each storm event. This is typical of streams in urban areas that have relatively high impervious surface areas. In stream systems that have greater permeable surface areas, flow stage decreases more slowly thus allowing for a more efficient utilization by fish and other aquatic organisms of the increased instream flows (Lucchetti and Furstenberg 1992).

There currently are two US Geological Survey (USGS) stream gages in this subbasin. USGS gage number 12113346 is located in Garrison Creek and 12113349 is in Mill Creek. Together, Mill and Hill creeks drain approximately 14.5 square miles (~60 percent of the subbasin). Based on the most recent 5 years for water years 1995 through 1999 the combined annual yields for these two tributaries is approximately 29 cfs. The one-day average annual minima/maxima for the same time period and combined gage records is approximately 3.1 cfs with the individual tributaries average annual minima between 1 and 1.5 cfs. The Garrison Creek system, which is smaller than the Hill Creek system produces more annual yield (Burkey pers comm). Because of stream gage location, these analyses do not include the lower 40 percent of Springbrook Creek subbasin.

SEDIMENT CONDITION

As previously stated in the hydrology section, Bortz (1981) observed that extreme volumes of water associated with storm events caused streambank erosion, scouring and siltation in the three creeks. Harza (1995) found evidence of severe downcutting in Mill and Garrison Creeks and low to moderate downcutting in Springbrook Creek.

It is likely that construction practices observed in the basin in the 1990s which removed vegetation to the water's edge was a significant contributor to sediment entering Springbrook Creek. [Location is ambiguous. See Draft original page 2 Riparian Habitats, Springbrook Creek, paragraph 4.] The lower reaches of Springbrook Creek are in the slack water pond behind the BRPS and upstream as far as the SR 167 crossing the instream substrate consists exclusively of silts.

The upper reaches of Mill Creek have been extensively modified. According to anecdotal information, the historic upper reaches of Mill Creek used to flow through a gravel bedded channel. The headwaters are now a poorly channelized swale as the result of excavation and backfilling in an historic riparian wetland. Once Mill Creek enters the forested ravine upstream of the Earthworks Parks Detention Pond, there are patches of gravel suitable for spawning present. The first evidence of sands is seen in the vicinity of the EPDP. The lower reaches of Mill Creek are typical of low-gradient streams and are composed primarily of silt. Also in this reach, instream garbage increases. Bank erosion is present where Mill Creek flows within 5 feet of an apartment complex in the Kent City limits.

The North Fork Garrison Creek upstream from its mouth has numerous small and large boulders present, apparently recruited from streambanks. Gravel patches, while not plentiful were present.Those streambanks without large boulders present showed numerous signs of erosion in the 1993 habitat survey.

On Garrison Creek, as the stream gradient increased upstream in the vicinity of SE 218th Street, the streambed substrate was comprised of primarily gravel with some silt, sand and cobbles. upstream of the confluence with the South Fork Garrison Creek had increasing amounts of gravel with some cobble and boulders. The streambanks are comprised of highly erodible alluvial soils consisting of sand and gravel. Once Garrison Creek enters the ravine, the instream substrate was predominantly gravel, cobble and boulders. There were signs of erosion in this ravine during a 1993 habitat survey. The lower reaches of Garrison Creek are comprised of silts and fine sands typical of low-gradient streams and the drainage ditch that it resembles.

The South Fork Garrison Creek instream substrate is very different from the other forks of Garrison Creek. The stream substrate is a mixture of cobble, boulder and bedrock and significant portions of the streambank were observed to have eroded in the 1993 habitat survey. Investigators from Harza (1995) observed several rock gabions in the canyon. A pipe from the top of the ravine led into these gabions and they were possibly being used as erosion protection.

WATER QUALITY

Water quality within the Springbrook subbasin has been the subject of several intensive studies. Those studies and their focus area are shown in table Springbrook-3.

Table Springbrook-3: Water Quality Studies of the Springbrook Subbasin

Investigator (Date)	Study Title	Focus Subject
Renton (1993)	Black River basin water quality management plan	Water quality, erosion and sedimentation
Parametrix (1992)	Mill Creek erosion control project	Water quality in upper Mill Ck. And literature review
Herrara (1990)	City of Kent Water Quality Assessment	Water quality
Parametrix (1990)	Mill Creek water quality monitoring report	Water quality
Wilsey and Ham (1972)	Mill Creek answer book	Water quality
Entranco (1992)	Garrison Creek wetland/erosion control facilities	Water quality and erosion
Resource Planning Associates and Herrara (1991)	City of Kent water quality program 1992-1996	Water quality
Bortz (1981)	Streambed, habitat, beneficial use and recommendations towards enhancement of Kent stream ecosystems	Water quality

These studies are important in that many report similar water quality parameter concerns (table Springbrook-4). Concentrations of metals that acutely affect salmonids differ according to site specific water chemistry parameters. Copper has been demonstrated to have adverse impacts on rainbow trout and chinook fry at 20 and 18 ug/liter respectively. Lead has been demonstrated

to have adverse impacts to salmonids at levels <20 ug/liter while zinc levels at 10, 9 and 103 ug/liter adversely impact 7 gram rainbow trout, cutthroat trout and chinook fry respectively.

Table Springbrook-4: Reported Concentrations of Metals of Concern in the Springbrook Creek Subbasin

Metal	Water Body	Concentration (ug/liter)	Flow Conditions	Reference
Copper	Springbrook Ck.	2.7 – 3.9	base flow	Renton 1993
Copper	Springbrook Ck.	10.8 – 11.3	Storm flow	Renton 1993
Copper	Springbrook	5.0	NA	Harza 1995
Copper	Mill Creek	4.0 – 12.0	Storm flow	Parametrix 1990
Copper	Mill Creek	(1)	NA	Bortz 1981
Lead	Springbrook Ck.	0.5 – 0.7	Base flow	Renton 1993
Lead	Springbrook Ck.	8.1 – 11.7	Storm flow	Renton 1993
Lead	Mill Creek	2.0 – 14.0	Storm flow	Parametrix 1990
Lead	Springbrook Ck.	2.7	NA	Harza 1995
Lead	Mill Creek	(1)	NA	Bortz 1981
Zinc	Springbrook Ck.	117.0 – 154.0	Base flow	Renton 1993
Zinc	Mill Creek	19.0 – 88.0	Storm flow	Parametrix 1990
Zinc	Mill Creek	1560.0	Base flow	Bortz 1981
Zinc	Springbrook Ck.	32	NA	Harza 1995
Cadmium	Mill Creek	< detection limit	NA	Parametrix 1990
Cadmium	Mill Creek	(1)	NA	Bortz 1981
Chromium	Mill Creek	(1)	NA	Bortz 1981

(1) State water quality parameters were exceeded but no values provided.

One of the single most important environmental variables influencing the reproductive success of salmonids is water quality. Poor water quality may be responsible for direct mortality or indirectly impact adult salmonids through increasing metabolic demands.

The Springbrook Creek subbasin appears on the EPA Clean Water Act 1996 and 1998 303(d) lists for water quality violations (Table xxx NOTE: This table will be included at a later date) for high temperature and low dissolved oxygen levels at multiple locations low in the subbasin. Low dissolved oxygen levels have been reported by numerous sources at sampling locations throughout the subbasin and appear to be a chronic seasonal occurrence. These water quality violations are believed to be the result of low water flows, lack of adequate riparian vegetation and shade, point and non-point pollution sources (Harza 1995). Low dissolved oxygen levels in water decreases the swimming stamina and respiratory efficiency in fall chinook salmon when levels are below 5 mg/l (Smith et. al 1971).

The presence of heavy toxic metals is thought to work synergistically with other water quality environmental stresses to further compromise fish health. A low pH in water results in an increase in the amount of metal ions in solution. This in turn increases the potential for juvenile and adult salmonids to be adversely affected by the toxic effects of these heavy metals.

During 1994, adult chinook salmon entered the BRPS between September 17 and October 22. Water temperatures during this same time period were as high as 19.5 C at the Mill Creek USGS gage and 20.2 C at the BRPS location. At the same time, the dissolved oxygen levels at the Mill Creek gage averaged 4.5 mg/l with a range from 0.9 mg/l to 10.1 mg/l. Temperature, dissolved

oxygen and percent saturation levels at the lower levels of this rangeare lethal to adult chinook salmon, juvenile coho, cutthroat and steelhead (Piper et al 1982).

In 1994, coho salmon that entered the Springbrook Creek subbasin before October 26 would have faced similar lethal water quality issues as chinook. It was only after the first large storm of the season that year that most water quality parameters began to improve. However, Parametrix (1990) suggested that concentrations of heavy metals in Mill Creek increase during the first storm event after a dry period. The rapid influx of heavy metals at this time would almost certainly have placed these adult coho under additional stress and compromised their reproductive success.

Investigators in the 1993 Harza habitat survey noted dead trees and shrubs on both sides of Mill Creek in the vicinity of the West Valley Highway and South 204th Street. A culvert with a reddish discharge was observed entering Mill Creek immediately upstream of the area of dead trees. Subterranean iron was also observed upwelling in Mill Creek immediately downstream of 76th Avenue South.

LAND USE

No information.

NON-NATIVE SPECIES

ANIMALS

Eight species of fish were captured during the 1993 Harza habitat surveys. Pumpkinseed sunfish (*Lepomis gibbosus*) were the only non-native species identified. A total of 26 pumpkinseed sunfish were captured, of which 25 were captured in Mill Creek and 1 in Springbrook (downstream of the confluence with Mill Creek). Pumpkinseed sunfish are also reported to be present in the detention pond in upper Mill Creek in the vicinity of 104th Avenue SE.

PLANTS

Reed canarygrass (*Phalaris arundinacea*) is abundant throughout this subbasin and was historically removed by dredging. Although it can provide some streambank erosion protection functions, it generally affords minimal fish habitat and prevents native shrubs and trees from becoming established in the riparian habitat zone.

Private property owners have planted riparian areas in non-native species of maple, willow and cherry trees in limited sections of the Middle Fork Garrison Creek.

Japanese knotweed (*Polygonum cuspidatum*), an aggressive non-native weed that spreads rapidly in moist environments, was found in a wetland associated with Springbrook Creek between Highway 167 and Talbot Road.

HYDROMODIFICATION

The entire Springbrook Creek subbasin has been adversely impacted by floodplain modifications. The most significant of which is the Black River Pump Station. BRPS initially

consisted of an earthen dam constructed in 1958. The dam was located on the Black River approximately 1,000 feet upstream of the confluence with the Green River and designed to control outflows from the Black River and prevent flows on the Green River from backing up into the Black River/Springbrook Creek floodplain during periods of high water. In 1972, the U.S. Soil Conservation Service (SCS) replaced the dam with the BRPS, to provide a means of releasing flood flows from the Black River/Springbrook Creek system when the Green River is at high flows. Currently, the BRPS is operated and maintained by King County Surface Water Management.

During flood periods on the Green River, the pumping station acts as a dam, preventing water from backing upstream into the Black River and the wide valley floor of the lower Springbrook Creek subbasin. Water levels downstream of the pumping station range from –4.0 to +21.5 feet MSL, depending on tidal conditions and the water level of the Green River. Water surface elevations upstream of the pumping station are normally held in the range of 0.0 to 2.0 feet, but can reach as high as 13.0 feet. The pumping station consists of a series of eight pumps, and are designed to pass flows of up to 2,945 cfs. Two large pumps with a capacity of approximately 1,028 cfs are also present, but have not yet been brought on line.

The BRPS represents a barrier to the upstream passage of salmonids. In addition, the ability to control the water surface elevations upstream of the BRPS often results in situation where the downstream water surface is higher than the upstream water surface. In order to pass upstream and downstream migrating salmonids around the structure, a unique fish passage system has been constructed and is in operation. A combination of a fish ladder and fishway chute are used for upstream passage. Fish migrating downstream are diverted around the pumps using an air lift pump to raise the fish to the downstream water levels. The general layout of the BRPS and fish passage facilities are illustrated by Figure Pass-11.

The upper reaches of Springbrook Creek shown in Williams (1975) have been diverted into Mill Creek (09.0015). The date and reason for this diversion are not clear to individuals involved in this report.

OFF CHANNEL HABITAT

Information describing the current or historic extent of the floodplain in the Springbrook Creek subbasin is scarce, and it is unknown whether channelization, bank armoring or disconnection of off-channel habitats have influenced off-channel habitat connectivity.

No information was made available during the course of this report to assess either the historic or existing extent or condition of off-channel habitat in the Springbrook Creek subbasin.

FLOODPLAIN CONNECTIVITY

The Springbrook Creek subbasin is isolated from the Green River floodplain by the Black River Pump Station discussed previously in this chapter. While there was no direct information provided during this report, it is evident that the creeks in this subbasin have undergone extensive alterations to their historic stream channels by their drainage ditch appearance, right angle turns along property lines and straight channel lines.

KEY FINDINGS AND IDENTIFIED HABITAT-LIMITING FACTORS

- Historically, it is believed that these creeks were important areas of refugia to anadromous salmonids that reared year round in the Green River basin.

- Water quality is degraded throughout much of this subbasin.

- There is no functioning riparian habitat throughout the lower reaches of Mill and Springbrook Creeks. This absence of this habitat contributes to the lack stream channel diversity, complexity and ultimately successful salmonid rearing capabilities.

- The Black River Pump Station is a partial fish passage barrier and does not meet current fish screening criteria. Adult salmonids that migrate upstream of this structure cannot migrate back into the mainstem Green River because of facility design.

- There are several known barriers to adult salmonid fish passage in Springbrook, Mill and Garrison Creeks. Some of these barriers are seasonal and/or dependent on annual precipitation patterns.

- Degraded water quality throughout the lower reaches of Springbrook and Mill Creeks adversely impact adult chinook and coho reproductive success along with coho, cutthroat and steelhead juvenile survival.

DATA GAPS

- No information was available during the course of this report to assess either the historic or existing extent or condition of off-channel habitat in the Springbrook Creek subbasin.

- The extent to which plant and animal non-native species are impacting salmonid survival is not fully understood. A comprehensive assessment of non-native species needs to be initiated, completed and action plan developed.

- The diversion of the upper reach of Springbrook Creek into Mill Creek appears to occur in the vicinity of downtown Kent. Information was not readily available regarding the diversion method which could be a barrier to upstream access.

- There was no land use information easily accessible for use in this report.

EARLY ACTION RECOMMENSATIONS

- Conduct a comprehensive fish barrier survey to determine the full extent of lost habitats

- A quantitative baseline habitat inventory needs to be undertaken.

LIST OF TABLES

Table Springbrook-1: Summary of Various Habitat Types in the Springbrook Creek Subbasin

Table Springbrook-2: Springbrook Creek Subbasin Fish Passage Barriers

Table Springbrook-3: Water Quality Studies of the Springbrook Subbasin

Table Springbrook-4: Reported Concentrations of Metals of Concern in the Springbrook Creek Subbasin

3.4 MILL CREEK AND MULLEN SLOUGH SUBBASIN

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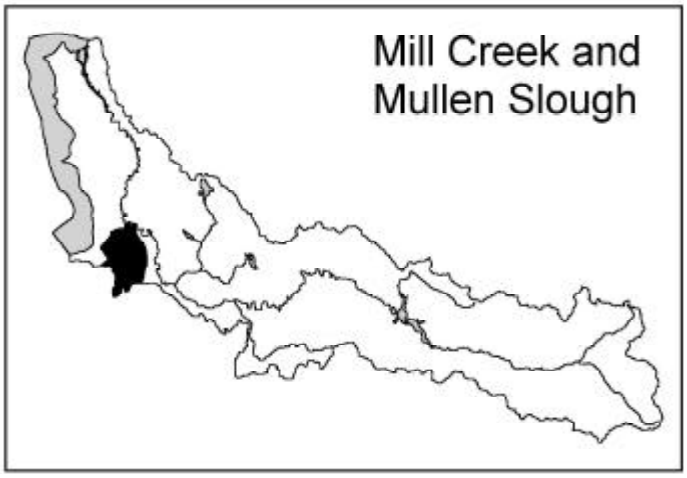
3.4 MILL CREEK AND MULLEN SLOUGH SUBBASIN



PHYSICAL DESCRIPTION

SUBBASIN

For the purposes of this report, the Mill Creek (09.0051; sometimes referred to as Hill Creek in literature sources) and Mullen Slough (09.0045) subbasin is defined as an area bordered by Kent to the north, Algona to the south, the valley wall to the west, and the Green River channel to the east. It includes all areas and tributaries that drain into:

- Mill Creek and tributaries (09.0052, 09.0054, and 09.0055);
- Mullen Slough and tributaries (09.0046, 09.0047, 09.0048, and 09.0049);
- Midway Creek (09.0041) and tributary (09.0043); and
- The northeast Auburn Drainage Systems (09.0056, 09.0058, 09.0059, 09.0060, and 09.0065) that flow independently into the Green River.

All of these drainages are included in this chapter because they share a similar geographic location and a sizeable floodplain immediately adjacent to the mainstem Green River. Together, these tributaries constitute the second-largest subbasin to the Lower Green River.

STREAM COURSE AND MORPHOLOGY

Mill Creek is a left-bank tributary that joins the Green River at approximately RM 23.9. Its stream length is approximately 8.35 miles (Williams 1975). The basin is comprised of two distinct physical settings.

In the western half of the Mill Creek subbasin, rolling hills rise to elevations of 300 – 400 feet above the valley floor. In this area, the origins of stream courses are often not well defined. Four significant lakes (Dolloff, Fenwick, Geneva and Star) are present, along with several smaller ponds (such as Bingaman Pond (09.0049)), and wetlands. These lakes and seeps are the headwater sources for Mill Creek, Midway Creek, Mullen Slough and their respective tributaries. Creeks originating from these upland sources drop abruptly through sharply defined steep canyons to the valley floor, where stream gradients flatten quickly. Typically, these canyons are short and have high gradients. The notable exception is Mill Creek, which drops through a sizeable ravine (Peasley Canyon) before entering the valley floor.

The eastern half of the subbasin lies on the valley floor and stream gradients are virtually flat. Mill Creek and Mullen Slough are the primary drainage courses of this section. Historically, both Mill Creek and Mullen Slough conveyed water received from nearby wetlands to the mainstem Green River, served as important flood storage areas, and provided refugia to anadromous salmonids from winter high flows.

Several studies have examined the Mill Creek subbasin in recent years. The most pertinent of these studies are outlined in the table Mill-1 below. The objective of most of these studies has been flood control (some even refer to Mill Creek as a "conveyance channel" (King County, undated) It is only recently that restoration initiatives have been examined. There have been at least eight other studies (table Mill-1) that also examined hydraulic issues in the Mill Creek subbasin.

Table Mill-1. Summary of Some Pertinent Mill Creek Subbasin Studies.

Study Title	Sponsor/Author	Study Objectives
West Side Green River Watershed Workplan (1965)	Soil Conservation Service, King County, Auburn, Kent, Tukwila, Renton	Flood protection
Urban Drainage Study for the Green River Valley (1974)	Seattle District Corps of Engineers	Flood control
Mill Creek Basin Profile (1980)	Basin Technical Committee	Flood control
Mill Creek Water Quality Management Plan (1993)	King County and Washington Department of Ecology	Flood and water quality issues.
Reconnaissance Report No. 4, Mill Creek Basin (1987)	King County	Compilation of flooding, erosion, water quality and habitat problems
Mill Creek Basin Study (~ 1988)	King County	Flood control
Mill Creek Flood Control Plan (Phase II)	King County, Auburn and Kent	Flood control
Mill Creek Basin, Aquatic Resources Restoration Plan (1997)	Auburn, Kent, King County, Environmental Protection Agency, Corps of Engineers	Guidance for aquatic resource restoration and enhancement

SALMONID USE

MILL CREEK

The known freshwater distribution of anadromous salmonids is depicted in the report Appendix. Coho, chum, and winter steelhead adults have been observed spawning in Mill Creek (Washington Department of Fish and Wildlife *Spawning Ground Survey Database* 1998;

Malcom 1999). Because of the low stream gradients and the anthropogenic barriers to anadromous fish in Mullen Slough and its tributaries, spawning ground surveys are not routinely conducted in this system. Juvenile coho, chum, winter steelhead, cutthroat and chinook have been captured in Mill Creek (Williams 1975; Malcom 1999; Schneider 1999).

MULLEN SLOUGH

Juvenile coho salmon and cutthroat and rainbow trout are documented as using Mullen Slough and portions of its tributary system (Malcom 1999; Shannon and Wilson 2000). Harza (1999) notes chinook and chum salmon juveniles present near the confluence with the Green River (from pers. comm. with (b) (6) June 9, 1998).

FACTORS OF DECLINE

FISH PASSAGE

MILL CREEK

Historically, anadromous fish migrated up Mill Creek at least as far as approximately RM 6.7. Portions of the short, high-gradient canyons of this subbasin may have been accessible to anadromous salmonids.

However, numerous road culverts block access. For example, tributary 09.0049 (which flows into and out of Bingaman Pond) is blocked by three road culverts (45th Avenue South, 46th Avenue South, and 55th Avenue South). Coho salmon and cutthroat trout habitat suitable for spawning and rearing has been reported upstream of Bingaman Pond (b) (6) pers. comm.). Currently, an impassable culvert at approximately RM 5.0 blocks anadromous fish passage. The stream reaches of Mill Creek upstream of Peasley Canyon Way South are not currently accessible to anadromous salmonids due to a road culvert and King County paving of the streambed immediately upstream of the culvert. The concrete trapezoidal channel has been identified as a complete barrier to all upstream fish passage ((b) (6) pers. comm.).

Stream channel constrictions as a result of debris left by illegal dumping has been implicated in some reaches as a serious problem (Auburn et al. 1997).

MULLEN SLOUGH

Barriers to resident and anadromous fish populations are significant throughout Mullen Slough and its tributaries. A potential low-flow barrier occurs at the confluence of Mullen Slough with the Green River. The cause of this potential barrier is not fully understood but is believed to be from a combination of wetland filling, water withdrawal, and the hydrologic maturity of the watershed.

Other flow barriers (channel encroachment by reed canary grass, and beaver dams) occur throughout the valley floor above and downstream of 277th Avenue bridge.

Anthropogenic barriers in the form of hanging culverts occur at the base of the valley floor for tributaries 09.0046 and 09.0049. Several culverts may be partial or complete barriers to anadromous fish during some flows occur in the agricultural lands of the valley floor. In addition, the wetland above 277th Avenue may impede fish access to the upper reaches of streams 09.0045, 09.0047, and 09.0048.

RIPARIAN CONDITION

A comprehensive riparian assessment has not been completed in this subbasin. The riparian habitat conditions that have been examined, of Mill Creek vary from fair to poor, with some reaches rated as high possibility of recovery while others as unrecoverable (Auburn 1997). However, the 1979 report, *River of Green* (King County 1979) provides an important insight to the habitat losses of the previous 18 years from its publication date.

The riparian areas in these streams do not meet any criteria of properly functioning riparian habitat. Development has greatly eliminated functioning riparian habitat along the stream courses. Once it enters the valley floor, Mill Creek riparian habitat generally consists of small stands of early-growth deciduous trees and borders of non-native shrubs and grasses. Remnant stands of native vegetation are rare. This fragmentation effectively limits where interconnections between formerly functioning elements of the larger ecosystem can be restored. The lack of a functioning riparian habitat is a major limiting factor to natural salmonid production in these streams.

LARGE WOODY DEBRIS

Comprehensive surveys for the presence of LWD were not located during the development of this report for this subbasin. However, it was the professional judgement of fisheries biologist and ecologists involved in the development of this document (Green River Technical Advisory and Factors of Decline Group, 2000) that LWD is extremely limited within the anadromous zone of this subbasin.

Additionally, the current status of riparian habitats within the anadromous zone generally precludes any recruitment of LWD within the next 80 to 100 years. There is more potential for recruitment of LWD from the ravines of the valley wall, as they contain relatively mature stands of a mixed coniferous/deciduous forest.

HYDROLOGY

MULLEN SLOUGH

Mullen Slough has its headwaters from several small streams originating from the uplands along the west side of the Green River valley wall. Three such small streams originate from the outflow of Bingaman Pond, Star, and Fenwick lakes. The later stream flows intermittently while the former flow throughout the year.

The remainder of the system is contained within the valley floor, where it maintains its historic low gradient in the valley floor. Historically it is believed to have functioned as important over-wintering refugia for anadromous salmonids from flood flows.

SEDIMENT CONDITION

MILL CREEK

Erosion in the upper reaches, especially in the ravines along the valley wall has been identified as an adverse impact (King County, undated; King County 1993; King County 1996).

Sedimentation problems in the lower reaches were identified in a former report. Since the last major rain events (1990, 1996), extensive amounts of stream-associated sediments have been transported downstream and areas of the Mill Creek floodplain, and wetlands in Auburn and Kent have been filled and/or eliminated as part of development in the lower valley. This filling of wetlands may cause low-lying and unfilled areas to flood during the next major storm event. The effect on fish could include stranding out of the channel and pollutant collection by the floodwaters.

Some contributory factors include sediments from borrow pit and construction sites, erosion along the streambank in Peasley Canyon, and runoff from urban and agricultural sources.

MULLEN SLOUGH

Because of its low gradient, only limited areas of suitable spawning gravels were believed to have been historically present. These gravels would have been in areas of upwelling groundwater and above existing anadromous barriers that have long since disappeared.

Today, sedimentation problems believed to originate from nearby agricultural lands and their conversion to light industry continues to plague this stream. The slough suffers from extensive ditching in its lower reaches and can best be characterized as a drainage ditch in this area. Exposed banks are common in both the ravines and valley floor and most likely are a source of turbidity and sedimentation. Sediments in the lower reaches of Mullen Slough have high biological oxygen demand and nutrient concentrations.

WATER QUALITY

MILL CREEK

Mill Creek is designated as a Class A stream by the Washington State Department of Ecology (WDOE). However, water quality has become so degraded throughout the Mill Creek system that it appears on the federal Environmental Protection Agency (EPA) 303(d) list in 1996 and the 1998 (see table Mill-2) candidate list for numerous water quality excursions beyond acceptable limits.

Table Mill-2. EPA Clean Water Act 303(d) 1998 Candidate List Parameters and Locations for Mainstem Green River Tributaries (WRIA 9).		
Stream	**Sampling Location (RM)**	**Parameter**
Springbrook	1.5	Dissolved oxygen
	1.5	Temperature
	0.1	Temperature
	0.1	Dissolved oxygen
Mill Creek	1.4	Temperature
	0.3	Dissolved oxygen
	0.2	Temperature
	0.2	Dissolved oxygen
	1.0	Dissolved oxygen
	2.2	Dissolved oxygen
	2.2	Temperature
Mullen Slough	0.5	Dissolved oxygen
	0.5	Temperature
	1.6	Dissolved oxygen
	1.6	Temperature
Newaukum Creek	5.2	Dissolved oxygen
	10.1	Dissolved oxygen
Soos Creek	1.0	Dissolved oxygen
Little Soosette Creek	3.1	Dissolved oxygen
	3.9	Dissolved oxygen
Little Soos Creek	3.2	Temperature
	4.7	Dissolved oxygen
	10.5	Dissolved oxygen
Gale Creek	0.3	Temperature

Water quality was also cited as a degraded by several studies including the Municipality of Metropolitan Seattle (Metro) Draft Priorities for Water Quality (Metro 1989), and the Mill Creek Water Management Plan (Metro 1993). The sampling station at the mouth of Mill Creek maintained by Metro showed the lowest overall water quality of the 44 sites monitored in the Green River valley (Metro 1989). The stream exhibits water quality degradation through:

- Low dissolved oxygen levels;
- Seasonal high water temperatures;
- Streambank erosion and associated water turbidity; and
- High nutrient concentrations (i.e., phosphorus, nitrate, and ammonia).

WDOE and EPA standards for dissolved oxygen, water temperature, turbidity and fecal coliform bacteria are commonly not met. While fecal coliforms are typically of greater concern as a human health threat, they are an indicator of overall water quality and biological oxygen demand (BOD) (King County 1993).

Additionally, especially associated with storm events, the stream water has elevated levels of heavy metals which exceed state and federal water quality standards (King County 1993).

Seasonal high stream water temperatures are linked to low flows, low water velocity and lack of riparian canopy.

An extreme dissolved oxygen sag has been detected between West Main Street in Auburn and 29th Street NW. Dissolved oxygen levels in this reach drop to as low as 3 mg/l. The minimum dissolved oxygen level for salmonids is considered to be 5 mg/l and the state water quality standard is 8 mg/l. Factors believed to be contributing to these low dissolved oxygen levels include;

- Demand from accumulated organics trapped in the reed canarygrass;
- High BOD from pollutants;
- High benthic demand;
- Low gradient of the stream that results in low reaeration rates; and
- Increased seasonal stream temperatures due to lack of suitable canopy (which has also been identified as the primary factor affecting stream temperatures (King County 1996)).

Water quality degradation from point and non-point pollution sources as well as turbidity caused by land clearing and development has also been identified as requiring corrective action (Auburn et al. 1997).

MULLEN SLOUGH

Mullen Slough exhibits much of the same water quality degradation as Mill Creek. Several water quality studies (Shapiro 1989; King County and Ecology 1993) point to exceedance of state and federal standards for temperature, dissolved oxygen, fecal coliform, turbidity, un-ionized ammonia, and total phosphorous and nitrate. Water quality studies (Shapiro 1989)suggest that heavy metals are in lower concentrations than Mill Creek.

The slough appears on EPA's 1996 303(d) list and the 1998 candidate list for excursions beyond allowable criteria for both dissolved oxygen and water temperature. These temperature and low dissolved oxygen violations occur during seasonal low flows in the late summer in Mullen Slough because:

- It is a low-gradient stream;
- Much of its channel is choked with thick concentrations of reed-canary grass;
- It lacks riparian canopy; and
- Its historical wetlands have been removed.

LAND USE

MILL CREEK

Throughout the western area of this subbasin, increased residential development has removed large tracts of forested areas. Impervious surfaces in the Mill Creek subbasin were estimated at 20 percent in 1986, with total build out predictions of 45 percent in upland areas and 70 percent in lowland areas (Author Unknown 1988). These figures were for total impervious areas and are not reflective of effective impervious areas.

MULLEN SLOUGH

Impervious surfaces are significant in the upper reaches of Mullen Slough.

NON-NATIVE SPECIES

FISH

A single large channel catfish (*Ictalurus spp)* has been captured in Mill Creek ((b) (6) pers. comm.). Other warmwater fish species, including yellow perch (*Perca fluviatilus*), pumpkinseed sunfish (*Lepomis gibbosus*), goldfish (*Carassius auratus*), black crappie (*Pomoxis nigromaculatus*), largemouth bass (*Micropterus salmoides*) and smallmouth bass (*M. dolomieui*) are found in many of the headwater lakes of this subbasin ((b) (6) pers. comm.). The lakes that these fish typically inhabit do not have any structures (screens) that would prevent them from migrating out of the lake or being washed out during a period of high flow. Thus, it is assumed that these fish are present in Mill Creek, but their numbers are significantly small enough to not turn up in previous electroshocking surveys, and as such they are not believed to be a limiting factor.

PLANTS

Reed canarygrass (*Phalaris arundinacea*) and Himalayan blackberry (*Rubus procerus*) are abundant throughout this subbasin. King County conducted a mapping project to assess the existing and potential threats of invasive, non-native aquatic plants in King County Lakes during 1994 and 1995. That report, published in 1996 (Walton 1996) examined lakes Dolloff, Geneva and Star in this subbasin, and found Eurasian watermilfoil (*Myriophyllum spicatum*) in Dolloff and Star lakes. However, these are currently outside the geographic distribution of naturally producing salmonid populations and therefore do not have an immediate adverse impact to salmonids. A 1999 survey of Lake Geneva found Purple loosestrife (*Lythrum salicaria*) and reed canarygrass (King County 2000).

HYDROMODIFICATION

MILL CREEK

The historic stream channel of Mill Creek and its tributaries have been significantly altered and constrained in a variety of ways. In some places, they are diverted from the natural channel and placed into straight channels or ditches. Often this was done to meet the needs of landowners so

that the creek would be the defining property boundary line. At other times, channels were altered during road construction to facilitate drainage.

The construction of State Route 167 and the expansion of the associated road network further constricted the ability of Mill Creek to migrate laterally. In the mid 1980s, the reach of Mill Creek from 29th Street N.W. to 37th Street N.W. was relocated parallel to SR 167 to allow construction of the Puget Power Christopher Substation as part of the Mill Creek Restoration (relocation) Plan. The new 100-year flood capacity channel was slightly meandered, and revegetated with shrubs and trees. More recently, the stream reach from 37th Street NW to the north was relocated in a similar fashion to allow a warehouse construction ((b) (6), pers. comm.).

Mill Creek has at a minimum 21 road crossings that are comprised of a mixture of culvert and bridge types. The construction of State Route 167 resulted in the movement of Mill Creek from its historic channel into its current location.

MULLEN SLOUGH

The entire Mullen Slough has undergone a systematic change from historic uses. Historically these channels and streams are thought to have been important flood storage uses. Today, the upper tributary reaches, ravines, and hillsides have been culverted and channelized by suburban development. Reaches along the valley floor are also heavily channelized, although few road crossings and culverts exist in lower Mullen Slough. The stream channel has three bridge crossings; two at the mouth and one on 277th Avenue.

OFF CHANNEL HABITAT

MILL CREEK

Wetlands temper peak flows by slowly releasing storm waters, protecting vital fish habitat from damages due to erosion and sedimentation.

However, much of Mill Creek's historical wetland complexes have been divided up and drained/ditched to improve agricultural lands or development. As noted in Land Use (above), this subbasin's high level of impervious surfaces causes adverse impacts to streams (Booth 1997).

Approximately 2,400 acres of remaining wetlands were inventoried in 1996/97, and the type and acreage are shown in table Mill-3.

Table Mill-3. Existing Wetland Types and Acreage in Mill Creek Subbasin.	
Wetland Type	**Acreage**
Emergent	1,870
Scrub-shrub	108
Forested	236
Open water	213
Total	2,427
Source: Auburn et al 1997.	

The majority of the forested and open water wetlands are in headwater and hillside areas of the basin. Approximately half of the open water acreage (101 acres) is contained in the four major lakes in this subbasin.

Of the 1,870 acres of emergent wetlands, the majority was in some type of agricultural use in 1996-97. The King County Farmland Preservation Program (KCFPP) preserves approximately 900 of those acres for agricultural purposes only. Approximately 650 of the KCFPP acres contain wetlands. These 650 wetland acres represent the last remaining large tract of land in the entire subbasin that is free of impervious surfaces. It is therefore an important potential area for salmonid stream ecosystem restoration.

MULLEN SLOUGH

For anadromous salmonids, the low-gradient lower river streams such as Mullen Slough were historically more important as over-wintering refugia from flood flows than as suitable spawning habitats. In the larger ecosystem, these streams provided an important tool for anadromous salmonids survival. In addition, palustrine streams like Mullen Slough most likely offered good rearing habitat for anadromous and resident salmonids during all but the driest summer months.

Currently, because of extensive ditching and water diversions, much of the habitat complexity of Mullen Slough is lost and the system can no longer properly function at its historic level of productivity.

FLOODPLAIN CONNECTIVITY

MILL CREEK

Within the Mill Creek subbasin, Auburn et al. (1997) identified 14 corridor wetland sites that were suitable for restoration.

Under current conditions, flooding of this subbasin is strongly influenced by backwater effects of the mainstem Green River, and as a result of locally generated runoff. High flows in the Green River can result in the inundation of up to 900 acres of primarily agricultural land in the Mill Creek and Mullen Slough subbasins (Army Corps of Engineers 1997).

MULLEN SLOUGH

Auburn et al. (1997) identified an additional eight off-corridor wetland sites that were suitable for restoration in the Mill Creek and Mullen Slough subbasins. Flooding in Mullen Slough is caused by either high water levels in the mainstem Green River that cause water to back up the

tributary or as a result of increased surface flows due to increases in impervious surfaces in the subbasin. King County (1996) found that flooding in the backwater sections of Mullen Slough is exacerbated by the increasing volumes and rates of runoff from new development in the subbasin, in both the valley floor and upland slopes.

KEY FINDINGS AND IDENTIFIED HABITAT-LIMITING FACTORS

- Mill Creek continue to support spawning of adult coho salmon and juvenile rearing of coho, cutthroat, steelhead, and to a limited extent chinook. Chinook adults were reported to have been observed in Mill Creek in 1999.

- Mullen Slough most likely supports rearing of coho, cutthroat and steelhead along with some cutthroat trout spawning.

- The remaining riparian habitats are fragmented.

- Some of poorest water quality conditions sampled in the Green/Duwamish River occur in Hill Creek and Mullen Slough.

- Water quality is a significant adverse issue impacting anadromous fish productivity and survival.

- Much of the floodplain area is agricultural and within the Farmland Preservation Program.

- Numerous fish blockages are present from degraded water quality, low-flow barriers, and culverts. Unlike many lower Green tributaries, no flap gates or pumping stations are present at the confluence of Mill Creek or Mullen Slough and the Green River.

- Channel relocations have resulted in a simplification of stream channel configuration that limits diversity.

- Impervious surfaces that exceed 20 percent in Mill Creek contribute significantly to storm-associated flood flows.

- Road-associated culverts block anadromous fish access to significant upstream portions of streams in this chapter.

- There is a significant lack of LWD and associated stream habitat complexity throughout the streams in this subbasin.

- Although no quantifiable information was available, it was the professional judgement of the TAG that flood flows due to increased impervious surfaces limit successful salmonid incubation.

- Degraded water quality, streambed condition, invasive and non-native plant species, lack of a properly functioning riparian buffer, channel complexity, floodplain connectivity, and suitable pool quality and quantity all limit natural salmonid production.

DATA GAPS

- Comprehensive barrier surveys need to be initiated in this subbasin.
- Comprehensive base line riparian habitat and bank condition surveys should be initiated.
- An inventory of LWD should be initiated.
- Very little data was found on Midway Creek.
- Historic channel location information needed.
- Comprehensive review of the effects of non-native plant species (reed canarygrass and Himalayan blackberry) on aquatic biota should be documented.

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3.5 EAST HILL TRIBUTARIES OF THE LOWER GREEN RIVER

PHYSICAL DESCRIPTION

SUBBASIN

This chapter will cover the following streams (identified by local names and/or Williams' (1975) catalog number system):

- Olson Creek [09.0061];
- Lea Hill Creek [09.0069];
- Cobble Creek [09.0068]; and
- The Hillside Drainages [09.0068A-G].

In addition, there are numerous unnumbered channels and ditches that are included where information on them was provided.

Booth et al. (1994) summarized many of the conditions of these tributaries, and most of the information in this chapter is attributed to that report unless otherwise noted.

The boundaries of these creeks follow drainage basin lines but can be defined as those areas east of the Soos Creek subbasin, south of the Mill Creek subbasin and tributaries west and south to the Green River from approximately River Mile 28.5 to 30.0. These eastern tributaries that flow into the Lower Green River share many of the same attributes, including headwater locations on the east Kent plateau, drainage basin size and land use.

Historically, all of these stream systems traversed old-growth coniferous forests, down the relatively steep hillsides into the Green River Valley where stream gradients flattened before flowing through extensive wetland complexes prior to entering the mainstem Green River. The old-growth forests were removed beginning approximately 140 years ago, and the valley floor was then converted to agricultural purposes. During the last 25 years, this subbasin has been rapidly urbanized, a trend that continues today. Most of the wetlands historically found on the valley floor have been filled, drained or otherwise altered.

STREAM COURSE AND MORPHOLOGY

OLSON CREEK

Olson Creek drains approximately 1,022 acres, with approximately three miles of defined stream channel. Most of this stream system lies on the upland plateau between 350 and 500 feet in elevation. Williams (1975) identified two tributaries (09.0064 and 09.0063).

Olson Creek is formed from surface water of two Class 2 wetlands (King County Sensitive Areas Map Folio—Wetland Criteria 1990). A third wetland drains into the combined flow of the first

two at a series of constructed ornamental ponds at RM 1.08 just before the creek descends steeply through Olson Canyon to the valley floor.

LEA HILL CREEK

Lea Hill Creek drains approximately 406 acres and has approximately one mile of defined stream channel. It enters the left (east) bank of the Green River at approximately RM 30.15. Most of the subbasin lies on the upland plateau between 400 and 450 feet in elevation.

Its primary source is a forested swamp on the north side of SE 312th Street immediately upstream of 116th Avenue S.E. A secondary source lies in the vicinity of 112th Avenue S.E., where two large gullies have eroded from the road's end into the main stream channel.

COBBLE CREEK

Cobble Creek drains approximately 165 acres and is less than one mile long. Ames (1981) identified this creek as entering the right (east) bank of the Green River at RM 30.05. Most of the subbasin lies in areas of the valley floor and east wall.

The source of Cobble Creek appears to be surface runoff.

THE HILLSIDE DRAINAGES

The Hillside Drainages are a series of short streams originating a short distance above the bluff line. They are mentioned here because of their historic effects rather than current utilization by anadromous and resident salmonids.

SALMONID USE

The known freshwater distribution of anadromous salmonids is depicted in the report Appendix.

Historically, these creeks were thought to contain year-round populations of coho salmon, cutthroat trout and steelhead trout.

Williams (1975) either did not list these streams, or indicated that their utilization by anadromous salmonids was unknown. The WDFW Spawning Ground Survey Database (1999) does not note the presence of adults of any salmonid species in any of these creeks. Juvenile coho have been observed in several creeks (Booth 1994), but are probably the result of hatchery fry releases (Baranski 1999).

FACTORS OF DECLINE

FISH PASSAGE

OLSON CREEK

The upper limit of anadromous fish access on Olson Creek is defined by a natural 10-foot-high waterfall located at RM 0.49.

A culvert under Green River Road has been identified as a partial barrier at approximately RM 0.05.

An alluvial fan episodically builds out where Olson Creek enters the mainstem Green River channel (see Sediment Condition—Olson Creek). The alluvial fan may form a temporary access barrier until it erodes away each fall.

LEA HILL CREEK

A near-vertical 6- to 8-foot-high waterfall at RM 0.75 marks the historic upper extent of anadromous access. Downstream of this point, fish passage barriers are numerous throughout the stream. Within the alluvial fan between RM 0.13 and 0.25, loss of channel definition may cause temporary passage barriers depending on seasonal flows. The large concrete pipe under Green River Road (RM 0.13) periodically fills with sediment and small organic debris that can block anadromous fish passage.

COBBLE CREEK

A perched culvert blocks anadromous fish access as it enters the right (east) bank of the Green River at RM 30.05.

THE HILLSIDE DRAINAGES

In their original configurations, these drainages would have been important temperature and flooding refugia for overwintering anadromous salmonids. At present, upstream movement of salmonids from the Green River mainstem into many of these tributaries is blocked, and most of the remaining utilization by salmonids is the result of hatchery supplementation.

RIPARIAN CONDITION

OLSON CREEK

In the stream reach downstream of the confluence with 09.0061B, Olson Canyon widens and the riparian corridor consists of a deciduous second-growth forest. Between RM 0.65 and 0.17, the riparian corridor is somewhat intact and better functioning. However, downstream of RM 0.17, Olson Creek lacks any functioning riparian cover.

LEA HILL CREEK

The riparian habitat varies considerably throughout the Lee Hill Creek channel system. Second-growth coniferous and deciduous trees are present within the headwater wetland. Dead coniferous trees in one portion of the wetland are evidence of recent hydrologic changes. Sometime between 1981 (when the King County Wetlands Inventory was prepared) and 1994 (when King County carried out a reconnaissance study in this group of subbasins), approximately 20 percent of this headwater wetland was eliminated during the construction of the Auburn Hills Mobile Court.

At approximately RM 0.78, the stream channel begins a rapid descent to the valley floor through a high-gradient ravine. Historically a mature old growth coniferous forest, this uneven-aged

second growth deciduous forest presently provides adequate shading for the creek. Once the creek reaches the valley floor, the riparian zone largely consists of a narrow to nonexistent band of deciduous trees, willows and non-native plant species including reed canarygrass and Himalayan blackberry.

Downstream of SE 116th Street, the stream channel is confined within a 70-foot-wide forested corridor. Lawns border the edge of the stream in several places and there is no intact riparian canopy.

COBBLE CREEK

The riparian habitat in this stream ranges from fair to degraded.

THE HILLSIDE DRAINAGES

As can be expected given current levels of urbanization in these subbasins, current riparian habitats range from degraded to fair.

LARGE WOODY DEBRIS

Olson Creek

Remnant old-growth coniferous stumps are still present in the riparian corridor and streambed downstream of the confluence of Olson Creek with 09.0061B. However, most of the remaining LWD in the stream is small and of poor quality, suggesting that LWD sources have decreased and/or LWD has been deliberately removed from the stream channel over the past hundred or so years. The channel character changes in the vicinity of RM 0.3 – 0.4, where incision has been less than one foot over the last several decades. Instream LWD is more abundant although no counts or volume estimates have been made. LWD is again virtually absent downstream of RM 0.17.

Lee Hill Creek

At approximately RM 0.78, Lee Hill Creek descends rapidly to the valley floor through an uneven-aged second growth deciduous forest that provides some degree of LWD recruitment. Numerous old-growth stumps are also present on the hillside and in the creek.

HYDROLOGY

Hydrologic information on these systems is limited at this time.

SEDIMENT CONDITION

In general, Booth's 1994 study determined that sediment quality exceeded state standards. Modeling of study parameters indicates that large-scale future development will likely result in future sediment degradation.

OLSON CREEK

Anthropogenic activities appear to have increased the rate of erosion of the naturally unstable hillslopes within this subbasin, compared to rates of erosion that carved the original stream channel. Increased erosion and sedimentation in Olson Creek is the result of clearing of trees on the steep slopes to enhance views, piping of stormwater by inadequately engineered water conveyance systems, and grading activities. However, no data is currently available to quantify these sediment loads.

At RM 0.48, tributary 09.0061B enters Olson Creek from the north. This tributary descends off the plateau at such a steep gradient that it has eroded a large gully that has delivered several hundred cubic yards of sediment into Olson Creek . The recruitment of this material is believed to be slowing as less loose material remains. The deposition of coarse sediments is particularly evident between RM 0.0 – 0.8. An alluvial fan episodically builds out into the mainstem Green River channel and erodes away each fall.

LEA HILL CREEK

As would be expected of a stream system with such a high impervious area, erosion and sediment loads are major factors contributing to the poor functioning of this stream. The upper portion of the ravine is rapidly incising. Between November 1990 and November 1994 it was estimated that approximately 3,000 cubic yards of sediment had entered Lea Hill Creek from this source alone. Other smaller gullies also exhibit erosion problems. Channel incision and landslides are ubiquitous between RM 0.75 and 0.3. Once the creek reaches the valley floor and the stream gradient decreases, these sediments settle out, forming multiple high-flow channels that wind across an alluvial fan that covers the valley floor between RM 0.25 and 0.13. Spawning gravels are limited and often times cemented with fine sediments that settle out in the low-gradient reaches of the valley floor. The large concrete pipe under Green River Road (RM 0.13) periodically fills with sediment and small organic debris.

COBBLE CREEK

Neither flooding nor erosion are believed to be major problems. No major wetlands remain in the subbasin, and fine sediments along the entire stream channel now cement any remaining gravels.

WATER QUALITY

None of these creeks currently appear on the EPA Clean Water Act 303(d) list for water quality impairments. However, although this list is extensive in scope, numerous bodies of water may not appear on this list due to lack of adequate assessments. Booth (1994) examined a number of water quality parameters and modeled future pollutant loadings within this group of subbasins. Overall, for the parameters examined, stream water quality was determined to exceed state standards. Modeling of these parameters indicates that water quality will continue to exceedence state and federal standards.

LAND USE

All of the tributaries lie either wholly or mostly within the King County Urban Growth Boundary and on lands that are already urbanized, or expected to undergo future urbanization. Typically, urbanization is responsible for the degradation of both the form and function of the downstream aquatic ecosystem, as is the case in all of these systems.

The level of impervious surfaces adjacent to these streams is significant. Table East Hill-1 shows the level of land use as of 1992 and, where available, the projected impervious surface area at grow-out.

EH-1: Land Use of the East Hill Tributaries to the Green River				
	Olson Creek	**Lea Hill Creek**	**Cobble Creek**	**Hillside Drainages**
Wetland	88.1	11.3	0.0	11.2
Forest	202.5	167.7	54.5	748.8
Grass	230.9	34.2	11.0	91.0
Single Family (low density)	469.2	110.5	54.7	296.0
Single Family (high density)	22.3	43.5	44.8	185.0
Multifamily	2.5	2.0	0.0	22.1
Industrial/Commercial	6.2	36.8	0.0	1.3
Total Acres	1021.7	406.0	165.0	1355.4
1994 Total Effective Impervious Surface (%)	3.0	11.7	8.1	5.1
Projected Total Effective Impervious Surface (%)	18.0	33.0	20.0	15.0

OLSON CREEK

Urban development has been slower in the Olson Creek subbasin than in many others addressed in this chapter. Standard provisions in King County and local jurisdiction sensitive area ordinances or similar regulations govern current development. In 1994, the effective impervious area was determined to be 3 percent, primarily in the form of low-density single family residences. However, future zoning would allow the impervious surface to increase to a projected 18 percent (Booth 2000), which will almost certainly have an adverse impact on aquatic resources.

LEA HILL CREEK

Urban development has been extensive in this subbasin. In 1994, 12 percent of this subbasin was covered with impervious surfaces, and impervious area was projected to climb to 33 percent under buildout conditions. This impervious area is largely of multifamily residential developments and two schools.

COBBLE CREEK

Urban development has been substantial in this subbasin. In 1994, the total impervious surface area was measured at 8 percent, and is projected to reach 20 percent at buildout.

THE HILLSIDE DRAINAGES

Development within all of these small watersheds consists of a mixture of low- to high-density single family residences.

NON-NATIVE SPECIES

ANIMALS

Information on the presence of non-native aquatic animal species in these streams is currently unavailable.

PLANTS

Non-native plant species found in the riparian zone of these streams include numerous ornamental species associated with plantings by private and public landowners. Examples include mountain ash (*Sorbus* spp.), blue beech (*Carpinus* spp.), butterfly bush (*Buddleia* spp.), cherry laurel (*Laurocreasus officenalis*), dogwoods (*Cornus* spp.), and non-native rhododendrons (*Rhododendron* spp.). Non-native species of plants more closely associated with riparian and aquatic environments include: Scot's broom (*Cytisus scoparius*), reed canarygrass (*Phalaris arundinacea*) (which is abundant throughout these subbasins), and Himalayan and evergreen blackberries (*Rubus discolor and R. laciniatus*).

HYDROMODIFICATION

THE HILLSIDE DRAINAGES

Minimally detained stormwater in this developed area has caused varying degrees of the stream channel damage. For example, in stream 09.0068A, channel incision of up to two feet was noted in the vicinity of the outfall pipe from SE 293rd Street.

In some reaches, the streambank consists of gabion basket bank armoring, while elsewhere the stream has been diverted through pipes into ornamental fountains.

KEY FINDINGS AND IDENTIFIED HABITAT-LIMITING FACTORS

- Historically, these creeks appear to have served as important refugia for anadromous salmonids that reared year round in the Green River basin.

- The impervious area of many of these subbasins is expected to range from 15 to 33 percent in the near future.

- Current and future development has and will likely continue to generate increased stream flows, channel instability problems and instream and riparian habitat degradation.

- Wetlands played an important function in maintaining streamflows in many these small streams. Many of these wetlands have been partly or completely eliminated and the remaining wetlands are continuing to be degraded.

- There is currently only very limited utilization by anadromous salmonids in these streams.
- Known and suspected anthropogenic barriers limit access to spawning and rearing habitat.
- The quality and quantity of gravels in the stream limits spawning success and, to a lesser degree, juvenile rearing habitat.
- Although only limited quantitative information is currently available, it is the professional judgement of the Factors of Decline Subcommittee that flood flows due to increased impervious surfaces effectively preclude successful incubation.

DATA GAPS

- There is no evidence that these streams can support all life stages of anadromous salmonids.
- Fish passage barriers have not been comprehensively assessed for the subbasin.
- Information regarding existing riparian conditions and functions for supporting salmon habitat is limited.
- There is no LWD inventory for the subbasin..
- Aquatic invertebrate populations should be monitored and the cause of lack of diversity and presence should be determined and addressed.

EARLY ACTION RECOMMENDATIONS

A comprehensive baseline habitat survey (including elements that address the above-referenced data gaps) should be initiated to shape a subbasin-wide strategy and rehabilitation objectives. This strategy should be used to direct the type and timing of rehabilitation efforts to maximize resource potential and promote efficient monetary expenditures. It is important that this subbasin strategy is well integrated with the overall WRIA 9 Strategy to recover salmon.

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3.6 MIDDLE GREEN RIVER TRIBUTARIES

PHYSICAL DESCRIPTION

SUBBASIN

This section includes the following tributary streams to the mainstem Green River upstream of the confluence of Soos Creek (RM 33.65) and downstream from the confluence with Newaukum Creek (RM 40.7):

- Burns Creek (09.0105);
- Crisp Creek (09.0113) (locally referred to as Keta Creek);
- O'Grady Creek (09.0107); and
- Nine other locally named or unnamed tributaries (09.0100 through 09.0110).

These streams are grouped together because of their similar drainage basin size, geomorphic characteristics, flows, geographic location and salmonid resource utilization.

STREAM COURSE AND MORPHOLOGY

Burns Creek (a right-bank tributary to the Green River) has its origins from a spring. It drains much of the east valley floor in this reach and enters the Green River at the upstream end of the Loans Levee (RM 38.0). Burns Creek is fed by three tributaries, all located along the north valley wall. The upstream tributary has its origins as a wall-based spring, while the two downstream tributaries flow from steep-sided ravines. Once Burn Creek enters the valley floor, it flows through old river channels before joining the mainstem Green River.

Crisp Creek enters the Green River at RM 40.1 as a right bank tributary. It drains an area of approximately 5.0 square miles and is approximately 3.0 miles long. The creek has its origins from several groundwater sources and springs (including Keta Creek Springs) which augment the flow of Crisp Creek. The origins of Crisp Creek appear to be a 20-acre, relatively pristine bog at approximately 600 feet in elevation. Crisp Creek moves across a natural plateau before it drops steeply over the topographic break that discerns the plateau from the valley walls of the Green River. The stream becomes slower with a lower gradient when it reaches the alluvial valley floor and then travels roughly parallel to the Green River before entering it. Two lakes important to surface water flow (Horseshoe and Keevies) are located within the subbasin. The Keta Creek Hatchery (one of two Muckleshoot Indian Tribe (MIT) hatcheries) and two adjacent former WDFW rearing ponds are located at approximately RM 1.05 of Crisp Creek.

The mainstem of O'Grady Creek originates from wetlands and is approximately 2.4 RM long, with a single wall-based tributary that contributes an additional mile (total of 3.4 RM). O'Grady Creek (09.0107) joins the Green River through an oxbow (side channel) along the left bank at

approximately RM 39. The O'Grady Creek subbasin and drainage basin area includes 1.3 square miles. The creek is best characterized when it is divided into three distinctive reaches or sections:

- An upper headwater reach (approximately 1 mile long) with a low gradient that meanders through plateau farmland;
- A middle reach (approximately 0.8 miles long) that descends from the plateau through a high-gradient, steep-walled ravine to the Green River valley floor; and
- A lower reach (approximately 0.5 mile long) that comprises the alluvial fan.

O'Grady Creek subbasin is impacted by the Osceola Mudflow, a natural geologic feature that originated from a past eruption of Mt. Rainier and is the dominant geologic feature of the plateau. The mudflow deposited a large area of unsorted clay sediments which created a flat, riverine topography combined with significant numbers of depressions. These depressions formed the wetlands and are similar to the features of the Newaukum Creek subbasin (see Hydromodification—Off Channel Habitat, below).

Stream course and morphology information on the several small tributaries mentioned above (09.0098 through 09.0106) was not located or made available during the course of this report.

SALMONID USE

More than 10 miles of stream length of the combined Middle Green River tributaries are accessible to anadromous salmonids.

The known freshwater distribution of anadromous salmonids is depicted in the report Appendix. Chinook, sockeye, coho, pink and chum salmon (along with winter steelhead adults) have been observed spawning in these tributaries (WDFW Spawning Ground Survey database). Burns and Crisp Creeks provide spawning and rearing habitat for coho, chinook, chum and winter steelhead. Coho and chum salmon adults and juveniles utilize O'Grady Creek.

Resident and anadromous cutthroats have been observed throughout the these streams and lakes. Crisp Creek also serves as the water supply for the MIT Keta Creek Hatchery and rearing ponds.

The lower reaches of the primarily smaller, wall-based streams (09.0098 through 09.0106) are utilized for spawning by coho and chum, and rearing by chinook, coho, chum, and winter steelhead.

FACTORS OF DECLINE

FISH PASSAGE

King County is currently conducting a comprehensive investigation of culvert and bridge crossings of county roads in the Green River basin. It is expected that this investigation will produce a database identifying barriers or constrictors of stream channels on King County Roads.

That survey should be completed in late 2000 or early 2001 and does not include city or private roads.

The known barriers to anadromous salmonids are shown in the report Appendix.

CRISP CREEK

The Keta Creek Hatchery (one of two Muckleshoot Indian Tribe (MIT) hatcheries) and two adjacent former WDFW rearing ponds are located at approximately RM 1.05 Crisp Creek. A dam at the facility ponds water upstream and also creates an anadromous barrier. The hatchery rears and releases at both on and off-station locations chum, coho, chinook salmon. Winter steelhead are reared at this facility and released off-station.

O'GRADY CREEK

Within O'Grady Creek there are no known passage barriers for salmonid juveniles in the reach downstream of the culvert and upstream of the confluence.

However, O'Grady Creek chronically overflows its banks during fall and winter at a point about 1,000 feet upstream from the confluence with the Green River. This causes much of the stream to flow in a shallow, sheet-like manner across the remnant pasture. In the past, adult chum and coho and juvenile salmonids have been stranded as the creek drops back into its banks. This reach is currently the recipient of a King County restoration project to construct a more stable channel.

Boehm (1999) noted that during seasonal low-flow periods there was insufficient flow across the alluvial fan for adult salmonids to access O'Grady Creek in the most recent four years (1995-1999). He also noted that "…strandings have occurred...", but no species were identified.

RIPARIAN CONDITION

CRISP CREEK

The upper reaches of Crisp Creek contain deciduous trees, primarily red alder and black cottonwood, with some conifers where the stream traverses through commercial timberlands. There is a sparse, mixed coniferous and deciduous stand of second-growth trees along Crisp Creek just upstream of the Auburn-Black Diamond Road. Downstream of the commercial timberlands, the stream gradient flattens and the riparian area becomes wider and larger with mostly deciduous trees growing from the top of the stream bank to the stream. Downstream of the MIT Keta Creek Hatchery, Crisp Creek flows past several farms and houses and has little functioning riparian habitat (primarily willows), until just prior to its confluence with the Green River. The riparian habitat at the confluence of Crisp Creek and the mainstem Green River is comprised primarily of large cottonwood trees (Kerwin 2000).

O'GRADY CREEK

Native vegetation riparian buffers are lacking within the upper plateau reaches of the O'Grady Creek subbasin. There are sections of willow (*Salix sp*.), ninebark (*Physocarpus capitus*), vine

maple (*Acer circinatum*), black cottonwood (*Populus trichocarpa),* and scattered stands of Sitka spruce (*Picea sitchensis*), and western red cedar (*Thuja plicata*).

Historic logging practices harvested the old-growth forest within the ravine in the early 1900s. The riparian zone throughout most of this reach is vegetated with second-growth deciduous forest and shrubs. Boehm (1999) found the mid-section riparian buffer of O'Grady [0–450 meters (0-1320 feet)] to be dominated by willow, red-osier dogwood, red alder and black cottonwood saplings. The overstory vegetation pattern of the upper section of his study area, (2,600-5,600 feet below the ravine above the culvert) was dominated by red alder, big leaf maple, black cottonwood, and bitter cherry (*Prunus emarginata*). There were a few sections of coniferous overstory in the study area and the upper reaches of the wall-based tributary included western red cedar (*Thuja plicata*), western hemlock (*Tsuga heterphylla*), sitka spruce (*Picea sitchensis*), and Douglas fir (*Pseudotsuga menziesii*). Additional upland plants found in the shrub layer include red elderberry (*Sambucus racemosa*), beaked hazelnut (*Corylus cornuta*), and indian plum (*Oemleria cerasiformis*). Sword fern, bleeding heart (*Dicentra formosa*), Pacific waterleaf (*Hydrophyllum tenuipes*), and trillium (*Trillium ovatum*) were the dominant plants found in the understory. In the moist upland areas, and in wet areas, piggy-back plant (*Tolmiea menziesii*), Scouler's corydalis (*Corydalis scouleri*), false lily-of-the-valley (*Maianthemum dilatatum*), current (*Ribes bracteosum*), and salmonberry were all present. Scouler's corydalis, skunk cabbage, water parsley (*Oenanthe sarmentosa*), horsetail, reed canary grass, and scattered cattails (*Typha latifolia*) were identified in sections of the wetland and overflow area adjacent to O'Grady Creek approximately 828 feet-1159 feet downstream of the culvert.

In the lower stream reach, adjacent to the mainstem Green River, there is no development adjacent to the stream buffer other than past clearing and a remnant pasture within the alluvial fan downstream of the access road culvert. Boehm (1999) examined three study reaches in the lower portion of O'Grady Creek, including the wall-based tributary in that area. He found that a riparian coniferous forest overstory was lacking in the stream buffer from the outlet with the Green River side channel upstream 993 meters (3,287 feet). He did note the presence of "patches" of conifers in the upstream reaches of both streams. In the study areas examined by Boehm (1999), the riparian vegetation was is dominated by a young, hardwood forest consisting of young red alder (*Alnus rubra*), larger and older individual black cottonwood *(Populus trichocarpa*) and occasional big-leaf maple (*Acer macrophyllum*). There was also a shrub layer is dominated by willow (*Salix spp*.), red-osier dogwood (*Cornus stolonifera*), vine maple (*Acer circinatum*), Himalayan blackberry (*Rubus discolor*), snowberry (*Symphoricarpos alba*), and salmonberry (*Rubus spectabilis*). There was a sparse herbaceous layer in the wet depressions/small wetlands adjacent to the stream consisting of skunk cabbage (*Lysichitum americanum*), giant horsetail (*Equisetum telmatiea*), reed canarygrass (*Phalaris arundinacea*), and lady fern (*Athyrium filix-femina*).

LARGE WOODY DEBRIS

There have not been any quantitative surveys of LWD abundance in the creeks in this reach. An active program to remove LWD from the Burns, Crisp and O'Grady Creek systems over the past 150 years, combined with the loss of the historic coniferous riparian buffer and associated potential recruitment of large trees/key pieces of wood with rootwads, have impacted stream

process formation and morphology, and ultimately salmonid species production and composition.

Crisp Creek

While no quantitative counts of large woody debris were found, there is a limited amount of large, functional woody debris in the channel to buffer changes in sediment and water flow (Malcom 2000).

O'Grady Creek

Within the reach of O'Grady Creek examined by Boehm (1999), there was an almost complete lack of both small and large woody debris (LWD) within both the active channel and the floodway. However there were some areas with lateral and side channel LWD accumulation. Winter high flow events have evidently placed most of the LWD as debris dams, lateral logs or bridges. Most of the debris accumulations were upstream of the access road culvert within the ravine. For the purpose of his study, Boehm defined LWD as being in excess of 10 inches in diameter and 10 feet) long. Using this definition, he found 17 pieces of wood within the study reach of O'Grady Creek that qualified as LWD, and about 3 pieces for the wall-based tributary. Calculating this on a piece-per-distance basis, there are 1.7 pieces/100 meters and 1.4 pieces/100 meters respectively.

Boehm (1999) also examined pool quality formed according to the methodology presented by Platts et al. (1987). This protocol assigns each pool a score ranging from 1 to 5. A pool with a value of 1 has little habitat value for salmonids while a rating of 5 would have superior habitat value for salmonids. In the study area, the average pool quality index (PQI) rating was 2, with an average maximum and residual depth of 0.54 meters (1.8 feet) and 0.41 meters (1.4 feet), respectively. LWD or an LWD/ boulder matrix combination were the responsible pool-forming features.

Therefore, the lack of LWD is a limiting factor in the production of anadromous salmonids in the O'Grady.

HYDROLOGY

CRISP CREEK

At present, increases in peak flows caused by precipitation do not appear to substantially adversely impact Crisp Creek. However, this scenario could easily change if the stream receives more overland flow as a result of increased impervious surfaces and loss of forest cover. This change in hydrology will cause higher and more frequent stormflow peaks and could cause channel instability.

Crisp Creek's existing mean annual flow is fairly low. Based on King County stream flow gage 40D, mean annual flow for the period of water year 1995 through 2000, is approximately 8.8 cfs. The mean annual 1-day minima stream flow is about 2.5 cfs with the lowest stream flow occurring in 1995 (Burkey 2000). If too much water were to be withdrawn or groundwater

recharge were to be interrupted, it is likely that the stream could go dry during seasonal low flow periods.

O'GRADY CREEK

The O'Grady system responds quickly to rainfall from seasonal storm events that move through the watershed, generating high-peaked flash flows. Increases in impervious surface areas due to urbanization in combination with changes in historic land use practices (i.e., conversion of coniferous forests to pasture land) and the impermeable Osceola mudflow that covers most of the upper watershed the Enumclaw plateau have collectively created this hydrologic sensitivity and poor hydrologic. The natural impervious layer of the Enumclaw plateau and the lack of LWD in the O'Grady Creek system has created high-velocity conditions with high bedload mobility (see Riparian Condition—Large Woody Debris; and Sediment Condition0).

Peak flows coincide with the winter storm season of November through March. Based on 4 years of data from King County stream gage number 40C (water years 1992 – 1995 inclusive), the annual maxima mean daily flow is just under half of the annual maxima daily maximum. The mean annual flow rate for O'Grady Creek for those 4 years is approximately 1.5 cfs. The annual 1-day minimum flow ranges from 0 - 0.4 cfs. However at low flow, the gaging records may not accurately measure stream flow (Burkey 2000).

The transport of sediments and movement within the lower reaches of the O'Grady Creek system is also high (see Sediment Condition).

Water Rights

The tributaries to the Green River have been closed to additional surface water withdrawals since 1980 (Chapter 173-509 WAC). However, potable water wells that produce less than 5,000 gallons per day do not require a water right. It is not known how many of these wells are present in the subbasin, nor their cumulative impacts on groundwater discharge and stream baseflow to these creek systems.

SEDIMENT CONDITION

Substrate conditions of the creeks within this subbasin have not been thoroughly investigated.

BURNS CREEK

Burns Creek is impacted by sediments originating from landslides in one of its tributaries, locally known as Doll Creek. Doll Creek originates on the plateau approximately 240 feet above the Green River valley. The landslides are located in a section of the creek locally referred to as the Bell Ravine. The Bell Ravine is a young geologic process that is formed by the creek cutting down through softer sediments on its way to the Green River valley floor. Landslides in Bell Ravine are a part of a natural process, but may be exacerbated by historic and current land use practices.

Landslides are present in aerial photographs taken of Doll Creek in 1936 and 1985. However, they are not believed to have caused the sedimentation problems in Burns Creek (Perkins 1999).

During the winters of 1990 and 1995-96, sustained, intense rainstorms caused large landslides that reactivated sediment fans (in 1990) and led to sediment deposition in Burns Creek. Perkins (1999) indicates between 1985 and 1999, between 12,000 and 34,000 cubic yards of sand and gravel probably entered Doll Creek. Between 4,000 to 8,000 cubic yards were deposited in the alluvial fan at the confluence of Doll and Burns creeks.

Perkins (1999) examined sediments in the lower reaches of Burns Creek downstream of the confluence with Doll Creek. This area has an average stream gradient of 0.2 percent (Perkins 1999). She found this reach to be comprised of either sands or silts up to three feet thick. These sediments have reduced pool depths and buried salmonid spawning gravels. Coho and chum salmon continue to spawn in this reach, but their reproductive success is thought to be marginal.

This sediment buildup has largely been responsible for local flooding. The response by local property owners has been to conduct a maintenance dredging program once or twice each year since 1996. However, the landslides are believed to be a natural process and not directly the result of land use activities (Perkins 1999). Typically, permits have allowed up to 49 cubic yards of sediments to be removed during each maintenance dredging. This dredging is supposed to be in the vicinity of residential driveways, but dredge spoils are present on both banks from approximately 250 feet downstream of private property along Burns Creek. During 1997, King County also removed sediments from Burns Creek stream channel below the confluence with Doll Creek in an effort to minimize flooding of the S.E. Green Valley Road.

Williams (1975) noted the presence of only “patchy” gravels in Burns Creek and either gravels were absent or covered at that time.

CRISP CREEK

Crisp Creek is similar to Burns Creek in that the lower reaches are heavily silted and significantly altered where they pass through agricultural lands (primarily pastureland). The creek has its origins from a wetland northwest of Keevies Lake. The hydrology of the creek is dominated by groundwater and baseflow is the main component of the annual hydrograph (MIT, 1993).

The upper reaches of Crisp Creek are relatively stable and capable of accommodating winter stream flows, in part due to limited urban and residential development and the low channel gradient. However, immediately above the MIT Keta Creek Hatchery, Crisp Creek flows through a confined area that is surrounded by unstable landforms. These landforms are a source of fine sediment and landslides when disturbed (MIT, 1994). Crisp Creek has the potential to become degraded through aggradation and erosion processes due to peak flows.

O’GRADY CREEK

Excessive scour and deposition has been documented by Bill Priest (Bill Priest 1999 as contained in Boehm 1999). The intensity of scour and sediment movement is severely a limiting factor for salmonid production in the O’Grady Creek system. This would be adversely impacting the survival rate of cutthroat, coho and chum eggs during incubation and coho and steelhead during rearing.

Boehm (1999) found that winter flood-flows were responsible for substantial sediment loading and bed movement within the study reach of O'Grady Creek. Within the reach examined, he found that substrates were moderately imbedded within a fine-grain matrix. The area poorest in spawning gravels was the 1,225 feet – 2,259 feet reach of channel with a lower stream gradient and a sand dominated substrate. The wall-based tributary had a substrate with less sand present and was dominated by large gravel (25 mm to 100 mm) (40%), cobble (100mm-256mm) (30%), small gravel (20%) (<25mm), and sand (10%). There are also a few cobbles present within the stream channel.

WATER QUALITY

Burns, Crisp and O'Grady creeks are all classified as a Class A waters (WAC 173-201A).

Burns and O'Grady Creeks currently meet all numeric water quality standards for all monitored chemical constituents, including fecal coliforms, water temperature and dissolved oxygen.

Crisp Creek currently meets all numeric water quality standards for a variety of chemical constituents, including water temperature and dissolved oxygen. However, like many other streams in the Green River basin, Crisp Creek does not currently meet water quality standards for fecal coliform, and appears on the Environmental Protection Agency 1998 303(d) list (WSDOE 2000) for exceeding the upper criteria in samples collected between 1991 and 1997.

Water quality information on several other tributary streams in this reach was not available.

Water quality in Burns, Crisp and O'Grady Creeks is not believed to be a limiting factor at this time.

LAND USE

BURNS CREEK

Aerial photographs from 1936 of the Burns Creek subbasin show an immature forest, probably the result of logging activities in the early part of the 20th century. Numerous old landslide bowls are also present in these photographs. These landslides may be the result of reduced root strength of immature trees and/or more winter storms with high and intense precipitation patterns.

CRISP CREEK

The historic old-growth forest around Crisp Creek was also logged sometime near the beginning of the 20th Century. There are some remnant old-growth Sitka spruce and Western red cedar trees widely scattered throughout the subbasin.

Currently, approximately 69 percent of the watershed upstream of approximately RM 11 is managed for commercial timber production (Malcom 2000). Beginning in 1991, commercial logging activities harvested the majority of the second-growth timber on the commercial forest land tracts. Within the Crisp Creek drainage area there are at least six concentrated areas of residential development with densities of 1 house per acre or less. The remaining land use is

considered rural residential with lot sizes of 1 to 10 acre. The residential sites vary in vegetative conditions from clear-cut to pastureland to small private woodlots with a single residential house.

O'GRADY CREEK

O'Grady Creek has experienced significant and substantial changes since historic times (prior to 1860). Virtually all of the original pre-settlement wetland forests of Sitka spruce and western red cedar, and upland forests within the subbasin have been logged (in some cases twice) and then cleared. Following clearing, land use on the plateau was dominated by hay and straw production, and dairy farms (King Co. Basin Recon. 1990). Currently, the subbasin is predominantly rural in character, but under increasing pressures to convert to new single-family residences on smaller parcels, and a breakup of the large-acreage pasture into "hobby" farms. Currently, there are several large horse stables and horse breeding farms on the plateau.

NON-NATIVE SPECIES

ANIMALS

No information on non-native fish species was located during the course of this investigation.

PLANTS

Reed canarygrass (*Phalaris arundinacea*) is abundant throughout this subbasin. Himalayan blackberry (*Rubus discolor)* is present in O'Grady Creek subbasin.

HYDROMODIFICATION

O'GRADY CREEK

In 1984, a land owner channelized the lower 600 meters (1980 feet) of O'Grady Creek. This removed all of the meanders (and LWD) from the historic channel to force stream flows into the newly excavated and straightened channel. This lower section has experienced the greatest habitat damage from property owners. This damage limits natural production of salmonids.

Local channelization is extensive in the lower reaches of Burns and Crisp Creeks where they traverse across the valley floor through agricultural lands.

SOUTH FORK BURNS CREEK

The South Fork of Burns Creek has its origins in a wetland that historically received flow from Crisp Creek during floods. Prior to the construction and operation of Howard Hanson Dam in 1962, the South Fork of Burns Creek also received flood waters from the mainstem Green River. These flood waters are believed to have flushed the fine sediments from the South Fork of Burns Creek, leaving behind spawning gravels that were capable of supporting spawning salmon.

After the dam was constructed in 1962, flood flows from the mainstem Green River no longer occurred in the upper reaches of Burns Creek. Williams (1975) noted that in the previous 15 years, stream habitat degradation had occurred due to "…heavy silting, extensive aquatic weed

growths, and reduced flows." He attributed the observed siltation problems to land use practices and illegal hydraulic projects of that time period.

In addition to the flow changes believed to be caused by the building and operations of Howard Hanson Dam, changes in mainstem Green River channel location is also thought to contribute to increased siltation of this area in Burns Creek. A comparison of aerial photographs between 1936 and 1958 indicates that the Green River abandoned a meander bend upstream of Burns Creek during this time period. As a result, this channel migration moved the mainstem river away from Burns Creek, and contributed to a reduction of flood flows from the mainstem Green River into Burns Creek.

OFF CHANNEL HABITAT

Crisp Creek

The upper portion of the Crisp Creek has numerous adjacent wetlands that mostly remain connected to the stream.

O'Grady Creek

There are still large wetlands present in the upper reaches of this subbasin. The largest include O'Grady Creek No. 85b, 94b, 5 (51 acres), and O'Grady Creek No. 88b (King Co. Wetlands Inventory 1990). However, most of the plateau wetlands have either been cleared, ditched, filled and/or are extensively grazed by livestock.

FLOODPLAIN CONNECTIVITY

As previously mentioned, O'Grady Creek originates from a group of wetlands and then descend westerly into a series of ditched streams that coalesce at the eastern edge of the Osceola flow area before entering a steep-walled, high-gradient ravine. The grazed wetlands are often inundated with water during the winter. This is evidence of highly compacted soils and poor permeability that is a characteristic of the Osceola mudflow. The poor permeability of the Osceola flow area and the compacted soil caused by extensive grazing generates a combination of conditions that favor a severe rapid runoff pattern during rain and rain-on-snow storm events.

KEY FINDINGS AND IDENTIFIED HABITAT-LIMITING FACTORS

- There is a general lack of habitat information for this subbasin.
- The subbasin is undergoing a rapid conversion from forest and rural to a more urbanized environment.
- The riparian buffer in this subbasin is insufficient and is limiting natural salmonid production.
- There is a lack of LWD throughout the streams in this subbasin.

- Summer low flows limit available rearing production for species of salmonids that require over-summer residency.

- High winter flows limit the reproductive success of coho and chum salmon because of scour and bedload movement and coho and steelhead because of lack of refugia.

- Channelization of the lower reach of O'Grady Creek has eliminated stream channel complexity and limits natural production of salmonids.

- Sediments in the lower reaches of Burns, Crisp, and O'Grady creeks are believed to be limiting the success of egg incubation of anadromous salmonids in this reach.

DATA GAPS

- Information on several small tributaries (09.0098 through 09.0108) was not located or made available during the course of this investigation.

- Baseline habitat information is lacking for all or portions of the creeks in this reach.

- The impact level of non-native and invasive aquatic plants on naturally producing salmonids is not well understood..

- Use and importance of these streams as overwintering refuge habitat for juvenile salmonids from high mainstem flows is not fully known.

- The amount and type of LWD is not known. .

- The amount of loss of streambed channel and complexity after channel relocation is not known.

- The quality of the sediments in the lower reaches of Burns, Crisp, and O'Grady creeks are not fully known .

EARLY ACTION RECOMMENDATIONS

- Conduct baseline habitat inventory surveys

- Comprehensive barrier surveys need to be initiated in this subbasin.

- Comprehensive base line riparian habitat and bank condition surveys should be initiated.

- An inventory of LWD should be initiated.

- Historic channel location information needed.

3.7 SOOS CREEK SUBBASIN

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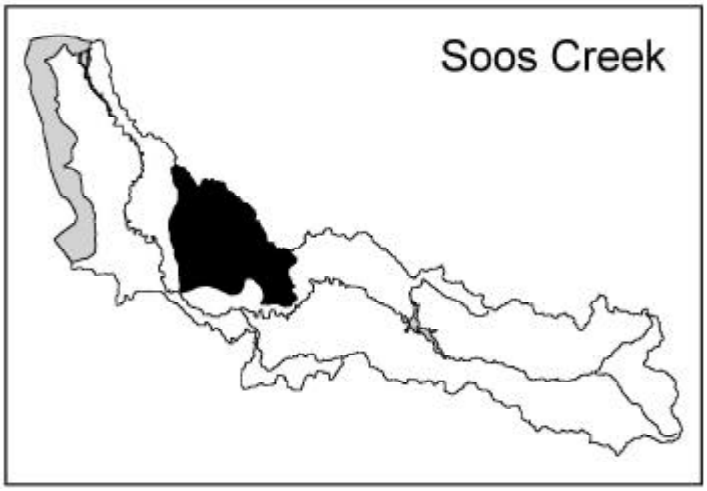
3.7 SOOS CREEK SUBBASIN



PHYSICAL DESCRIPTION

SUBBASIN

The Soos Creek subbasin is best defined as an area in south King County, north and east of the Green River and southeast of the City of Renton. The Soos Creek subbasin consists of the mainstem Big Soos Creek (09.0072) with approximately 25 identified tributary streams totaling over 60 lineal miles. There are three major tributaries:

- Covington (09.0083);
- Jenkins (09.0087); and
- Soosette (09.0073, also known as the West Branch of Soos Creek).

STREAM COURSE AND MORPHOLOGY

The subbasin drains an area of approximately 44,800 acres (70 square miles). The basin is comprised of three distinct physical settings (Figure HM-2 in the Hydromodifications Appendix).

The headwaters of Soos Creek originate on a rolling glacial outwash plain. The channel is unconfined, has a gradient of less than 0.1 percent, and flows through extensive wetland complexes. Stream flows are generally small, with little erosive energy, and the channel is described as alternating between “sections of good gravel and sections of swampy channel splits with mud bottoms” (Williams 1975), characteristic of a Palustrine channel type.

At approximately RM 4.75, Soos Creek enters a narrow, steep-sided ravine containing long riffles with pools. The channel becomes a Moderate Gradient Mixed Control type, with a

gradient of approximately 1.4 percent. Major lakes in this system include Lake Youngs (a domestic water supply for the City of Seattle), Shadow Lake, Lake Meridian, Lake Sawyer, Morton, Pipe/Lucerne and Wilderness Lakes. These lakes have a combined surface acreage of approximately 1,370 surface acres (Wolcott 1973).

Downstream of RM 2, the channel gradient decreases to around 0.5 percent, and Soos Creek becomes a Floodplain channel type that occupies a steep-sided valley.

Pool-to-riffle ratios differ considerably between the upper and lower reaches of Soos, Little Soos, Covington, Jenkins and Soosette Creeks (Table Soos-1). Ideal pool-to-riffle ratios should have approximately equal frequencies of each element.

Table Soos-1. Pool - to - Riffle Ratios of Streams in the Soos Creek Subbasin.

Stream Name	Upper Reaches	Lower Reaches
Little Soos Creek	20:80	50:50
Big Soos Creek	30:70	20:80
Covington Creek	90:10	5:95
Jenkins Creek	90:10	10:90

Source: King County 1990.

SALMONID USE

The known freshwater distribution of anadromous salmonids is depicted in the report Appendix.

The headwaters of Soos Creek arise on a rolling glacial outwash plain. In such landforms, streams often originate in wetlands, and exhibit low-gradient, palustrine-type channels until flows become sufficient to regularly transport coarse sediment. The gradient of mainstem Soos Creek is 1 to 2 percent throughout its course (Cutler 2000), and no natural barrier falls or cascades have been identified (Williams et al.1975). The upstream extent of spawning by anadromous fish, is not known, but is presumed to be limited by flow, substrate or in-stream vegetation and not gradient. Juvenile fish are expected to use the entire length of available channel and associated wetlands for rearing.

Chinook, sockeye, coho, pink and chum salmon (along with winter steelhead adults) have been observed spawning in the Soos Creek subbasin (WDFW Spawning Ground Survey database).

A single bull trout was reported captured at the Soos Creek State Fish Hatchery (SFH) in 1956 (Beak Consultants 1996). Resident and anadromous cutthroats have been observed throughout the streams and lakes.

SFH captures adult chinook and coho for on- and off-station releases, with an annual production of approximately 3.2 million fall chinook sub-yearlings and 600,000 coho yearlings.

FACTORS OF DECLINE

FISH PASSAGE

Known barriers to anadromous salmonids are shown in the report Appendix.

SOOS CREEK SALMON HATCHERY

The Soos Creek Salmon Hatchery (located at RM 0.7) was constructed in 1901 and has been in continuous operation since that time. Between 1902 and 1924, portable double racks were installed in the mainstem Green River at the mouth of Soos Creek to provide eggs for the hatchery, since chinook salmon did not enter Soos Creek at that time (Becker 1967). Annual installation of the portable weirs on the mainstem was discontinued in 1924, as large numbers of chinook had begun to return to Soos Creek by that time (Becker 1967).

The existing hatchery rack consists of two removable weirs located approximately 100 feet apart that are used to create a holding pond (Figure Pass-15). The weirs are generally installed around August 15, when the first chinook begin to arrive , and removed around the 3rd week of November when coho egg take requirements have been met (Chamblin 2000). A sheet-pile dam (used to divert water into the hatchery) is located just upstream. The diversion dam is equipped with a fish ladder (Figure Pass-16).

The hatchery rack acts as a barrier when it is in place. However, large storm events or other unforeseen occurrences may wash out the weirs or allow fish to pass the structure. For example, during a storm in September 1997, over 8,000 chinook were able to leave the hatchery and move upstream into Soos Creek when the weir failed (Finney 2000). Beavers have also been responsible for causing holes that allow adult salmonids to migrate upstream (Kerwin 2000). When the hatchery weirs are not in place, anadromous salmonids can move freely upstream. The hatchery does not interfere with the downstream movement of juvenile fish.

CULVERTS

Although a number of barriers associated with road crossings have been identified on tributary streams (Figure Pass-4 located in the Fish Passage Appendix), no existing barriers to upstream migration in mainstem Soos Creek have been identified.

King County is currently conducting a comprehensive Green River Basin investigation of culvert and bridge crossings of county roads. It is expected that this investigation will lead to a database that identifies culverts and other structures that block or constrict stream channels. That survey should be completed in late 2000 or early 2001.

LOW INSTREAM FLOWS

Low flows reportedly reduce the ability of chinook to reach the Soos Creek hatchery (WDFW and WWTT 1994), and thus influence the amount of natural spawning downstream of the hatchery as well as the number of chinook that may be released upstream of the hatchery rack. The specific location of low flow concerns was not identified, and could include low flow concerns in the mainstem (WDFW and WWTT 1994). However, a declining trend in the average

7-day low flows just upstream of the hatchery has been identified (Culhane 1995), and is discussed in more detail in this chapter(see Hydrology). Declining flows support the hypothesized low flow concerns in Soos Creek.

WATER TEMPERATURE

There are no segments of mainstem Soos Creek listed on the 1998 Washington State 303(d) list for temperature concerns (WDOE 1998), thus temperature is currently assumed not to limit the upstream migration of adult salmonids in Soos Creek. However, temperature concerns that represent potential passage barriers have been identified on a number of tributaries (Figure Pass-4 in the Fish Passage Appendix). In addition, DO levels less than 8 mg/l have been recorded near RM 10. Low DO levels could cause salmonids to avoid entering this section of the stream, thereby delaying upstream migration.

RIPARIAN CONDITION

No data was obtained during the course of this investigation that provided additional information concerning riparian types, canopy, depth, seral stage or composition.

LARGE WOODY DEBRIS

There have not been any quantitative surveys of LWD abundance.

King County (1990) reported moderate, but not sufficient, amounts of LWD to all but the steepest reaches of Soos Creek. That same document did not supply additional qualitative information on other tributaries in this subbasin.Typically, as structure (i.e.: LWD) is eliminated, the ratio shifts towards riffle-dominated reach.

HYDROLOGY

The Soos Creek subbasin is changing from forested/rural to one heavy urbanized (particularly in the western areas). The subbasin has an extensive system of interacting lakes, wetlands and infiltrating soils that collectively attenuate peak stream flows. In the 1980s, Soos Creek discharged about 8-10 cfs during the summer (Metro, 1988) 400 cfs during one-year event high flows (King County , 1990) to the Green River. The Soos Creek Basin Plan provides a detailed subcatchment peak flow tables and maps for various future and existing conditions HSPF modeling.

Existing flow-related problems are found in the upper stream reaches that undergo natural and anthropogenic low stream flows. In 1990, it was predicted that stream flows would increase by an average factor of 1.8 under build-out conditions. However, some areas were expected to have stream flows increase 3.5 times the 1985 levels (King County 1990). These higher flow increases should be in areas that had highly infiltratable soils that are converted to urban areas with impervious surfaces.

WATER RIGHTS

The majority of water rights issued by the Washington Department of Ecology (WDOE) in the Soos Creek subbasin are for groundwater. The City of Kent, the Covington Water District, and King County Water District #111 are the largest consumers of water in the subbasin. Water rights and water claims are shown in table Soos-2.

Table Soos-2. Big Soos Creek Subbasin Water Rights and Claims.

Source	Qi* (cfs)	Qa** (acre-feet)	Irrigated Acres	Total Number of Rights (R) or Claims (C)
Ground	40.8	19,297	369	99 (R)
Surface	6.1	891	103	89 (R)
Ground	43.3	3.194	1,118	1,374 (C)
Surface	21.2	357	309	296 (C)
Total Ground	84.1	22,491	1,487	1,473
Total Surface	27.3	1,248	412	385

* Qi = Allocated instantaneous water quantity.
** Qa = Annual water quantity.
Source: Culhane 1995.

The usable period of record for streamflow data for the Big Soos Creek subbasin extends from 1967 to 1995. During this period, the amount of ground water allocated (Qi) increased from 5.3 cfs to 40.8 cfs and the annual quantity (Qa) increased from 1,412 acre-feet to 19,297. In 1995, there were 30 applications for water rights for ground water in the Soos Creek subbasin. These applications totaled 40.9 cfs. This is an almost equal amount to that allocated.

The tributaries to the Green River are closed to additional surface water withdrawals since 1980 (Chapter 173-509 WAC). However, declining trends in the average 7-day low flows have been detected in Soos Creek for all years between 1968 to 1993 (Culhane 1995). The likely causes for these instream flow declines includes a combination of decreased precipitation 1993 (Culhane 1995), increases in the percentage of impervious surfaces associated with urbanization, and increased groundwater withdrawal. Potable water wells that produce less than 5,000 gallons per day do not require a water right. It is not known how many of these wells are present in the subbasin and what might cumulative impacts might be. However, it is not entirely clear if this is a long-term trend or just part of a cycle; further data would be useful.

Information in the Ground Water Management Plan (SKCGWAC 1989) and studies conducted by the USGS, ground water withdrawals from the Covington Upland have adversely impacted streamflow in Soos Creek.

The increase in percentage of impervious surfaces in the basin mentioned previously have contributed to decreases in summertime low flows. Increases in winter stormwater flows have been observed (King County 1990) and the King County Surface Water Management Division estimated a three-fold increase in impervious area from 1985 to build-out conditions.

The mean annual streamflow in Soos Creek decreased about 14 percent and the low mean monthly flow decreased about 33 percent during the time period from 1967 to 1992. Precipitation as measured at Palmer decreased only 5 percent during that same period. In the Newaukum Creek subbasin, the mean annual flow decreased 20 percent, the low mean monthly flow decreased about 24 percent and precipitation at Palmer decreased 16 percent from 1953 to

1992. A comparison of this data indicates that while annual streamflow declines were similar between the two basins, the low mean summer monthly flows in the more urbanized Soos Creek subbasin were significantly greater. The declines cannot be attributed to decreases in precipitation alone, but more likely a combination of ground water removal, increases in the percentage of impervious surfaces and decreases in precipitation 1993 (Culhane 1995).

Culhane (1995) concluded that additional groundwater removal from the Soos Creek subbasin upper three or four aquifers would likely contribute to an additional reduction of surface flows.

The amount of water actually used has not been compared against the allocated water rights and water claims in the basin. However, as previously mentioned, the amount of water allocated has risen. Carlson (1994) did a comparison of potential safe water yield within the Soos Creek subbasin. It was the conclusion of this study that the hypothetical ground water yield of the basin is less than the quantity of water already allocated through exempt well water withdrawals and water rights. When water claims are factored into this analysis, the difference is increased even more significantly.

SEDIMENT CONDITION

Erosion and sediment problems were identified in the Soos Creek Basin Plan (King County 1990). That document indicated that while areas of significant bank erosion would expand only marginally, they would likely increase in intensity. Further, the rates of bedload material transported by increased flows and enlarged stream channels will increase several fold. This will increase the magnitude of sedimentation problems where the transported material settles out. Finally, because of uncertainties in the analysis, it is believed that there is an underestimation of actual future sediment movement. Erosion problems (including associated sedimentation and flooding issues) were also identified in Soos Creek Basin Annual Reports (King County 1993, King County 1994).

Investigation within the Soos Creek subbasin (King County 1990) identified six sites with erosion problems, four sites with debris and related erosion problems, and five sites with sedimentation-related problems. In the upper reaches of Soos Creek, sedimentation was identified as a problem between RM 7.2 to 10.4 (King County 1990). In the lower reaches of Soos Creek, sedimentation was identified as a problem in the vicinity of the Green River SFH (RM 0.8). Bank failures and bank erosion was identified as problems in Soos Creek between Jenkins and Covington Creeks, at RM 4.6 and, in the lower 0.6 miles of Covington Creek.

Erosion and sediment problems were also identified in the 1992/93 and 1994 Soos Creek Basin Annual Reports (King County 1993, King County 1994).

In January 1990, Soosette Creek experienced a dam break flood at about RM 1.0 when a gravel pit road culvert became plugged by a cottonwood during a storm event. An estimated 30,000 cubic yards of fill from the road crossing scoured the stream bed and delivered much of the sediment to Soos Creek, about 0.5 mile upstream of the SFH.

Gravels within this subbasin have not been investigated but also have not been identified as a limiting factor. None of the published literature (Williams et al. 1975; Goldstein 1982; King County 1989)on Soos Creek describing fish habitat and environmental conditions contains

specific information on the extent of gravel bars in mainstem Soos Creek. King County (1990) found spawning gravels "dispersed" and occurring as patches rather than extensive beds. In that same document it was noted that Little Soos and Soosette Creeks had patches of gravels with smaller particle size throughout the upper reaches of these creeks. These gravels were believed to be both consolidated and unconsolidated, the former condition probably the result of low stream gradients and streambank erosion immediately upstream. Substrate in the floodplain channel segment was described as predominantly gravel (70-80 percent), and "remarkably few areas of problematic erosion or sedimentation were identified" (King County 1989). Aerial photograph coverage of Soos Creek was 1:12,000 scale or larger, and the channel was generally obscured by vegetation, thus no information on either the historic or current extent of gravel bars is available.

Gravels in Covington and Jenkins Creeks tended to be "clean and unconsolidated" but still patchy (King County 1990).

WATER QUALITY

Although no direct pre-development data was found as a part of this report, it is assumed that Soos Creek water quality was historically excellent for salmonids due to the large acreage of headwater wetlands and lakes. This historic wetland /lake complex allows for natural filtration and ground water adsorption keeping flows clean, cool and steady (qualities most likely led to the siting of the SFH near the mouth of the system in 1902).

The Soos Creek Basin Plan (King County, 1990) notes that localized water quality degradation has been observed, including high levels of fecal coliforms in Little Soos Creek and high nutrient levels in the lakes. Non-point pollution of these types are expected to become an increasing threat to fish habitat ands the subbasin develops.

Water quality existing conditions, trends and data gaps for this subbasin is covered in detail in The Water Quality Chapter (Part II, Chapter 1.2) of this report. This chapter notes the recent chemical and biological (B-IBI) monitoring efforts within the subbasin.

Prych (1995) sampled streambed sediments for the presence of metals. Seven streambed samples were collected from three sites. Two sites were in Big Soos Creek (one each upstream and downstream of the confluence with Little Soos Creek), and the third site was in Little Soos Creek. Streamwater samples were also collected at the time of the streambed samples were collected. The concentrations of metals in the streambed sediments were typical of or slightly higher than those in soils from the same subbasins. Cadmium, copper, mercury, manganese, lead, arsenic, antimony, selenium and zinc had maximum observed concentrations in streambed sediments approximately twice as high as terrestrial soil samples (Prych 1995). None of the levels were high enough by themselves to be a limiting factor to fish production.

LAND USE

Land within in this subbasin been converted from old-growth forest to commercial timber production, then to agricultural uses, and now to hobby farms and urban uses and has had significant and adverse effects.

In the Soos Creek subbasin, riparian and instream habitat contributes to the stream diversity and complexity. King County (1987) estimated the riparian forest in the Soos Creek subbasin (table Soos-3.)

Table Soos-3. Riparian Forest Cover in the Soos Creek Subbasin.

Creek Name	Total Length Surveyed (miles)	Forested Length* (miles)	Percent
Soos Creek	14.2	8.9	63
Little Soos Creek	4.5	2.1	47
Soosette Creek	5.1	3.0	59
Covington Creek	11.3	8.7	77
Jenkins Creek	6.0	3.7	62
Cranmar Creek	3.8	3.4	90

* Forested is defined as having >51 percent upper canopy cover in an area of undisturbed natural vegetation.

The northern and western portions of the Soos Creek and Big Soos Creek subbasins exhibit the highest density of urban subdivisions; commercial retail centers, and scattered single-family residences. The land along the borders with Kent and Renton (along the Kent-Kangley Road) are the most urbanized. The effective impervious area of Soosette Creek subbasin had reached 8.5 percent by 1985.

Elsewhere in the subbasin, the land is predominantly rural but under increasing pressure of urbanization. The cities of Black Diamond, Covington and Maple Valley are all within the Urban Growth boundaries (UGB) of the Growth Management Act (GMA) as adopted by King County Ordinance 11575 in August 1994 (Appendix C, Map 1). The UGB is a 20-year growth and development line.

The entire subbasin is currently one of the most rapidly developing in the county. As such, these lands are expected to see increased urbanization and the demands on habitats. It should be expected that adverse impacts would increase, especially in those areas inside the UGB. The Soos Creek Basin Plan (King County, 1990) predicted that under future conditions, the flood peaks with a reoccurrence interval of two years would increase up to 3.5 times with an average of 1.8 times over 1985 land use.

NON-NATIVE SPECIES

ANIMALS

Several non-native fish species (primarily warmwater species) are known to be present in the subbasin lakes (table Soos-4). It is not known what adverse impacts these fish have on salmonid populations in this subbasin. However, small- and large-mouth bass and yellow perch are pisceverous and it should be expected that salmonids will make up a portion of their prey.

Table Soos-4. Non-native Fish Species Present in Soos Creek Subbasin.	
Lake/Creek Name	**Fish Species Present**
Meridian Lake	LMB, SMB, PS, YP, BBH
Lake Sawyer	LMB, SMB, BC, YP, BBH
Shadow Lake	LMB, BC, PS, YP
Soosette Creek[1]	BC
Jenkins Creek[1]	PS, C
Unnamed tributary 0089[1]	PS
Unnamed tributary 0090[1]	PS, SMB, BC
Soos Creek[2]	BC, LMB
C = Catfish BBH = Brown Bullhead BC = Black Crappie LMB = Large-Mouth Bass 1 Source: Nelson 2000. 2 Source: Wilson 1999.	PS = Pumpkinseed SMB = Small-Mouth Bass YP= Yellow Perch

PLANTS

Reed canarygrass (*Phalaris arundinacea*) is abundant throughout this subbasin. King County conducted a mapping project to assess the existing and potential threats of invasive, non-native aquatic plants in King County Lakes during 1994 and 1995. That report, published in 1996 (Walton 1996) examined lakes Lucerne/Pipe, Meridian, Morton, Sawyer, Shadow, Shady, and Wilderness in this subbasin and found Eurasian watermilfoil (*Myriophyllum spicatum*) in Lucerne/Pipe, Meridian, Sawyer, Shadow, Shady and Wilderness lakes. Hydrilla (*Hydrilla verticillata*) was identified in Lucerne/Pipe lakes during the 1994 survey. At that time, this identification was the only known infestation in the Pacific Northwest and represented the northern-most occurrence of the plant in North America. Eradication efforts, while successful in reducing total biomass, have not fully eliminated this non-native from these lakes. Purple loosestrife (*Lythrum salicaria*) was identified in Lucerne/Pipe and Meridian lakes.

The survey was not inclusive of all the lakes and ponds in the subbasin. It is not clear what adverse impacts these non-native plant species have on salmonids in this subbasin.

HYDROMODIFICATION

The Soos Creek Basin Plan indicated that channelization has occurred since the early 1900s in the upper Soos Creek system (King County 1989). However, no specific information on the extent and location of bank protection structures was located. No levees maintained by King County or the USACE appear in the GIS database.

Local channelization has occurred in streams in the upper plateau since the early 1900's. No quantitative data has been collected that shows the loss of stream habitat in this subbasin. The result has been the overall reduction of channel complexity, reduction of diversity and abundance of aquatic organisms (King County 1989).

OFF CHANNEL HABITAT

None of the published literature on Soos Creek describes off-channel habitat either qualitatively or quantitatively (Williams et al. 1975; Goldstein 1982; King County 1989). Available aerial photograph coverage of Soos Creek is 1:12000 scale or larger, and except for the lower reaches, the channel was generally obscured by vegetation, thus no information is currently available to assess either the historic or existing extent or condition of off-channel habitat.

Within the floodplain, the Soos Creek subbasin has one of the largest wetland areas in the Green River basin. Wetland complexes are common throughout the upper plateau of Soos Creek and include open-water, scrub-shrub, forested, emergent marsh, wet meadow and bog wetlands. Wetland surveys conducted by King County (King County 1986, 1987a, 1987b) listed over 225 individual wetlands in the Soos Creek subbasin. These wetlands covered approximately 2,076 acres (4.8 percent of the land area in the subbasin). When combined with the lakes in the system over 3,436 acres of the subbasin area are covered with water (7.7 percent of the land in the subbasin).

There has been a trend of filling and draining of wetlands to create agricultural lands, mine peat and create building sites. A comparison of aerial photographs from 1936 to 1995 showed extensive draining and/or filing of wetlands. The loss of wetlands appeared to peak in the mid to late 1960s, when approximately 800 acres disappeared in the upper plateau area of Soos Creek (King County 1990).

The draining and filling of wetlands is still occurring despite regulatory protection (King County 1990). Edge encroachment is also another threat, particularly to the larger wetlands. The cumulative effect of the long-term historic loss is difficult to quantify, but is known to adversely impact groundwater recharge and create greater magnitude and duration flood events.

FLOODPLAIN CONNECTIVITY

Outside of the plateau area (RM 5.0), streams within this subbasin have not had significant modifications to their historic floodplains. There are no identified out-of-subbasin water diversions or regional flood control facilities present. However, Lake Youngs acts as a reservoir for water diverted from the Cedar River and does supply some base flow to Little Soos Creek (Nelson 2000). Immediately downstream of Lake Wilderness, water from Jenkins Creek is pumped to irrigate a golf course and the creek is often dry (King County 1990). Most of the stream channels are formed near their historic channels with only limited changes in the vicinity of road crossings.

The lower 2.5 miles of Soos Creek downstream of the confluence with Covington Creek has typical floodplain geomorpholgy. The channel in this segment is 30 to 40 feet wide (King County 1989) and occupies an alluvial valley that is approximately 500 to 800 feet wide. However, there is channel constriction, due to bank hardening, to protect roads, residential and

hatchery development throughout this reach. No information was located describing the current or historic extent of the floodplain in lower Soos Creek, and it is unknown whether bank armoring or disconnection of off-channel habitats have influenced off-channel habitat connectivity. The increased flashiness of the flow regime (Section 5.1.1) has most likely increased the frequency at which floodplain surfaces are inundated, but reduced the duration of time that water is present, thus reducing floodplain recharge. Agriculture and rural development are also hypothesized to have impaired floodplain function in portions of this segment, but the extent of these impacts are unknown at this time.

Flood plains in most parts of the system are predicted to widen, some by more than twice their current width, due to increases in peak stream flows from eventual basin build-out (King County 1990).

KEY FINDINGS AND IDENTIFIED HABITAT-LIMITING FACTORS

- There is a general lack of habitat information for this subbasin, especially since the mid 1980s.

- The subbasin is undergoing a rapid transition from forest and rural to urbanization, resulting in a disturbed hydrological regime that leads to salmon habitat degradation.

- Summer low flow discharges are decreasing, which limits available rearing production for species of salmonids that require over-summer residency.

- Due to the King County Basin Plan and other efforts, this subbasin is the best studied of any downstream of Howard Hanson Dam. The existing monitoring and modeling information may make this an ideal basin to direct future studies, especially in the areas of land use and associated impacts upon salmonids (i.e., an indicator subbasin).

- The hatchery rack operation near the mouth of the subbasin has disturbed the natural migration patterns of all salmonids in the subbasin. Hatchery strays (chinook and coho) into the subbasin may be interfering with native subbasin fish spawning success.

- Future water quality and sedimentation impacts from increasing urbanization in the subbasin could threaten hatchery success.

- Although no quantifiable information was available, it was the professional judgement of Technical Advisory Group (TAG) members that the riparian buffer in this subbasin was insufficient. This is in at least partly due to historic land use practices.

- There is a lack of LWD throughout the streams in this subbasin.

- Although limited information was available, it was the professional judgement of the TAG that the increased frequency of flood flows attributed to increased impervious surfaces has been at least partially responsible for degrading salmon habitat through channel incision and excessive sedimentation. These degradations limit successful incubation by scouring and smothering redds and limit rearing by reducing channel complexity.

DATA GAPS

- Little data is available on hydromodifications or habitat in Soos Creek.
- Water quality (particularly during stormwater events) and potential adverse impacts to salmonids are unknown.
- Actual, instantaneous water use within the basin is not known.
- While there is insufficient data to determine if adequate gravel is present and of suitable quality for successful spawning, the available data does indicate that this is a concern that requires additional investigation.

EARLY ACTION RECOMMENDATIONS

- Comprehensive barrier surveys need to be completed in this subbasin.
- Comprehensive base-line habitat surveys should be initiated. These surveys should at a minimum include an inventory of LWD, riparian habitats present, quality and quantity of spawning gravels, quality and quantity of pool, an evaluation of streambank stability and associated mass wasting and erosion/sedimentation problems.
- The loss of stream channel due to channelization should be quantified.
- A flow analysis examining the impacts of seasonal high flow peaks and durations on salmonid production should be initiated.
- A water use and water level monitoring program should be established.
- Additional water flow data should be gathered to provide more certainty about long-term flow trends in this subbasin.

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3.8 NEWAUKUM CREEK SUBBASIN

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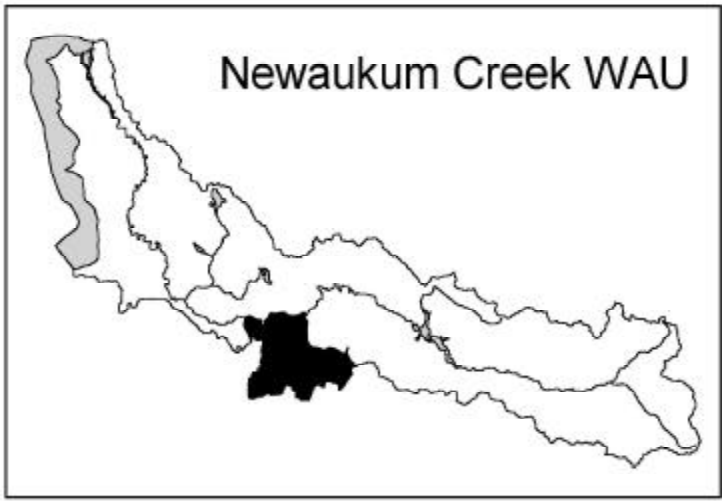
3.8 NEWAUKUM CREEK SUBBASIN



PHYSICAL DESCRIPTION

SUBBASIN

The Newaukum Creek (09.0114) subbasin drains an area of approximately 27.8 square miles. It flows from the mountains east of Enumclaw, across the Enumclaw Plateau, and enters the Green River at River Mile 40.7. The creek and its tributaries lie totally within the boundaries of King County. Portions of the subbasin lie within the Urban Growth Boundary (UGB).

The subbasin land area can be broken into the three segments:

- The upper subbasin (25 percent of the land area);
- The Enumclaw Plateau (57 percent of the land area); and
- The ravine (18 percent of the land area).

Newaukum Creek is unique in this reach of the Green River due to the large size of its drainage basin, flow, biological utilization and geographic location. It is one two large tributaries that flow into the middle reaches of the Green River, and is the most significant post-dam source of spawning gravel in to the middle reach of the mainstem Green River.

STREAM COURSE AND MORPHOLOGY

Newaukum Creek is approximately 14.0 miles long, and has eight tributaries that provide an additional 13.5 miles of stream length.

Its headwaters are formed by diffuse springs, snowmelt, and groundwater runoff in the 2,500- to 3,900-foot elevation range of Boise Ridge (a feature of the Grass Mountains, which are a part of the foothills to the Cascade Mountains).

The mainstem Newaukum Creek (09.0114) and the North Fork Newaukum Creek (09.0122) drop down steep ravines and gullies to the Enumclaw Plateau, where they join and flow across a relatively low-gradient area. The Osceola Mudflow originated from historic eruptions of nearby Mt. Rainier approximately 4,800 years ago and is the dominant geologic feature forming the Enumclaw Plateau. This mudflow was responsible for the deposition of large areas of unsorted clay sediments, which in turn have created a flat riverine topography.

After flowing across the plateau, they again enter a steep-walled ravine for the last three river miles before entering the Green River.

Newaukum Creek (RM 0.0 – 14.0) is subdivided into three channel types (Figure HM-2):

- The upper subbasin (RM 14 to RM 9) is classified as a High Gradient Contained Channel.
- The Enumclaw Plateau (RM 9 to RM 3) is classified as a Floodplain Channel (the channel is unconfined and has a gradient of 0.5).
- The ravine (RM 3) is classified as a Moderate Gradient Mixed Control Channel (the gradient increases to 2.7 percent (Boehm 1999). The channel is moderately to tightly confined but an area near the mouth of the creek has been severely altered by local landowners. The ravine extends to the confluence with the Green River, with only a short segment of alluvial fan (about 1,500 feet) extending into the Green River valley.

SALMONID USE

The known freshwater distribution of anadromous salmonids is depicted in the report Appendix. The presumed upstream distribution by chinook, coho and steelhead has been estimated by identifying the location at which the channel gradient steepens to over 12 percent. For Newaukum Creek, this 12 percent gradient break occurs at approximately RM 13.5 (Cutler 2000), about a half a mile upstream of an impassable cascade near RM 13.0 identified by Williams et al. (1975). The WDFW Spawning Ground Survey database indicates chinook have been observed upstream as far as RM 11.3, and that sockeye, coho, sockeye and chum salmon (along with winter steelhead adults) have also been observed spawning in the Newaukum Creek subbasin. Resident and anadromous cutthroat have been observed throughout the streams and lakes.

No attempt is made in this report to include abundance estimates of salmon and steelhead in this subbasin. However, the subbasin is considered to be a major producer of winter steelhead, coho and chinook salmon (Washington Department of Fish and Wildlife and Western Washington Treaty Indian Tribes 1994). During typical years, hundreds of adult chinook and adult coho salmon enter this subbasin to spawn. Malcom (1999) calculated that between 1986 and 1997, a mean of 15.6 percent of the naturally spawning adult chinook salmon that entered the Green River Basin (excluding Soos Creek because of the large hatchery returns), spawned in the lower 4 miles of Newaukum Creek.

FACTORS OF DECLINE

FISH PASSAGE

Known barriers to anadromous salmonids are shown in the reportAppendix.

King County is conducting (completion date early 2001) a comprehensive Green River Basin investigation of culvert and bridge crossings of county roads. This investigation should produce a basin-wide database identifying anthropogenic barriers or constrictors of stream channels.

In 1998, a culvert and remnants of an old dam were removed from RM 2.0 of the North Fork Newaukum Creek in order to improve access for anadromous salmonids to 1,200 meters of habitat. Subsequent smolt trap monitoring at the project site documented coho and trout use upstream (Dimock 2000).

Deposition of gravel at the mouth of Newaukum Creek where it enters the Green River floodplain has created a small alluvial fan that has impeded fish migration in at least two years (see Sediment Condition, below). Passage impediments are further exacerbated by the lack of deep holding pools on the fan (see Hydromodification) and throughout the lower mile of channel in Newaukum Creek (Malcom 1999).

Shallow or subsurface flows (see Hydrology—Low Flows) have impeded the upstream migration of adult chinook salmon into Newaukum Creek, especially the early run component (Malcom 1999; Boehm 1999).

RIPARIAN CONDITION

Riparian habitat is severely degraded in this subbasin and is believed to be contributing to the decline of natural salmonid production within this subbasin. The headlands of both Newaukum Creek and the North Fork of Newaukum Creek are used for commercial timber production.

From RM 10.0 to RM 4.0, the riparian habitat consists of a narrow (typically less than five meters wide) strip of vegetation (pers. comm. (b) (6) as reported in Malcom 1999). The forest can best be described as in transition. With the cooperation of landowners and local enhancement groups, selected locations between RM 3.0 and RM 10.5 have undergone riparian vegetation enhancement to widen the habitat (Anderson, 2000).

Because of the importance Newaukum Creek has for anadromous salmonids (particularly chinook), there have been at least two recent comprehensive surveys of the lower reaches of the mainstem creek. Boehm (1999) and Malcom (1999) separately examined the lower river mile. The riparian habitat in the lower mile consists of second-growth deciduous hardwoods and shrubs with a few conifers.

At approximately RM 0.5 the riparian forest begins to mature as additional numbers of coniferous trees are present, consisting of western red cedar, Sitka spruce, Douglas fir (*Pseudotsuga menziesii*), and western hemlock (*Tsuga heterophylla*). The deciduous trees are also more mature, with older big leaf maples and red alders present. The shrub layer also

includes snowberry (*Symphoricarpos alibis*), red elderberry (*Sambucus racemosa*), indian plum (*Oemleria cerasiformis*), sword fern, and devil's club (*Oplopanax horridus*) (Boehm 1999).

Young deciduous soft and hardwoods dominate the riparian zone of the lower 0.5 river miles of Newaukum Creek. Young red alders (*Alnus rubra*), scattered 20- to 30-year-old black cottonwoods (*Populus trichocarpa*), and big-leaf maples (*Acer macrophyllum*) dominate this reach. There are a few young western red cedars and Sitka spruce. The understory shrub layer consists of Himalayan blackberry (*Rubus discolor*), salmonberry (*R. spectabilis*), willows (*Salix spp.*), vine maples (*Acer circinatum*) and red-oiser dogwood (*Cornus stolonifera*).

Between 1996 and 1997, approximately 1,155 feet of the stream channel was realigned beginning at approximately RM 0.1 upstream to 0.25. During this time, the right bank was cleared, riprapped within the floodplain, and sprayed with a herbicide (pers. comm. (b) (6) (WDFW) reported in Boehm 1999).

LARGE WOODY DEBRIS

There is no quantitative information on the historic abundance of LWD in Newaukum Creek. In the 1950s, LWD was reportedly systematically removed from lower Newaukum Creek to protect a bridge located approximately 1,000 feet upstream of the confluence with the Green River (Boehm 1999).

Separate investigations by both Malcom (1999) and Boehm (1999) indicate that the quantity and quality of pools, riffles and LWD in the lower Newaukum Creek are insufficient. When NMFS habitat rating parameters (NMFS 1995) are applied Malcom' data, this reach of Newaukum Creek is rated as "Not Properly Functioning" for LWD. Malcom concluded that the habitat quality in this reach would continue to decline due to the age and condition of the riparian corridor and passive restoration would not be successful in the near term.

Data concerning current LWD amounts elsewhere in the Newaukum Creek subbasin is lacking. However, observations ((b) (6) pers. comm.; (b) (6) pers. comm., Boehm 1999) indicate that amounts of LWD are low and possibly average five pieces per 100 meters of stream. When NMFS criteria (NMFS 1995) is applied to LWD amounts in this range, the entire subbasin would be rated as "Not Properly Functioning."

Severe scouring and a lowering of the stream channel of the Newaukum Creek bed (see Hydrology, and Sediment Condition—Scouring, below) has thwarted attempts to place wood in the streambed (Malcom 1999).

HYDROLOGY

LOW FLOWS

Because alluvial fans are formed of deep, porous deposits of generally coarse sediment that readily transmits water, streams flowing across such sites are naturally highly vulnerable to low or subsurface flows (Levin 1981).

The Muckleshoot Indian Tribe conducted a low flow trend analysis for Newaukum Creek to determine if surface and ground water withdrawals were reducing stream low flows ((b) (6) pers. comm.). The analysis of 7-day low flows from 1967 to 1992 did not indicate a declining trend.

However, data from two other studies (Carlson 1994; Culhane 1995) indicate evidence to the contrary.

Carlson's study examined three streams similar in drainage basin size to Newaukum Creek. He concluded that declining flows were not caused primarily by declines in precipitation, but by water withdrawals.

Culhane's analysis of data from 1953 to 1992 showed a significant decline in 7-day low flows. The analysis in this investigation found an estimated 20 percent decline in mean annual flows and a 24 percent decline in low flows from 1953 to 1992When the decline in annual precipitation is compared to the measured declines in Newaukum Creek subbasin's mean annual flows and low flows, it suggests that precipitation alone is not responsible for the declining stream flows. It is reasonable to conclude that a combination of water withdrawal (surface and ground water), the conversion of historic forest lands to agricultural lands, and the elimination of the historic wetland complex of the Enumclaw Plateau have contributed to a reduction in the low flows of Newaukum Creek in the reaches of the Enumclaw Plateau and further downstream. The reaches of Newaukum Creek and the North Fork Newaukum Creek upstream of the Enumclaw Plateau are predominantly in private commercial timberland. The impacts of this land use management on flows within this reach and downstream are not known. The average 7-day low flow generally occurs during the period when chinook salmon are migrating upstream, suggesting that additional areas of low flow concerns may be present in Newaukum Creek.

WATER RIGHTS AND CLAIMS

Culhane (1995) indicated that there are 41 ground water rights in the Newaukum Creek subbasin. Three of these are for municipal use and represent 56 percent of the allocated instantaneous water quantity and 75 percent of the annual water quantity. While the majority of the number of water rights and claims in the subbasin are for irrigation and small domestic systems, the majority of the water used is for domestic purposes. Table Newaukum-1 shows water rights and claims.

NEW-1: Newaukum Creek Subbasin Water Rights

Source	Total Number of Water Rights	Qi (cfs)	Total Number of Water Claims	Qi (cfs)
Ground	41	14.2	163	6.3*
Surface	36	8.4	32	1.2

Source: Culhane 1995.
* = Estimated quantities

The tributaries to the Green River have been closed to additional surface water withdrawals since 1980 (Chapter 173-509 WAC). Potable water wells that produce less than 5,000 gallons per day

are exempt to a water right requirement. It is not known how many of these wells are present in the subbasin and what their cumulative impact might be.

SEDIMENT CONDITION

SCOUR

From RM 0.0 to RM 3.0, Newaukum Creek traverses a steep ravine. Soils in this ravine have been classified as a mixture of Alderwood and Kitsap soils (SCS 1985). These soil types exhibit a natural tendency to erode and become unstable, and this is exacerbated by historic land use practices within the ravine (e.g., timber removal and clearing for upland development). Scour has removed much of the suitable substrate in this reach and deposited gravels at the mouth of Newaukum Creek. In some years, this gravel fan can create a barrier to the upstream migration of adult chinook. In 1996 and 1998, a channel had to be hand excavated through this gravel bar to allow for upstream chinook migration. No adult chinook had been observed in Newaukum Creek prior to this excavation . Adult chinook were observed spawning immediately after the channel was excavated (pers. comm. (b) (6) as reported in Malcom 1999).

Scour surveys conducted by MIT indicate that Newaukum Creek has sufficient flows to scour salmon redds during periods when eggs would be incubating (MIT 1996). During 1997, in the lower mile of Newaukum Creek scour was so extreme that the scour survey chains could not be recovered because over 14 inches of scour occurred.

Gravels are transported rapidly through the reach and deposited in lower-gradient stream reaches. Boehm (1999) found the lower river mile of Newaukum Creek to be a mixture of large gravel (35%), cobble (30%), small gravel (20%) and sand (15%). The stream reach that had the poorest spawning gravels was the lower 1,500 feet that had been channelized by a private landowner (see Hydromodification).

A desired pool-to-riffle ratio is 1:1. Typically, as structure (LWD) is eliminated, the ratio shifts towards a riffle-dominated reach. Newaukum Creek is deficient in LWD (see Large Woody Debris, above). In many places in lower Newaukum Creek, the streambed is eroded down to a stable channel bottom with long riffle sections (Williams 1975). These long riffle sections limit holding areas (pools) for adult and juvenile salmonids and rearing areas for some species of salmonids. When NMFS habitat rating parameters (NMFS 1995) are applied Malcom's 1999data, this reach of Newaukum Creek is rated as "Not Properly Functioning" for pool frequency and quality, and for off-channel habitat.

The lower 500 feet of Newaukum Creek flow across the floodplain of the lower Green River, forming an alluvial fan composed of cobble and smaller sized sediments. No data on the historic extent or distribution of gravel bars was located. A gravel bar that has built up at the confluence with the Green River currently impairs upstream migration of adult chinook at some flows (Malcom 1999). The gravel bar may be an intermittent migration impediment as during a October 2000 field review it was observed that the channel had regraded to a consistent 2 percent grade through the bar (b) (6), pers. com.). No additional information on the existing or historic extent of gravel bars in the remainder of Newaukum Creek was located during the course of this investigation.

The Moderate Gradient Mixed Control segment of Newaukum Creek (RM 0.3 to RM 4) is essentially unconfined by levees, revetments or riprap (Malcom 1999). No information was located describing current artificial channel constraints upstream of RM 4.0 in Newaukum Creek.

WATER QUALITY

Newaukum Creek is not listed on the Washington State Department of Ecology (WDOE) 1998 303(d) list for water quality problems associated with high temperatures or low dissolved oxygen. However, temperatures greater than the NMFS criteria for properly functioning habitat (57°F) have been recorded at the USGS gage near RM 1.0 (Malcom 1998).

While not directly an adverse impact to salmonids, there are numerous reaches of Newaukum Creek listed on the WDOE 303(d) list for exceeding allowable fecal coliform limits. Samples taken at 11 stations (RM 0.9 to RM 10.8) all met the criteria to be listed on the 303(d) list. This is more of an indicator of current land use practices that may be adversely impacting the natural reproduction of salmonids.

High turbidity discharges typically occur each year during high flows in Newaukum Creek, resulting in downstream turbidity plumes in the mainstem Green River. Malcom (pers comm.) noted that on October 29, 1997, the water discharge from Newaukum Creek created such high turbidity in the Green River that chinook redds could not be identified and enumerated for as far as 4 miles downstream of the mouth of Newaukum Creek. The specific source of these high-flow discharges is currently unknown, but it appears that contributions from the commercial forest production lands, runoff from agricultural lands, and direct incision of tributary stream channels near agricultural lands may all be sources. This increased turbidity and its impacts should be further investigated, since water quality problems associated with increases in turbidity may be a limiting factor to natural salmonid production in this subbasin and immediately downstream in the mainstem Green River.

LAND USE

The Newaukum Creek subbasin is one in transition from historic forested lands to agriculture and now to rural residential.

Land use in the headwater reaches zone consists primarily of commercial forest production with minor impacts by development to date. This area is located outside the Urban Growth Boundary (UGB) and most probably will remain in commercial forest production in the future. The upland part of the basin accounts for approximately 25 percent of the land area.

Agriculture (predominantly in the form of pasture) is the major land use on the Enumclaw Plateau. The subbasin currently has a diverse development pattern, ranging from low-density residential and pasture uses to high-density residential and commercial land uses. Presently, most commercial and low-to-high-density residential land uses are situated within the UGB. The UGB encloses an area beyond the incorporated city limits of Enumclaw and faces likely future annexations and zoning changes. These future land use changes within the UGB will lead to increases in impervious-area percentages in the subbasin. The Enumclaw Plateau area occupies approximately 57 percent of the subbasin.

Forestry has been the historical land use within the ravine area. However, an increasing number of single-family residences are appearing in the ravine area. The ravine reach accounts for about 18 percent of the basin area.

NON-NATIVE SPECIES

ANIMALS

No known exotic fish species are believed to occur in the waters accessible to anadromous salmonids of this subbasin. It is likely that warmwater fish occur in some of the farm ponds and lakes of the Enumclaw Plateau.

PLANTS

Reed canarygrass (*Phalaris arundinacea*) is abundant throughout this subbasin.

Neither non-native plant or animal species are believed to be a limiting factor to natural salmonid production in this subwatershed.

HYDROMODIFICATION

Channelization and bank modifications have altered channel morphology in the short alluvial fan of Newaukum Creek. Between 1984 and 1990, a landowner periodically bulldozed and re-aligned Newaukum Creek between RM 0.1 and RM 0.3, straightening meanders and piling LWD in the old channel to force flows into the newly excavated channel (Boehm 1999). In addition, the riparian zone was cleared and recently riprapped just downstream of RM .01 to protect a septic and well system (Boehm 1999).

OFF CHANNEL HABITAT

This riverine topography, when combined with numerous depressions has formed a complex of wetlands across the landscape of the Enumclaw Plateau. The historic wetlands of this subbasin were large enough that many have been named (King County 1990a). They include:

- Newaukum Creek No. 21 (158 acres);
- Newaukum Creek No. 51 (144 acres);
- Newaukum Creek No. 22 (63 acres);
- Newaukum Creek No. 14 (45 acres); and Newaukum Creek No. 31 (29 acres).

Most of these wetlands have been converted into agricultural lands (primarily pastures) through ditching, draining and filling activities over the past 100 years.

FLOODPLAIN CONNECTIVITY

Floodplain development is naturally limited in the High and Moderate Gradient Contained Channel segment, thus human activities have not substantially altered floodplain connectivity in upper (RM 9 to RM 14) or lower (RM 0 to RM 5) reaches of Newaukum Creek.

No quantitative data on historic or current floodplain connectivity was locate. However, the floodplain segment of Newaukum Creek (RM 5 to RM 9) is associated with a floodplain that typically would be able to support inundation-tolerant vegetation, contain side- and off-channel habitats, and serve as a groundwater re-charge zone. The palustrine channel segment is described as "cutting through pasture and flat farmlands with very little natural growth available to provide shade and protection to the creek" (Williams et al. 1975). Agricultural and rural residential development have continued to influence habitat in the palustrine segment of Newaukum Creek, and have resulted in altered floodplain function. In many places, the mainstem Newaukum Creek streambed is eroded down to a stable channel bottom with long riffle sections (Williams 1975).

Many of the tributaries to Newaukum Creek have been channelized into roadside and drainage ditches. The lower three miles of Newaukum Creek flow through a deep, confined ravine. The lower 500 feet of Newaukum Creek currently has a moderate gradient (about 2%) and during seasonal low flows a blockage to adult chinook may exist at the mouth (See Sediment Condition, above). The mainstem Newaukum Creek does flood in some localized areas, particularly in areas upstream of constriction points such as undersized culverts and riprap (Kerwin, pers. obs.).

There was no available data located on the historic frequency of off-channel habitats in Newaukum Creek. Based on channel type, it is expected that off-channel habitats are likely to be present only in the 1,500 foot long reach where the alluvial fan crosses the Green River floodplain or in the Palustrine segment (RM 5 to RM 10) under undisturbed conditions. There are considerable numbers of off-channel habitats between RM 2 and 3. These off-channel habitats consists of numerous side channels, many of them 100 meters or greater in length that have associated extensive wetland complexes. Numerous braided stream channels are visible from aerial photographs. Off-channel habitats are expected to be rare in the High Gradient Contained segment (RM 10 to RM 14) because the confining valley walls effectively limit lateral migration.

Surveys of lower Newaukum Creek conducted in 1998 categorized the area between RM 0 and RM 0.6 as having "few or no backwaters and no off channel ponds" (Malcom 1999) and are assumed to be representative of the entire Moderate Gradient Mixed Control segment. There is no information on the current extent of off-channel habitat available in the Palustrine segment between RM 5 and RM 10.

FLOODPLAIN CONNECTIVITY

Approximately 1,155 feet of the stream channel were realigned between 1996 and 1997 beginning at approximately RM 0.1 upstream to 0.25. This activity has reduced stream channel complexity (pers. comm. (b) (6) (WDFW) as reported in Boehm 1999). In response to the channelization, an adjacent landowner attempted to protect his property by clearing and riprapping the right bank (as well as removing LWD and applying herbicide to vegetation within the riparian zone).

KEY FINDINGS AND IDENTIFIED HABITAT-LIMITING FACTORS

- The virtual absence of LWD is believed to be a limiting factor to natural salmonid production in this subbasin.

- Stream scour is exacerbated by uncontrolled stormwater runoff from upstream roads that have no stormwater controls, farms, and urban areas in Enumclaw. Scour and bedload movement are believed to be a limiting factor to natural salmonid production throughout Newaukum Creek subbasin.

- Channel conditions are believed to be a limiting factor to natural salmonid production in this subbasin.
- There is a general lack of riparian habitat information for this subbasin.

- Newaukum Creek is the first significant source of stream transported spawning gravels for the mainstem Green River downstream of HHD.

- The Newaukum Creek subbasin supports significant numbers of spawning chinook along with coho, winter steelhead, chum, sockeye and coastal cutthroat.

- The lower 0.3 miles of Newaukum Creek have been dredged and straightened by private landowners.

- Stream cleaning and riparian harvest have reduced the frequency of LWD in the lower 1.4 miles of Newaukum Creek to 0.3 pieces per channel width, a level considered “poor” or “not properly functioning”. Pools are also scarce.

- Although the subbasin is undergoing a transition from forest to rural and urbanization land use there is still significant portions of the subbasin that could be effectively restored.

- Summer low flows are decreasing.

- Although no quantifiable information was available, it was the professional judgement of Technical Advisory Group members that the riparian buffer in this subbasin was insufficient. This is in at least partly due to current and historic land use practices.

- There is a lack of LWD throughout the streams in this subbasin.

- Summer low flows have decreased in the Newaukum Creek subbasin. These low flows effectively limit available rearing production for species of salmonids that require over-summer residency.

- Water quantity (both seasonal low flows and winter storm flows) due to changes from historic land use patterns and withdrawal, are limiting the natural production of salmonids in this subbasin.

DATA GAPS

- Little data available on hydromodifications channel condition, LWD and other critical habitat conditions or habitat in the Newaukum Creek Subwatershed.

- The impacts of seasonal high flow peaks and durations on salmonid production should be determined.

- Water quality, particularly during stormwater events and potential adverse impacts to salmonids are unknown.

- Actual, instantaneous water use within the basin is not known.

- There was no data available that provided the location and magnitude of mass wasting sites.

EARLY ACTION RECOMMENDATIONS

- Conduct a comprehensive inventory of current salmonid habitats.

- Conduct a comprehensive barrier assessment and habitats upstream of identified anthropogenic.

- Because of this lack of site specific habitat data, comprehensive base line habitat surveys should be initiated. These surveys should at a minimum include an inventory of LWD, riparian habitats present, quality and quantity of spawning gravels, quality and quantity of pool, an evaluation of streambank stability and associated mass wasting and erosion/sedimentation problems. We need to more adequately understand the spatial dynamics and distribution of LWD and associated habitats and identify opportunities for accelerated riparian forest recovery. To accomplish this, counts of wood loading, distribution and characteristics over time at key locations stratified by stream order, elevation and channel reach type, gradient, riparian zone features (width, species composition and age composition) should be made.

- A water use and water level monitoring program should be established.

- Additional water flow data should be gathered to provide more certainty about long-term flow trends in this subbasin.

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3.9 COAL AND DEEP CREEKS SUBBASINS

PHYSICAL DESCRIPTION

SUBBASIN

Coal (09.0126) and Deep creeks (09.0142) are grouped together in this report because of their close geographical location and their influence on groundwater. Neither of the creek systems are directly linked by surface connection to the mainstem Green River, and both drain into small lakes that do not have surface water outlets.

However, their importance to anadromous salmonids lies in the theory that water from these lakes seeps underground and surfaces as perched springs and/or riverbed springs in the Green River streambed in the vicinity of RM 48 – 50. Other lakes in the vicinity (i.e., Muskrat Lake) may also contribute to these springs.

STREAM COURSE AND MORPHOLOGY

COAL CREEK

Coal Creek is approximately 9.2 miles long. Its 15 tributaries have approximately 8.0 miles of combined additional stream length. The mainstem of Coal Creek empties into Fish Lake (which is only 3,500 feet west of Deep Lake). Fish Lake is located 729 feet above sea level, encompasses 16.5 surface acres, and has a maximum depth of 22 feet (Wolcott 1973). The basin lies largely below 2,500 feet in elevation and is subject to rain or snow events.

DEEP CREEK

Deep Creek is approximately 4.8 miles long. Its three small tributaries add approximately 1.5 additional stream miles. This creek drains into both Hyde and Deep Lakes. It is believed that both lakes are important groundwater source to the mainstem Green River (Wolcott 1973; Williams 1975).

Hyde Lake (sometimes referred to as Elizabeth Lake) is located approximately 2,300 feet north from Deep Lake at approximately 800 feet in elevation with a surface area of 5.4 acres (Wolcott 1973). The only water supply is from Deep Creek is via a small stream channel. Wolcott (1973) theorized the lake's outlet is subsurface to springs along the Green River.

Deep Lake is fed by Deep Creek and is located at approximately 770 feet in elevation with a surface area of 39.0 acres, a maximum measured depth of 76 feet. It is approximately 3,500 feet east of Fish Lake (Wolcott 1973). Wolcott (1973) and Williams (1975) theorized the lake's outlet is subsurface to the springs along the Green River between RM 48-50.

SALMONID USE

COAL CREEK

Cutthroat trout have been observed (Phil Schneider, WRIA 9 map info) and reported to use Coal Creek ((b) (6) pers. comm.). Locations of the observations are noted in the report Appendix.

DEEP CREEK

No observations were recorded for Deep Creek as part of the WRIA 9 mapping effort.

FACTORS OF DECLINE

FISH PASSAGE

Fish Passage information on these systems is limited at this time.

RIPARIAN CONDITION

The commercial timber in the middle reaches of both the Coal and Deep creek subbasins have largely been logged and replanted at various times in the last 25 years (Kerwin 2000). Fire scars are also present along some hillsides. Deep Lake State Park affords some protection for the riparian zone around the lake.

LARGE WOODY DEBRIS

LWD information on these systems is limited at this time.

HYDROLOGY

COAL CREEK

Coal Creek serves as the water source for Fish Lake and the lake does not have a surface water outlet. During seasonal low flows, water flows in Coal Creek are subsurface in some locations. No surface flows were observed in Coal Creek at the culvert immediately upstream of Fish Lake on October 30, 2000 (Kerwin, 2000). As the flows in Coal Creek diminish, the water surface elevation of Fish Lake begins to drop. These water surface elevations in fluctuate substantially from full pool at 729 mean sea level (m.s.l.) during the springtime to nearly empty at 694 m.s.l (Higgins 2000) during late summer and early fall. Water flows from Icy Creek Springs also begin to decrease throughout summer months and reach their lowest levels when the water surface elevation in Fish Lake is lowest (Mercer 2000).

Observations of the stream channel in the vicinity of Fish Lake and at the Cumberland-Kanaskat Road on October 30, 2000 indicate that the stream was deeply incised and was capable of carrying sizeable high flows.

It has been theorized that the glacial drift that underlies Fish Lake is sufficiently permeable to allow for the total infiltration of lake water rather than the lake having a surface water outlet. Previous studies (CH2M, Hill/Long and Associates, 1991; Brown and Caldwell, 1989; TCW Associates, 1989) concluded that this infiltrated water reemerges as the large-volume springs along the eastern banks of the Green River between RM 48 and RM 50. These springs include the Fish Hatchery Springs at Icy Creek, Black Diamond Springs, Palmer Spring, and Resort Spring. The exact path that this infiltrated water takes is not known but is thought to be controlled by the glacial drift and the buried topography of the bedrock contact with the glacial drift.

Water from the Icy Creek Springs is utilized for fish propagation purposes by the Washington Department of Fish and Wildlife. During low flow periods the rearing ponds are able to capture all the water flowing from these springs and flow measurements are taken monthly as they exit the rearing ponds. During seasonal high flows, the piping system into the ponds is not capable of handling the entire spring flows and flows are estimated. The range of these flows are shown in the table ICY-1. Springflows typically peak during the winter months when precipitation and lake levels are the highest and are they are at their lowest in October and November when lake water levels are low and groundwater is being recharged. Water temperatures as measured at the hatchery rearing pond typically range from 42 F (February) to 50 F (August) (Mercer 2000).

Table Coal-1: Icy Creek Rearing Ponds and Springs (Mercer 2000).

Month	Water Flows (gpm)
January	3700 - 5300
February	3700 - 5300
March	4000 - 5450
April	5300 - 5800
May	2800 – 5100
June	2800 - 3100
July	2500 - 3100
August	2600 -3300
September	1100 – 1580
October	700 - 915
November	1300 – 4500
December	3400 - 3900

The impacts on ground water hydrology at a proposed gravel surface mining operation in the vicinity of Fish Lake has caused some concerns about spring flow at the Icy Creek Spring.

No information on stream flows was located during the course of this investigation.

DEEP CREEK

The surface water elevation of Deep Lake is reported to fluctuate 12-15 feet with lower lake surface elevations reported during late summer and early fall during seasonal low flow conditions (Johnson 2000).

No information on stream flows was located during the course of this investigation.

SEDIMENT CONDITION

Sediment conditions are not applicable given the unique situation of these two stream systems.

WATER QUALITY

Water quality as monitored at the Icy Creek Springs and Black Diamond Springs indicates that both creeks meet or exceed all state water quality criteria for Class AA state waters.

LAND USE

Land use within the upper and middle reaches of both creeks is primarily commercial timber production. In the downstream reach land use is rural residential with a mixture of single family homes and hobby farms. Deep Lake is surrounded by Deep Lake State Park.

NON-NATIVE SPECIES

ANIMALS

Fish Lake and the headwater lakes have been planted with non-native rainbow trout but as previously stated the lake does not have direct surface water contact with the Green River. With the unique situation of these stream systems, the presence of non-native animal species in upstream reaches does not appear to have any adverse impacts to anadromous stocks.

PLANTS

The only non-native plant species observed in the vicinity of the Icy Creek and Black Diamond Springs was Himalayan blackberries.

Hydromodification

The surface elevations of Fish, Deep, and Hyde lakes are naturally controlled. There are several road crossings where culverts are utilized, but these do not appear to be fundamental habitat-limiting factors.

Hydromodification is present at the spring intake systems at Icy Creek (for non-consumptive use) and Black Diamond Springs (for consumptive use). Both facilities use low-head dams to divert water.

KEY FINDINGS AND IDENTIFIED HABITAT-LIMITING FACTORS

- The lakes provide an important function in maintaining springflows in the Green River between RM 48 – 50.

- No habitat-limiting factors were identified at this time.

DATA GAPS

- Stream flows, lake elevations and their relationship with spring flows should be established.

- The proposed gravel surface mining operation in the vicinity of Icy Creek and its potential impact to spring water should be verified.

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Table Coal-1: Icy Creek Rearing Ponds and Springs (Mercer 2000).

3.10. UPPER GREEN RIVER AND SUNDAY CREEK WATERSHED ADMINISTRATIVE UNIT

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3.10. UPPER GREEN RIVER AND SUNDAY CREEK WATERSHED ADMINISTRATIVE UNIT

EXECUTIVE SUMMARY

SUBBASIN

The Green River, upstream of River Mile 64.5 has been divided in to five Watershed Administrative Units (WAUs). WAUs are drainage basins delineated by the Washington Department of Natural Resources (WDNR) for the purpose of conducting Watershed Analysis. The purpose of a Watershed Analysis is two fold and dependent on land ownership. For State and private lands the purpose is to address the cumulative effects of commercial timber harvest upon public resources such as the Northern Spotted Owl or salmonids. This is for the purpose of maintaining a manageable land unit size in order to meet the intended timelines as established by the Washington Forest Practices Board.

For federal lands which are managed under the provisions of the Northwest Forest Plan, the purpose is to meet the watershed analysis requirements established in the Record of Decision for Amendments to U.S. Forest Service and Bureau of Land Management Planning Documents within the range of the Northern Spotted Owl, April 13, 1994.

Both of these processes are not decision making processes, but are intended to be used in a manner to set the stage for subsequent decision making processes. Both characterize ecosystems, or portions of ecosystems, by highlighting problem areas and suggesting solutions on a watershed scale.

Within the State and Private lands, a Watershed Analysis in four of the five WAUs in the upper Green River Subbasin have been completed and three of these have been released. Forest management recommendations have been approved for the Lester WAU and drafts are currently being reviewed for the Howard Hanson, Smay Creek, Upper Green River and Sunday Creek WAUs. The North Fork Green River WAU report has not been started.

Under the federal process, the Green River Watershed Analysis (U.S. Forest Service 1996) has been completed and released.

For the purposes of this report we will attempt to summarize, by WAU, the current habitat conditions and document the potential for recovery of the impaired habitats.

WATERSHED ANALYSIS METHODS

Because the methodology used in watershed analysis is somewhat unique, it is useful to outline that methodology. Stream segments are selected to represent an array of geomorphic channel types of salmonid bearing streams. Gradient, confinement, and bankfull width, are the parameters in which to base the selection. Other features such as land-use, riparian conditions, aspect, and channel disturbance history provide additional considerations for representation. Because the objective of this analysis is to determine habitat features and factors that limit

natural salmon production in the respective WAUs, segment selection is targeted on known salmonid-bearing streams and those that met the physical criteria to qualify as fish-bearing as defined by the draft stream typing emergency rule (later adopted on November 14, 1996). Delineation of the segments is initially done using topographic maps and aerial photos, then field verified during the surveys. Also, old aerial photographs helped to visually assess channel character in an undisturbed state (prior to forest management) and hypothesize habitat potential [1942 (partial coverage) and 1958 (first complete stereo coverage)].

Surveyed stream segments are grouped into geomorphic channel classifications for sub-basins within the two WAUs. Based on the work of Montgomery and Buffington (1993), Pleus and Schuett-Hames (1998), O'Connor (1997), as well as considering the actual distribution of segments surveyed, groupings in the Green River and Sunday Creek WAUs were sorted into 3 classes of channel gradient, 3 classes of confinement, and 5 classes of bankfull width for a total of 45 possible combinations. These classes and their criteria for inclusion are provided in table Upper Green-1.

Table Upper Green-1. Matrix of Possible Channel Classifications Used to Group Segments for the Purpose of Establishing Geomorphic Units.

Geomorphic Feature	Criteria				
Gradient (%)	0-2		>2-8		>8-20*
Confinement	Unconfined (valley width > 4 channel widths)		Moderately confined (valley width 2-4 channel widths)		Confined (valley width < 2 channel widths)
Bankfull width (m)	0-5	>5-10	>10-15	>15-20	>20
*No streams were surveyed with gradients exceeding 20%.					

FIELD MEASUREMENTS AND OBSERVATIONS

Information sources to determine sampling sites include topographic maps (USGS), aerial photographs (1989), and fisheries distribution information (WARIS). Sampling sites are prioritized based on (in descending order of importance): a) the location of fish producing (or potentially producing) stream reaches; b) the need for verification of geomorphic character; and c) riparian diversity. Typically physical habitat sample reaches are 100 meters in length. The analyst surveyed one to three evenly distributed reaches within a segment.

In the Green River and Sunday Creek WAUs, stream surveys are conducted and completed during moderate to low flow conditions from July through September 1995. The sampled parameters were quantitatively assessed using methodologies for field habitat collection outlined in the State's Ambient Monitoring Manual (Schuett-Hames et al., 1994), the U.S. Forest Service Stream Handbook, and the Watershed Analysis Manual Version 3.0. Sediment samples were collected in riffle crests in accordance to the method of Schuett-Hames et al. (1994) using a McNeil core sampler, and analyzed by the gravimetric method. Temperature recordings were obtained by maximum thermometers, and thermographs recording at 1 hour intervals from July through September, also in accordance to the temperature monitoring methods of Schuett-Hames et al. (1994). Scour information was obtained using scour chains placed in suitable spawning area. Substrate data were categorized into six size classifications (based on the U.S. Forest Service Stream Handbook, 1991), and frequency of occurrence calculated. All visual

observations of juvenile and adult fish were also recorded during the surveys to verify DNR Water Type maps.

A synopsis of the definitions used in this methodology as described in Schuett-Hames (1994) is included in table Upper Green-2. Minimum area and depths for a unit to be considered a pool are shown below in table Upper Green-3.

Table Upper Green-2. Definitions of Units and Terms Used in this Report.	
Term	**Unit Description**
Log or large woody debris (LWD)	For Washington State Watershed Analysis, a log, not part of a live tree greater, than 0.10 m (0.33 ft) diameter and greater 2 m (6.5 ft) in length. To qualify, the piece of wood must lie within the vertical axes of the bankfull width, or at least protrude into these vertical axes. If ten or more pieces are touching, it is considered a jam (jams are explained below). The NMFS defines LWD as a minimum of 0.6 m diameter and 15 m length
Key Piece	A log or rootwad independently stable in the stream bankfull width (not functionally held by another factor – see stability factors) and retaining or having the potential to retain other pieces of wood. The NMFS has no comparable parameter.
Rootwad	A rootball greater than 51 cm (20 in) in diameter and with a stem less than 2 m (6.5 ft) length. A stem longer than 2 m in length is considered LWD. To qualify, the piece of wood must lie within the vertical axes of the bankfull width, or at least protrude into these vertical axes. If ten or more pieces are touching, the piece is considered part of a jam (jams are explained below).
Wood Zone	Zone 1- Protruding into the low flow wetted channel surface. Zone 2- Not protruding into the wetted channel surface, but protruding below the horizontal axis of the ordinary high water mark (OHWM). Zone 3- Not protruding into zone 1 or 2, but protruding to within the vertical boundaries of the bankfull width (i.e. bridged or suspended over the channel).
Bankfull Width (BFW)	Bankfull width is the width of the channel at bankfull flow. It includes the BFW of all side channels and braids along the measured cross-section.
Log or Debris Jam	A cluster of ten or more touching pieces of wood with at least part of the jam located within zones one or two. To qualify as piece to be counted, the wood must meet the size requirements of LWD or a rootwad.
Category 1	The dominant unit within the cross section of the main channel, occupying at least 50% of the wetted channel width. There is only one category 1 habitat unit per linear length of the main channel.
Category 2	Units within, or adjacent to category 1 units, occupying less than 50% of the wetted channel width. Category 2 units are included in the total sum of the length of habitat units surveyed. Therefore, the total length of habitat units can exceed the total stream distance surveyed.
Category 3	Isolated channels, smaller than the main channel, connected to the main channel both at the upstream and downstream ends. Category 3 units are included in the total sum of the length of habitat units surveyed. Therefore, the total length of habitat units can exceed the total stream distance surveyed.
Category 4	Off-channel areas. These units are not defined in the Ambient Monitoring Manual, but are assigned to habitat units that provide off-channel rearing in summer or winter, but do not fall into any of the above categories. These units are typically wetlands that are not defined as the main channel, but are connected to it, and channels that are connected to the stream at only one point (i.e. not a side channel). Category 4 units are not included in the sum of the length of habitat units surveyed.
Residual Depth	The maximum depth minus the tail crest depth. This depth does not change with flow and can be measured even if the stream channel is dry.
Maximum Depth	The maximum depth of the sampled habitat unit. Unlike, residual depth, this measurement is influenced by flow.
LWD Total length	Measured distance from one end to the other end of the wood piece, including attached rootball. Logs are measured to the point where it no longer meets the minimum required diameter.
LWD Diameter	Measured at the mid-point of the log.
LWD Stability Factor	Factor responsible for the stability of the wood in the channel. A piece is either is stabilized by (1) a root system; (2) burial exceeding 50% of the length of the wood; (3) pinned by other pieces of wood, trees or rocks, or (4) is unstable.
LWD Sediment Storage	Wood that retains significant quantities of fine or coarse sediment of any size by influencing bed form. Wood does not need to be directly touching the stored sediment. Generally, fine sediments are those less than 0.85 mm in size
Sources: Schuett-Hames *et al.* (1994), WPFB (1997), and NMFS (1995, 1998). Important differences between State and Federal definitions are noted.	

Table Upper Green-3. Habitat Units.								
Minimum Area Criteria for Pools by Channel BFW					Minimum Residual Depth Criteria for Pools by Channel BFW			
BFW	Min. Unit Size				BFW	Min. Residual Pool Depth		
Metric	Imperial	Metric	Imperial		Metric	Imperial	Metric	Imperial
0-2.5 m	0-8 ft	0.5 m^2	2 ft^2		0-2.5 m	0-8 ft	0.10 m	0.3 ft
2.51-5 m	8.1-16 ft	1.0 m^2	10 ft^2		2.51-5 m	8.1-16 ft	0.20 m	0.7 ft
5.01-10 m	16.1-32 ft	2.0 m^2	20 ft^2		5.01-10 m	16.1-32 ft	0.25 m	0.8 ft
10.01-15 m	32.1-49 ft	3.0 m^2	32 ft^2		10.01-1 5 m	32.1-49 ft	0.30 m	1.0 ft
15.01-20 m	49.1-65 ft	4.0 m^2	43 ft^2		15.01-20 m	49.1-60 ft	0.35 m	1.1 ft
>20 m	>65	5.0 m^2	54 ft^2		>20 m	>65 ft	0.40 m	1.3 ft
Note: Minimum area required to form pool, riffle, tailout, cascade, or wetland habitat units. A habitat feature must meet the minimum size to be split from another unit. Pools must meet a minimum residual depth to qualify as a pool. Wetland units also include off-channel areas associated with the main channel, but not part of the main channel.								

Any presence of salmonids was determined by surveys that were conducted utilizing methods outlined in the Washington DNR Forest Practices Handbook, (DNR 1994), the Timber/Fish/Wildlife Ambient Monitoring Program Manual (Schuett-Hames 1994), and the Water Type Emergency Rule (Forest Practices Board, 1996). Other physical information collected in the surveys included habitat data, potential salmonid passage barriers, and evidence of recent disturbance (<20 years). Streams classified as Type 4 and 5 by the DNR water type maps were selected with priority given to streams on the basis of physical features that indicated a strong likelihood of salmonid presence (e.g. drainage area >50 acres, gradients <20 percent , low basin elevation, or any combination of these), although several streams beyond these parameters may also be surveyed at the discretion of the survey team. The basin areas selected were prompted by Watershed Analysis in other similar stream basins. Surveys are concentrated on visiting as many streams as possible over the three month survey period of each year.

SURVEYS

Surveys are conducted during sampling seasons that are typically during July to October. Survey seasons were limited to this particular window of opportunity to allow for a better chance to observe salmonids due to local salmonid life history cycles. The elevation of stream reaches has a bearing on the ability to observe salmonids. In the Green River Sunday Creek WAUs, the elevation is relatively high (1500-4000 feet) and resident salmonids or juvenile anadromous salmonids can be lodged deeply within gravels and organic debris. Typically, during colder air and water temperatures food sources are not present for feeding, thus making any salmonid detection more difficult. Also, high flows often occurring outside the survey window likely contribute to difficult detection of salmonids because they are either displaced downstream, under cover in inaccessible interstitial space, or are difficult to see because of water turbidity.

The physical stream characteristics were determined from topographic maps and aerial photographs as had occurred during the original DNR water typing in 1979. These characteristics are verified in the field utilizing the methods from the TFW Ambient Monitoring protocols (NWIFC, 1994) for determining channel bankfull widths and wetted widths, as well as the DNR Forest Practices Handbook (DNR, 1994) for calculating gradient. Channel length and bankfull width are measured by a hip-chain and tape measure, respectively. Length and width are typically measured to the nearest 1/10th meter. Stream gradient is measured by a hand-held

clinometer at 25 meter stations and averaged, and pool depth is measured with a stadia rod from the deepest part of the pool to the water surface. Gradient is measured to the nearest 1 percent and pool depth to the nearest 1/10th meter. Flood plain connectivity is determined by measuring the lineal meters of road adjacent to one or both sides of a stream segment, and dividing by the length of the stream segment to generate a percent reduction in connectivity. Width-to-depth ratio is calculated by dividing the bankfull width by the channel depth. Road density is obtained by measuring road lengths per stream sub-basin using a desktop GIS software product.

METHODS OF ANALYSIS

Surveyed reaches are assessed to whether the habitat is potentially used by each of the four salmon species identified previously, using the methods of the US Army Corps of Engineers (USACE 1998) for determining species utilization in the upper Green River. The USACE delineated specific stream segments in the upper Green River that provide habitat for coho, steelhead, fall chinook, and spring chinook. Thus, the segments where habitat surveys are conducted were grouped in accordance to respective species in which they serve. To this end, the quality of habitat pertaining to each of these salmon species can be evaluated.

An analysis of the stream survey data, as categorized by respective salmon use, is conducted to determine habitat condition in the respective WAUs. Applicable, collected data are typically quantified using a Watershed Analysis Stream Survey Program spreadsheet (Fox 1996). Habitat metrics can then analyzed using two methods. The first compares the indices of resource conditions for interpretation of field survey results and habitat analysis in accordance with the methodology specified for Watershed Analysis in the State of Washington (Washington Forest Practices Board [WFPB] 1997). The second method of analysis compares these indices with the National Marine Fisheries Service's Matrix of Pathways and Indicators for habitat function (NMFS 1995; NMFS 1998). These methods provide quantitative or descriptive guides that link critical input variables to the habitat requirements of salmon. By accomplishing this, the factors that limit salmon habitat can be identified.

Both the NFMS "Matrix of Pathways and Indicators" and the Washington State Watershed Analysis "Indices of Resource Conditions" compare observed stream habitat conditions to a standard numerical or narrative descriptions. Both systems group the observed habitat quality or quantity into three broad categories. The WFPB uses "poor", "fair", and "good" while the NMFS uses "Not Properly Functioning", "At Risk", and "Properly Functioning". As both systems use three tiers of habitat condition, one can compare the narrative rating of equivalent or roughly equivalent habitat parameters. For the purposes of this report, "poor" was considered equivalent to "not Properly Functioning" and "good" comparable to "Properly Functioning". As several of the Washington State "Indices of Resource Conditions" metrics are similar to those of the NMFS "Matrix of Pathways and Indicators", both were listed for the purpose of comparing methods.

Several habitat parameters of the NMFS Matrix of Pathways do not contain threshold criteria in which to determine a habitat condition. For example, "Holding Pools" by the WFPB definition, synonymous with "Pool Quality" by the NMFS matrix, define respective ratings of "Good" and "Properly Functioning" as having "sufficient" pools >1m deep. Terms such as "sufficient", "few", and "most" do not have threshold criteria in which to base a determination of whether or not it serves as functional habitat. For this reason, criteria were developed for the parameters that

lack thresholds based on best professional judgement based on knowledge of life history requirements of salmonids utilizing these WAUs. Data, as available, were also used to support these determinations. The following criteria were developed for these habitat parameters:

RIPARIAN CONDITIONS

Riparian habitat conditions were used to assess potential sources of riparian wood recruitment, which is used in conjunction with the NMFS parameter of "LWD Quantity". The condition of riparian habitat is estimated using the methods described in the Washington Forest Practices Board Manual for Conducting Watershed Analysis (1994 [revised in 1997]). This method determines the age, species, and density of riparian forest stands. Potential wood recruitment into streams is based on tree height (McDade et al. 1989), and coniferous wood has greater longevity in the channel than deciduous wood (Robison and Beschta, 1990). Thus, riparian stands were considered to contain "properly functional" recruitment conditions if they were comprised of conifer trees in an "old" seral stage, "At Risk" if riparian trees were comprised of mature conifer or deciduous species, and "Not Properly Functioning" if riparian trees were young, (deciduous or conifer). Any stand that is classified as "sparse" in terms of density, is considered to be "Not Properly Functioning". Age classifications of "old" is defined as trees having a $\geq$20 inches diameter breast height (dbh), "mature" as trees having $\geq$12 and <20 inches dbh, and young as <12 inches dbh (WFPB 1997).

The frequency of deep (>1m) holding pools is likely intended for adult salmon during upstream migration and spawning. Thus, limits in the distance a salmon can swim prior to reaching the next "resting place" is a function of body size and adult salmonid metabolic requirements, or spawning density. Due to the variability in holding pool requirements and the paucity of studies that quantify this need, a threshold is determined through "best professional judgement" based on knowledge of salmon body-size and densities that use these WAUs. Thus in these watershed analyses, $\geq$4 pools >1m deep per 100 meters of stream length will constitute as "good" (WFPB) and "Properly Functioning"(NMFS), 2-4 pools per 100 meters as "fair" and "At Risk", and <2 per 100 meters as "poor" and "Not Properly Functioning".

Flood plain connectivity was assessed and ranked using the following criteria: 1) Severe reduction in connectivity: greater than 50 percent of the stream segment is confined by anthropogenically constructed features on at least one banks (e.g. roads, levees, railroad grades, etc.); 2) Reduced connectivity: between 10-50 percent of the stream segment is confined by anthropogenically constructed features on one or both banks; or 3) insignificant reduction in connectivity: less than 10 percent of the stream segment is confined by anthropogenically constructed features on one or both banks.

Off-channel habitats typically comprise the areas of slower water velocities, often associated with winter-rearing life histories. Lack of suitable off-channel habitats can adversely affect winter-rearing, and also summer-rearing salmonids. Studies that determine threshold quantities of off-channel habitat are unavailable, thus an estimate to these quantities was made based on best professional judgement and knowledge of life history requirements of salmonids utilizing these WAUs. Data, as available, were also used to support these determinations. The NMFS criteria has no specified quantities of off-channel habitat to meet "Properly Functioning condition", although it makes reference to "few", "some", and "present". To this end, off-

channel habitat greater than 10 percent of the total channel surface area within the survey reach will be considered as "Properly Functioning", 5-10 percent off-channel habitat will be considered as "At Risk", and less than 5 percent will be considered as "Not Properly Functioning".

SPAWNING GRAVEL

Salmonids require sufficient quantities of gravel of a size range for spawning and incubation. Such gravels are small enough to be readily excavated during redd construction, yet large enough to promote oxygenation and metabolic waste removal through flow permeability. The NMFS criteria specify that gravel or cobble must be dominant with clear interstitial spaces in order to qualify as "Properly Functioning". To this end, stream reaches having a frequency of occurrence of 50 percent or greater of gravel and cobble will be considered as "Properly Functioning", 25 to ≤50 percent cobble/gravel will be considered "At Risk", and <25 percent cobble/gravel "Not Properly Functioning". Size definitions for gravel and cobble are presented in table Upper Green-4.

Table Upper Green-4. Size criteria Used to Classify Substrate in the Habitat Surveys in the Upper Green River and Sunday Creek WAUs.

Substrates
1- Sand, silt, clay. [<0.25" or <0.8 cm (smaller than pea size)]
2- Small Gravel [0.25"-1" or >0.8-2.5 cm (pea to golf-ball size)]
3- Large Gravel [>1" - 3" or >2.5-7.5 cm (golf-ball to baseball size)]
4- Small Cobble [>3"-6" or >7.5-15 cm (baseball to cantaloupe size)]
5- Large Cobble [>6"-12" or >15-30 cm (cantaloupe to basketball size)]
6- Small Boulders [>12"-40" or >30cm-1.0 m (basketball to car-tire size)]
7- Large Boulders [>40" or >1.0 m (greater than car-tire size)]
8- Bedrock

Also in accordance to the NMFS criteria, suitable substrate must have less than a certain degree of embeddedness (see Table 4). Embeddedness data are typically not collected during the surveys; however, data regarding the quantity of spawning gravel are shown where they were obtained for each reach. These data indicate the percent of total substrate that meets the life-history requirements for spawning and incubation such as flow velocity, particle size, the ability to excavate, etc.. This parameter, when coupled with the percent frequency of habitat units containing gravel/cobble as substrate, indicates how much of this substrate is embedded or does not possess the qualities of suitable spawning gravels. To this end, gravel/cobble substrates meeting the required frequency percentage as discussed above also occupy a minimum of 10 percent of the reach area. This is a combined percent of both anadromous and resident spawning area. For example, if greater than 50 percent of the habitat units contain gravel/cobble, the total spawning area for anadromous and resident species must be greater than 10 percent to qualify as "Properly Functioning". If the area quantity is less than 10 percent, the gravel will be considered embedded or otherwise "non-spawnable", and will be considered "Not Properly Functioning" regardless of the percent frequency of habitat units containing gravel/cobble. The methods and definitions for determining anadromous and resident spawning gravel are provided immediately below:

Anadromous: Within the habitat unit, the surface area of suitable spawnable gravel for large bodied or anadromous fish (gravel sizes ranging from 0.76 inches to 1.5 inches) will be determined and quantified. The site must have favorable characteristics for successful spawning, and incubation to emergence (i.e.: loose gravel, non-embedded, little evidence of scour, and sufficient flow depth and velocity).

Resident: Within the habitat unit, the surface area of suitable spawnable gravel for small bodied or resident fish (gravel sizes ranging from 0.25 inches to 0.75 inches) will be determined and quantified. This site must have favorable characteristics for successful spawning, incubation, and emergence (i.e.: loose gravel, little evidence of scour, and sufficient flow depth and velocity).

Table Upper Green-4. Some of the Habitat Rating Parameters used by the NMFS (NMFS 1995; NMFS 1998) and the Washington State Forest Practices Board (WFPB 1997) to Assess the Quality of Salmonid Habitat.			
HABITAT PARAMETER	**HABITAT QUALITY RATING**		
WFPB (1997)	**Poor**	**Fair**	**Good**
Percent Pool	<30%	30 - 40%	>40%
Pool Frequency	> 4 channel widths/pool	2 - 4	< 2 channel widths/pool
LWD/BFW	< 1	1 – 2	>2
Key pieces/ BFW	<0.20	0.20 - 0.50	>0.50
Holding Pools	Few pools/km (> 1 m deep)		Sufficient pools/km (> 1 m deep)
% wood cover in pools	Most pools 0-5%	Most pools 6-20%	Most pools >20%
Fine Sediment in spawning gravels (<0.85mm)	>17% fines	12-17% fines	<12% fines
NMFS (1995, 1998)	**Not Properly Functioning**	**At Risk**	**Properly Functioning**
Temperature	>60°F (spawning) >64°F (migration & rearing)	57-60°F(Spawning) 57-64°F (migration & rearing)	50-57°F
Fine Sediment in spawning gravels (<0.85mm)	>17% fines	12-17% fines	<11% fines
Physical Barriers	Any man-made barriers present in watershed do not allow upstream and/or downstream fish passage at a normal range of flows	Any man-made barriers present in watershed do not allow upstream and/or downstream fish passage at a base/low flows or at normal high flow conditions	Any man-made barriers present in watershed allow upstream and/or downstream fish passage at all flows
Substrate	Bedrock, sand, silt or small gravel dominant, or if gravel and cobble dominant, embeddedness > 30%.	Gravel and cobble is subdominant, or if dominant, embeddedness 20-30%	Dominant substrate is gravel or cobble (interstitial spaces clear), or embeddedness < 20%
Large Woody Debris			
Quantity	Does not meet standards for Properly Functioning and lack potential recruitment	Meets standards for Properly Functioning, but lacks potential sources of woody debris to maintain that standard	>80 piece/mile > 24" diameter and >50 ft length and adequate sources of woody debris recruitment in the riparian areas
Frequency of LWD by channel width	Does not meet standards for Properly Functioning and lack potential recruitment	Meets standards for Properly Functioning, but lacks potential sources of woody debris to maintain that standard	2.44-2.04 pieces/bankfull channel width for streams 13-62 ft. wide, respectively.
Volume of LWD per piece by channel width	Does not meet standards for Properly Functioning and lack potential recruitment	Meets standards for Properly Functioning, but lacks potential sources of woody debris to maintain that standard	0.25-3.70 m^3/piece for streams 13 ft.-62 ft. wide

Stream Habitat Elements Pool Frequency Channel width Pools/mi. 5 (feet) 184 (pools) 10 96 15 70 20 56 25 47 50 26 75 23 100 18	Does not meet pool frequency standards	Meets pool frequency standards, but large woody debris recruitment inadequate to maintain over time	Meet pool frequency standards
Pool Quality	no deep pools (>1 meter) and inadequate cover/temperature, major reduction of pool volume by fine sediment	Few deeper pools (>1 meter) present or inadequate cover/temperature, moderate reduction of pool volume by fine sediment	Pools> meter deep (holding pools) with good cover and cool water, minor reduction of pool volume by fine sediment
Off-channel habitat	Few or no backwaters, no off-channel ponds	Some backwaters and high energy side channels	Backwater with cover, and low energy off-channel areas
Channel & Watershed Conditions: Width/Depth Ratio	>12	10-12	<10
Floodplain Connectivity	Severe reduction in hydrologic connectivity between off-channel, wetland, floodplain and riparian areas; wetland extent drastically reduced, riparian vegetation/succession altered significantly, and channel degradation apparent	Reduced linkage of wetland, floodplains and riparian areas to main channel; overbank flows are reduced relative to historic frequency, as evidenced by moderate degradation of wetland function, riparian vegetation/succession	Off-channel areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession
Road Density & location	< 2mi/mi^2, no valley bottom roads	2-3 mi/mi^2, some valley bottom roads	>3 mi/mi^2, many valley bottom roads

Table Upper Green-5 presents estimated specific area recommendations required for successful anadromous salmonid spawning.

Table Upper Green-5. Average Observed Redd Area and Recommended Area per Pair Including Defended Area.

Species	Area Recommended per Pair (m²)
Summer/fall chinook	19
Spring Chinook	13
Coho	11
Steelhead	11

Source: Bjorn and Reiser 1991.

After assessing the quality of salmon habitat for each of the four previously mentioned salmon species, the results are compared to the critical input variables for each life history stage to determine the habitat factors that potentially limit natural salmon production in the Sunday Creek and Upper Green River WAUs.

INFORMATION SOURCES

Information is collected from various sources: USFS stream surveys; Tacoma Public Utilities (TPU) stream flow data, water quality, and anecdotal information; the United States Geological Survey (USGS), the Washington Department of Natural Resources (DNR), the US Army Corps of Engineers (Corps), Washington Department of Fish and Wildlife (WDFW), aerial photos , and the U.S. Fish and Wildlife Service (USFW&S). Field surveys conducted by the fish, channel, and riparian module teams provide the required information not previously collected or available. Fish distribution data for salmonid species was provided by the WDFW Washington Rivers Information System (WARIS), WDFW Priority Habitat and Species list, Washington State Salmon and Steelhead Stock Index (SASSI) (WDFW and WWTIT 1994), and was supplemented by field observations by fisheries biologists.

UPPER GREEN RIVER AND SUNDAY CREEK WAUS

STREAM COURSE AND MORPHOLOGY

The Upper Green and Sunday Creek WAUs, are situated on the west side of the central Cascade Mountains divide, approximately 23 miles (34 km) east of Enumclaw, Washington and entirely within King County. The Green River is the largest water body within the two WAUs, followed by Sunday Creek. The Sunday Creek WAU can best be defined as beginning at its confluence with the Green River (at RM 84.2) and continues in a northeast direction for approximately 7.9 miles to the divide at Stampede Pass. The Sunday Creek WAU has numerous tributaries contribute an additional 29.5 linear miles of stream to the mainstem Sunday Creek (Williams 1975). The Green River WAU, can be defined as beginning at the confluence of the Green River (RM 84.2) with Sunday Creek, extending upstream to the headwaters of the Green River in the vicinity of Blowout Mountain (approximately 10 linear miles). Numerous tributaries contribute over 41 linear miles of stream to the drainage. The drainage basin of the combined Green River and Sunday Creek WAUs encompass 39,237 acres.

The base elevation of the Green River and Sunday Creek WAUs is approximately 1,700 feet (519 meters) at the confluence of Sunday Creek. The basins rise to the top of the Cascade divide with an average basin elevation of 5,400 ft (1,646m). Approximately 12 miles (19.5 kilometers (km)) downstream of the lower WAU boundary, the Green River discharges into Howard Hanson Reservoir, a flood control reservoir operated by the Army Corps of Engineers. Downstream of Howard Hanson Dam (HHD) (at RM 64.5) the Green River flows past the Tacoma Headworks Dam (at RM 61) and enters the Green River Gorge and flows west and eventually flows through the City of Auburn where it turns north and flows through the lower Green River valley and into Elliott Bay near West Seattle. The details of habitat downstream of HHD are contained elsewhere in this report.

SALMONID DISTRIBUTION

The known freshwater distribution of anadromous salmonids is depicted the report Appendix. There is no historical information concerning salmonid species distribution or abundance in the upper Green River and Sunday Creek WAUs. However, three is substantial anecdotal information that implies anadromous fish migrated upstream of the Tacoma Headworks Project prior to its completion in 1911. Anadromous access into the Upper Green River and Sunday Creek WAUs seem likely, since there are no natural or anthropogenic passage barriers located on the mainstem Green River downstream of the WAUs. Historically, adult salmonids were documented at the Tacoma Headworks Diversion Dam (Grette and Salo, 1986), and adults have been documented upstream of the diversion dam site (Riseland, 1913).

Currently, the salmonid species inhabiting the upper Green River and Sunday Creek WAUs include chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), resident and anadromous (steelhead) rainbow trout (*O. mykiss*), cutthroat trout (*O. clarki*), and mountain whitefish (*Prosopium williamsonni*). Currently, only anadromous steelhead adults are passed upstream of the Tacoma Headworks Project and HHD. Spawning steelhead adults have been observed in the Green River as far upstream as RM 83.5 but they have not been observed in these WAUs. Juvenile steelhead, chinook and coho salmon have been released as hatchery plants

into numerous streams in these WAUs and are depicted in Appendix B. Mountain whitefish, cutthroat and resident rainbow trout are known to inhabit the primary tributaries. As of the date of this report there are no reported observations of bull trout (*Salvalinus confluentus*) within the Upper Green River or Sunday Creek WAUs (Plum Creek Timber Company, 1994).

There are known resident trout populations in the Upper Green River and Sunday Creek WAUs that include rainbow and cutthroat. These species have a wide distribution, but since no formal inventory has been done, an exact distribution and abundance estimate cannot be determined. Adfluvial trout populations have been observed throughout the lower portions of the Green River and Sunday Creek in the WAUs. Resident trout are found in most of the major Green River and Sunday Creek tributaries and extend into tributaries classified as "Type 3" waters. Type 4 waters are also likely to contain resident trout populations where the stream gradient is less than 14 percent.

The mainstem Green River and all the primary tributary channels support resident rainbow and/or cutthroat trout. While not demonstrated, it is likely that hybridization between the two species has occurred ((b) (6), WDFW, pers. comm.). Trout in reaches of isolated high-gradient streams are often segregated from other strains by passage barriers, although dispersal by downstream migration frequently occurs. The mainstem Green River, support a population of cutthroat trout that attain lengths of 20 inches ((b) (6), WDFW, pers. comm.). These large and mature fish may represent a stock of adfluvial cutthroat that have matured in the reservoir and ascend the streams to spawn. Spawning activity of the adfluvial strains of trout are believed to occur primarily in the mainstem Green River and in the lower reaches of the accessible tributaries (Wunderlich and Toal, 1992). The stream rearing habitat requirements for resident trout are similar to those of steelhead. As with all species of salmonids using the WAUs, relatively shallow, channel margin and pool habitat is important during the earliest stages of life soon after incubation.

HABITAT CONDITIONS

In the Upper Green River and Sunday Creek WAUs Watershed Analyses (WSA), a total of forty-seven segments were sampled and surveyed. Anecdotal evidence was noted between sample reaches to obtain inferences on channel character and habitat condition and whether or not the segment was representative of the surveyed. In those 47 segments, a total of 7,202 meters of channel were quantitatively surveyed. As a part of the WSA, an additional 5,800 meters of stream channel were walked, in which observations were made regarding the character of the segment and incorporated into descriptions for their respective channel classifications. This was conducted for the purpose to verify that the reaches surveyed are representative of the stream.

The classification of segments by salmon species for which it serves resulted in 24 segments for coho (3,652 meters of stream), 29 segments for steelhead (4,352 meters of stream), 6 segments for fall chinook (1,118 meters of stream), and 12 segments for spring chinook (1,742 meters of stream). The field metrics identified in the NMFS "Matrix of Pathways" were quantified for habitats utilized by each species.

The following discussion relates the existing quality of habitat in the upper Green and Sunday Creek WAUs for each species to their respective life history requirements. This is accomplished

by evaluating the effects associated with each respective critical input variable, which often dictates habitat quality.

FALL CHINOOK HABITAT CONDITIONS

Information was reviewed from six survey reaches that covered 1,118 meters of stream channel. These six survey reaches represent 18.3 percent of the presumed fall chinook habitat available in the Green River and Sunday Creek WAUs as identified by the Army Corps of Engineers (1998). Overall, the quality of fall chinook habitat is rated as "Not Properly Functioning". The key parameters examined are identified in table Upper Green-6.

Table Upper Green-6. Examined Key Habitat Parameters for Fall Chinook Reaches in the Green River and Sunday Creek WAUs.

Parameter	Minimum	Maximum	Mean	SD	N=
Survey Reach Length (m)	100	218	186	43.0	6
BFW (m)	5.3	20.9	11.2	5.3	6
Bankfull Depth (m)	0.40	0.6	0.5	0.1	6
Gradient (%)	1.5	3.0	2.4	0.7	6
Elevation (m)	558	607	588	18.7	6
Pools/mile	22.2	80.5	41.7	27.1	6
Holding Pools/mile	0	48.3	18.7	16.7	6
Percent of all pools that are holding/pools per mile	0%	67	43.6	26.5	6
Off-channel Habitat	0	45	11.7	16.9	6
Riparian Species 1=conifer, 2=deciduous	1	2	1.7	0.52	6
Riparian Age 1=old, 2=mature, 3=young	2	3	2.7	0.52	6
Riparian density: 1=dense, 2=sparse	1	2	1.2	0.41	6
Percent wood cover in pools	0-5%	5-10%	4.5%	2.7%	5
Width/depth ratio	13.3	37.3	21.2	8.4	6
Occurrence of sand, silt, clay (%)	0	25	4.17	10.21	6
Occurrence of gravel, cobble (%)	10	90	57.38	32.37	6
Occurrence of boulder/bedrock (%)	0	90	38.00	36.46	6
Anadromous Spawning Area (%)	0	2	0.67	0.82	6
Percent fines	16	16	16	0	1
Temperature (F)	62.24	62.24	62.24	0	1
Canopy Closure (%)	0%	78%	16.2%	30.9%	6
Min. shade requirement (%)*	47%	51%	48.5%	1.5%	6
NMFS wood pieces/mile	0	29.5	4.92	12.06	6

* Source: WFPB 1998.

RIPARIAN HABITAT

Watershed Analysis found that the bulk of the riparian habitats in the Green River and Sunday Creek WAUs are generally dense, but young deciduous trees. This condition is insufficient as a new LWD supply to the stream channel and hence maintain or improve the associated habitat forming processes. This situation will likely not ameliorate until the riparian stands reach a size and age that would allow for sufficient size and number to restore instream LWD loadings to a more natural level. The riparian condition is currently considered to be "Not Properly Functioning" for fall chinook in four of the six reaches surveyed and "At Risk" in the remaining

two. These ratings are due to: (1) the deciduous component of trees that dominate the assessed riparian reaches for fall chinook; and (2) the young age of the trees present in the riparian area.

The young tree age and large deciduous component are likely directly responsible for the scarcity of NMFS criteria LWD present in the stream channel. The quantity of LWD within the fall chinook reaches is insufficient to maintain many of the necessary habitat elements and habitat forming elements. Though pieces of wood are numerous, they are typically small. Only four pieces of wood were found that meet NMFS size criteria within the survey fall chinook reaches. This represents only 7.1 percent of the 56 pieces needed to be considered "Properly Functioning". None of the reaches surveyed met NMFS criteria for wood quantity, nor are the channel adjacent stands considered to be adequate to maintain LWD recruitment processes in the near term. Thus, for fall chinook this yields a "Not Properly Functioning" assessment.

SUBSTRATE

WSA indicates that spawning gravels are in short supply throughout the reaches examined. Surveys indicate that a mean of 0.76 percent of the total surveyed stream channel was observed to contain potential suitable spawning substrate. Three of the six reaches surveyed were dominated by boulder/bedrock and the remaining three reaches were dominated by gravel/cobble with very little gravel distributed in areas that were deemed useful for fall chinook spawning. Overall, the paucity of suitable spawning gravels in the reaches surveyed are a limiting factor for fall chinook production and were rated as "Not Properly Functioning."

Mass wasting and hillslope erosion was determined not to be a significant contributor to the overall levels of fine sediment produced in the Green River and Sunday Creek WAUs. Secondary sediment erosion from mass wasting scarps generally was below the 50 percent of the natural background sediment input cutoff point for a moderate hazard rating designation. There was one exception, the Pioneer Creek subbasin, where the estimated sediment yield is 57 percent of the background.

POOLS

Of the 24 reaches surveyed, the number of pools varied considerably. Using pool frequencies as calculated from the pool frequency regression curve, 16 of the 24 surveyed reaches do not meet NMFS criteria for "Properly Functioning" for pool frequency. When taken in the aggregate, the streams had roughly the required number of pools required to meet MNFS criteria as "Properly Functioning". Cumulatively, the surveyed reaches had 26 pools in fall chinook reaches where 28.4 were to be expected. Two of the six reaches surveyed had more pools than required and overly compensated for the other four reaches that had far fewer than the required number of pools. However, despite the number of pools present, all of the reaches, including those that met NMFS pool criteria to be considered "Properly Functioning" are assigned an "At Risk" factor because of the inadequacy of the riparian zone to recruit LWD into the stream channel to form pools.

Approximately 44 percent of the pools surveyed met minimum depth requirements (>1 meter). The ability of the pools to provide cover and holding areas is further reduced by the pool in-water and overwater cover, again because of the lack of LWD. Pool quality was deemed insufficient to provide suitable habitat for fall chinook as was assigned an "At Risk" rating.

CHANNEL CONDITIONS

Reach specific and cumulative observations suggest that the stream channel has become shallow and wide. This may also be an influencing factor in decreased pool quality and adversely impacts the ability of the available habitat to successfully hold adult and rear juvenile salmonids. The mean width:depth ratio was 21.22. This indicates increased proportion of riffles and glides that leads to reduced high flow refugia and available over-winter rearing habitats, an increased water surface area exposed to solar radiation that in turn could lead to increased stream water temperatures. Additionally, the high width to depth ratio may influence fall chinook spawning through decreases in wetted stream areas with acceptable depths for spawning fall chinook. A designation of "Not Properly Functioning" was assigned to stream channel conditions because of the high width:depth ratio.

There are a number of barriers, primarily culverts, that prevent adult and juvenile access to tributaries in this subbasin. A detailed listing of known anthropogenic barriers in this subbasin are contained in the Barriers Chapter of this report. However, a comprehensive survey has not been initiated that lists all known anthropogenic barriers.

OFF CHANNEL HABITAT

Six reaches were surveyed for the quantity of off-channel habitat. Only one of these six reaches was ranked as "Properly Functioning" with 45 percent of the off-channel habitat in this reach skewed the mean value to 11.7 percent. However, this single reach is not representative of the other five stream reaches as noted by the high variability, which is illustrated by a standard deviation of 16.9 percent. Three of the six reaches are rated as "Not Properly Functioning" while the others are rated as "At Risk". Overall, off-channel habitats are rated as "Not Properly Functioning" again due to the scarceness of LWD and the off-channel habitat forming processes associated with LWD.

WATER QUALITY

Water temperature was measured in one stream as 62.2 F, which would give a rating of "Not Properly Functioning". A probable cause of elevated stream temperatures is that the mean canopy closure is only 24.0 percent while 41.3 percent canopy coverage is required to meet shade standards (WFPB 1998) to avoid solar radiation and induced water temperature increases.

SPRING CHINOOK HABITAT

Information was reviewed from twelve (12) survey reaches that covered 1,742 meters of stream channel. These twelve survey reaches represent 16.6 percent of the presumed spring chinook habitat available in the Green River and Sunday Creek WAUs as identified by the Army Corps of Engineers (1998). The key parameters examined are identified in table Upper Green-7.

Table Upper Green-7. Examined Key Habitat Parameters for Spring Chinook Reaches in the Green River and Sunday Creek WAUs.					
Parameter	**Minimum**	**Maximum**	**Mean**	**SD**	**N=**
Survey Reach Length (m)	24	218	145	64.1	12
BFW (m)	4	21	10	438	12
Bankfull Depth (m)	0.4	1.5	1	0.4	12
Gradient (%)	1.5	5	2.5	0.4	12
Elevation (m)	558	723	635.4	58.4	12
Pools/mile	0	134.1	44.1	38.5	12
Holding Pools/mile	0	48.3	9.3	14.9	12
Percent of all pools that are holding/pools per mile	0%	67	26	30	10
Off-channel Habitat	0	45	1.3	16.2	9
Riparian Species 1=conifer, 2=deciduous	1	3	1.8	0.4	6
Riparian Age 1=old, 2=mature, 3=young	2	3	2.8	0.4	6
Riparian density: 1=dense, 2=sparse	1	2	1.2	0.4	6
Percent wood cover in pools	0.5%	5-10%	0-5%	---	9
Width/depth ratio	7.3	37.3	16.1	7.9	6
Occurrence of sand, silt, clay (%)	0	25	3.0	7.6	6
Occurrence of gravel, cobble (%)	10	100	69.1	30.4	6
Occurrence of boulder/bedrock (%)	0	90	27.80	32.4	6
Anadromous Spawning Area (%)	0	6	1.3	1.8	10
Percent fines	16	16	16	0	1
Temperature (F)	58.1	67.2	60.2	2.9	5
Canopy Closure (%)	0%	93%	20.7%	31.9%	12
Min. shade requirement (%)*	37%	51%	44.3%	5.1%	12
NMFS wood pieces/mile	0	257.6	27.3	73.8	12
* Source: WFPB 1998.					

RIPARIAN HABITAT

Watershed Analysis found that the bulk of the riparian habitats that could be utilized by spring chinook in the Green River and Sunday Creek WAUs are generally dense, but young deciduous trees. This condition is insufficient as a new LWD supply to the stream channel and hence maintain or improve the associated habitat forming processes. This situation will likely not ameliorate until the riparian stands reach a size and age that would allow for sufficient size and number to restore instream LWD loadings to a more natural level. The riparian condition is currently considered to be “Not Properly Functioning” for spring chinook in ten of the twelve reaches surveyed and “At Risk” in the remaining two. These ratings are due to: (1) the deciduous component of trees that dominate the assessed riparian reaches for fall chinook; and (2) the young age of the trees present in the riparian area.

The young tree age and large deciduous component are likely directly responsible for the scarcity of NMFS criteria LWD present in the stream channel. The quantity of LWD within the spring chinook reaches is insufficient to maintain many of the necessary habitat elements and habitat forming elements. None of the reaches surveyed met NMFS criteria for wood quantity, nor are the channel adjacent stands considered to be adequate to maintain LWD recruitment processes in the near term. Thus, for spring chinook this yields a “Not Properly Functioning” assessment.

SUBSTRATE

WSA indicates that spawning gravels are in short supply throughout the reaches examined. Surveys indicate that a mean of 1.3 percent of the total surveyed stream channel was observed to contain potential suitable spawning substrate. Individual reaches also reflected poor spawning gravel quality. Eleven of the twelve reaches were rated as “Not Properly Functioning” due to inadequate area of spawnable gravels. Boulder/bedrock was the dominant feature in four reaches while gravel/cobble dominated the remaining eight. The gravel/cobble reaches contained very little gravel distributed in areas that could be utilized by spawning spring chinook. Only one reach (mainstem Green River at RM 86.4) that contained 6 percent spawning gravel was considered “At Risk”, the remaining reaches were all considered to be “Not Properly Functioning”. Overall, the paucity of suitable spawning gravels in the reaches surveyed are a limiting factor for spring chinook production and were rated as “Not Properly Functioning”.

Mass wasting and hillslope erosion was determined not to be a significant contributor to the overall levels of fine sediment produced in the Green River and Sunday Creek WAUs. Secondary sediment erosion from mass wasting scarps generally was below the 50 percent of the natural background sediment input cutoff point for a moderate hazard rating designation. There was one exception, the Pioneer Creek subbasin, where the estimated sediment yield is 57 percent of the background.

POOLS

Overall, the spring chinook reaches surveyed had 85 percent of the required number of pools to meet NMFS as “Properly Functioning”. However, the poor quality of the pools and the inadequate stream adjacent riparian reserves strongly suggest that a lower habitat quality rating be assigned than consideration of pool frequency alone would suggest.

Of the twelve reaches surveyed, the number of pools varied considerably. Using pool frequencies as calculated from the pool frequency regression curve, nine of the twelve surveyed reaches do not meet NMFS criteria for “Properly Functioning” for pool frequency. When taken in the aggregate, the streams had roughly the required number of pools required to meet MNFS criteria as “Properly Functioning.” Cumulatively, the surveyed reaches had 41 pools in spring chinook reaches where 48 were to be expected. Individually, nine of the twelve reaches had a pool deficit and are rated as “Not Properly Functioning”. However, on a system wide basis, these numerical deficiencies were almost compensated by reaches containing more pools than required. However, despite the number of pools present, all of the reaches, including those that met NMFS pool criteria to be considered “Properly Functioning” are assigned an “At Risk” factor because of the inadequacy of the riparian zone to recruit LWD into the stream channel to form pools. Without LWD inputs into the stream channel it should be expected that there will be a net decrease over time of pool quality and pool numbers.

Approximately 26 percent of the pools surveyed met minimum depth requirements (>1 meter). The ability of the pools to provide cover and holding areas is further reduced by the pool in-water and overwater cover, again because of the lack of LWD. Cover in all pools was considered poor, with a mean coverage in the 0-5 percent range. Pool quality was deemed insufficient to provide suitable habitat for spring chinook as was assigned an “At Risk” rating.

CHANNEL CONDITIONS

Reach specific and cumulative observations suggest that the stream channel has become shallow and wide. This may also be an influencing factor in decreased pool quality and adversely impacts the ability of the available habitat to successfully hold adult and rear juvenile salmonids. The mean width:depth ratio was 16.1. This indicates increased proportion of riffles and glides that leads to reduced high flow refugia and available over-winter rearing habitats, an increased water surface area exposed to solar radiation that in turn could lead to increased stream water temperatures. Additionally, the high width to depth ratio may influence fall chinook spawning through decreases in wetted stream areas with acceptable depths for spawning fall chinook.

Individually, two of the twelve surveyed reaches met the NMFS criteria to be defined as "Properly Functioning" while two were "At Risk" and the remaining eight were "Not Properly Functioning".

A designation of "Not Properly Functioning" was assigned to stream channel conditions because of the high width:depth ratio.

OFF CHANNEL HABITAT

Nine reaches were surveyed for the quantity of off-channel habitat. Only two of these nine reaches was ranked as "Properly Functioning", three were ranked as "At Risk" and five at "Not Properly Functioning". Two reaches with exceptionally large percentages of off-channel rearing (45 percent and 32 percent) skewed the mean value to 11.3 percent. However, this single reach is not representative of the other five stream reaches as noted by the high variability, which is illustrated by a standard deviation of 16.2 percent. Overall, off-channel habitats are rated as "Not Properly Functioning" again due to the scarceness of LWD and the off-channel habitat forming processes associated with LWD.

WATER QUALITY

Water temperature was measured in one stream as 60.2 F, which would give a rating of "Not Properly Functioning". A probable cause of elevated stream temperatures is that the mean canopy closure is only 20.7 percent while 44 percent canopy coverage is required to meet shade standards (WFPB 1998) to avoid solar radiation and induced water temperature increases.

COHO

Information was reviewed from 24 reaches that were surveyed that were considered to support coho salmon. This represented an area covering 3,652 meters of stream channel and further represents approximately 17.8 percent of the presumed coho habitat in the Green River and Sunday Creek WAUs. Key parameters of the coho habitat survey are presented in table Upper Green-8 below.

Table Upper Green-8. Examined Key Habitat Parameters for Coho Reaches in the Green River and Sunday Creek WAUs.					
Parameter	**Minimum**	**Maximum**	**Mean**	**SD**	**N=**
Survey Reach Length (m)	24	300	152.0	77.0	24
BFW (m)	4	38	13.2	8.3	24
Bankfull Depth (m)	0.37	2.5	0.98	0.66	24
Gradient (%)	1.0	6.0	2.6	1.4	24
Elevation (m)	529	723	612	59.7	24
Pools/mile	0	134.1	37.0	32.6	24
Holding Pools/mile	0	48.3	9.2	11.8	24
Percent of all pools that are holding/pools per mile	0	100	35	35	21
Off-channel Habitat	0	49	10.2	16.6	16
Riparian Species 1=conifer, 2=deciduous	1	2	1.8	0.4	23
Riparian Age 1=old, 2=mature, 3=young	2	3	2.9	0.3	23
Riparian density: 1=dense, 2=sparse	1	2	1.2	0.4	23
Percent wood cover in pools	0-5%	5-10%	0-5%	2.7	16
Width/depth ratio	6.0	37.3	15.2	6.6	24
Occurrence of sand, silt, clay (%)	0	25	3.2	7.6	24
Occurrence of gravel, cobble (%)	0	100	66.7	32.4	24
Occurrence of boulder/bedrock (%)	0	100	24.3	32.0	24
Anadromous Spawning Area (%)	0	13.0	2.1	3.1	21
Percent fines	6	16	11.0	7.1	2
Temperature (F)	57.2	62.24	59.1	2.0	5
Canopy Closure (%)	0	93	21.3	25.7	24
Min. shade requirement (%)*	20%	54	42.8	9.6	24
NMFS wood pieces/mile	0	257	30.2	65.7	24
* Source: WFPB 1998.					

RIPARIAN HABITAT

Watershed Analysis found that the bulk of the riparian habitats that could be utilized by coho in the Green River and Sunday Creek WAUs are generally dense, but consist of young deciduous trees. This condition is insufficient as a new LWD supply to the stream channel and hence maintain or improve the associated habitat forming processes. This situation will likely not ameliorate until the riparian stands reach a size and age that would allow for sufficient size and number to restore instream LWD loadings to a more natural level. The riparian condition is currently considered to be “Not Properly Functioning” for coho in 20 of the 23 reaches surveyed and “At Risk” in the remaining three. These ratings are due to: (1) the deciduous component of trees that dominate the assessed riparian reaches for fall chinook; and (2) the young age of the trees present in the riparian area. The condition of the riparian habitat is currently not sufficient in the near term to provide suitable amounts and quality of LWD to the stream channel to maintain associated habitat and other ecological forming processes. Without large coniferous trees for recruitment and retention, the existing level of coho production should be expected to decline.

The mean pieces of WSA size wood (>10 centimeters diameter, >2 meters length) per channel width was 3.0. A rating of good is assigned to stream channels with at least 2.0 pieces per channel width (WFPB 1997). However, this good rating is strongly influenced by one reach in the mainstem Green River (RM85.8) where a segment long log jam contained an average of 34

pieces per channel width. In the absence of this log jam, the number of wood pieces per channel width over the surveyed habitat would be 1.7, yielding a rating of "Fair" under WSA standards. This patchy distribution of wood in the stream channel is indicated by the standard deviation of 7.1 pieces per channel width.

WSA key pieces are also below the desired target numbers, averaging only 0.02 pieces per channel width. This represents less than 10 percent of the target goal of 0.3 pieces per channel width.

When NMFS criteria are applied, only 56 pieces of wood were identified within the reaches surveyed for coho salmon. This represents only 31 percent of the target level of 181 pieces required to be considered "Properly Functioning" by NMFS. This yields an overall habitat rating as "Not Properly Functioning".

SUBSTRATE

WSA indicates that spawning gravels are in short supply and inadequate for adult coho salmon spawning throughout the reaches examined. Surveys indicate that a mean of 2.1 percent of the total surveyed stream channel was observed to contain potential suitable spawning substrate where the desired threshold is 10 percent. Individual reaches also reflected poor spawning gravel quality. Twenty of the twenty-one reaches were rated as "Not Properly Functioning" due to inadequate area of spawnable gravels. The gravel/cobble reaches category dominated (67 percent) the reaches but contained very little gravel distributed in areas that could be utilized by spawning coho. Only one reach (mainstem Green River at RM 86.4) that contained 13 percent spawning gravel was considered "Properly Functioning", while the remaining reaches were all considered to be "Not Properly Functioning". Overall, the paucity of suitable spawning gravels in the reaches surveyed are a limiting factor for coho production and were rated as "Not Properly Functioning".

Mass wasting and hillslope erosion was determined not to be a significant contributor to the overall levels of fine sediment produced in the Green River and Sunday Creek WAUs. Secondary sediment erosion from mass wasting scarps generally was below the 50 percent of the natural background sediment input cutoff point for a moderate hazard rating designation. There was one exception, the Pioneer Creek subbasin, where the estimated sediment yield is 57 percent of the background.

Fine sediment sampled in two reaches was measured at 6 percent and 16 percent. A mean of fines of 11.0 percent is considered to be "Properly Functioning" (NMFS).

POOLS

Overall, the coho reaches surveyed had 81 percent of the required number of pools to meet NMFS as "Properly Functioning". However, the poor quality of these pools and the inadequate stream adjacent riparian reserves strongly suggest that a lower habitat quality rating be assigned than consideration of pool frequency alone would suggest.

Of the 24 reaches surveyed, the number of pools varied considerably. Using pool frequencies as calculated from the pool frequency regression curve, 16 of the 24 surveyed reaches do not meet

NMFS criteria for “Properly Functioning” for pool frequency. When taken in the aggregate, the streams had roughly the required number of pools required to meet MNFS criteria as “Properly Functioning”. Cumulatively, the surveyed reaches had 75 pools in coho reaches where 91 were to be expected. However, on a system wide basis, these numerical deficiencies were almost compensated by reaches containing more pools than required. However, despite the number of pools present, all of the reaches, including those that met NMFS pool criteria to be considered “Properly Functioning” are assigned an “At Risk” factor because of the inadequacy of the riparian zone to recruit LWD into the stream channel to form pools. Without LWD inputs into the stream channel it should be expected that there will be a net decrease over time of pool quality and pool numbers.

Approximately 35 percent of the pools surveyed met minimum depth requirements (>1 meter). The ability of the pools to provide cover and holding areas is further reduced by the pool in-water and overwater cover, again because of the lack of LWD. Cover in all pools was considered poor, with a mean coverage in the 0-5 percent range. Pool quality was deemed insufficient to provide suitable habitat for spring chinook as was assigned an “At Risk” rating.

CHANNEL CONDITIONS

Reach specific and cumulative observations suggest that the stream channel has become shallow and wide. This may also be an influencing factor in decreased pool quality and adversely impacts the ability of the available habitat to successfully hold adult and rear juvenile salmonids. The mean width:depth ratio was 15.2. This indicates increased proportion of riffles and glides that leads to reduced high flow refugia and available over-winter rearing habitats, an increased water surface area exposed to solar radiation that in turn could lead to increased stream water temperatures. Additionally, the high width to depth ratio may influence coho spawning through decreases in wetted stream areas with acceptable depths for spawning coho.

Individually, three of the 24 surveyed reaches met the NMFS criteria to be defined as “Properly Functioning” while five were “At Risk” and the remaining 18 were “Not Properly Functioning”.

A designation of “Not Properly Functioning” was assigned to stream channel conditions because of the high width:depth ratio.

OFF CHANNEL HABITAT

The quantity of off-channel habitat is cumulatively 10.2 percent of the total wetted area and is considered to be “Properly Functioning”. However, on an individual basis, only four of the 16 reaches surveyed achieve a rating of “Properly Functioning”.

WATER QUALITY

Water temperature as measured in five streams averaged 59.1 F giving an overall rating of “At Risk”. A probable cause of elevated stream temperatures is that the mean canopy closure is only 20.5 percent while 42 percent canopy coverage is required to meet shade standards (WFPB 1998) to avoid solar radiation and induced water temperature increases.

STEELHEAD

Information was reviewed from 29 surveyed reaches that were considered to support steelhead. This represented an area covering 4,352 meters of stream channel and further represents approximately 20.3 percent of the presumed steelhead habitat in the Green River and Sunday Creek WAUs. Key parameters of the steelhead habitat survey are presented in table Upper Green-9 below.

Table Upper Green-9. Examined Key Habitat Parameters for Steelhead Reaches in the Green River and Sunday Creek WAUs.

Parameter	Minimum	Maximum	Mean	SD	N=
Survey Reach Length (m)	24	300	150.1	77.7	29
BFW (m)	4.0	38.0	13.0	7.8	29
Bankfull Depth (m)	0.4	2.5	1.1	0.7	29
Gradient (%)	1.0	11.0	3.0	2.0	29
Elevation (m)	529	838	635.7	78.1	29
Pools/mile	0	134.1	40	34.5	29
Holding Pools/mile	0	48.3	8.6	11.7	29
Percent of all pools that are holding/pools per mile	0	100	29	34	26
Off-channel Habitat	0	49	9.5	15.8	18
Riparian Species 1=conifer, 2=deciduous	1	2	1.8	0.4	28
Riparian Age 1=old, 2=mature, 3=young	2	3	2.9	0.3	28
Riparian density: 1=dense, 2=sparse	2	1	1.1	0.4	28
Percent wood cover in pools	0-5%	5-10%	0-5%	N/A	18
Width/depth ratio	6.0	37.3	14.3	6.4	29
Occurrence of sand, silt, clay (%)	0	25	2.9	7.1	28
Occurrence of gravel, cobble (%)	0	100	61.5	33.5	28
Occurrence of boulder/bedrock (%)	0	100	34.2	36.3	28
Anadromous Spawning Area (%)	0	13	2	2.9	25
Percent fines	6	16	11.0	7.1	2
Temperature (F)	57.2	62.2	59.6	2.2	5
Canopy Closure (%)	0	93.0	24.0	25.3	29
Min. shade requirement (%)*	20	54	41.3	9.4	29
NMFS wood pieces/mile	0	257.6	26.6	60.3	29

* Source: WFPB 1998.

RIPARIAN HABITAT

Watershed Analysis found that the bulk of the riparian habitats that could be utilized by steelhead in the Green River and Sunday Creek WAUs are generally dense, but consist of young deciduous trees. This condition is insufficient as a new LWD supply to the stream channel and hence maintain or improve the associated habitat forming processes. This situation will likely not ameliorate until the riparian stands reach a size and age that would allow for sufficient size and number to restore instream LWD loadings to a more natural level. The riparian condition is currently considered to be “Not Properly Functioning” for steelhead in 25 of the 28 reaches surveyed and “At Risk” in the remaining three. These ratings are due to: (1) the deciduous component of trees that dominate the assessed riparian reaches for steelhead; and (2) the young age of the trees present in the riparian area. The condition of the riparian habitat is currently not sufficient in the near term to provide suitable amounts and quality of LWD to the stream channel

to maintain associated habitat and other ecological forming processes. Without large coniferous trees for recruitment and retention, the existing level of steelhead production should be expected to decline.

The mean pieces of WSA size wood (>10 centimeters diameter, >2 meters length) per channel width was 2.8. A rating of good is assigned to stream channels with at least 2.0 pieces per channel width (WFPB 1997). However, this good rating is strongly influenced by one reach in the mainstem Green River (RM85.8) where a segment long log jam contained an average of 34 pieces per channel width. In the absence of this log jam, the number of wood pieces per channel width over the surveyed habitat would be 1.7, yielding a rating of "Fair" under WSA standards. This patchy distribution of wood in the stream channel is indicated by the standard deviation of 7.0 pieces per channel width.

WSA key pieces are also below the desired target numbers, averaging only 0.03 pieces per channel width. This represents less than 20 percent of the target goal of 0.15 pieces per channel width.

When NMFS criteria are applied, only 59 pieces of wood were identified within the reaches surveyed for steelhead. This represents only 27.3 percent of the target level of 216 pieces required to be considered "Properly Functioning" by NMFS. Individually, two of the 29 reaches met NMFS wood requirement criteria. However, due to the young deciduous conditions adjacent to the stream channel, potential wood recruitment sources will be unable to maintain or improve the necessary wood loadings. This yields an overall habitat rating as "Not Properly Functioning."

SUBSTRATE

WSA indicates that spawning gravels are in short supply and inadequate for adult steelhead spawning throughout the reaches examined. Surveys indicate that a mean of 2.0 percent of the total surveyed stream channel was observed to contain potential suitable spawning substrate where the desired threshold is 10 percent. Individual reaches also reflected poor spawning gravel quality. Twenty-four of the twenty-five reaches were rated as "Not Properly Functioning" due to inadequate area of spawnable gravels. The gravel/cobble reaches category dominated 17 of the 28 reaches (60.7 percent) but contained very little gravel distributed in areas that could be utilized by spawning steelhead. Only one reach (mainstem Green River at RM 86.4) that contained 13 percent spawning gravel was considered "Properly Functioning", while the remaining reaches were all considered to be "Not Properly Functioning". Overall, the paucity of suitable spawning gravels in the reaches surveyed are a limiting factor for steelhead production and were rated as "Not Properly Functioning".

Mass wasting and hillslope erosion was determined not to be a significant contributor to the overall levels of fine sediment produced in the Green River and Sunday Creek WAUs. Secondary sediment erosion from mass wasting scarps generally was below the 50 percent of the natural background sediment input cutoff point for a moderate hazard rating designation. There was one exception, the Pioneer Creek subbasin, where the estimated sediment yield is 57 percent of the background.

POOLS

Overall, the steelhead reaches surveyed had more than the required number of pools to meet NMFS as “Properly Functioning”. However, the poor quality of these pools and the inadequate stream adjacent riparian reserves strongly suggest that a lower habitat quality rating be assigned than consideration of pool frequency alone would suggest.

Of the 29 reaches surveyed, the number of pools varied considerably. Cumulatively, using pool frequencies as calculated from the pool frequency regression curve, the reaches contained 98 pools and exceeded the NMFS requirement of 90 pools. However, on an individual basis, 18 of the 29 surveyed reaches do not meet NMFS criteria for “Properly Functioning” for pool frequency and in fact would be considered as “Not Properly Functioning”. However, on a system wide basis, these numerical deficiencies were almost compensated by reaches containing more pools than required. Despite the number of pools present, all of the reaches, including those that met NMFS pool criteria to be considered “Properly Functioning” are assigned an “At Risk” factor because of the inadequacy of the riparian zone to recruit LWD into the stream channel to form pools. Without LWD inputs into the stream channel it should be expected that there will be a net decrease over time of pool quality and pool numbers.

Approximately 29 percent of the pools surveyed met minimum depth requirements (>1 meter). The ability of the pools to provide cover and holding areas is further reduced by the pool in-water and overwater cover, again because of the lack of LWD. Cover in all pools was considered poor, with a mean coverage in the 0-5 percent range. Pool quality was deemed insufficient to provide suitable habitat for spring chinook as was assigned an “At Risk” rating.

CHANNEL CONDITIONS

Of the 29 surveyed reaches for steelhead, only five met the NMFS criteria for “Properly Functioning”, eight can be described as “At Risk” and the remaining sixteen as “Not Properly Functioning”. Reach specific and cumulative observations suggest that the stream channel has become shallow and wide. This may also be an influencing factor in decreased pool quality and adversely impacts the ability of the available habitat to successfully hold adult and rear juvenile salmonids. The mean width:depth ratio was 14.3, where a target of less than 10 is required to meet favorable channel conditions. This indicates increased proportion of riffles and glides that leads to reduced high flow refugia and available over-winter rearing habitats, an increased water surface area exposed to solar radiation that in turn could lead to increased stream water temperatures. Additionally, the high width to depth ratio may influence steelhead spawning through decreases in wetted stream areas with acceptable depths for spawning steelhead.

A designation of “Not Properly Functioning” was assigned to stream channel conditions because of the high width:depth ratio.

OFF CHANNEL HABITAT

The quantity of off-channel habitat is cumulatively 9.5 percent of the total wetted area and is considered to be “At Risk”. However, on an individual basis, only four of the 18 reaches surveyed achieve a rating of “Properly Functioning”. Therefore, natural production of steelhead

is considered to be limited by the lack of off-channel rearing opportunities in the Green River and Sunday Creek WAUs.

WATER QUALITY

Water temperature as measured in five streams averaged 59.6 F giving an overall rating of "At Risk" for juvenile steelhead rearing and adult summer steelhead that might be migrating, holding or spawning in these reaches. A probable cause of elevated stream temperatures is that the mean canopy closure is only 24.0 percent while 41.3 percent canopy coverage is required to meet shade standards (WFPB 1998) to avoid solar radiation and induced water temperature increases.

SUBSTRATE

The quality of spawning habitat is dictated by the abundance of spawnable gravels, adjacent cover, and riparian shade. This is in turn affected by coarse and fine sediment, large wood, riparian vegetation, and flow. Spawning gravel is considered to be "Not Properly Functioning" for any of the salmon species present. A number of factors could be contributing to this alone or collectively. This could be a result influenced by the lack of LWD that serves to trap gravels, which is at levels considered to be "Not Properly Functioning" (NMFS) or poor (WFPB). Also, the cover component in pools, important for salmonid spawning may also be limiting due to is present rating of "poor" (WFPB). Furthermore, the stream temperatures for spawning is considered to be "At Risk" (NMFS) for all species except fall chinook, in which this condition is considered to be "Not Properly Functioning" (NMFS). The influence of the riparian area is likely to contribute to the lack of large wood, elevated stream temperatures, and lack of cover. The riparian condition is considered to be "Not Properly Functioning" (NMFS) for all the aforementioned salmon species.

Fine sediment is considered to be "At Risk" for coho and steelhead. Fine sediment can inhibit redd excavation and incubation, as noted previously. Fine sediment does not currently limit fall and spring chinook spawning, in which this metric is considered to be Properly Functioning (NMFS).

Mass wasting and hillslope erosion was determined not to be a significant contributor to the overall levels of fine sediment produced in the Green River and Sunday Creek WAUs. Secondary sediment erosion from mass wasting scarps generally was below the 50 percent of the natural background sediment input cutoff point for a moderate hazard rating designation. There was one exception, the Pioneer Creek subbasin, where the estimated sediment yield is 57 percent of the background.

SUMMARY

In summary, anadromous salmonid spawning habitat is limited by 1) the lack of suitable spawning gravels, 2) the lack of cover in pools, and 3) at times by elevated water temperatures. These components are influenced by the loss of LWD, which is lacking in the system, a poor riparian condition, which is also "Not Properly Functioning" condition, and fine sediment for coho and steelhead spawning habitat, which is considered to be "At Risk".

Summer rearing habitat requires the use of large deep pools and off-channel areas that provide adequate water flow, ample cover, cool water temperatures, optimal feeding opportunities, inter- and intra- species interaction, and opportunities, depending on needs, to hold in slow or fast moving water. The factors that influence summer-rearing habitat are channel form, gradient, small and large in-stream wood, canopy closure, and food input. Riparian vegetation and in-stream wood provide cover and channel complexity during this phase. Pool area and pool quality, large wood, cover in pools, and riparian vegetation are considered to be "Not Properly Functioning" for coho, steelhead, fall and spring chinook, and thus are likely to limit summer rearing opportunities and success.

Winter rearing areas provide stable and non-turbid stream flow during storm events. This habitat also must provide adequate flow, cover, and temperatures that facilitate metabolic conservation. The majority of the confined streams in the Upper Green River and Sunday Creek WAUs have only limited ability to form off-channel and wetland areas due to their confinement by road and railway grades. In the absence of side channels, salmonids typically are forced to over-winter in the substrate and under the protection of wood. Off-channel habitat is in short supply for coho and steelhead, and considered to be "At Risk"; however, this habitat is considered to be "Properly Functioning" for fall and spring chinook (NMFS).

The "At Risk" condition of winter-rearing habitat for coho and steelhead in the upper Green and Sunday Creek WAUs is likely caused by several factors. When LWD abundance is compared to NMFS criteria the large logs that contribute to off-channel habitat formation are in short supply and thus are likely to limit winter rearing. The riparian canopy, which helps to maintain ambient stream temperatures at night, is also in a "Not Properly Functioning" condition (NMFS). Interstitial substrate is adversely affected by overloading the stream with fine sediment, as indicated by the "At Risk" rating for fine sediment (NMFS), which reduces the available winter rearing habitat.

To summarize, winter-rearing habitat is limited for coho and steelhead in the Green and Sunday Creek WAUs. The lack of LWD is likely a limiting factor that contributes to the formation of these habitats. The quality of winter-rearing habitat is also reduced by the inadequate riparian condition, the elevated levels of fine sediment, and the lack of cover in pools.

Cover is an important component for juvenile salmonid migration, as is a normal temperature regime. LWD, which helps to provide cover to protect salmonids from predators, direct sunlight, and high water temperatures, is in short supply for all the species considered in this analysis (NMFS). The riparian vegetation, which provides shade and cover to the stream, is also considered to be lacking (NMFS). The elevated stream temperatures for migration, considered to be "At Risk", are an indication that the riparian canopy is insufficient to provide the necessary habitat for this life history.

To summarize, the paucity of LWD necessary for adequate cover, lack of suitable riparian areas to product shade, and the elevated stream temperatures may be factors that limit successful juvenile salmonid migration in the Upper Green and Sunday Creek WAUs.

KEY FINDINGS AND IDENTIFIED HABITAT-LIMITING FACTORS

- The Watershed Analysis indicates the riparian habitat is insufficient in the near term to meet the needs of habitat forming processes throughout the study area.
- LWD, low gravel sediment levels, canopy cover, the poor riparian habitat zone and pool quantity and quality are all considered limiting factors to natural salmonid production in the study area.

DATA GAPS

- Comprehensive barrier surveys need to be completed in this subbasin.

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3.11 LESTER WATERSHED ADMINISTRATIVE UNIT

INTRODUCTION

The Lester WAU consists of an area that is 32,776 acres in size that is drained by the Green River downstream of the confluence with Sunday Creek to the point of its confluence with Smay Creek. Approximately 39 percent of the land in the WAU is administered by the U.S. Forest Service, 39 percent by Plum Creek Timber Company, 16 percent by the City of Tacoma, 5 percent by the Weyerhauser Company and 1 percent by Burlington Northern.

For purposes of the Watershed Assessment (WSA), the Lester WAU was divided into twelve subbasin. The mainstem of the Green River and its smaller tributaries were divided into two subbasins and the ten major tributary subbasins were also delineated. The major tributary basins were: Morgan Creek, Wolf Creek, Champion Creek, Rock Creek, Lester Creek, Sawmill Creek, Friday Creek, Bald Creek, McCain Creek and Green Canyon Creek. These subbasins will be referred to throughout this chapter.

FIELD MEASUREMENTS AND OBSERVATIONS

In the Lester WAUs, stream surveys are conducted and completed during moderate to low flow conditions during 1994 and 1995. The sampled parameters were quantitatively assessed using methodologies for field habitat collection outlined in the State's Ambient Monitoring Manual (Schuett-Hames et al. 1994), the U.S. Forest Service Stream Handbook, and the Watershed Analysis Manual Version 3.0. Sediment samples were collected in riffle crests in accordance to the method of Schuett-Hames et al. (1994) using a McNeil core sampler, and analyzed by the gravimetric method. Temperature recordings were obtained by maximum thermometers, and thermographs recording at 1 hour intervals from July through September, also in accordance to the temperature monitoring methods of Schuett-Hames et al. (1994). Scour information was obtained using scour chains placed in suitable spawning area. Substrate data were categorized into six size classifications (based on the U.S. Forest Service Stream Handbook, 1991), and frequency of occurrence calculated. All visual observations of juvenile and adult fish were also recorded during the surveys to verify DNR Water Type maps.

Any presence of salmonids was determined by surveys that were conducted utilizing methods outlined in the Version 2.0 of the Standard Methodology for Conduction Watershed Analysis (WFPB 1993). Other physical information collected in the surveys included habitat data, potential salmonid passage barriers, and evidence of recent disturbance (<20 years). Streams classified as Type 4 and 5 by the DNR water type maps were selected with priority given to streams on the basis of physical features that indicated a strong likelihood of salmonid presence (e.g. drainage area >50 acres, gradients <20%, low basin elevation, or any combination of these), although several streams beyond these parameters may also be surveyed at the discretion of the survey team. The basin areas selected were prompted by Watershed Analysis in other similar stream basins. Surveys are concentrated on visiting as many streams as possible over the three month survey period of each year. A total of 38 segments were surveyed.

Landslide hazard assessments drew heavily from empirical data obtained by aerial photo analysis. The photo record spanned 34 years from 1958 to 1992 inclusive.

SURVEYS

Surveys are conducted during sampling seasons that are typically during July to October. Survey seasons were limited to this particular window of opportunity to allow for a better chance to observe salmonids due to local salmonid life history cycles. The elevation of stream reaches has a bearing on the ability to observe salmonids. In the Lester WAU, the elevation is relatively high (1400-5400 feet) and resident salmonids or juvenile anadromous salmonids can be lodged deeply within gravels and organic debris. Typically, during colder air and water temperatures food sources are not present for feeding, thus making any salmonid detection more difficult. Also, high flows often occurring outside the survey window likely contribute to difficult detection of salmonids because they are either displaced downstream, under cover in inaccessible interstitial space, or are difficult to see because of water turbidity.

The physical stream characteristics were determined from topographic maps and aerial photographs from 1958 through 1992 inclusive. Where possible, these characteristics are verified in the field utilizing the methods from the TFW Ambient Monitoring protocols (NWIFC, 1994) for determining channel bankfull widths and wetted widths for calculating gradient. Channel length and bankfull width are measured by a hip-chain and tape measure, respectively. Length and width are typically measured to the nearest 1/10th meter. Stream gradient is measured by a hand-held clinometer at 25 meter stations and averaged, and pool depth is measured with a stadia rod from the deepest part of the pool to the water surface. Gradient is measured to the nearest 1 percent and pool depth to the nearest 1/10th meter. Flood plain connectivity is determined by measuring the lineal meters of road adjacent to one or both sides of a stream segment, and dividing by the length of the stream segment to generate a percent reduction in connectivity. Width-to-depth ratio is calculated by dividing the bankfull width by the channel depth. Road density is obtained by measuring road lengths per stream sub-basin using a desktop GIS software product.

METHODS OF ANALYSIS

Both the NFMS “Matrix of Pathways and Indicators” and the Washington State Watershed Analysis “Indices of Resource Conditions” compare observed stream habitat conditions to a standard numerical or narrative descriptions. Both systems group the observed habitat quality or quantity into three broad categories. The WFPB uses “poor”, “fair”, and “good” while the NMFS uses “Not Properly Functioning”, “At Risk”, and “Properly Functioning”. As both systems use three tiers of habitat condition, one can compare the narrative rating of equivalent or roughly equivalent habitat parameters. For the purposes of this report, “poor” was considered equivalent to “not Properly Functioning” and “good” comparable to “Properly Functioning”. As several of the Washington State “Indices of Resource Conditions” metrics are similar to those of the NMFS “Matrix of Pathways and Indicators”, both were listed for the purpose of comparing methods.

Several habitat parameters of the NMFS Matrix of Pathways do not contain threshold criteria in which to determine a habitat condition. For example, “Holding Pools” by the WFPB definition,

synonymous with “Pool Quality” by the NMFS matrix, define respective ratings of “Good” and “Properly Functioning” as having “sufficient” pools >1m deep. Terms such as “sufficient”, “few”, and “most” do not have threshold criteria in which to base a determination of whether or not it serves as functional habitat. For this reason, criteria were developed for the parameters that lack thresholds based on best professional judgement based on knowledge of life history requirements of salmonids utilizing these WAUs. Data, as available, were also used to support these determinations. The following criteria were developed for these habitat parameters:

RIPARIAN CONDITIONS

Riparian habitat conditions were used to assess potential sources of riparian wood recruitment, which is used in conjunction with the NMFS parameter of “LWD Quantity” and are described previously in this chapter.

The frequency of deep (>1m) holding pools, flood plain connectivity, off-channel habitats, condition of spawning gravels habitat criteria were all discussed previoulsy in this chapter.

After assessing the quality of salmon habitat for four previously mentioned salmon species, the results are compared to the critical input variables for each life history stage to determine the habitat factors that potentially limit natural salmon production in the Sunday Creek and Upper Green River WAUs.

INFORMATION SOURCES

Information is collected from various sources: USFS stream surveys; Tacoma Public Utilities (TPU) stream flow data, water quality, and anecdotal information; the United States Geological Survey (USGS), the Washington Department of Natural Resources (DNR), the US Army Corps of Engineers (Corps), Washington Department of Fish and Wildlife (WDFW), aerial photos , and the U.S. Fish and Wildlife Service (USFW&S). Field surveys conducted by the fish, channel, and riparian module teams provide the required information not previously collected or available. Fish distribution data for salmonid species was provided by the WDFW Washington Rivers Information System (WARIS), WDFW Priority Habitat and Species list, Washington State Salmon and Steelhead Stock Index (SASSI) (WDFW and WWTIT 1994), and was supplemented by field observations by fisheries biologists.

LESTER WAU

The Lester WAU is situated on the west side of the central Cascade Mountains divide, approximately 16 miles (26 km) south of Snoqualmie Pass along Interstate 90 and entirely within King County, Washington. The Green River is the largest water body within the Lester WAUs.

The base elevation of the Lester WAU is approximately 1,400 feet (425 meters) at the confluence with the Green River. The basins rise to the top of the Cascade divide with an average basin elevation of 5,400 ft (1,646m). Approximately 8 miles (13 kilometers (km)) downstream of the lower WAU boundary, the Green River discharges into Howard Hanson Reservoir, a flood control reservoir operated by the Army Corps of Engineers. Downstream of Howard Hanson Dam (HHD) (at RM 64.5) the Green River flows past the Tacoma Headworks Dam (at RM 61)

and enters the Green River Gorge and flows west and eventually flows through the City of Auburn where it turns north and flows through the lower Green River valley and into Elliott Bay near West Seattle. The details of habitat downstream of HHD are contained elsewhere in this report.

SALMONID DISTRIBUTION

The known freshwater distribution of anadromous salmonids is depicted in the report Appendix. There is no historical information concerning salmonid species distribution or abundance in the Lester WAU. However, there is substantial anecdotal information that implies anadromous fish migrated upstream of the Tacoma Headworks Project prior to its completion in 1911. Anadromous fish access into the Lester WAU seems likely, since there are no natural or anthropogenic passage barriers located on the mainstem Green River downstream of the WAU. Historically, adult salmonids were documented at the Tacoma Headworks Diversion Dam (Grette and Salo, 1986), and adults have been documented upstream of the diversion dam site (Riseland, 1913).

Currently, the salmonid species inhabiting the Lester WAU include hatchery releases of fed fry of summer/fall chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), a combination of hatchery and natural production of resident and anadromous (steelhead) rainbow trout (*O. mykiss*), and natural populations of cutthroat trout (*O. clarki*), and mountain whitefish (*Prosopium williamsonni*). Currently, only anadromous steelhead adults are passed upstream of the Tacoma Headworks Project and HHD. Spawning steelhead adults have been observed in the Green River as far upstream as RM 83.5 but they have not been observed in the Lester WAU. The release locations of juvenile steelhead, chinook and coho salmon into the Lester WAU are depicted in Appendix B. Mountain whitefish, cutthroat and resident rainbow trout are known to inhabit the primary tributaries. As of the date of this report there are no reported observations of bull trout (*Salvalinus confluentus*) within the Lester WAU.

There are known resident trout populations in the Lester WAU that include rainbow and cutthroat. These species have a wide distribution, but since no formal inventory has been done, an exact distribution and abundance estimate cannot be determined. Adfluvial trout populations have been observed throughout the lower portions of the Green River in the Lester WAU. Resident trout are found in most of the major Lester WAU tributaries and extend into tributaries classified as "Type 3" waters. Type 4 waters are also likely to contain resident trout populations where the stream gradient is less than 14 percent. Resident trout were found during electrofishing surveys in several Type 4 streams during WSA sampling (Plum Creek 1996). No resident trout were found in streams with gradients in excess of 14 percent (Plum Creek 1996).

The mainstem Green River and all the primary tributary channels support resident rainbow and/or cutthroat trout. While not demonstrated, it is likely that hybridization between the two species has occurred ((b) (6), WDFW, pers. comm.). Trout in reaches of isolated high-gradient streams are often segregated from other strains by passage barriers, although dispersal by downstream migration frequently occurs. The mainstem Green River, supports a population of cutthroat trout that attain lengths of 20 inches ((b) (6), pers. comm.). These large and mature fish may represent a stock of adfluvial cutthroat that have matured in the reservoir and ascend the streams to spawn. Spawning activity of the adfluvial strains of trout are believed to occur pri-

marily in the mainstem Green River and in the lower reaches of the accessible tributaries (Wunderlich and Toal, 1992). The stream rearing habitat requirements for resident trout are similar to those of steelhead. As with all species of salmonids using the WAU, relatively shallow, channel margin and pool habitat is important during the earliest stages of life soon after incubation.

FISH HABITAT CONDITIONS

In the Lester WAU Watershed Analyses (WSA), a total of forty-six (46) segments were sampled and surveyed. Anecdotal evidence was noted between sample reaches to obtain inferences on channel character and habitat condition and whether or not the segment was representative of the surveyed. In those 46 segments, a total of 24,739 feet of channel were quantitatively surveyed. The length of sample reaches varied, but a minimum of 328 feet (100 meters) was surveyed. Field evaluations were completed during May thru August 1994.

The Lester WSA did not classify segments by salmon species as was done in the Green River and Sunday Creek WSA. Rather, metrics were repotred by stream segment as shown in Table Lester-1.

Table Lester 1: Pool Habitat in the Lester WAU (Source: Toth 1996)

Segment	Pools (% of channel area)	Pool Frequency*	Mean residual pool depth
2	22	1.2	17.6
5	10	1.3	12.9
B1	14	4.5	9.7
B5	26	2.8	7.4
C1	14	4.5	11.2
C2	18	1.3	13.1
C3	22	1.2	12.0
C9	10	2.1	11.5
D1	25	7.3	14.5
D1a	44	3.6	13.2
D6	37	1.5	10.3
E1	11	2.3	8.5
E14	29	1.1	8.0
E18	33	2.2	12.1
E3	44	0.9	12.6
H1	30	0.8	13.2
H2	17	1.9	0.5
E1H38	47	0.5	10.5
H6	29	1.0	12.3
H6A	42	0.8	23.0
I18	0		
I19	35	2.7	8.0
I2	8	2.1	0.9
I20	34	2.1	9.9
I3	30	0.7	11.6
I6	26	1.8	1.2
I7	24	1.4	1.0
I8	6	5.8	0.9
K2	29	4.7	1.2
K2A	25	1.4	14.1

The field metrics identified in the NMFS "Matrix of Pathways" were quantified for habitats utilized by each species.

The following discussion relates the existing quality of habitat in the upper Green and Sunday Creek WAUs for each species to their respective life history requirements. This is accomplished by evaluating the effects associated with each respective critical input variable, which often dictates habitat quality.

FALL CHINOOK

Information was reviewed from six survey reaches that covered 1,118 meters of stream channel. These six survey reaches represent 18.3 percent of the presumed fall chinook habitat available in the Green River and Sunday Creek WAUs as identified by the Army Corps of Engineers (1998). Overall, the quality of fall chinook habitat is rated as "Not Properly Functioning". The key parameters examined are identified in Table Lester-2.

Table Lester 2: Examined Key Habitat Parameters for Fall Chinook Reaches in the Green River and Sunday Creek WAUs

Parameter	Minimum	Maximum	Mean	SD	N=
Survey Reach Length (m)	100	218	186	43.0	6
BFW (m)	5.3	20.9	11.2	5.3	6
Bankfull Depth (m)	0.40	0.6	0.5	0.1	6
Gradient (%)	1.5	3.0	2.4	0.7	6
Elevation (m)	558	607	588	18.7	6
Pools/mile	22.2	80.5	41.7	27.1	6
Holding Pools/mile	0	48.3	18.7	16.7	6
Percent of all pools that are holding/pools per mile	0%	67	43.6	26.5	6
Off-channel Habitat	0	45	11.7	16.9	6
Riparian Species 1=conifer, 2=deciduous	1	2	1.7	0.52	6
Riparian Age 1=old, 2=mature, 3=young	2	3	2.7	0.52	6
Riparian density: 1=dense, 2=sparse	1	2	1.2	0.41	6
Percent wood cover in pools	0-5%	5-10%	4.5%	2.7%	5
Width/depth ratio	13.3	37.3	21.2	8.4	6
Occurrence of sand, silt, clay (%)	0	25	4.17	10.21	6
Occurrence of gravel, cobble (%)	10	90	57.38	32.37	6
Occurrence of boulder/bedrock (%)	0	90	38.00	36.46	6
Anadromous Spawning Area (%)	0	2	0.67	0.82	6
Percent fines	16	16	16	0	1
Temperature (F)	62.24	62.24	62.24	0	1
Canopy Closure (%)	0%	78%	16.2%	30.9%	6
Min. shade requirement (%)*	47%	51%	48.5%	1.5%	6
NMFS wood pieces/mile	0	29.5	4.92	12.06	6

* Source: WFPB 1998.

RIPARIAN HABITAT

Watershed Analysis found that the bulk of the riparian habitats in the Green River and Sunday Creek WAUs are generally dense, but young deciduous trees. This condition is insufficient as a new LWD supply to the stream channel and hence maintain or improve the associated habitat forming processes. This situation will likely not ameliorate until the riparian stands reach a size and age that would allow for sufficient size and number to restore instream LWD loadings to a more natural level. The riparian condition is currently considered to be "Not Properly Functioning" for fall chinook in four of the six reaches surveyed and "At Risk" in the remaining two. These ratings are due to: (1) the deciduous component of trees that dominate the assessed riparian reaches for fall chinook; and (2) the young age of the trees present in the riparian area.

The young tree age and large deciduous component are likely directly responsible for the scarcity of NMFS criteria LWD present in the stream channel. The quantity of LWD within the fall chinook reaches is insufficient to maintain many of the necessary habitat elements and habitat forming elements. Though pieces of wood are numerous, they are typically small. Only four pieces of wood were found that meet NMFS size criteria within the survey fall chinook reaches. This represents only 7.1 percent of the 56 pieces needed to be considered "Properly Functioning". None of the reaches surveyed met NMFS criteria for wood quantity, nor are the channel adjacent stands considered to be adequate to maintain LWD recruitment processes in the near term. Thus, for fall chinook this yields a "Not Properly Functioning" assessment.

SUBSTRATE

WSA indicates that spawning gravels are in short supply throughout the reaches examined. Surveys indicate that a mean of 0.76 percent of the total surveyed stream channel was observed to contain potential suitable spawning substrate. Three of the six reaches surveyed were dominated by boulder/bedrock and the remaining three reaches were dominated by gravel/cobble with very little gravel distributed in areas that were deemed useful for fall chinook spawning. Overall, the paucity of suitable spawning gravels in the reaches surveyed are a limiting factor for fall chinook production and were rated as "Not Properly Functioning".

Mass wasting and hillslope erosion was determined not to be a significant contributor to the overall levels of fine sediment produced in the Green River and Sunday Creek WAUs. Secondary sediment erosion from mass wasting scarps generally was below the 50 percent of the natural background sediment input cutoff point for a moderate hazard rating designation. There was one exception, the Pioneer Creek subbasin, where the estimated sediment yield is 57 percent of the background.

POOLS

Of the 24 reaches surveyed, the number of pools varied considerably. Using pool frequencies as calculated from the pool frequency regression curve, 16 of the 24 surveyed reaches do not meet NMFS criteria for "Properly Functioning" for pool frequency. When taken in the aggregate, the streams had roughly the required number of pools required to meet MNFS criteria as "Properly Functioning". Cumulatively, the surveyed reaches had 26 pools in fall chinook reaches where 28.4 were to be expected. Two of the six reaches surveyed had more pools than required and overly compensated for the other four reaches that had far fewer than the required number of pools. However, despite the number of pools present, all of the reaches, including those that met NMFS pool criteria to be considered "Properly Functioning" are assigned an "At Risk" factor because of the inadequacy of the riparian zone to recruit LWD into the stream channel to form pools.

Approximately 44 percent of the pools surveyed met minimum depth requirements (>1 meter). The ability of the pools to provide cover and holding areas is further reduced by the pool in-water and overwater cover, again because of the lack of LWD. Pool quality was deemed insufficient to provide suitable habitat for fall chinook as was assigned an "At Risk" rating.

CHANNEL CONDITIONS

Reach specific and cumulative observations suggest that the stream channel has become shallow and wide. This may also be an influencing factor in decreased pool quality and adversely impacts the ability of the available habitat to successfully hold adult and rear juvenile salmonids. The mean width:depth ratio was 21.22. This indicates increased proportion of riffles and glides that leads to reduced high flow refugia and available over-winter rearing habitats, an increased water surface area exposed to solar radiation that in turn could lead to increased stream water temperatures. Additionally, the high width to depth ratio may influence fall chinook spawning through decreases in wetted stream areas with acceptable depths for spawning fall chinook. A designation of "Not Properly Functioning" was assigned to stream channel conditions because of the high width:depth ratio.

OFF-CHANNEL HABITAT

Six reaches were surveyed for the quantity of off-channel habitat. Only one of these six reaches was ranked as "Properly Functioning" with 45 percent of the off-channel habitat in this reach skewed the mean value to 11.7 percent. However, this single reach is not representative of the other five stream reaches as noted by the high variability, which is illustrated by a standard deviation of 16.9 percent. Three of the six reaches are rated as "Not Properly Functioning" while the others are rated as "At Risk". Overall, off-channel habitats are rated as "Not Properly Functioning" again due to the scarceness of LWD and the off-channel habitat forming processes associated with LWD.

WATER QUALITY

Water temperature was measured in one stream as 62.2 F, which would give a rating of "Not Properly Functioning". A probable cause of elevated stream temperatures is that the mean canopy closure is only 24.0 percent while 41.3 percent canopy coverage is required to meet shade standards (WFPB 1998) to avoid solar radiation and induced water temperature increases.

SPRING CHINOOK

Information was reviewed from twelve (12) survey reaches that covered 1,742 meters of stream channel. These twelve survey reaches represent 16.6 percent of the presumed spring chinook habitat available in the Green River and Sunday Creek WAUs as identified by the Army Corps of Engineers (1998). The key parameters examined are identified in Table Lester-3.

Table Lester-3: Examined Key Habitat Parameters for Spring Chinook Reaches in the Green River and Sunday Creek WAUs

Parameter	Minimum	Maximum	Mean	SD	N=
Survey Reach Length (m)	24	218	145	64.1	12
BFW (m)	4	21	10	438	12
Bankfull Depth (m)	0.4	1.5	1	0.4	12
Gradient (%)	1.5	5	2.5	0.4	12
Elevation (m)	558	723	635.4	58.4	12
Pools/mile	0	134.1	44.1	38.5	12
Holding Pools/mile	0	48.3	9.3	14.9	12
Percent of all pools that are holding/pools per mile	0%	67	26	30	10
Off-channel Habitat	0	45	1.3	16.2	9
Riparian Species 1=conifer, 2=deciduous	1	3	1.8	0.4	6
Riparian Age 1=old, 2=mature, 3=young	2	3	2.8	0.4	6
Riparian density: 1=dense, 2=sparse	1	2	1.2	0.4	6
Percent wood cover in pools	0.5%	5-10%	0-5%	---	9
Width/depth ratio	7.3	37.3	16.1	7.9	6
Occurrence of sand, silt, clay (%)	0	25	3.0	7.6	6
Occurrence of gravel, cobble (%)	10	100	69.1	30.4	6
Occurrence of boulder/bedrock (%)	0	90	27.80	32.4	6
Anadromous Spawning Area (%)	0	6	1.3	1.8	10
Percent fines	16	16	16	0	1
Temperature (F)	58.1	67.2	60.2	2.9	5
Canopy Closure (%)	0%	93%	20.7%	31.9%	12
Min. shade requirement (%)*	37%	51%	44.3%	5.1%	12
NMFS wood pieces/mile	0	257.6	27.3	73.8	12

* Source: WFPB 1998.

RIPARIAN HABITAT

Watershed Analysis found that the bulk of the riparian habitats that could be utilized by spring chinook in the Green River and Sunday Creek WAUs are generally dense, but young deciduous trees. This condition is insufficient as a new LWD supply to the stream channel and hence maintain or improve the associated habitat forming processes. This situation will likely not ameliorate until the riparian stands reach a size and age that would allow for sufficient size and number to restore instream LWD loadings to a more natural level. The riparian condition is currently considered to be "Not Properly Functioning" for spring chinook in ten of the twelve reaches surveyed and "At Risk" in the remaining two. These ratings are due to: (1) the deciduous component of trees that dominate the assessed riparian reaches for fall chinook; and (2) the young age of the trees present in the riparian area.

The young tree age and large deciduous component are likely directly responsible for the scarcity of NMFS criteria LWD present in the stream channel. The quantity of LWD within the spring chinook reaches is insufficient to maintain many of the necessary habitat elements and habitat forming elements. None of the reaches surveyed met NMFS criteria for wood quantity, nor are the channel adjacent stands considered to be adequate to maintain LWD recruitment processes in the near term. Thus, for spring chinook this yields a "Not Properly Functioning" assessment.

SUBSTRATE

WSA indicates that spawning gravels are in short supply throughout the reaches examined. Surveys indicate that a mean of 1.3 percent of the total surveyed stream channel was observed to contain potential suitable spawning substrate. Individual reaches also reflected poor spawning gravel quality. Eleven of the twelve reaches were rated as "Not Properly Functioning" due to inadequate area of spawnable gravels. Boulder/bedrock was the dominant feature in four reaches while gravel/cobble dominated the remaining eight. The gravel/cobble reaches contained very little gravel distributed in areas that could be utilized by spawning spring chinook. Only one reach (mainstem Green River at RM 86.4) that contained 6 percent spawning gravel was considered "At Risk", the remaining reaches were all considered to be "Not Properly Functioning". Overall, the paucity of suitable spawning gravels in the reaches surveyed are a limiting factor for spring chinook production and were rated as "Not Properly Functioning".

Mass wasting and hillslope erosion was determined not to be a significant contributor to the overall levels of fine sediment produced in the Green River and Sunday Creek WAUs. Secondary sediment erosion from mass wasting scarps generally was below the 50 percent of the natural background sediment input cutoff point for a moderate hazard rating designation. There was one exception, the Pioneer Creek subbasin, where the estimated sediment yield is 57 percent of the background.

POOLS

Overall, the spring chinook reaches surveyed had 85 percent of the required number of pools to meet NMFS as "Properly Functioning". However, the poor quality of the pools and the inadequate stream adjacent riparian reserves strongly suggest that a lower habitat quality rating be assigned than consideration of pool frequency alone would suggest.

Of the twelve reaches surveyed, the number of pools varied considerably. Using pool frequencies as calculated from the pool frequency regression curve, nine of the twelve surveyed reaches do not meet NMFS criteria for "Properly Functioning" for pool frequency. When taken in the aggregate, the streams had roughly the required number of pools required to meet MNFS criteria as "Properly Functioning". Cumulatively, the surveyed reaches had 41 pools in spring chinook reaches where 48 were to be expected. Individually, nine of the twelve reaches had a pool deficit and are rated as "Not Properly Functioning". However, on a system wide basis, these numerical deficiencies were almost compensated by reaches containing more pools than required. However, despite the number of pools present, all of the reaches, including those that met NMFS pool criteria to be considered "Properly Functioning" are assigned an "At Risk" factor because of the inadequacy of the riparian zone to recruit LWD into the stream channel to form pools. Without LWD inputs into the stream channel it should be expected that there will be a net decrease over time of pool quality and pool numbers.

Approximately 26 percent of the pools surveyed met minimum depth requirements (>1 meter). The ability of the pools to provide cover and holding areas is further reduced by the pool in-water and overwater cover, again because of the lack of LWD. Cover in all pools was considered poor, with a mean coverage in the 0-5 percent range. Pool quality was deemed insufficient to provide suitable habitat for spring chinook as was assigned an "At Risk" rating.

CHANNEL CONDITIONS

Reach specific and cumulative observations suggest that the stream channel has become shallow and wide. This may also be an influencing factor in decreased pool quality and adversely impacts the ability of the available habitat to successfully hold adult and rear juvenile salmonids. The mean width:depth ratio was 16.1. This indicates increased proportion of riffles and glides that leads to reduced high flow refugia and available over-winter rearing habitats, an increased water surface area exposed to solar radiation that in turn could lead to increased stream water temperatures. Additionally, the high width to depth ratio may influence fall chinook spawning through decreases in wetted stream areas with acceptable depths for spawning fall chinook.

Individually, two of the twelve surveyed reaches met the NMFS criteria to be defined as "Properly Functioning" while two were "At Risk" and the remaining eight were "Not Properly Functioning".

A designation of "Not Properly Functioning" was assigned to stream channel conditions because of the high width:depth ratio.

OFF-CHANNEL HABITAT

Nine reaches were surveyed for the quantity of off-channel habitat. Only two of these nine reaches was ranked as "Properly Functioning", three were ranked as "At Risk" and five at "Not Properly Functioning". Two reaches with exceptionally large percentages of off-channel rearing (45% and 32%) skewed the mean value to 11.3 percent. However, this single reach is not representative of the other five stream reaches as noted by the high variability, which is illustrated by a standard deviation of 16.2 percent. Overall, off-channel habitats are rated as "Not Properly Functioning" again due to the scarceness of LWD and the off-channel habitat forming processes associated with LWD.

WATER QUALITY

Water temperature was measured in one stream as 60.2 F, which would give a rating of "Not Properly Functioning". A probable cause of elevated stream temperatures is that the mean canopy closure is only 20.7 percent while 44 percent canopy coverage is required to meet shade standards (WFPB 1998) to avoid solar radiation and induced water temperature increases.

COHO

Information was reviewed from 24 reaches that were surveyed that were considered to support coho salmon. This represented an area covering 3,652 meters of stream channel and further represents approximately 17.8 percent of the presumed coho habitat in the Green River and Sunday Creek WAUs. Key parameters of the coho habitat survey are presented in Table Lester-4 below.

Lester-4: Examined Key Habitat Parameters for Coho Reaches in the Green River and Sunday Creek WAUs

Parameter	Minimum	Maximum	Mean	SD	N=
Survey Reach Length (m)	24	300	152.0	77.0	24
BFW (m)	4	38	13.2	8.3	24
Bankfull Depth (m)	0.37	2.5	0.98	0.66	24
Gradient (%)	1.0	6.0	2.6	1.4	24
Elevation (m)	529	723	612	59.7	24
Pools/mile	0	134.1	37.0	32.6	24
Holding Pools/mile	0	48.3	9.2	11.8	24
Percent of all pools that are holding/pools per mile	0	100	35	35	21
Off-channel Habitat	0	49	10.2	16.6	16
Riparian Species 1=conifer, 2=deciduous	1	2	1.8	0.4	23
Riparian Age 1=old, 2=mature, 3=young	2	3	2.9	0.3	23
Riparian density: 1=dense, 2=sparse	1	2	1.2	0.4	23
Percent wood cover in pools	0-5%	5-10%	0-5%	2.7	16
Width/depth ratio	6.0	37.3	15.2	6.6	24
Occurrence of sand, silt, clay (%)	0	25	3.2	7.6	24
Occurrence of gravel, cobble (%)	0	100	66.7	32.4	24
Occurrence of boulder/bedrock (%)	0	100	24.3	32.0	24
Anadromous Spawning Area (%)	0	13.0	2.1	3.1	21
Percent fines	6	16	11.0	7.1	2
Temperature (F)	57.2	62.24	59.1	2.0	5
Canopy Closure (%)	0	93	21.3	25.7	24
Min. shade requirement (%)*	20%	54	42.8	9.6	24
NMFS wood pieces/mile	0	257	30.2	65.7	24

* Source: WFPB 1998.

RIPARIAN HABITAT

Watershed Analysis found that the bulk of the riparian habitats that could be utilized by coho in the Green River and Sunday Creek WAUs are generally dense, but consist of young deciduous trees. This condition is insufficient as a new LWD supply to the stream channel and hence maintain or improve the associated habitat forming processes. This situation will likely not ameliorate until the riparian stands reach a size and age that would allow for sufficient size and number to restore instream LWD loadings to a more natural level. The riparian condition is currently considered to be "Not Properly Functioning" for coho in 20 of the 23 reaches surveyed and "At Risk" in the remaining three. These ratings are due to: (1) the deciduous component of trees that dominate the assessed riparian reaches for fall chinook; and (2) the young age of the trees present in the riparian area. The condition of the riparian habitat is currently not sufficient in the near term to provide suitable amounts and quality of LWD to the stream channel to maintain associated habitat and other ecological forming processes. Without large coniferous trees for recruitment and retention, the existing level of coho production should be expected to decline.

The mean pieces of WSA size wood (>10 centimeters diameter, >2 meters length) per channel width was 3.0. A rating of good is assigned to stream channels with at least 2.0 pieces per channel width (WFPB 1997). However, this good rating is strongly influenced by one reach in the

mainstem Green River (RM85.8) where a segment long log jam contained an average of 34 pieces per channel width. In the absence of this log jam, the number of wood pieces per channel width over the surveyed habitat would be 1.7, yielding a rating of "Fair" under WSA standards. This patchy distribution of wood in the stream channel is indicated by the standard deviation of 7.1 pieces per channel width.

WSA key pieces are also below the desired target numbers, averaging only 0.02 pieces per channel width. This represents less than 10 percent of the target goal of 0.3 pieces per channel width.

When NMFS criteria are applied, only 56 pieces of wood were identified within the reaches surveyed for coho salmon. This represents only 31 percent of the target level of 181 pieces required to be considered "Properly Functioning" by NMFS. This yields an overall habitat rating as "Not Properly Functioning".

SUBSTRATE

WSA indicates that spawning gravels are in short supply and inadequate for adult coho salmon spawning throughout the reaches examined. Surveys indicate that a mean of 2.1 percent of the total surveyed stream channel was observed to contain potential suitable spawning substrate where the desired threshold is 10 percent. Individual reaches also reflected poor spawning gravel quality. Twenty of the twenty-one reaches were rated as "Not Properly Functioning" due to inadequate area of spawnable gravels. The gravel/cobble reaches category dominated (67%) the reaches but contained very little gravel distributed in areas that could be utilized by spawning coho. Only one reach (mainstem Green River at RM 86.4) that contained 13 percent spawning gravel was considered "Properly Functioning", while the remaining reaches were all considered to be "Not Properly Functioning". Overall, the paucity of suitable spawning gravels in the reaches surveyed are a limiting factor for coho production and were rated as "Not Properly Functioning".

Mass wasting and hillslope erosion was determined not to be a significant contributor to the overall levels of fine sediment produced in the Green River and Sunday Creek WAUs. Secondary sediment erosion from mass wasting scarps generally was below the 50 percent of the natural background sediment input cutoff point for a moderate hazard rating designation. There was one exception, the Pioneer Creek subbasin, where the estimated sediment yield is 57 percent of the background.

Fine sediment sampled in two reaches was measured at 6 percent and 16 percent. A mean of fines of 11.0 percent is considered to be "Properly Functioning" (NMFS).

POOLS

Overall, the coho reaches surveyed had 81 percent of the required number of pools to meet NMFS as "Properly Functioning". However, the poor quality of these pools and the inadequate stream adjacent riparian reserves strongly suggest that a lower habitat quality rating be assigned than consideration of pool frequency alone would suggest.

Of the 24 reaches surveyed, the number of pools varied considerably. Using pool frequencies as calculated from the pool frequency regression curve, 16 of the 24 surveyed reaches do not meet NMFS criteria for "Properly Functioning" for pool frequency. When taken in the aggregate, the streams had roughly the required number of pools required to meet MNFS criteria as "Properly Functioning". Cumulatively, the surveyed reaches had 75 pools in coho reaches where 91 were to be expected. However, on a system wide basis, these numerical deficiencies were almost compensated by reaches containing more pools than required. However, despite the number of pools present, all of the reaches, including those that met NMFS pool criteria to be considered "Properly Functioning" are assigned an "At Risk" factor because of the inadequacy of the riparian zone to recruit LWD into the stream channel to form pools. Without LWD inputs into the stream channel it should be expected that there will be a net decrease over time of pool quality and pool numbers.

Approximately 35 percent of the pools surveyed met minimum depth requirements (>1 meter). The ability of the pools to provide cover and holding areas is further reduced by the pool in-water and overwater cover, again because of the lack of LWD. Cover in all pools was considered poor, with a mean coverage in the 0-5 percent range. Pool quality was deemed insufficient to provide suitable habitat for spring chinook as was assigned an "At Risk" rating.

CHANNEL CONDITIONS

Reach specific and cumulative observations suggest that the stream channel has become shallow and wide. This may also be an influencing factor in decreased pool quality and adversely impacts the ability of the available habitat to successfully hold adult and rear juvenile salmonids. The mean width:depth ratio was 15.2. This indicates increased proportion of riffles and glides that leads to reduced high flow refugia and available over-winter rearing habitats, an increased water surface area exposed to solar radiation that in turn could lead to increased stream water temperatures. Additionally, the high width to depth ratio may influence coho spawning through decreases in wetted stream areas with acceptable depths for spawning coho.

Individually, three of the 24 surveyed reaches met the NMFS criteria to be defined as "Properly Functioning" while five were "At Risk" and the remaining 18 were "Not Properly Functioning".

A designation of "Not Properly Functioning" was assigned to stream channel conditions because of the high width:depth ratio.

OFF-CHANNEL HABITAT

The quantity of off-channel habitat is cumulatively 10.2 percent of the total wetted area and is considered to be "Properly Functioning". However, on an individual basis, only four of the 16 reaches surveyed achieve a rating of "Properly Functioning".

WATER QUALITY

Water temperature as measured in five streams averaged 59.1 F giving an overall rating of "At Risk". A probable cause of elevated stream temperatures is that the mean canopy closure is only

20.5 percent while 42 percent canopy coverage is required to meet shade standards (WFPB 1998) to avoid solar radiation and induced water temperature increases.

STEELHEAD

Information was reviewed from 29 surveyed reaches that were considered to support steelhead. This represented an area covering 4,352 meters of stream channel and further represents approximately 20.3 percent of the presumed steelhead habitat in the Green River and Sunday Creek WAUs. Key parameters of the steelhead habitat survey are presented in Table Lester-5 below.

Table Lester-5: Examined Key Habitat Parameters for Steelhead Reaches in the Green River and Sunday Creek WAUs

Parameter	Minimum	Maximum	Mean	SD	N=
Survey Reach Length (m)	24	300	150.1	77.7	29
BFW (m)	4.0	38.0	13.0	7.8	29
Bankfull Depth (m)	0.4	2.5	1.1	0.7	29
Gradient (%)	1.0	11.0	3.0	2.0	29
Elevation (m)	529	838	635.7	78.1	29
Pools/mile	0	134.1	40	34.5	29
Holding Pools/mile	0	48.3	8.6	11.7	29
Percent of all pools that are holding/pools per mile	0	100	29	34	26
Off-channel Habitat	0	49	9.5	15.8	18
Riparian Species 1=conifer, 2=deciduous	1	2	1.8	0.4	28
Riparian Age 1=old, 2=mature, 3=young	2	3	2.9	0.3	28
Riparian density: 1=dense, 2=sparse	2	1	1.1	0.4	28
Percent wood cover in pools	0-5%	5-10%	0-5%	N/A	18
Width/depth ratio	6.0	37.3	14.3	6.4	29
Occurrence of sand, silt, clay (%)	0	25	2.9	7.1	28
Occurrence of gravel, cobble (%)	0	100	61.5	33.5	28
Occurrence of boulder/bedrock (%)	0	100	34.2	36.3	28
Anadromous Spawning Area (%)	0	13	2	2.9	25
Percent fines	6	16	11.0	7.1	2
Temperature (F)	57.2	62.2	59.6	2.2	5
Canopy Closure (%)	0	93.0	24.0	25.3	29
Min. shade requirement (%)*	20	54	41.3	9.4	29
NMFS wood pieces/mile	0	257.6	26.6	60.3	29

* Source: WFPB 1998.

RIPARIAN HABITAT

Watershed Analysis found that the bulk of the riparian habitats that could be utilized by steelhead in the Green River and Sunday Creek WAUs are generally dense, but consist of young deciduous trees. This condition is insufficient as a new LWD supply to the stream channel and hence maintain or improve the associated habitat forming processes. This situation will likely not ameliorate until the riparian stands reach a size and age that would allow for sufficient size and number to restore instream LWD loadings to a more natural level. The riparian condition is currently considered to be “Not Properly Functioning” for steelhead in 25 of the 28 reaches surveyed and “At Risk” in the remaining three. These ratings are due to: (1) the deciduous com-

ponent of trees that dominate the assessed riparian reaches for steelhead; and (2) the young age of the trees present in the riparian area. The condition of the riparian habitat is currently not sufficient in the near term to provide suitable amounts and quality of LWD to the stream channel to maintain associated habitat and other ecological forming processes. Without large coniferous trees for recruitment and retention, the existing level of steelhead production should be expected to decline.

The mean pieces of WSA size wood (>10 centimeters diameter, >2 meters length) per channel width was 2.8. A rating of good is assigned to stream channels with at least 2.0 pieces per channel width (WFPB 1997). However, this good rating is strongly influenced by one reach in the mainstem Green River (RM85.8) where a segment long log jam contained an average of 34 pieces per channel width. In the absence of this log jam, the number of wood pieces per channel width over the surveyed habitat would be 1.7, yielding a rating of "Fair" under WSA standards. This patchy distribution of wood in the stream channel is indicated by the standard deviation of 7.0 pieces per channel width.

WSA key pieces are also below the desired target numbers, averaging only 0.03 pieces per channel width. This represents less than 20 percent of the target goal of 0.15 pieces per channel width.

When NMFS criteria are applied, only 59 pieces of wood were identified within the reaches surveyed for steelhead. This represents only 27.3 percent of the target level of 216 pieces required to be considered "Properly Functioning" by NMFS. Individually, two of the 29 reaches met NMFS wood requirement criteria. However, due to the young deciduous conditions adjacent to the stream channel, potential wood recruitment sources will be unable to maintain or improve the necessary wood loadings. This yields an overall habitat rating as "Not Properly Functioning".

SUBSTRATE

WSA indicates that spawning gravels are in short supply and inadequate for adult steelhead spawning throughout the reaches examined. Surveys indicate that a mean of 2.0 percent of the total surveyed stream channel was observed to contain potential suitable spawning substrate where the desired threshold is 10 percent. Individual reaches also reflected poor spawning gravel quality. Twenty-four of the twenty-five reaches were rated as "Not Properly Functioning" due to inadequate area of spawnable gravels. The gravel/cobble reaches category dominated 17 of the 28 reaches (60.7%) but contained very little gravel distributed in areas that could be utilized by spawning steelhead. Only one reach (mainstem Green River at RM 86.4) that contained 13 percent spawning gravel was considered "Properly Functioning", while the remaining reaches were all considered to be "Not Properly Functioning". Overall, the paucity of suitable spawning gravels in the reaches surveyed are a limiting factor for steelhead production and were rated as "Not Properly Functioning".

Mass wasting and hillslope erosion was determined not to be a significant contributor to the overall levels of fine sediment produced in the Green River and Sunday Creek WAUs. Secondary sediment erosion from mass wasting scarps generally was below the 50 percent of the natural background sediment input cutoff point for a moderate hazard rating designation. There was

one exception, the Pioneer Creek subbasin, where the estimated sediment yield is 57 percent of the background.

POOLS

Overall, the steelhead reaches surveyed had more than the required number of pools to meet NMFS as "Properly Functioning". However, the poor quality of these pools and the inadequate stream adjacent riparian reserves strongly suggest that a lower habitat quality rating be assigned than consideration of pool frequency alone would suggest.

Of the 29 reaches surveyed, the number of pools varied considerably. Cumulatively, using pool frequencies as calculated from the pool frequency regression curve, the reaches contained 98 pools and exceeded the NMFS requirement of 90 pools. However, on an individual basis, 18 of the 29 surveyed reaches do not meet NMFS criteria for "Properly Functioning" for pool frequency and in fact would be considered as "Not Properly Functioning". However, on a system wide basis, these numerical deficiencies were almost compensated by reaches containing more pools than required. Despite the number of pools present, all of the reaches, including those that met NMFS pool criteria to be considered "Properly Functioning" are assigned an "At Risk" factor because of the inadequacy of the riparian zone to recruit LWD into the stream channel to form pools. Without LWD inputs into the stream channel it should be expected that there will be a net decrease over time of pool quality and pool numbers.

Approximately 29 percent of the pools surveyed met minimum depth requirements (>1 meter). The ability of the pools to provide cover and holding areas is further reduced by the pool in-water and overwater cover, again because of the lack of LWD. Cover in all pools was considered poor, with a mean coverage in the 0-5 percent range. Pool quality was deemed insufficient to provide suitable habitat for spring chinook as was assigned an "At Risk" rating.

CHANNEL CONDITIONS

Of the 29 surveyed reaches for steelhead, only five met the NMFS criteria for "Properly Functioning", eight can be described as "At Risk" and the remaining sixteen as "Not Properly Functioning". Reach specific and cumulative observations suggest that the stream channel has become shallow and wide. This may also be an influencing factor in decreased pool quality and adversely impacts the ability of the available habitat to successfully hold adult and rear juvenile salmonids. The mean width:depth ratio was 14.3, where a target of less than 10 is required to meet favorable channel conditions. This indicates increased proportion of riffles and glides that leads to reduced high flow refugia and available over-winter rearing habitats, an increased water surface area exposed to solar radiation that in turn could lead to increased stream water temperatures. Additionally, the high width to depth ratio may influence steelhead spawning through decreases in wetted stream areas with acceptable depths for spawning steelhead.

A designation of "Not Properly Functioning" was assigned to stream channel conditions because of the high width:depth ratio.

OFF-CHANNEL HABITAT

The quantity of off-channel habitat is cumulatively 9.5 percent of the total wetted area and is considered to be "At Risk". However, on an individual basis, only four of the 18 reaches surveyed achieve a rating of "Properly Functioning". Therefore, natural production of steelhead is considered to be limited by the lack of off-channel rearing opportunities in the Green River and Sunday Creek WAUs.

WATER QUALITY

Water temperature as measured in five streams averaged 59.6 F giving an overall rating of "At Risk" for juvenile steelhead rearing and adult summer steelhead that might be migrating, holding or spawning in these reaches. A probable cause of elevated stream temperatures is that the mean canopy closure is only 24.0 percent while 41.3 percent canopy coverage is required to meet shade standards (WFPB 1998) to avoid solar radiation and induced water temperature increases.

SUBSTRATE

The quality of spawning habitat is dictated by the abundance of spawnable gravels, adjacent cover, and riparian shade. This is in turn affected by coarse and fine sediment, large wood, riparian vegetation, and flow. Spawning gravel is considered to be "Not Properly Functioning" for any of the salmon species present. A number of factors could be contributing to this alone or collectively. This could be a result influenced by the lack of LWD that serves to trap gravels, which is at levels considered to be "Not Properly Functioning" (NMFS) or poor (WFPB). Also, the cover component in pools, important for salmonid spawning may also be limiting due to is present rating of "poor" (WFPB). Furthermore, the stream temperatures for spawning is considered to be "At Risk" (NMFS) for all species except fall chinook, in which this condition is considered to be "Not Properly Functioning" (NMFS). The influence of the riparian area is likely to contribute to the lack of large wood, elevated stream temperatures, and lack of cover. The riparian condition is considered to be "Not Properly Functioning" (NMFS) for all the aforementioned salmon species.

Fine sediment is considered to be "At Risk" for coho and steelhead. Fine sediment can inhibit redd excavation and incubation, as noted previously. Fine sediment does not currently limit fall and spring chinook spawning, in which this metric is considered to be Properly Functioning (NMFS).

Mass wasting and hillslope erosion was determined not to be a significant contributor to the overall levels of fine sediment produced in the Green River and Sunday Creek WAUs. Secondary sediment erosion from mass wasting scarps generally was below the 50 percent of the natural background sediment input cutoff point for a moderate hazard rating designation. There was one exception, the Pioneer Creek subbasin, where the estimated sediment yield is 57 percent of the background.

SUMMARY

In summary, anadromous salmonid spawning habitat is limited by 1) the lack of suitable spawning gravels, 2) elevated stream temperatures, and 3) the lack of cover in pools. These components are influenced by the loss of LWD, which is lacking in the system, a poor riparian condition, which is also "Not Properly Functioning" condition, and fine sediment for coho and steelhead spawning habitat, which is considered to be "At Risk".

Summer rearing habitat requires the use of large deep pools and off-channel areas that provide adequate water flow, ample cover, cool water temperatures, optimal feeding opportunities, inter- and intra- species interaction, and opportunities, depending on needs, to hold in slow or fast moving water. The factors that influence summer-rearing habitat are channel form, gradient, small and large in-stream wood, canopy closure, and food input. Riparian vegetation and in-stream wood provide cover and channel complexity during this phase. Pool area and pool quality, large wood, cover in pools, and riparian vegetation are considered to be "Not Properly Functioning" for coho, steelhead, fall and spring chinook, and thus are likely to limit summer rearing opportunities and success.

Winter rearing areas provide stable and non-turbid stream flow during storm events. This habitat also must provide adequate flow, cover, and temperatures that facilitate metabolic conservation. The majority of the confined streams in the Upper Green River and Sunday Creek WAUs have only limited ability to form off-channel and wetland areas due to their confinement by road and railway grades. In the absence of side channels, salmonids typically are forced to over-winter in the substrate and under the protection of wood. Off-channel habitat is in short supply for coho and steelhead, and considered to be "At Risk"; however, this habitat is considered to be "Properly Functioning" for fall and spring chinook (NMFS).

The "At Risk" condition of winter-rearing habitat for coho and steelhead in the upper Green and Sunday Creek WAUs is likely caused by several factors. When LWD abundance is compared to NMFS criteria the large logs that contribute to off-channel habitat formation are in short supply and thus are likely to limit winter rearing. The riparian canopy, which helps to maintain ambient stream temperatures at night, is also in a "Not Properly Functioning" condition (NMFS). Interstitial substrate is adversely affected by overloading the stream with fine sediment, as indicated by the "At Risk" rating for fine sediment (NMFS), which reduces the available winter rearing habitat.

To summarize, winter-rearing habitat is limited for coho and steelhead in the Green and Sunday Creek WAUs. The lack of LWD is likely a limiting factor that contributes to the formation of these habitats. The quality of winter-rearing habitat is also reduced by the inadequate riparian condition, the elevated levels of fine sediment, and the lack of cover in pools.

Cover is an important component for juvenile salmonid migration, as is a normal temperature regime. LWD, which helps to provide cover to protect salmonids from predators, direct sunlight, and high water temperatures, is in short supply for all the species considered in this analysis (NMFS). The riparian vegetation, which provides shade and cover to the stream, is also considered to be lacking (NMFS). The elevated stream temperatures for migration, considered

to be “At Risk”, are an indication that the riparian canopy is insufficient to provide the necessary habitat for this life history.

To summarize, the paucity of LWD necessary for adequate cover, lack of suitable riparian areas to product shade, and the elevated stream temperatures may be factors that limit successful juvenile salmonid migration in the Upper Green and Sunday Creek WAUs.

KEY FINDINGS

- The Watershed Analysis indicates the riparian habitat is insufficient in the near term to meet the needs of habitat forming processes throughout the study area.

DATA GAPS

- Comprehensive barrier surveys need to be completed in this subbasin.

IDENTIFIED LIMITING FACTORS TO NATURAL SALMONID PRODUCTION

- LWD, low gravel sediment levels, canopy cover, the poor riparian habitat zone and pool quantity and quality are all considered limiting factors to natural salmonid production in the study area.

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3.12 INDEPENDENT NEARSHORE TRIBUTARIES IN WRIA 9)

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3.12 INDEPENDENT NEARSHORE TRIBUTARIES IN WRIA 9

INTRODUCTION

The nearshore tributaries of WRIA 9 include 15 independent streams that directly enter Puget Sound (Longfellow Creek was historically an independent tributary but it currently flows into the West Waterway and is discussed as a Green River tributary). The numbering system used in this report is that described by Williams (1975). The first two digits designate the WRIA number, and the remaining numbers identify individual streams. Bordered by Fauntleroy Creek to the north and Joe's Creek to the south, these streams include:

- Joe's Creek (09.0369) (also called Younglove Creek in some of the literature);
- Lakota Creek;
- Cold Creek
- Buenna Creek;
- Salmon Creek;
- Miller Creek;
- Des Moines Creek;
- Fauntleroy Creek;
- McSorley Creek;
- Woodmont Creek;
- Redondo Creek;

Three unnamed creeks north of Three Tree Point (09.0367, 09.0353 and 09.070); and an un-named creek (09.0380) immediately south of Des Moines Creek. All are typical of Puget Sound lowland drainages that receive their flow from springs, seeps, lake outlets, rainfall and ground-water runoff. All of these creeks have experienced the types of habitat degradation associated with industrial development and/or urbanization.

This chapter presents information on Joe's, Lakota, Cold, Buenna, Salmon, Miller, De Moines, and Fauntleroy creeks. Miller and Des Moines creeks are the largest and generally have the largest amount of information. Little or no information is available for McSorley, Woodmont, and Redondo creeks, or for the unnamed creeks.

JOE'S CREEK

PHYSICAL DESCRIPTION

STREAM COURSE AND MORPHOLOGY

The East Fork of Joe's Creek (09.0369) is a seasonal stream fed by surface runoff. A stormwater detention pond on the south side of 340th Street empties into the streambed via a culvert with the stream first surfacing immediately south of SW 338th Street. This fork then flows through

Olympic View Park and the Twin Lakes Golf Course to meet the West Fork Joe's Creek at the stormwater detention pond on SW 320th Street.

The West Fork Joe's Creek is a fed by groundwater and surface runoff that begins at a storm-water detention pond at the Wedgewood Apartments and Golf Course. The streambed then follows Hoyt Road North to the constructed Lakes Lorene and Jeane (also known as Twin Lakes). It flows out of the northeast portion of Lake Jeane, through the Twin Lakes Golf Course and into another holding pond and joins the East Fork.

The mainstem of Joe's Creek currently has its origins from this stormwater detention pond on the south side of SW 340th Street. Joe's Creek then drops into a high-gradient stream channel that falls through a wooded ravine, eventually flattening immediately prior to entering Puget Sound on the east side of Dumas Bay.

SALMONID USE

Historically, salmon were observed as far upstream as the first culvert beneath 320th Street. However, salmon have not been observed this far upstream for at least several decades (Kimpo and Maher 1997).

The known freshwater distribution of anadromous salmonids is depicted in the Fish Distribution Maps located in the Appendix. In Joe's Creek there is the occasional report by local residents of adult salmon observed. However, the species of salmon is unknown.

Several age classes of juvenile cutthroat trout have been observed by Puyallup tribal fisheries biologists ((b) (6) pers. comm.).

Both creeks flow directly into Dumas Bay and provide an important freshwater input into this area of Puget Sound. Dumas Bay has been characterized as a 253-acre intertidal sandflat habitat integral to the nearshore ecosystem in this part of Puget Sound. No data are available detailing juvenile or salmonid usage of this area. However, coastal cutthroat trout have been observed being caught ((b) (6) pers. obser.), and juvenile chinook salmon, chum salmon, and steelhead have been captured in beach seine sets (NRC 1995) in Dumas Bay.

FACTORS OF DECLINE

RIPARIAN CONDITION

The riparian habitat in this stream does not meet any criteria of properly functioning. The lack of adequate riparian habitat is a limiting factor to natural salmonid production.

The riparian communities along Joe's Creek are composed primarily of young trees, shrubs, non-native species, and ornamental plantings. It is almost completely lacking medium or large trees that would provide the shade necessary to support salmonid habitat. Aerial photos show that most of Joe's Creek streambed channel is visible from above, indicating that existing shade levels are less than 25 percent. The target shade percentage deemed necessary to maintain temperatures below 16°C at this elevation ranges from 80 to 90 percent.

Only the riparian habitat in the reach from RM 0.1 to 1.0 is considered suitable to provide good shade at the present time. This area support stands of maturing deciduous and coniferous trees are considered to be in fair condition. Left undisturbed and allowed to mature, they will provide shade for this area of the channel.

Land use activities upstream of this point will preclude achieving good shade conditions along the remainder of Joe's Creek. In particular, the residential development, recreational land use in areas adjacent to the channel upstream of RM 1.0 will continue to prohibit development of mature riparian vegetation capable of providing shade.

Large Woody Debris

No specific information on historic amounts of LWD was located during this investigation. However, based on channel type, it is assumed that laterally-stable, moderate- to high-gradient reaches of the lower mile supported dense stands of conifers (including Douglas-fir, western red cedar, and western hemlock). The trees were removed through logging and development.

There is no systematic survey of present amounts of LWD in Joe's Creek. The lack of tall, mature trees effectively limits the supply of organic matter and terrestrial insects delivered to Joe's Creek. Limited amounts of LWD is present in the lower river mile (Kerwin 2000). If left undisturbed, the trees in these areas will mature and begin to provide functional LWD.

The potential for LWD recruitment throughout the remainder of Joe's Creek subbasin is poor, as land use activities effectively preclude the development of mature riparian stands.

HYDROLOGY

Impervious surfaces associated with single and multi-family residences, commercial activities and roads are the primary contributors to high flows and large sediment loads in the tributaries and mainstem of Joe's Creek. Peak flows are believed to be exceed 150 percent over historical flows (Federal Way 1990). Because the land is largely built out, current peak flows in these creeks are likely to approximate future flows.

SEDIMENT CONDITION

Impervious surfaces associated with single- and multi-family residences are the primary contributors to high flows and large sediment loads in this creek. Because riparian communities along Joe's Creek are composed primarily of young trees, shrubs, non-native species, and ornamental plantings, none of the stream system is considered to have good bank stability.

The presence of dense stands of young coniferous or deciduous trees or shrubs is sufficient to provide good sediment filtration where the riparian zone is at least 150 feet wide. Only in the reach between RM 0.1 to 1.0 are there sufficient amounts and distance to provide good sediment filtration. However, this is the high-gradient ravine where the creek transitions from the headwater to beach. Upstream of this point, roads, development or other contributing activities adjacent to the stream effectively eliminate the ability of riparian area to filter fine sediment.

The substrate within this creek consists of pebbles and cobble-sized particles with localized sand depositions. Gravel deposits are very local and spawning opportunities are typically few. These features are typical of flow alterations caused by unretained or underretained stormwater.

With the conversion of the historic forested uplands into low- and high-density residences, water fluctuation and sedimentation have increased (King County 1991). Siltation (caused by construction activities, increases of impervious surfaces and associated peak flood flows) have resulted in local flooding concerns that further degrade salmonid habitats.

WATER QUALITY

Joe's Creek appears on the 1998 Department of Ecology 303(d) water quality violations list for exceeding fecal coliforms.

High percentages of impervious surfaces in this area indicate that contaminates in surface water runoff likely adversely impact salmonids.

LAND USE

Upstream, the creek is bordered by residential areas with little or no riparian habitat present. Olympic View Park is located immediately downstream of the confluence of the East and West forks. This public park has a thin wooded strip along the creek of approximately 100 feet on either side of the creek. Numerous bicycle and pedestrian trails transect this buffer and impair its ability to function as a riparian habitat. Joe's Creek passes also through low- and high-density residential housing areas, Twin Lakes and Northshore golf courses, and Twin Lakes (two constructed ornamental lakes not identified in Wolcott (1965)).

The lower river mile of this creek passes through a ravine bordered by a 200- to 500-foot-wide corridor of second-growth (up to 28 inches in diameter) red cedar, western hemlock and Douglas fir. This vegetation stabilizes the slopes that are up to 150 feet high with slopes in the range of 60 to 90 percent.

NON-NATIVE SPECIES

Animals

No exotic aquatic animal species were identified in the stream reaches that anadromous salmonids inhabit during the course of this investigation. Warmwater fish species have been reported in some of the lakes in the upper reaches of Joe's Creek and its tributaries.

Plants

Reed canarygrass (*Phalaris arundinacea*) is abundant throughout this subbasin. Other exotic plant communities in the riparian zone consist of Himalayan blackberries and willow species (*Salix spp.*), and numerous ornamental plantings associated with the golf courses and residential communities.

HYDROMODIFICATION

No information was located that showed current vs. historic stream channel. However, given the extensive residential development and the presence of several thousand feet of culvert in this subbasin, there is little doubt that the streambed has been relocated in some reaches.

The mainstem creek and its tributaries are crossed by nine roads in a relatively short distance. In addition, the mainstem Joe's Creek travels for approximately 600 feet through a culvert as it exits a water detention pond at the Twin Lakes Golf Course. The West Fork of Joe's Creek travels through five culverts for a combined distance of approximately 1,350 feet. The East Fork of Joe's Creek travels through two culverts for a combined approximate distance of 1,150 feet.

Off Channal Habitat

No information was located that described site specific-historical riparian conditions along mainstem Joe's Creek. In general, it is likely that vegetation in the Joe's Creek subbasin was similar to that elsewhere in the Puget Sound region. There are numerous small ponds and lakes in the upland areas that form the headwaters of the tributaries. Soils maps suggest there were also numerous wetlands in the upper Soos Creek basin. A mixture of emergent wetlands probably characterized these areas or wet meadows intermixed with forested wetlands and uplands supporting Douglas-fir on the dryer sites. The canyon reach (RM 0.1 to RM 1.0) most likely supported a dense stand of conifers. Riparian vegetation communities would have been similar to that described for the middle Green River in the vicinity of Soos Creek.

LAKOTA CREEK (09.0386)

PHYSICAL DESCRIPTION

SUBBASIN

The Lakota Creek subbasin is located entirely within the City of Federal way. It drains an area of approximately 1,387 acres, and has 24 acres of lakes and 8 acres of wetlands. The subbasin contains a complex system of tributaries; many of which are roadside-associated drainage ditches, stormwater detention ponds, and ornamental ponds.

STREAM COURSE AND MORPHOLOGY

In the eastern portion of the subbasin, all of the tributaries (Northeast Limb, Southeast Limb, Southeast Wetland and Mirror Lake Overflow) drain into Fisher's Pond. Water from this pond flows into the South Central Limb, the Southwest Wetlands and the North Central Limb, which converge at the North Fork Wetlands. These collectively form the North Fork (NF) Lakota Creek which meets the South Fork (SF) Lakota Creek along SW Dash Point Road. Lakota Creek then continues along the road in a northwesterly direction, passing through the Lakehaven Sewage and Wastewater Treatment Plant before entering Puget Sound at Dumas Bay. Lakota Creek provides an important freshwater input into this area of Puget Sound.

SALMONID USE

The known freshwater distribution of anadromous salmonids is depicted in Appendix B, Figures 1-6. Adult salmon have been reported spawning in the lower reaches of Lakota Creek (WDFW Spawning Ground Survey Database, Anthony and Catton 1996). Chum salmon were observed spawning in the 1990s, and an occasional coho adult has been reported. Surveys in 1987 found juvenile coho salmon (as well as cutthroat and steelhead trout and sculpins) (Shapiro and Assoc. 1987). Several age classes of juvenile cutthroat trout have been observed by Puyallup tribal fisheries biologists (Ladley 1999).

No data are available detailing juvenile or salmonid usage of Dumas Bay. However, coastal cutthroat trout have been observed being caught in Dumas Bay (Kerwin 2000). Juvenile chinook salmon, chum salmon, and steelhead were captured in beach seine sets in Dumas Bay during surveys conducted in 1995 (NRC 1995).

FACTORS OF DECLINE

FISH PASSAGE

A culvert under Highway 509 (Dash Point Road) creates a blockage to anadromous fish and eliminates further upstream access.

RIPARIAN CONDITION

Very little intact riparian habitat exits in the subbasin. Narrow strips of young coniferous forests are present in the vicinity of Decatur High School but generally the creek flows through residential areas and alongside roads. The riparian habitat along the lower reaches of Lakota Creek currently consists of small deciduous trees with an understory of shrubs.

Similar to bank stability, shade is considered to be in good condition only where there are dense stands of medium or large sized coniferous or deciduous trees. The Lakota Creek streambed channel was generally visible on aerial photos, indicating that existing shade levels are less than 25 percent. The target shade percentage deemed necessary to maintain temperatures below 16°C at this elevation ranges from 80 to 90 percent. Land use activities throughout the Lakota Creek subbasin will preclude achieving good shade. In particular, the residential development, recreational land use in areas adjacent to the channel upstream of RM 1.0 will continue to prohibit development of mature riparian vegetation capable of providing shade.

Large Woody Debris

No specific information on historic amounts of LWD was located during the investigation for this report. Based on channel type, it is assumed that laterally-stable moderate to high gradient contained reaches of the lower mile supported dense stands of conifer including Douglas-fir, western red cedar, and western hemlock. The riparian communities associated with unconfined low- and moderate-gradient reaches upstream of the crest of the bluff were probably similar stands to those in the ravine.

There were not any systematic surveys of current LWD amounts located as a part of this investigation for this subbasin.

Without exception, the potential for LWD recruitment throughout the Lakota Creek subbasin is poor. Within the lower 1.0 creek mile corridor, if left undisturbed and as the riparian stand matures, it will begin to provide functional LWD within the next 50 – 100 years. LWD recruitment along the remainder of Lakota Creek is expected to remain low, as land use activities effectively preclude the development of mature riparian stands.

HYDROLOGY

Impervious surfaces associated with single and multi-family residences, commercial activities and roads are the primary contributors to high flows and large sediment loads in the tributaries and mainstem of Lakota Creek. Peak flows are believed to exceed 150 percent over historical flows (Federal Way 1990). Because the land is largely built out, current peak flows in these creeks are likely to approximate future flows.

SEDIMENT CONDITION

Because riparian communities along Lakota Creek are composed primarily of young trees, shrubs, non-native species and ornamental plantings none of the stream system is considered to have good bank stability. The substrate within this creek consists of pebbles and cobble-sized particles with localized sand depositions. Gravel deposits are very local and spawning opportunities are typically few. These features are typical of flow alterations caused by unretained or underretained stormwater. A sediment detention basin constructed at the entrance to the Dakota Treatment Plant is emptied after major storms. This is indicative of continuing erosion problems upstream of this point

With the conversion of the historic forested uplands into low and high density residences increases in water fluctuation and sedimentation have occurred (King County 1991). Siltation, caused by construction activities, increases in impervious surfaces and associated peak flood flows have all contributed to local flooding concerns.

WATER QUALITY

Water quality is adversely impacted by the high percentage of impervious surfaces within the subbasin and the presence of domestic trash throughout the stream channel is both an aesthetic and water quality problem.

Lakota Creek appears on the 1998 Department of Ecology 303(d) water quality violations list for exceeding fecal coliforms.

LAND USE

No information was located that described site specific historical riparian conditions along mainstem Lakota Creek or its tributaries. A land survey conducted by the U.S. Geological Survey in

1897 (USGS 1900) indicates that in the lower reaches of Lakota Creek, the timber had been harvested and restocked while the upper reaches appeared to be unharvested and were described as "Merchantable forests." One area around Mirror Lake appeared as a "Burnt area restocking."

With the exception of the lower river mile, all of the area adjoining Lakota Creek is heavily developed.

NON-NATIVE SPECIES

Reed canarygrass, Himalayan blackberries and numerous ornamental plantings are abundant throughout this subbasin. Other exotic plant communities in the riparian zone consist of Himalayan blackberries and willow species, and numerous ornamental plantings associated with the golf courses and residential communities.

HYDROMODIFICATION

Floodplain Modifications

No information was located during the course of this investigation that compared or showed current vs. historic stream channel.

The lower reach of the stream was relocated as a part of an upgrade to the Lakehaven Sewage and Wastewater Treatment Plant in 1987. A bypass (overflow) culvert takes the portion of the creek that is not accommodated in the stream channel and empties directly into Dumas Bay southwest of the Lakota Creek mouth. Given the extensive residential development, the parallel stream course to roads, the presence of numerous road crossings, and stormwater detention ponds there is little doubt that the streambed has been relocated in numerous reaches.

Off Channel Conditions

In general, it is likely that vegetation in the Lakota Creek subbasin was similar to that elsewhere in the Puget Sound region. There are numerous small ponds and lakes in the upland areas that form the headwaters of the tributaries. Soils maps suggest there were also numerous wetlands in the Lakota Creek subbasin. A mixture of emergent wetlands or wet meadows intermixed with forested wetlands and uplands supporting Douglas-fir and western Hemlock on the dryer sites probably characterized these areas. Riparian vegetation communities would have been similar to that described elsewhere in this report for the middle Green River in the vicinity of Soos Creek.

The majority of these wetlands have been drained and filled for development purposes

COLD CREEK (09.0381)

PHYSICAL DESCRIPTION

STREAM COURSE AND MORPHOLOGY

Located entirely within the city limits of Federal Way, Cold Creek is listed by Williams (1975) as an unnamed tributary and designated as stream number 09.0382. The creek originates from Easter Lake and together with its tributary (09.0382) is approximately 1.55 miles in length (8,200 feet) ((b) (6) pers. comm). After leaving Easter Lake the creek follows S 308th Street prior to entering a culvert and resurfaces in the vicinity of South 306th Street where it almost immediately enters a steep ravine prior to entering Puget Sound.

SALMONID USE

The known freshwater distribution of anadromous salmonids is depicted in Appendix B, Figures 1-6. Local residents occasionally report adult coho and chum salmon in the lower reaches, but dates and numbers could not be confirmed during this investigation. The Washington Department of Fish and Wildlife Spawning Ground Survey Database does not have any information showing observations of any salmonid species in this creek.

FACTORS OF DECLINE

RIPARIAN CONDITION

The upstream portion of Cold Creek passes through low- and high-density residential housing areas, and commercial developments and the riparian corridor is severely degraded.

The lower reach of Cold Creek and into the lower end of the ravine has a riparian habitat consisting of second-growth deciduous and coniferous trees, shrubs, non-native species, and ornamental plantings. Areas such as the reach between RM 0.1 and RM 0.33 that support stands of mixed deciduous and coniferous trees are considered to be in fair condition, and will attain good condition if left undisturbed and allowed to mature.

Similar to bank stability, shade is considered to be in good condition only where there are dense stands of medium or large sized coniferous or deciduous trees. The Cold Creek streambed channel was generally visible on aerial photos, indicating that existing shade levels are less than 25 percent. The target shade percentage deemed necessary to maintain temperatures below 16°C at this elevation ranges from 80 to 90 percent. Only the riparian habitat in the reach from RM 0.05 to 0.33 is considered suitable to provide good shade at the present time. Land use activities upstream of this point will preclude achieving good shade conditions along the remainder of Cold Creek. In particular, the residential development, recreational land use in areas adjacent to the channel upstream of RM 0.33 will continue to prohibit development of mature riparian vegetation capable of providing shade.

Large Woody Debris

No data was located that indicated the current condition of riparian zones with respect to organic matter and terrestrial insect recruitment. The lack of tall, mature trees is thought to effectively limit the supply of organic matter and terrestrial insects delivered to Cold Creek.

No specific information on historic amounts of LWD was located during the investigation for this report. Based on channel type, it is assumed that laterally-stable moderate to high gradient contained reaches of the lower mile supported dense stands of conifer including Douglas-fir, western red cedar, and western hemlock. The riparian communities associated with unconfined low and moderate gradient reaches upstream of the crest of the bluff probably similar stands to those in the ravine. In Cold Creek there have not been any systematic surveys of current LWD amounts that could be located as a part of this investigation for this subbasin.

With the exception of the lower 0.33 mile of Cold Creek, the potential for LWD recruitment throughout the subbasin is poor. Within the lower 0.33 mile corridor, if left undisturbed and as the riparian stand matures, it will begin to provide functional LWD. LWD recruitment along the remainder of Cold Creek is expected to remain low, as land use activities effectively preclude the development of mature riparian stands.

HYDROLOGY

Impervious surfaces associated with commercial development, single- and multi-family residences are the primary contributors to high flows and large sediment loads in the tributaries and mainstem of Joe's Creek. Localized flooding around Easter Lake has been the cause of some concern by local residents. Because the land is largely built out, current peak flows in this creek are likely to approximate future flows.

SEDIMENT CONDITION

The presence of dense stands of young coniferous or deciduous trees or shrubs are sufficient to provide good sediment filtration where the riparian zone is at least 150 feet wide. Only in the reach between RM 0.1 to 0.5 (the canyon reach) are there sufficient amounts and distance to provide good sediment filtration. However, this is the high gradient reach of the stream that is in the ravine where the creek transitions from the headwater to beach. Upstream of this point, roads, development or other contributing activities adjacent to the stream effectively eliminate the ability of riparian area to filter fine sediment.

The substrate within this creek consists of pebble and cobble sized particles with localized sand depositions. Gravel deposits are very local and spawning opportunities are typically few. These features are typical of flow alterations caused by unretained or underretained stormwater.

WATER QUALITY

Water quality is adversely impacted by the high percentage of impervious surfaces within the subbasin.

The presence of domestic trash throughout the stream channel is both an aesthetic and water quality problem.

Cold Creek appears on the 1998 Department of Ecology 303(d) water quality violations list for exceeding fecal coliforms.

HYDROMODIFICATION

No information was located during the course of this investigation that showed current vs. historic stream channel. However, given the extensive residential and commercial development present there is little doubt that the streambed has been relocated in some reaches.

There are a minimum of nine storm drains that contribute stormwater runoff to Cold Creek. Four of these enter Easter Lake and five directly enter the creek. The Easter Lake drains convey water from a largely commercial area.

NON-NATIVE SPECIES

Animals

No exotic aquatic animal species were identified in the stream reaches that anadromous salmonids inhabit during the course of this investigation.

Plants

Reed canarygrass (*Phalaris arundinacea*) is abundant throughout this subbasin. Other non-native plant communities in the riparian zone consist of Himalayan blackberries and willow species (*Salix spp.*), and numerous ornamental plantings associated with residential communities and commercial developments.

HYDROMODIFICATION

No information was located that described site-specific historical riparian conditions along mainstem Cold Creek. In general, it is likely that vegetation in the Cold Creek subbasin was similar to that elsewhere in the Puget Sound region. A mixture of emergent wetlands probably characterized the upper reaches and wet meadows intermixed with forested wetlands and uplands supporting Douglas-fir on the dryer sites. The canyon reach (RM 0.05 to RM 0.5) most likely supported a dense stand of conifers. Riparian vegetation communities would have been similar to that described for the middle Green River in the vicinity of Soos Creek.

The majority of these wetlands have been drained and filled for development purposes

BUENNA CREEK (09.0384)

PHYSICAL DESCRIPTION

STREAM COURSE MORPHOLOGY

Buenna Creek (and its unnamed, unnumbered tributary stream) is a seasonal intermittent stream system fed by surface runoff that flows directly into Puget Sound just south of Redondo. The mouth of the creek is perched above the normal high water tide line, effectively limiting access by anadromous fish.

SALMONID USE

There is no known utilization of this creek by salmonids. The known freshwater distribution of anadromous salmonids is depicted in Appendix B, Figures 1-6.

FACTORS OF DECLINE

FISH PASSAGE

No impediments to fish passage were identified from existing databases during the course of this investigation.

RIPARIAN CONDITION

No information was located that described site-specific historical riparian conditions along main-stem Buenna Creek. Jones (2000) described riparian land use as a combination of existing residential and early successional forest with a 15-foot buffer from the stream channel at the development of Redondo Bay. Plant communities included an overstory of deciduous trees with an understory of Himalayan blackberry, salmonberry, vine maple and stinging nettle (Jones 2000). In general, it is likely that vegetation in the Buenna Creek subbasin was similar to that elsewhere in the Puget Sound region. Historic riparian vegetation communities would have been similar to that described for the middle Green River in the vicinity of Soos Creek.

No data was located that indicated the current condition of riparian zones with respect to organic matter and terrestrial insect recruitment. The lack of tall, mature trees is thought to effectively limit the supply of organic matter and terrestrial insects delivered to Buenna Creek. The absence of suitable riparian habitat is an indicator that effective sediment filtration can not occur in this creek.

Section 22-1306 of the Federal Way Code requires a 50-foot setback from the ordinary. The City of Federal Way Code, Section 22-1, divides streams into two definitions. Major streams are defined as supporting under normal circumstances resident or migratory fish. Minor streams is defined as any stream that does not mean the definition of a major stream. Buenna Creek has been determined by the City of Federal Way to be a “minor creek”. It was not clear how the development of Redondo Bay was granted a 15-foot stream buffer.

The Buenna Creek streambed channel was generally visible on aerial photos, indicating that existing shade levels are less than 25 percent. Land use activities will preclude achieving good shade conditions along Buenna Creek.

Large Woody Debris

No specific information on historic amounts of LWD was located during the investigation for this report. Based on channel type, it is assumed that laterally-stable moderate- to high-gradient contained reaches of the lower 0.25 mile once supported dense stands of conifer including Douglas-fir, western red cedar, and western hemlock. The riparian communities associated with unconfined low- and moderate-gradient reaches upstream of the crest of the bluff probably similar stands to those in the ravine. In Buenna Creek there were not any systematic surveys of current LWD amounts located as a part of this investigation for this subbasin.

Without exception, the potential for LWD recruitment throughout the Buenna Creek subbasin is poor and is expected to remain poor, as land use activities effectively preclude the development of mature riparian stands.

HYDROLOGY

No information was located that provided an approximation of historic, current or future flows during the course of this investigation. Because the land is largely built out, current peak flows in these creeks are likely to approximate future flows.

SEDIMENT CONDITION

Impervious surfaces associated with single and multi-family residences, commercial development and roads are the primary contributors to high flows and large sediment loads in these creeks.

Because riparian communities along Buenna Creek are composed primarily of young trees, shrubs, non-native species, and ornamental plantings, none of the stream system is considered to have good bank stability.

The substrate within this creek consists of pebble and cobble sized particles with localized sand depositions. Gravel deposits are very local and spawning opportunities are typically few. These features are typical of flow alterations caused by unretained or underretained stormwater.

WATER QUALITY

Water quality is adversely impacted by the high percentage of impervious surfaces within the subbasin. The presence of domestic trash throughout the stream channel is both an aesthetic and water quality problem.

Buenna Creek does not appear on the 1998 Department of Ecology 303(d) water quality violations list for exceeding any water quality parameters.

LAND USE

Jones (2000) described riparian land use as a combination of existing residential and early successional forest.

NON-NATIVE SPECIES

Animals

No exotic aquatic animal species were identified in the stream reaches that anadromous salmonids inhabit during the course of this investigation.

Plants

Reed canarygrass (*Phalaris arundinacea*) is abundant throughout this subbasin. Other non-native plant communities in the riparian zone consist of Himalayan blackberries and willow species (*Salix spp.*), and numerous ornamental plantings associated with the golf courses and residential communities.

HYDROMODIFICATION

No information was located during the course of this investigation that showed current vs. historic stream channel. However, with the extensive residential development and the presence of several culvert sections of stream channel there is little doubt that the streambed has been relocated in some reaches.

SALMON CREEK (09.0362)

PHYSICAL DESCRIPTION

STREAM COURSE AND MORPHOLOGY

Salmon Creek and its tributaries encompass a 2.3-square-mile drainage basin in western King County. The basin's northern boundary is in the vicinity of Southwest Henderson Street inside the city limits of the City of Seattle. The eastern boundary is in the vicinity of Fourth Avenue SW, the western boundary is immediately east of 21st Avenue SW, and the southern boundary borders the Miller Creek subbasin along approximately 126th Street.

Williams (1975) lists the headwaters as Garrett Lake, locally called Hicks Lake (Wolcott 1967), while Heller et al (1987) determined that the headwaters are located in a wetland just north of Southwest 100th Street. Ames (1981) listed four unnamed tributaries, while Heller et al. (1987) found 13 unnamed tributaries. The stream system empties directly into Puget Sound south of Seola Beach.

SALMONID USE

The known freshwater distribution of anadromous salmonids is depicted in Appendix B, Figures 1-6. While the name of the mainstem creek suggests that anadromous salmonids may have been historically present, there have been no recent observations of any species of anadromous salmonids in this system. The only recorded observations are from a spot spawning ground survey conducted on December 27, 1956. One hundred twenty-eight chum salmon adults were observed in unnamed tributary 09.0365, and 95 chum salmon adults were observed in unnamed tributary 09.0366 (WDFW Spawning Ground Survey Database).

FACTORS OF DECLINE

FISH PASSAGE

Access for anadromous salmonids is blocked by a total barrier at approximately RM 0.3.

RIPARIAN CONDITION

Only limited information was located that described site-specific historical riparian conditions along mainstem Salmon Creek or any of its tributaries.

The riparian habitat in the reach where Salmon Creek drops off the bluff through a ravine is the best of any riparian habitats in this subbasin. Consisting of a deciduous-dominated second-growth forest with some conifers and a shrub understory, the riparian zone in this reach is “Fair” according to the criteria contained in the report Appendix.

Similar to bank stability, shade is considered to be in good condition only where there are dense stands of medium or large sized coniferous or deciduous trees. Where the Salmon Creek subbasin streambed channel was on the surface it was generally visible on aerial photos, indicating that existing shade levels are less than 25 percent. Inside the ravine, the stream channel was more difficult to observe. The riparian habitat appears good but the target shade percentage deemed necessary to maintain temperatures below 16°C at this elevation ranges from 80 to 90 percent. Land use activities throughout this subbasin will preclude achieving good shade conditions. In particular, the residential and commercial development in the areas adjacent to the stream channels will continue to prohibit development of mature riparian vegetation capable of providing shade.

Overall, the riparian habitat in this stream does not meet any criteria of properly functioning. The lack of adequate riparian habitat is a limiting factor to natural salmonid production.

Large Woody Debris

No specific information on historic amounts of LWD was located during the investigation for this report. Based on channel type, it is assumed that laterally-stable moderate- to high-gradient contained reaches of the lower mile supported dense stands of conifer including Douglas-fir, western red cedar, and western hemlock. The riparian communities associated with unconfined

low- and moderate-gradient reaches upstream of the crest of the bluff probably had similar stands to those in the ravine.

No data was located that indicated the current condition of riparian zones with respect to organic matter and terrestrial insect recruitment. The lack of tall, mature trees is thought to effectively limit the supply of organic matter and terrestrial insects delivered to creeks in this subbasin.

Without exception, the potential for LWD recruitment in the low gradient reaches in this subbasin is poor. The stream reach in the ravine has better potential due to better riparian habitat but land use practices throughout the subbasin generally preclude any LWD recruitment.

HYDROLOGY

Local flooding, undersized water conveyance systems associated with the streams in this subbasin, and impervious surfaces associated with single and multi-family residences are the primary contributors to high flows and large sediment loads throughout this subbasin (Heller 1987). Because of local channelization there is little opportunity to buffer peak flows in the lower reaches. Because the land is largely built out, current peak flows in this creek are likely to approximate future flows.

SEDIMENT CONDITION

Impervious surfaces associated with single- and multi-family residences, commercial development, and the road infrastructure are the primary contributors to high flows and large sediment loads. Stream flows directed over the steep slopes in the western portion of this subbasin have caused excessive downcutting and created several ravines.

No quantitative information on substrate composition was found during the course of this investigation. Heller (1987) noted several instances where sedimentation problems associated with landslides resulted in poor water quality.

Because riparian communities in this subbasin are composed primarily of young trees, shrubs, exotic species (i.e.: reed canary grass along roadside ditches) and ornamental plantings none of the stream system is considered to have good bank stability.

WATER QUALITY

Water quality is adversely impacted by the high percentage of impervious surfaces within the subbasin. The presence of domestic trash throughout the stream channel is both an aesthetic and water quality problem.

This creek does not appear on the 1998 Department of Ecology 303(d) water quality violations list for exceeding fecal coliforms.

LAND USE

The land use within this subbasin is primarily single-family residences, followed by multi-family, commercial development, and schools and parks that have large tracts. It is expected that this land use pattern will continue, although there may be some conversion of single-family residences to multi-family residences.

NON-NATIVE SPECIES

Reed canarygrass (*Phalaris arundinacea*) is found in localized areas along the stream throughout this subbasin. Other exotic plant communities in the riparian zone consist of Himalayan blackberries and willow species (*Salix spp.*), and numerous ornamental plantings associated with the private and public facilities.

HYDROMODIFICATION

In general, it is likely that the historic vegetation communities in the Salmon Creek subbasin was similar to that elsewhere in the Puget Sound region. There are numerous small ponds and lakes in the upland areas that form the headwaters of the tributaries. Soils maps suggest there were also numerous wetlands in the upper Salmon Creek subbasin. A mixture of emergent wetlands probably characterized these areas or wet meadows intermixed with forested wetlands and uplands supporting Douglas-fir on the dryer sites. The canyon reach (RM 0.1 to RM 0.8) most likely supported a dense stand of conifers. Riparian vegetation communities would have been similar to that described for the middle Green River in the vicinity of Soos Creek.

No information was located during the course of this investigation that showed current vs. historic stream channel. However, given the extensive residential development and the presence reaches that are within culverts in this subbasin there is little doubt that the streambed has been relocated in some reaches.

Development throughout the Salmon Creek subbasin has had numerous impacts to channel conditions.

Approximately the first 400 feet of the lower reaches of the mainstem creek have been engineered and are channelized and rock lined in an effort to stabilize the streambanks and channel bottom. At several points, the stream is entirely within long stretches of culverts. Upstream of that point, the next approximate 1,500 feet are unmodified.

Heller (1987) noted at least four points where Salmon Creek or one of its tributaries entered pipes. The unnamed tributary 09.0362 from RM 0.0-0.15 has been straightened and channelized. An impassable barrier occurs in that same stream at RM 0.01.

The placement of the stream inside pipes in the central and northern portions of the basin have left no functioning riparian habitat. A sewer line has been placed in the remaining natural system in the lower 1/3 of the subbasin. Numerous single-family residences have been constructed on potential landslide terrain along the incised ravines of the lower one-third of the subbasin.

Localized flooding as a result of stream channel alterations and undersized water conveyance facilities were found to be problems in the subbasin.

Heller (1987) noted several concerns with erosion and landslides. These included tributaries 09.0362C and 09.0363 that had numerous locations where the channels were downcutting and flow associated landslides were present, and drainage from a roof that had apparently caused a landslide, which in turn endangered a private single-family residence.

Heller (1987) also noted the presence and accumulation of trash in the stream channel and ravines of this subbasin.

MILLER CREEK (09.0371)

PHYSICAL DESCRIPTION

STREAM COURSE AND MORPHOLOGY

The Miller Creek subbasin is located in southwest King County, with the eastern boundary formed by SeaTac Airport, the City of Normandy Park to the south, with the plateau edge above Seahurst and the hill line north of Arbor Lake forming the western and northern boundaries respectively. A complex system of at least 15 locally named and unnamed tributaries form the Miller Creek subbasin. The tributaries of the upper basin have their origins on a rolling till plateau with glacial outwash sediment partially filling broad swales from which small lakes, bogs and depressions serve as the origins for these tributaries. Arbor and Tubs (sometimes referred to as Bug Lake) Lakes form the headwaters of two of the tributary streams. The other tributaries are fed by Lake Burien, stormwater runoff, and groundwater seeps.

SALMONID USE

The known freshwater distribution of anadromous salmonids is depicted in Appendix B, Figures 1-6. In Miller Creek, there are annual observations for the last eight years of adult coho spawning, and one report from the 1980s of a single sockeye adult observed (WDFW Spawning Ground Survey Database).

FACTORS OF DECLINE

FISH PASSAGE

An impassable cascade was identified at RM 1.0, an impassable fall at RM 1.9 and 2.5 by Williams (1975). A reconnaissance survey conducted by King County (Heller 1987a) did not identify any impassable barriers. Additionally, the SSHIAP database does not indicate that these barriers exist as of 1999.

RIPARIAN CONDITION

Only limited information was located that described site-specific riparian conditions along mainstem Miller Creek. A functioning riparian habitat along this stream is limited to the stream reaches in the creek where it drops over the top of the bluff down a steep ravine. Even in this area, residential housing encroaches on the stream. Consisting of a deciduous-dominated second-growth forest with some conifers and a shrub understory, the riparian zone in this reach is "Fair" according to the criteria contained in the report Appendix.

The riparian habitat does not meet criteria of properly functioning. The lack of adequate riparian habitat is a limiting factor to natural salmonid production.

Large Woody Debris

No specific information on historic amounts of LWD was located during the investigation for this report. Based on channel type, it is assumed that laterally-stable moderate to high gradient contained reaches of the lower mile supported dense stands of conifer including Douglas-fir, western red cedar, and western hemlock.

The potential for the natural recruitment of LWD throughout the Miller Creek subbasin is poor and land use activities effectively preclude the development of mature riparian stands.

No data was located that indicated the current condition of riparian zones with respect to organic matter and terrestrial insect recruitment. However, the lack of tall, mature trees is thought to effectively limit the supply of organic matter and terrestrial insects delivered to this subbasin.

HYDROLOGY

Impervious surfaces associated with single and multi-family residences are the primary contributors to high flows and large sediment loads in the tributaries and mainstem of Miller Creek.

SEDIMENT CONDITION

Outside of the ravine stream reach, the riparian communities along Miller Creek and its tributaries are composed primarily of young trees, shrubs, exotic species and ornamental plantings and none of the stream system is considered to have good bank stability.

Heller (1987a) noted landslides in the steep ravines of the lower basin as a significant problem that contributed silt and sediment to downstream reaches. Natural soil conditions in the ravine are likely promoting the landslides in this location that is then transported downstream by higher water events.

Heller (1987a) also noted significant sedimentation problems at the outlet to Tubs Lake, which was filled with sediment that reversed flow direction of roadway associated drainage ditches allowing runoff to discharge directly into the lake. He also found erosion problems associated with culverts and concrete-lined stream channel.

Impervious surfaces associated with single- and multi-family residences, commercial development and SeaTac Airport that reach 40 percent and are expected to be 50 percent when the land is fully built-out (Heller 1987a), are believed to be the primary contributors to high flows and large sediment loads in these creeks.

WATER QUALITY

Water quality is adversely impacted by the high percentage of impervious surfaces within the subbasin. The presence of domestic trash throughout the stream channel is both an aesthetic and water quality problem.

Miller Creek does not appear on the 1998 Department of Ecology 303(d) water quality violations list.

NON-NATIVE SPECIES

Animals

No exotic aquatic animal species in the subbasin were identified during the course of this investigation.

Plants

Reed canarygrass (*Phalaris arundinacea*) is found in localized reaches of stream channels throughout this subbasin. Other exotic plant communities in the riparian zone consist of Himalayan blackberries and willow species (*Salix spp.*), and numerous ornamental plantings associated with the residential communities.

HYDROMODIFICATION

No information was located that described site specific historical riparian conditions along the mainstem Miller Creek or any of its tributaries. In general, it is likely that vegetation in the Miller Creek subbasin was similar to that elsewhere in the Puget Sound region. There are numerous wetlands, bogs, small ponds and lakes in the upland areas that form the headwaters of the tributaries. A mixture of emergent wetlands probably characterized these areas or wet meadows intermixed with forested wetlands and uplands supporting Douglas-fir on the dryer sites. Riparian vegetation communities would have been similar to that described for the middle Green River in the vicinity of Soos Creek.

Heller (1987a) was unable to locate any unaltered streams in this subbasin. With the headwaters of all seven main tributaries in pipelines or roadside ditches, and major stream reaches of all the tributaries and mainstem channelized or otherwise modified, these creeks have been altered from their natural state. The lower three miles of the mainstem Miller Creek have been straightened, have a streamside-associated sewer line, and all LWD removed.

As is the case in many urbanized stream setting, the filling of wetlands has reduced natural stormwater storage capabilities of the subbasin and the construction of single family residences

within the 100-year floodplain and associated flood control efforts has altered the stream channel in numerous locations. Because the land is largely built out, current peak flows in these creeks are likely to approximate future flows.

DES MOINES CREEK (09.0377)

PHYSICAL DESCRIPTION

STREAM COURSE AND MORPHOLOGY

Des Moines Creek drains an area of approximately 5.8 square miles of heavily urbanized lands. As is true with most independent tributary streams, Des Moines Creek originates from a diverse series of groundwater seeps on a plateau where it has a fairly low gradient. The creek drops through a steep canyon shortly prior to entering into Puget Sound.

Des Moines Creek has two major tributaries, two smaller tributaries and uncounted small diverse seeps. Inside the subbasin are also Bow Lake and the Northwest Ponds complex. The east fork (09.0377) has its origins from Bow Lake, while the west fork (09.0379) originates from the Northwest Ponds complex along the western edge of the Tyee Golf Course. Both forks merge on the grounds of the Tyee Golf Course. Both forks are fed by a combination of groundwater and surface runoff.

Previous studies (King County 1974 and 1987; METRO 1987 and 1989) conducted by King County have established that this subbasin has been severely degraded by urbanization. The habitat problems and processes identified in these studies include channel and bank erosion, degraded fisheries and flooding.

Stream habitats within Des Moines Creek have been surveyed and inventoried several times in recent years. The results of these studies are reported below.

SALMONID USE

The known freshwater distribution of anadromous salmonids is depicted in Appendix B, Figures 1-6. Juvenile coastal cutthroat trout, coho salmon and steelhead have all been recently observed in Des Moines Creek(King County 1997). Adult coastal cutthroat, coho and pink salmon have also been observed in Des Moines Creek (King County 1997). Juvenile hybrid rainbow/cutthroat trout have also been reported being captured in the creek.

FACTORS OF DECLINE

FISH PASSAGE

There are several known and/or potential fish passage barriers in Des Moines Creek. Table Near-shore-1 gives barrier name, location and type.

At Marine View Drive, there is a 4 x 6 foot box culvert that at almost all flows presents a velocity barrier to adult salmonids. During low flows, the shallow water depth may also pose a barrier. Finally, the gradient within this culvert is steeper at the upper end than the lower, which allows the collection of sediments in the lower end.

Table Nearshore-1. Fish Passage Barriers in the Des Moines Creek Subbasin.

Barrier Name	RM Location	Type/Comments
Marine View Drive Culvert	RM 0.4	Velocity and water depth barrier at most flows
Midway Treatment Plant Log and Concrete Weirs	RM 0.9	Partial barrier depending on stream flows
Tyee Golf Course Weirs	RM 2.1	Complete barrier, three 3- to 4- foot-high weirs

Source: King County 1997.

RIPARIAN CONDITION

A functioning riparian habitat along this stream is virtually nonexistent. The headwaters of all the two major tributaries (East and West forks) and the two minor tributaries originate in heavily urbanized areas.

The East Fork Des Moines Creek originates from Bow Lake and for the first half mile of its existence flows through buried pipes and finally surfaces in the vicinity of 26th Avenue South. The West Fork originates from a regional stormwater detention facility called the Northwest Ponds complex in the vicinity of the Tyee Golf Course. SeaTac airport straddles the boundary between the two forks and contributes flows to both through a complex series of subsurface drainage pipes.

The first functional riparian habitat is encountered downstream of South 200th Street where Des Moines Creek passes through a large wetland with a developed riparian zone before the creek enters a ravine at RM 1.85. At this point, the creek is paralleled by a service road that contains a sewer district trunk line. In many places, the service road functions as the stream bank. Only downstream of the Midway Sewage Treatment plant does the creek again have a stream adjacent riparian zone that provides limited function. In the vicinity of Marine View Drive (RM 0.4) the creek enters a 225-foot-long box culvert before entering Beach Park. Two buildings in this park are built directly over the stream.

No data was located that indicated the current condition of riparian zones with respect to organic matter and terrestrial insect recruitment. However, the lack of tall, mature trees is thought to effectively limit the supply of organic matter and terrestrial insects delivered to this subbasin.

The riparian habitat present consists primarily of young red alder and few coniferous trees. Himalayan blackberry, salmonberry, vine maple and Indian plum are the dominant species that are found along the streambanks.

The riparian habitat does not meet any criteria of properly functioning. The lack of adequate riparian habitat is a limiting factor to natural salmonid production.

Large Woody Debris

A 1993 survey (King County 1997) of LWD amounts identified only an average of seven to ten pieces per 100 yards. Most of the wood was described as small, located along the stream edge, or suspended over the channel. Debris complexes were described as “very limited” (King County 1997). Surveys conducted in 1986 and 1993 indicate that the amount of LWD may be decreasing (King County 1997).

The short- and long-term potential for LWD recruitment throughout the Des Moines Creek subbasin is poor, and land use activities effectively preclude the development of mature riparian stands.

HYDROLOGY

The hydrology problems in the Des Moines Creek subbasin are a classic example of an area that historically was covered with coniferous and deciduous forests and then developed to permit the construction of cities and their associated infrastructure. The understanding of the importance of the need to control stormwater quantity and quality, and the importance of rainfall to base flows, has lagged behind the development and urbanization process in this subbasin.

This subbasin now has an impervious surface area of 35 percent. Impervious surfaces associated with single- and multi-family residences and SeaTac International Airport are the primary contributors to high flows and large sediment loads in these creeks. The existing stormwater retention and detention infrastructure is not sufficient to control the increased frequency and duration of storm event peak runoff flows into Des Moines Creek. These increased flood flows have resulted in channel erosion and the scour of spawning gravels with a resultant loss of spawning areas.

While impervious surface area is expected to increase by almost 58 percent the combined regional detention and water diversion recommendations contained in the Des Moines Creek Basin Plan (King County 1997) for flow control could be designed to reduce flood frequency through the diversion of flood lows associated with frequent but small flood events.

SEDIMENT CONDITION

The degree of damage to hillslopes from past land use activities is significantly less in Des Moines Creek than many of the other Puget Sound independent tributaries in this chapter. This is primarily due to the stream’s geologic origin and history. While most stream systems are formed in advance glacial outwash deposits, Des Moines Creek was formed largely in recessional glacial outwash formations. As a result, erosion (and especially hillslope erosion from increased storm-water flows) has resulted in some loss of the overlying soil layers, but the catastrophic downcutting seen in many other systems is not evident here.

That is not to say that there are not problem areas in Des Moines Creek. Three hillside failures are present just upstream of road fill of Des Moines Memorial Way (between RM 0.45 and 0.55). During the February 1996 storm, debris flows from these bank failures carried substantial amounts of sediments several hundred feet downstream.

There is also evidence of hillslope erosion sites that appear to be the result of road end stormwater discharges. The largest known of these sites is the expansion of the natural channel at RM 1.35 where additional runoff from 18th Avenue South enters the creek. Thirteen bank erosion or slope failure problems were identified during a 1993 habitat survey (King County 1997).

Two conditions that adversely effect stream channel condition: the confinement of the original stream floodplain by fill that surrounds a sewer trunk line and the access road exacerbate channel conditions in this ravine. This creates a situation where storm flows scour stream sediments down to rock and clay deposits that while relatively stable, little or no suitable pools are available that would allow for salmonid rearing. Of the 133 residual pool depths identified during a 1993 stream habitat inventory, the median pool depth was 0.9 feet and the substrate consisted mostly of 15 to 80 mm sands and gravels.

Outside of the ravine, the stream channel conditions can be summarized as composed of low-gradient riffles with a few lateral scour pools and shallow pools. Sediments varies from silt and sands to small gravels, boulders and large areas of exposed clay (the later two found primarily in the incised ravine).

WATER QUALITY

The quality of water in Des Moines Creek is also directly linked to the land use activities in the subbasin. Because of the urbanization throughout the subbasin, the nonpoint source pollution from anthropogenic activities is the primary source of pollutants entering the creek.

Des Moines Creek appears on the EPA 1998 303(d) list for fecal coliform violations. The source of the elevated levels of fecal coliforms may come from failing septic systems, leaking sewer lines, illicit sewer connections, birds (geese) residing on the Tyee Golf Course, domestic animals or some combination of any of the previous examples. The presence of elevated fecal coliform levels is in itself not necessarily detrimental to salmonid production, but may be an indicator of other urbanization-associated problems.

Water quality problems that have been identified in the Des Moines Creek subbasin include the following:

- Previous studies have indicated that the Tyee Golf Course may be contributing excess phosphorus and nitrogen to the creek.
- Turbidity and suspended solids concentrations increase substantially during storm events. Some likely sources include surface runoff, streambank erosion and streambank failure. The increase in concentrations also suggest high levels of gravel scour and deposition of fines.
- Stream water temperatures exceed the optimal upper temperature limit of 14°C for salmonids. They also exceeded the current Washington State standard of 22°C on numerous occasions from April through September 1996. However, they did not reach the lethal limit of 22°C. during that same time period.

- Dissolved oxygen (DO) concentrations are directly linked to stream water temperature (Boyle's Law) and they fell as low as 2 mg/L in the West Fork and typically to 7 mg/L in the East Fork (measured upstream of the Tyee Golf Course weir). While DO levels recovered before the waters reached the salmonid fish zone they are of concern.

It should be noted that both the Port of Seattle (SeaTac Airport) and the City of Des Moines have ongoing water quality monitoring programs in Des Moines Creek or stormwater outfalls into the creek.

LAND USE

The effects of urbanization that have occurred on the natural and historic riparian habitats in Des Moines Creek are as profound as anywhere in the urbanized Puget Sound ecoregion. Approximately 35 percent of the subbasin is currently covered with impervious surfaces (King County 1997). This in turn causes elevated flow levels following storm events, accelerated rates or streambed erosion and sedimentation, aquatic habitat degradation and elevated pollutant levels. Under future conditions, it is estimated that 46 percent of this subbasin will be covered by impervious surfaces.

NON-NATIVE SPECIES

Animals

The only non-native fish species identified in this subbasin are pumpkinseed sunfish. The likely source of these fish is Bow Lake and/or the Tyee Golf Course Ponds. No other non-native aquatic animal species in the subbasin were identified during the course of this investigation.

Plants

Reed canarygrass (*Phalaris arundinacea*) is abundant throughout this subbasin. Other exotic plant communities in the riparian zone consist of Himalayan blackberries and willow species (*Salix spp.*), and numerous ornamental plantings associated with the residential communities.

HYDROMODIFICATION

No information was located during the course of this investigation that showed current vs. historic stream channel. However, given the extensive residential and commercial development and the presence of regional stormwater detention facilities, several thousand of feet of pipes and culverts in this subbasin there is little doubt that the streambed has been relocated in some reaches.

FAUNTLEROY CREEK (09.0361)

PHYSICAL DESCRIPTION

STREAM COURSE AND MORPHOLOGY

With a drainage basin of approximately 98 acres, Fauntleroy Creek is a small independent tributary stream to Puget Sound. It is bounded by Williams and Brace Points and enters Puget Sound in the vicinity of the Vashon-Fauntleroy Ferry Dock. Similar to many of these small independent creeks, Fauntleroy Creek originates from a diverse series of groundwater seeps and bogs on the plateau, most of which are in or adjacent to Fauntleroy Park. With six small low-gradient tributaries, the creek traverses the plateau before it drops through a steep canyon, losing approximately 300 feet in elevation shortly prior to entering into Puget Sound in Fauntleroy Cove.

SALMONID USE

The known freshwater distribution of anadromous salmonids is depicted in Appendix B, Figures 1-6. Juvenile and adult coho salmon have been observed to spawn and rear respectively in Fauntleroy Creek (Seattle, In Progress). No information was obtained that indicates utilization by other salmonid species.

FACTORS OF DECLINE

FISH PASSAGE

There are several known and/or potential fish passage barriers throughout Fauntleroy Creek. A partial barrier exists at the edge of tidewater where the creek flows over a rock revetment that requires anadromous fish to jump at least one foot. A series of 6- to 12-inch anthropogenic weirs in the lower reach may also be partial barriers. At approximately RM 0.2, there is a 14-inch cascade that is a barrier to all anadromous salmonids. Approximately 410 feet upstream of this initial barrier is a 2-foot-high, 3-square box structure with a sheer water drop of six feet that is also a barrier.

RIPARIAN CONDITION

The effects of urbanization that have occurred on the natural and historic riparian habitats in Fauntleroy are profound. A comprehensive inventory of riparian habitats is currently not available. However, the Fauntleroy Watershed Plan (Seattle, In Progress) does provide some preliminary insight into the condition of the riparian zone of Fauntleroy Creek. That work breaks the creek into the following critical stream reaches:

- Tidewater to Initial Fishway;
- Initial Fishway to 45th Ave S.W.;
- 45th Ave. S.W. to Kilbourne Park; and
- Kilbourne Park to Fauntleroy Park.

Each reach is assessed for riparian habitat. Reaches 1 and 3 were determined to NOT have adequate vegetation in the riparian zone. The native vegetation in Reach 2 was assessed as good to excellent. Reach 4 was assessed as a mixture of good to excellent native vegetation in the lower portion, while the upper portion was dominated by non-native and invasive species. The riparian habitat present consists primarily of young-to-maturing red alders and few coniferous trees. In Reach 1, property owners have expressed concern that any vegetation not block their views. Of the native plants found in the shrub canopy zone, salmonberry, vine maple, stink current, hazelnut, oceanspray, twinberry, red huckleberry, osoberry and Indian plum are the dominant species that are found along the streambanks. Numerous non-native species are found throughout the stream reaches (see Non-Native Species, below).

No data was located that indicated the current condition of riparian zones with respect to organic matter and terrestrial insect recruitment. However, Seattle (In Progress) did note pollution-intolerant (Class 1) macroinvertebrates were present in all four reaches. However, while the macroinvertebrates are present, they do not appear to be in sufficient numbers to support populations of salmonid fry (Seattle, In Progress). The lack of tall, mature trees is thought to effectively limit the supply of organic matter and terrestrial insects delivered to this subbasin.

The riparian habitat does not meet any criteria of properly functioning. The lack of adequate riparian habitat is a limiting factor to natural salmonid production.

Large Woody Debris

LWD amounts have not been completely surveyed, but Seattle (In Progress) noted that LWD was “sparse” throughout the stream. The short- and long-term potential for LWD recruitment throughout Fauntleroy Creek is poor, and land use activities effectively preclude the development of mature riparian stands.

HYDROLOGY

Kendra (1989) measured seasonal flows in June and August of 1988 at several locations throughout the stream. Flow was 0.1 cfs downstream of the headwater tributaries and 0.3 to 0.4 cfs at the three downstream sampling sites. Seattle (In Progress) stated that many of the current culverts are significantly undersized for the conveyance of current flood flows.

The hydrology problems in the Fauntleroy Creek are a classic example of an area that was historically covered with coniferous and deciduous forests, then developed to construct city infrastructure, As a result, a significant portion of the land in the subbasin becomes covered with effective impervious surface areas.

SEDIMENT CONDITION

Streambanks in most instances appear stable, with some streambed incision noted in a few reaches. There is also evidence of hillslope erosion sites in the ravine.

Confinement of the original stream floodplain by channelized stream reaches, roads, and road crossings create storm flows that scour stream sediments, causing sedimentation in downstream

reaches and embedded gravels. Many of the pools associated with fishways in the lower reaches routinely fill with sediments and their usefulness as fishways is diminished or lost.

WATER QUALITY

The quality of water in Fauntleroy Creek is also directly linked to the land use activities in the subbasin. Because of the urbanization throughout the subbasin, the nonpoint source pollution from anthropogenic activities is the primary source of pollutants entering the creek. Water quality is adversely impacted by the high percentage of impervious surfaces within the subbasin and the presence of domestic trash throughout the stream channel is both an aesthetic and water quality problem.

Fauntleroy Creek appears on the EPA 1998 303(d) list for fecal coliform violations. The source of the elevated levels of fecal coliforms may come from failing septic systems, leaking sewer lines, illicit sewer connections, birds (geese) residing Fauntleroy Park, domestic animals or some combination of any of the previous examples. METRO (1988) examined fecal contamination in Fauntleroy Creek and found higher levels in summer than those in winter. The presence of elevated fecal coliform levels is in itself not necessarily detrimental to salmonid production, but may be an indicator of other urbanization-associated problems.

Kendra (1989) examined water quality in Fauntleroy Creek and found relatively uniform results from the headwaters to the mouth for temperature, pH, conductivity, dissolved oxygen, phosphorus and total suspended solids. The sample results did not indicate any concerns that may impact salmonids.

LAND USE

Impervious surfaces associated with single- and multi-family residences are the primary contributors to high flows and large sediment loads in these creeks. While no information was located that provided the amount of effective impervious surface area in the basin, based on adjacent subbasins it is expected to exceed 20 percent.

Non-Native Species

Animals

There were no reports of exotic fish species identified in this subbasin during the course of this investigation.

Plants

Reed canarygrass (*Phalaris arundinacea*) is abundant throughout this subbasin. Other exotic plant communities in the riparian zone consist of Himalayan blackberries, English laurel, English ivy, English holly, clematis, polygonum, morning glory, nightshade, and giant hogweed along with numerous ornamental plantings associated with the residential communities.

No information was located during the course of this investigation that showed current vs. historic stream channel. However, given the extensive residential and commercial development along with at least five road crossings, several hundred feet of channelized streambank and several hundred feet of pipes and culverts in this subbasin there is little doubt that the streambed has been relocated in some reaches.

HYDROMODIFICATION

In all four reaches, various distances of Fauntleroy Creek were contained in culverts, channelized though property right-of-ways and along roads.

KEY FINDINGS AND HABITAT-LIMITING FACTORS

- There is currently only very limited utilization by anadromous salmonids in these streams.
- The impervious surface area of many of these subbasins is expected to range from 15 to 58 percent in the near future.
- Current and future development is (and will likely continue) generating increased stream flows, channel instability problems, excessive sediment loadings, instream and riparian habitat degradation.
- Wetlands played an important function in maintaining streamflows in many of these small streams. Many of these wetlands have been partly or completely eliminated, and the remaining wetlands are continuing to be degraded.
- Water quality is adversely impacted by the high percentage of impervious surfaces within these subbasins, and the presence of domestic trash throughout the stream channels is both an aesthetic and water quality problem.
- LWD is absent or deficient throughout these streams. Current land use activities effectively preclude any short- or long-term recruitment of LWD into most of these streams. The only passive source of LWD recruitment potential is generally in the stream reaches that cascade down the bluffline.
- Known and suspected anthropogenic barriers limit access to spawning and rearing habitat.
- Both the quality and quantity of gravels in the streams limit spawning success and, to a lesser degree, juvenile rearing habitat.
- Flood flows due to increased impervious surfaces adversely impact successful salmonid incubation.
- Riparian habitats are degraded and in poor condition.
- Generally, habitat trends are showing strong indications of a downward trend.

DATA GAPS

- Comprehensive barrier surveys in this group of subbasins need to be initiated and/or updated.
- Comprehensive baseline riparian habitat surveys should be initiated.
- Aquatic invertebrate populations should be monitored.
- An inventory of LWD should be initiated.
- The level and impacts to salmonids from contaminated surface water is unknown.

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3.13 VASHON AND MAURY ISLANDS SUBBASIN

PHYSICAL DESCRIPTION

STREAM COURSE AND MORPHOLOGY

The larger of the streams in terms of stream length, flow and drainage basin, on Vashon and Maury Islands (the Island) typically originate from small, diverse series of groundwater seeps in the upland areas of the Island. In these reaches, the streams are generally low gradient and meander across the landscape. These upland areas are usually between 300 to 500 feet above sea level. The larger stream systems (such as Judd and Shinglemill Creeks) flow through an extensive system of long, high-gradient ravines before entering the Puget Sound estuary. The streams that have smaller drainage areas and lower flows may also originate from upland seeps and/or seeps and springs present inside of the steep incised ravines that drop through the bluffline that rings the Island. All of these streams drop through steep (gradients of 10-15 percent) stream channels before they enter the Puget Sound estuary with little or no freshwater to saltwater interface.

For many of the streams on the Island, basic habitat quality data has not been collected. Much of the data and information in this chapter was collected by survey crews from Washington Trout (In Progress) from surveys conducted during the summer of 2000. Most of their data is qualitative and was subject to the best professional judgement of the survey crews involved in the collection. Unless otherwise noted, the information below is attributed to Washington Trout (In Progress).

Williams identified only a few of the Island streams, and Ames (1981) identified 28 streams with 18 tributaries on Vashon Island and 11 tributaries with 4 tributaries on Maury Island. Because many of the creeks were not identified by these sources, a numbering system devised by Washington Trout is utilized here. That system begins at the north end of Vashon Island with the number “1” and assigns individual independent creeks a successively higher number as one moves counter-clockwise around the Island. Where known, WRIA numbers from Williams (1975) and Ames (1981) are included in parentheses in table Vashon-1. Stream numbers and local names, where known, are shown in the table Vashon-1 and on the Fish Distribution Maps located in the Report Appendix.

Table Vashon-1. Vashon-Maury Island Streams, Fish Presence, Barriers and Water Withdrawals.					
Stream Number	**Name**	**Species of Fish Present**	**Barrier Present**	**Water Withdrawals**	**Comments**
1	McCloud Ck.	None	Yes–mouth	Yes - Private	
2	Sylvan Ck.	None	Yes-mouth	Yes- Private	
3	Corbin Beach Ck.	None	No data		
4	Unnamed	None	No data		
5	Unnamed	None	No data		
6	Unnamed	None	No data		
7	Water Wheel Ck.	None, but possibly historic	Yes–bulkhead at mouth & diversion	Yes--Private	Mouth altered by water wheel diversion
8	Unnamed	None	No data		
9	Cedarhurst Landing Ck.	None	No data		
10	McCormick Ck.	Cutthroat – juv.	Yes–Burma Dr	Historic	Old diversion structure may be barrier.
11	Baldwin Ck.	Cutthroat – juv. Coho – juv.	Yes – Cedarhurst Rd.	Yes--Private	
12 (0159) 12 –A 12 – C 12 – D 12 – E	Shinglemill Ck Needle Ck J + Y Creek Pit Bull Ck. Unnamed	Cutthroat–juv. & adult. *O. mykiss* – juv. & adult Coho - adult Coho – juv. & adults Cutthroat – juv. Cutthroat – juv. Cutthroat – juv Cutthroat – juv.	 Yes Yes-constructed Falls Yes – natural falls	Yes – Westside Water District Historic Yes - private Historic	Some mass wasting sites in ravines. Headwater diversion, poss ble origin of mass wasting
13	Unnamed	None	Yes–bulkhead	None identified	
14	Unnamed	None	No data	No data	
15 (0158)	Ober Ck.	Possible cutthroat	Yes – Ober Drive	None identified	Dredged every 10+/- years by homeowners
16 (0157)	Skeeder Ck.	None	Possible - bulkhead	Yes-- multiple private	
17	Cove Ck.	None	None identified	Historic	
18	Unnamed	None	None identified	Nodata	
19	Leo's Ck.	None	Possible – debris barrier at mouth	Yes--Multiple private	
20 (0155)	Robinwood Ck.	Cutthroat juvenile	None identified	None identified	County landfill in basin
21 (0154)	Green Valley Ck.	None	Yes – Dam near mouth	Historic	Old water wheel
22	Unnamed	None	No data	No data	
23 (0153)	Christianson (Jod) Ck.	Cutthroat – juv *O. mykiss* – juv.	Yes – Redding Beach Rd.	Yes – Multiple private systems	
24	Unnamed	None	Possible at mouth. Yes-Redding Rd. culvert	None identified	Hand dug water diversion near mouth
25	Unnamed	None	No data	No data	
26	Unnamed	None	Possible at mouth	None identified	
27	Unnamed	None	Yes-bulkhead	None identified	
28	Unnamed	None	Yes-bulkhead	None identified	
29	Unnamed	None	Yes-bulkhead	None identified	
30 (0152)	Bates Ck.	Cutthroat juvenile	Probable-culverts	None identified	
31	Paradise Cove Ck.	None	No data		
32 (149)	Sealth Ck.	None	Yes-bulkhead	None identified	
33	S 1 Ck.	None	Sand and debris bar at mouth	None identified	

Table Vashon-1. Vashon-Maury Island Streams, Fish Presence, Barriers and Water Withdrawals (contd.).					
34	Spring Beach Ck.	None	Yes–culvert and bu khead at mouth	None identified	
35	S 2 Ck.	None	Sand and debris bar at mouth	None identified	
36	Slaighters Ck.	None	Yes-pipe at Pohl Rd. & ponds.	None identified	Impacted by ponds at mouth.
37 (0147)	Tahlequah Ck.	Cutthroat Juvenile	Yes on tributary "B"	None identified	½ to ¾ - acre pond with standpipe outlet
38	Chen Ck.	None	No data	No data	
39	Lost Lake Ck.	None	No data	No data	
40	Shawnee Ck.	Cutthroat Juvenile	Yes–bulkhead and pipes	None identified	
41 (0139)	Fisher Ck.	Cutthroat juvenile	Possible culvert barrier at 232nd St.	Yes	Burton Water Co. present in upper reaches
42 (0129)	Judd Ck.	Chinook, Coho & chum–adults Cutthroat – juv.	Needs to be surveyed.	Needs to be surveyed	Not surveyed by Washington Trout
43 (0126)	Tsugwalla Ck.	None	Yes – mouth and culvert	None identified	Stream flows thru 3 ponds
44	Raab's Lagoon Ck.	None	Possible at bulkhead	None identified	
45	Mileta Ck.	Cutthroat – juv.	Yes-culvert	None identified	
46	N. Dockton Ck	None	No data	No data	
47	Mid Dockton Ck.	None	No data	No data	
48	S. Dockton Ck.	None	No data	No data	
49	Unnamed	None	No data	No data	
50	Unnamed	None	No data	No data	
51	Unnamed	None	No data	No data	
52	Unnamed	None	No data	No data	
53	Unnamed	None	No data	No data	
54	Unnamed	None	No data	No data	
55	Unnamed	None	No data	No data	
56	Unnamed	None	No data	No data	
57	Maury Island Park Ck.	None	No data	No data	
58	Unnamed	None	No data	No data	
59	Unnamed	None	No data	No data	
60	Unnamed	None	No data	No data	
61	Unnamed	None	No data	No data	
62	Ellis (Tramp Harbor) Ck.	Cutthroat Juvenile	Yes - Culvert & dam	Yes – Municipal District 19	Water diversions into ponds
63	Ellisport (Fuller) Ck.	Cutthroat Juvenile	Partial barrier	None identified	Soil contamination at mouth
64	Beal Ck.	Cutthroat juvenile	Yes – Water Station	Yes – Municipal District 19	
65	Gorsuch Ck.	Cutthroat Juvenile	Yes – several natural and anthropogenic	None identified	Sewage treatment plant
66	Dillworth Ck.	Cutthroat juvenile	Yes -Dillworth Road	None identified	
67	Glen Acres Ck.	None	Yes - bu khead	None identified	
68	Unnamed	No data	No data	No data	
69	Unnamed	No data	No data	No data	
70	Unnamed	No data	No data	No data	
72	Unnamed	No data	No data	No data	
73	Unnamed	No data	No data	No data	
74	Unnamed	No data	No data	No data	

SALMONID USE

The known freshwater distribution of anadromous salmonids for Vashon and Maury Islands is depicted in the Fish Distribution Maps located in the Report Appendix. Known distribution was obtained from the Washington Department of Fish and Wildlife Spawning Ground Survey Database, StreamNet, SASSI, and the year 2000 survey conducted by Washington Trout.

Many of the cutthroat observations are of juveniles. Coastal cutthroat trout are a subspecies of cutthroat trout (*O. clarkii*) and are thought to have four life history forms. Since it is possible for all forms to occur in a stream at once and since it is not possible to distinguish between resident and anadromous forms, we have chosen to use the term coastal cutthroat in this document.

O. mykiss has both resident (rainbow trout) and anadromous (steelhead) life history forms. Juvenile observations of *O. mykiss* face similar challenges to that of coastal cutthroat. Rather than make attempts to distinguish between the two forms we have chosen to use the term *O. mykiss* in this document.

In many cases, the documented observations of salmonids (resident and anadromous) likely underestimates the actual distribution. This is particularly true of coastal cutthroat trout and coho.

A map illustrating the presumed freshwater distribution of salmonids (but not coastal cutthroat) is depicted in the Fish Distribution Maps located in the Report Appendix.

All of these creeks flow directly into Puget Sound and as such are believed to provide an important localized freshwater input into this area of Puget Sound. No data are available detailing the complete utilization by juvenile, sub-adult or adult salmonid usage of these marine areas. However juvenile and adult coho, chinook, and coastal cutthroat trout have been observed at numerous points along the marine shorelines (Kerwin 2000).

FACTORS OF DECLINE

LAND USE

Vashon and Maury Islands have experienced significant and substantial changes since historic times (prior to 1860). Virtually all of the original pre-settlement wetland forests of Sitka spruce and western red cedar, and upland forests of western hemlock and Douglas fir within the subbasin were logged and removed by 1897 (USGS 1900). In many cases, the forests have been logged a second time and then the land cleared.

Currently, land use throughout the Island is typically a mixed rural residential, small scale agriculture and service related commercial development. The development of residential and commercial areas has resulted in the alteration of the natural drainage patterns, but no data was located that provided an indication of total or effective impervious surfaces in any of the Island's stream subbasins.

HYDROLOGY

Hydrology in many of these basins has exhibited changes due to development of upland areas and water withdrawals for domestic and agricultural use by private landowners and water districts. Known flows of selected creeks is shown in table Vashon-2

Table Vashon-2. Stream Flows of Selected Streams on Vashon-Maury Islands.

Stream Name	Flow (cfs) Low	Flow (cfs) High	Base Flow (cfs)
Beall Creek (64)	0.01	4.28	0.3-1.0
Mileta Creek (45)	0	91	0.0-2.0
Fisher Creek (41)	0.6	ND	1.0
Green Valley Creek (21)	0.44	ND	0.44
Paradise Cove Creek[1] (31)	0.12	0.45	[1.]
Tahlequah Creek (37)	0.3	ND	0.5
Judd Creek (42)	2.25	ND	2.0
Upper Judd Creek (42)	1.5	ND	1.5-2.0
Needle (Shinglemill) Creek (12A)	1.4	ND	1.5-2.5

ND = Not Determined. The data obtained exceeded the range of the discharge rating curve.
1. Flows may not be accurate due to data collection limitations. (King County. 1998)

Selected streams in WRIA 15, and specifically on Vashon Island, were closed to water withdrawal by the Washington Department of Ecology in 1988. These streams were closed in as a part of an Instream Resources Protection Program (IRPP) under the authority of Chapter 173-515 WAC. The streams closed are the mainstem reaches of Judd, Fisher and Christianson (Jod) Creeks and Shinglemill Creek and all of its tributaries. No minimum instream flows have been established for streams on the Island.

A survey that compared permitted water withdrawal quantities with actual water withdrawal quantities of the six (Burton Water Company, Dockton Water Association, Heights Water Association, MMC, Water District No. 19 and the Westside Water Association) water purveyors indicated two (Heights Water Association and Water District Number 19) exceeded maximum permitted quantities for instantaneous water withdrawal (Seattle King County Health Department 1995). In that same survey, three (Dockton Water Association, Heights Water Association, and Water District No. 19) of four (Dockton Water Association, Heights Water Association, MMC, and Water District No. 19) water purveyors exceeded the permitted maximum annual water withdrawal quantities.

The exact number of private surface water withdrawals and wells on the Island is not known. A search of 243 water rights, as listed in the WSDOE Water Rights Application Tracking System, showed 178 to be surface water, 56 groundwater and 9 unknown water withdrawals. While there are procedures for private wells to be tagged and entered into the South King County Health Department database, many of the older wells and surface water withdrawals do not appear in that database.

WATER QUALITY

Surface water quality sampling occurred at eight stream stations on Vashon Island on approximately 14 occasions (monthly) between August 1991 and September 1992 as part of the Vashon-Maury Island Groundwater Management Plan (1998) effort. The eight streams and their watershed areas are given in table Vashon-3. Freshwater samples were collected near the staff gauge in the middle of the creek near the mouth. Samples were analyzed for temperature, pH, coliforms (fecal, total), metals, chloride, nitrate-N, and sulfate. In addition, the Judd Creek site was sampled for volatile organic compounds, pesticides, and PCBs in August and September 1991. Results are presented in this section for temperature, pH, metals, and organics for purposes of assessing potential factors of decline for salmonids.

Table Vashon-3. Streams and Drainage Areas for Water Quality Sampling Stations.

Stream (Station Name)	Drainage Area (Acres)
Beall Creek	211
Fisher Creek	1,549
Green Valley Creek	762
Judd Creek	3,149
Mileta Creek	700
Paradise Cove Creek	200
Shinglemill (Needle) Creek	1,996
Tahlequah Creek	780

A summary of the water quality testing results in this survey indicates that most metals were below standards on most occasions. Cadmium, copper and zinc exceeded acute standards on one occasion at between one and four locations. With the exception of lead, the mean values of all metals were below chronic levels at all stations. Elevated lead levels (above the chronic standard) occurred on several occasions at Beall, Fisher and Mileta creeks.

Water was sampled at the Judd Creek site and analyzed for volatile organic compounds, pesticides, and PCBs in August and September 1991. All parameters were below detectable levels on both occasions.

NON-NATIVE SPECIES

There are numerous non-native plant species throughout these subbasins, but none appear to be a fundamental habitat-limiting factor to natural salmonid production at this time.

KEY FINDINGS AND IDENTIFIED HABITAT-LIMITING FACTORS

- Surface water is used for domestic purposes and demand is highest when instream flows are lowest.
- There are numerous anthropogenic barriers to anadromous fish migration on streams within this subbasin.
- Mass wasting and streambed scour may be limiting natural production of salmonids in Shinglemill Creek.

DATA GAPS

- There are no dissolved oxygen, turbidity or total suspended solids data for Island streams. There is no continuous temperature data, so it was not possible to determine maximum water temperatures. Available metals data is only for total metals; therefore, it was not possible to make comparisons with dissolved metal standards. There are no data available for storm conditions.
- There has not been a comprehensive barrier assessment conducted.
- There is not a comprehensive base line habitat survey for all Island streams.
- The loss of stream channel due to channelization has not been quantified.
- Actual, instantaneous water use from subbasin streams is not known.
- A water use and water level monitoring program should be established.
- Minimum instream flows are not identified on Island streams where private and municipal water withdrawals occur.
-

EARLY ACTION RECOMMENDATIONS

- Conduct a detailed assessment of the existing stream habitat conditions for use in evaluating enhancement opportunities and constraints.
- Conduct a comprehensive fish barrier and habitat assessment project to identify access barriers and the quantity and quality of habitat upstream throughout Vashon-Maury Islands.
- Screen all water diversions properly to avoid fish entry.
- Conduct an island wide investigation of (legal and illegal) surface and ground water withdrawal. As a part of this investigation examine the impacts of surface and groundwater withdrawals on stream subbasins and evaluate the effects on salmonids.

INDIVIDUAL FRESHWATER STREAMS

Varying amounts of information and data are available on the different freshwater stream systems of the Island. Information obtained on 38 of them is presented below.

MCCLOUD CREEK (1)

FISH PASSAGE

The creek enters the Puget Sound estuary via a 5-foot-high drop from a boxed wooden pipe that is a barrier. This structure eliminates anadromous fish access.

LAND USE

Land use is a mixture of forest and rural residential.

RIPARIAN CONDITION

Deciduous trees dominate the riparian habitat of this small stream along with grasses and brush such as salmonberry, Himalayan blackberry and thimbleberry. Very few coniferous trees are present. Stream channel complexity is provided by abundant amounts of tree limbs and brush with lessor amounts of logs. Approximately 60 percent of the stream is in a shaded condition.

SEDIMENT CONDITION

The pool-to-riffle ratio is approximately 30:70. Overall, substrate types include gravel (20 percent), sand (60 percent), and mud (20 percent).

HYDROLOGY

No information was located on stream hydrology. There is a private well house on the mainstem.

HYDROMODIFICATION

The obvious hydromodification is the boxed wooden pipe where the creek enters saltwater. A footpath along the left bank locally limits lateral stream migration.

SYLVAN BEACH CREEK (2)

FISH PASSAGE

The creek enters the Puget Sound estuary via a 4-foot high drop through a bulkhead. This drop is a complete barrier and eliminates anadromous fish access.

LAND USE

Land use is a mixture of forest and rural residential.

RIPARIAN CONDITION

Only limited information was available about current riparian conditions of this small creek. Trees were described as sparse, shrubs and grasses as moderate. The percentage of the stream afforded shading is approximately 50 percent. Instream structure of any type was described as sparse and solely from deciduous trees.

SEDIMENT CONDITION

The pool-to-riffle ratio is approximately 20:80. Substrate types include gravel (50 percent) and sand (50 percent).

HYDROLOGY

No information was located on stream hydrology. A private water tank is located over a spring on the mainstem.

WATER WHEEL CREEK (7)

FISH PASSAGE

The creek enters the Puget Sound estuary via a 5-foot high drop from a bulkhead. This bulkhead is a barrier that eliminates anadromous fish access. Further upstream, a 2-foot-high diversion dam funnels the stream flow through a water wheel and this is a probable barrier at some flows.

LAND USE

Land use is a mixture of forest and rural residential.

RIPARIAN CONDITION

In the lower 300 feet, English ivy dominates the stream-associated riparian habitat. Upstream of this point, the stream enters a steep, incised ravine where second-growth deciduous and coniferous trees are present. Instream channel complexity is provided by moderate amounts of logs, rootwads, tree limbs and brush. Approximately 10 percent of the stream is in a shaded condition.

SEDIMENT CONDITION

The pool-to-riffle ratio is approximately 10:90. Substrate types include gravel (50 percent) and sand (50 percent). Some natural erosion is occurring at points approximately 800 feet upstream of the creek mouth where a diverse series of small seeps are eroding unconsolidated soils.

HYDROLOGY

No information was located on stream hydrology. There are two water tanks that sit on springs about 300 feet upstream of the creek mouth.

MCCORMICK CREEK (10)

FISH PASSAGE

A culvert underneath Burma Drive that is perched approximately 2 feet high at its downstream end is believed to be a barrier to upstream fish migration. Approximately 80 feet upstream of Burma Drive there is a water diversion structure that is also believed to be a barrier. Finally, further upstream approximately 220 feet is a 4-foot-high drop from a natural logjam that is also believed to be a barrier to upstream fish migration.

LAND USE

Land use is a mixture of forest and rural residential.

RIPARIAN CONDITION

No quantitative data was available to indicate riparian conditions of this system. Deciduous trees dominate the riparian habitat with moderate numbers of conifers. Stream channel complexity is provided by moderate amounts of structure such as logs, rootwads, limbs and brush. Approximately 60 percent of the stream is in a shaded condition.

SEDIMENT CONDITION

The pool-to-riffle ratio is approximately 40:60. Substrate types include boulder (5 percent), cobble (15 percent), gravel (30 percent), sand (40 percent), and mud (10 percent).

HYDROLOGY

No information was located on stream hydrology. A capped well and water system are located on the mainstem creek. There is an abandoned private potable water supply system on this creek.

BALDWIN CREEK (11)

NOTE: The WDNR hydrolayer currently has this stream mapped as a tributary to Shinglemill Creek. That is incorrect. The creek enters the Puget Sound estuary directly, albeit via the alluvial fan of Shinglemill Creek.

FISH PASSAGE

Coho salmon juveniles and coastal cutthroat trout juveniles have been observed in this creek. A 2-foot-high perched culvert and associated concrete energy dispersion apron at Cedarhurst Drive is believed to be a barrier to upstream salmonid migration.

LAND USE

Land use is a mixture of forest and rural residential.

RIPARIAN CONDITION

The riparian habitat has approximately equal amounts of coniferous and deciduous trees along with an understory of brush such as salmonberry, Himalayan blackberry, salal and stinging nettle. Stream channel complexity is provided by abundant amounts of tree limbs, rootwads, logs and brush. Approximately 80 percent of the stream is in a shaded condition.

SEDIMENT CONDITION

the pool-to-riffle ratio is approximately 40:60. substrate types include cobble (10 percent), gravel (40 percent), sand (40 percent), and mud (10 percent).

HYDROLOGY

No information was located on stream hydrology. There is a private well house on the mainstem.

SHINGLEMILL CREEK AND ITS TRIBUTARIES (12)

FISH PASSAGE

This stream system is the second-largest subbasin on the Island with a drainage area of 1,966 acres and is utilized by chum and coho salmon, along with steelhead and coastal cutthroat trout. No anthropogenic barriers are reported in this stream system. However, Munday (1999) reported that culverts on several tributaries were blockages. However, Washington Trout (In Progress) did not report similar observations.

LAND USE

Land use is a mixture of forest, agriculture and rural residential.

RIPARIAN CONDITION

Riparian habitats vary from older second-growth coniferous and deciduous forests to grasslands where stock grazing occurs and animals have access to the creek. Some logging activity occurs on larger interior parcels that is believed to impact the creek. Of the stream reaches examined by Washington Trout survey crews in 2000, approximately 70 percent were shaded.

SEDIMENT CONDITION

Table Vashon-4 shows substrate types in Shinglemill Creek and selected tributaries

Table Vashon-4. Shinglemill Creek and Selected Stream Substrate Types.

Stream Name	Boulder %	Cobble %	Gravel %	Sand %	Mud %	Bedrock %
Shinglemill Ck.	10	20	30	30	5	5
Needle Ck.	0	20	50	20	5	5
J & Y Creek	0	10	50	30	0	10
Pit Bull Creek	5	10	50	20	10	5
Unnamed trib.	0	20	50	20	5	5

Source: Washington Trout (In Progress).

Table Vashon-5 illustrates approximate overall pool-to-riffle ratios within the Shinglemill Creek subbasin.

Table Vashon-5. Pool-to-Riffle Ratios in Shinglemill Creek Subbasin.

Stream Name	Pool-to-Riffle Ratio
Shinglemill Creek	50:50
Needle Creek	30:70
J & Y Creek	40:60
Pit Bull Creek	30:70
Unnamed trib	30:70

Stream channel bed load and scour was identified as a problem during coho egg incubation periods (Vashon-Maury Island Land Trust 1999). Bed scour of up to 8.75 inches and redeposited sediments of up to 6 inches occurred at some locations in Shinglemill Creek. This data is from only one season sampling effort but is indicative of adverse egg incubation or fry emergent success.

HYDROLOGY

A flow survey was conducted during the 1998/99 winter. Flow discharge rates remained at 5 cfs or less from early August trough mid-November. The highest flows measured were in late November 1998 and January 1999 at 37 cfs and 39 cfs respectively. A more typical seasonal flow during winter months was approximately 10 cfs (Vashon-Maury Island Land Trust 1999).

There are municipal water system wells (Westside Water District) on the mainstem Shinglemill Creek, and historic private water supply systems on Pit Bull Creek and the unnamed tributary.

UNNAMED STREAM (13)

FISH PASSAGE

The creek enters the Puget Sound estuary through a bulkhead that is perched 3 feet above the beach, eliminating access to anadromous salmonids. The creek moves upstream from this point through a culvert approximately 200 feet long underneath two private driveways. Between the two driveways is a perched culvert that is approximately 3-feet high.

LAND USE

Land use within this subbasin is a mixture of forest and rural residential.

RIPARIAN CONDITION

The riparian condition is typically a mix of second-growth deciduous and coniferous forest and rural residential. Coniferous and deciduous trees are sparse in the lower reaches of the stream and abundant in the upper reaches. Instream structure is dominated by brush with logs and rootwads sparse. Approximately 50 percent of the stream exists in a shaded condition.

SEDIMENT CONDITION

Overall,, the substrate condition of this unnamed stream was characterized as 50 percent gravel, 30 percent sand, and 20 percent mud. Pool-to-riffle ratios are reported as 20:80.

HYDROLOGY

No information was located that provided any insight into stream flow of this creek.

HYDROMODIFICATION

The lower reaches of the creek are contained within a culvert, and the stream is channelized along an access road for more than of 300 feet. The creek crosses under Cedarhurst Drive through a county culvert.

OBER CREEK (15)

FISH PASSAGE

Ober Creek enters the Puget Sound estuary via a ditched channel. Potential barriers exist at two culverts that are perched (12 and 18 inches) where the creek crosses underneath of Ober Drive. Salmonids have been observed downstream of the lower perched culvert, but no fish have been sighted upstream

LAND USE

Land use within this subbasin is a mixture of forest and rural residential. The mouth of creek is in the vicinity of single-family residences.

RIPARIAN CONDITION

The riparian condition is mix of second-growth deciduous and coniferous forest along with a brush understory. Instream structure is sparse in all aspects. Approximately 40 percent of the stream exists in a shaded condition.

SEDIMENT CONDITION

Overall, the substrate condition of Ober Creek was characterized as 10 percent cobble, 50 percent gravel, 20 percent sand, and 20 percent mud. Pool-to-riffle ratios are reported as 30:70.

HYDROLOGY

No data was located that indicated changes in stream flows.

HYDROMODIFICATION

Hydromodification occurs primarily in the reach from downstream of Ober Road to the point where the stream enters the Puget Sound estuary. Local residents remove stream sediments at approximately 10-year intervals to prevent flooding and septic system damage. Depending on the type of sediment removed, this could represent an adverse impact to spawning gravel quantity and quality as well as increase upstream and downstream scour of spawning areas.

SKEEDER CREEK (16)

FISH PASSAGE

There is a possible barrier to anadromous or resident salmonids where the creek enters the Puget Sound estuary through a perched bulkhead.

LAND USE

Land use within this subbasin is a mixture of forest and rural residential. The mouth of has numerous single-family residences

RIPARIAN CONDITION

The riparian condition is a mix of second-growth deciduous and coniferous forest with an understory of brush. Numerous second-growth cedars are present in the ravine. Instream structure is provided by abundant amounts of logs, rootwads, limbs and brush. Approximately 80 percent of the stream exists in a shaded condition.

SEDIMENT CONDITION

Overall, the substrate condition of Skeeder Creek was characterized as 10 percent boulder, 20 percent cobble, 30 percent gravel, 20 percent sand, 10 percent mud, and 5 percent bedrock. Clay banks and associated seeps on a small tributary stream located in the steep ravine reach provide fine materials to downstream reaches. Pool-to-riffle ratios are reported as 40:60.

HYDROLOGY

No data was located that indicated changes in stream flows. At least two private water supply systems that withdraw water are operating in this system.

HYDROMODIFICATION

No data was located that indicated hydromodification other than the water supply systems noted immediately above.

Cove Creek (17)

FISH PASSAGE

There are no known barriers to anadromous or resident salmonids on the mainstem Cove Creek. A culvert located at the mouth of the creek is not believed to be a barrier. No salmonids were found during the year 2000 survey.

LAND USE

Land use within this subbasin is a mixture of forest, agriculture and rural residential.

RIPARIAN CONDITION

The riparian condition is typically a mix of second-growth deciduous and coniferous forest, agriculture (pasture), public park (Beulah Park), and rural residential. In the lower stream reach (75 feet) in the vicinity of the power transfer station, most of the riparian habitat has been removed. Upstream of that location the stream enters a second-growth deciduous and coniferous forest with Himalayan blackberries adjacent to the stream. Stream channel complexity is provided by abundant amounts of brush, while only moderate amounts of logs, rootwads and tree limbs are present. Approximately 60 percent of the stream exists in a shaded condition.

SEDIMENT CONDITION

Overall, the substrate condition of Cove Creek was characterized as 10 percent cobble, 65 percent gravel, 10 percent sand, and 10 percent mud. A natural waterfall and associated bedrock chute is causing some localized stream erosion problems in the most downstream. Stream channel gradients as high as 30 percent are noted in the steeper reaches. Pool-to-riffle ratios are reported as 1:1.

HYDROLOGY

No data was located that indicated changes in stream flows.

The water in the mainstem Cove Creek between tributaries A and B had a brownish color during the 2000 surveys. The origin of this color was unknown. A satellite sewage treatment plant is scheduled for construction in this reach to address failing septic systems that may be the origin of the water color here.

HYDROMODIFICATION

Hydromodification occurs at points where the creek crosses private and county roads. Old private water supply systems in the upper reaches of the stream appear to be abandoned.

LEO'S CREEK (19)

FISH PASSAGE

A debris jam at the mouth of Leo's Creek may be a barrier to upstream migration of salmonids. No salmonids were found during surveys conducted in year 2000. Diversion of water by private water supply systems may reduce instream flows and limit natural production of salmonids. On tributary "B," the stream channel crosses a field with an access road. The culvert under this access road has headcut and undermined the culvert creating a 15-foot drop that would be a barrier to fish migration. Anecdotal information by local long-term residents indicates that salmonids were historically present in this stream.

LAND USE

Land use within this subbasin is a mixture of forest, agriculture and rural residential.

RIPARIAN CONDITION

The riparian condition is typically a mix of second-growth deciduous and coniferous forest, pastureland and rural residential. Instream channel complexity is provided my abundant amounts of brush and tree limbs while moderate amounts of logs and rootwads are present. Approximately 80 percent of the stream exists in a shaded condition.

SEDIMENT CONDITION

Overall, the substrate condition of Leo's Creek is characterized as 20 percent cobble, 40 percent gravel, 20 percent sand, and 20 percent mud. A possible source of bedload is associated with the undercut culvert in tributary B. Pool-to-riffle riffle ratios are reported as 30:70.

HYDROLOGY

No data was located that indicated changes in stream flows. A constructed pond forms the headwaters of tributary B, and there are some constructed ponds in the lower reaches of the mainstem creek.

HYDROMODIFICATION

Hydromodification occurs primarily in the reach from Tahlequah Road downstream to the where the stream enters the Puget Sound estuary. Water withdrawal occurs from the private water supply systems near the stream's headwaters.

ROBINWOOD CREEK (20)

FISH PASSAGE

There are no known barriers to anadromous or resident salmonids on the mainstem Robinwood Creek. Coastal cutthroat trout were observed in this creek.

LAND USE

The principal land use within this subbasin is characterized as rural residential.

RIPARIAN CONDITION

The riparian condition is typically a mix of second-growth coniferous and small deciduous trees. Streamside associated cover is provided by second-growth coniferous and deciduous trees and brush. Instream channel complexity is provided by abundant amounts of log, rootwads, limbs and brush. Approximately 80 percent of the stream exists in a shaded condition.

SEDIMENT CONDITION

Overall, the substrate condition of Robinwood Creek was characterized as 10 percent cobble, 50 percent gravel, 20 percent sand, 15 percent mud, and 5 percent bedrock. Pool-to-riffle ratios are reported as 1:1.

HYDROLOGY

No data was located that indicated changes in stream flows. A county landfill exists in this drainage basin, and there are some water quality monitoring wells associated with this landfill. These wells are located uphill from the tributary B headwater springs.

HYDROMODIFICATION

Hydromodification occurs at locations where the stream crosses private and county roads (i.e., Sunset Beach Drive).

GREEN VALLEY CREEK (21)

FISH PASSAGE

Green Valley Creek drains an area of 762 acres on the western side of Vashon Island. Approximately 150 feet upstream from the mouth of the creek is a 3-foot-high diversion dam associated with a small water wheel. There was no plunge pool on the downstream side of the diversion dam and this is believed to be a complete barrier to salmonid migration. No salmonids were observed during the year 2000 survey.

LAND USE

Land use within this subbasin is a mixture of forest, agriculture and rural residential.

RIPARIAN CONDITION

A cultivated garden and ornamental plantings dominate the lower reach of this stream. The landscaped area extends upstream for at least 1000 feet to an area immediately downstream of the first tributary. At this point the creek enters a steeper portion of the ravine and an area of second-growth coniferous and deciduous trees.

Instream structure is provided by moderate amounts of logs, rootwads, tree limbs and brush. Approximately 60 percent of the stream exists in a shaded condition.

SEDIMENT CONDITION

Overall, the substrate condition of Green Valley Creek was characterized as 10 percent cobble, 40 percent gravel, 30 percent sand, 15 percent mud, and 5 percent bedrock. Pool-to-riffle ratios are reported as 30:70.

HYDROLOGY

Stream base and low flow information is shown in table Vashon-2 previously. No data was located that indicated changes in stream flows. There are historic water diversion and private water supply structures in this system. The private water supply systems do not appear to be in use as of the year 2000 survey by Washington Trout (In Progress).

HYDROMODIFICATION

Lateral channel migration is constricted in the vicinity of the small foot bridges found at several locations. The diversion dam and water wheel identified above as a migration barrier are the only other known hydromodifications in this basin.

CHRISTIANSON (JOD) CREEK (23)

Note: Christianson Creek is also referred to as Jod Creek in some literature sources and by local residents.

FISH PASSAGE

Phil Schneider (WDFW) reported the presence of coastal cutthroat trout in this creek in 1995. A culvert perched approximately 3 feet high at Redding Beach Road is believed to be an impassable barrier to salmonids.

LAND USE

Land use within this subbasin is a mixture of forest, agriculture and rural residential. There is a single-family residence at the mouth of the creek.

RIPARIAN CONDITION

The lower stream reaches riparian habitat consists of ornamental plantings and landscaping associated with the residence there. Large boulders have been placed in the stream apparently in an effort to control bank erosion. Upstream of this reach, the riparian condition is typically a mix of second-growth deciduous and coniferous trees and rural residential. Stream channel complexity is provided by abundant amounts of brush and moderate amounts of logs, rootwads and tree limbs. Approximately 70 percent of the stream exists in a shaded condition.

SEDIMENT CONDITION

Overall, the substrate condition of Christianson Creek was characterized as 5 percent boulder, 15 percent cobble, 30 percent gravel, 30 percent sand, 15 percent mud, and 5 percent bedrock. A landslide approximately 600 feet downstream of Redding Beach Road is depositing a moderate amount of sediments into the creek.

There is an active landslide present in the mainstem Christianson Creek near the confluence with tributary "D" that contributes sediments to downstream reaches. This slide appears to be caused by stormwater discharge from a culvert that carries runoff from Redding Beach Road.

Pool-to-riffle ratios are reported as 1:1.

HYDROLOGY

No data was located that indicated changes in stream flows. There are at least two private water collection systems in this subbasin. The Christianson Creek Pond and the two ponds (approximately half an acre each) are constructed ponds and also alter stream flow characteristics.

HYDROMODIFICATION

As noted above there are at least three constructed ponds in this stream system.

UNNAMED STREAM (24)

FISH PASSAGE

No salmonids have been identified in this creek and there is no direct access to saltwater. A culvert at the mouth of the creek is buried and full of sediment. A hand-dug channel diverts the stream into a wetland immediately upstream of the creek mouth, and inflowing surface water exits the wetland subsurface.

There also is a 4-foot perched culvert upstream of the junction of Cross Landing and Redding roads that would be a barrier if fish were present.

LAND USE

Deciduous and coniferous forests dominate land use within this subbasin.

RIPARIAN CONDITION

The riparian condition is typically a mix of second-growth deciduous and coniferous trees. Instream complexity is provided by moderate amounts of logs, tree limbs and brush, while rootwads are sparse. Approximately 90 percent of the stream exists in a shaded condition.

Riprap has been placed into the creek at two locations in an apparent effort to stabilize the streambank along a road.

SEDIMENT CONDITION

Overall, the substrate condition of this unnamed stream (#24) was characterized as 10 percent boulder, 45 percent gravel, 30 percent sand, and 15 percent mud. Pool-to-riffle ratios are reported as 20:80.

HYDROLOGY

No data was located that indicated changes instream flows. As noted above, the creek enters the Puget Sound estuary through porous soils at the mouth after being diverted via a hand-dug channel into a wetland.

HYDROMODIFICATION

Local road crossings and associated culverts effectively limit lateral channel migration in the vicinity of the Cross Landing and Redding roads.

UNNAMED STREAM (26)

FISH PASSAGE

There are no known barriers to anadromous or resident salmonids on the mainstem Unnamed Stream (26). A possible barrier exists at the mouth of the creek where it enters the Puget Sound estuary through a bulkhead. No salmonids were observed in this creek during the year 2000 survey.

LAND USE

Land use within this subbasin is a mixture of forest and rural residential.

RIPARIAN CONDITION

The riparian condition is typically a mix of second-growth deciduous and coniferous forest and rural residential. Approximately 90 percent of the stream exists in a shaded condition.

SEDIMENT CONDITION

Overall,, the substrate condition of unnamed Stream (#26) is characterized as 60 percent gravel and 40 percent sand. Pool-to-riffle ratios are reported as unknown.

HYDROLOGY

No data was located that indicated changes in stream flows. Anecdotal information indicates that this stream occasionally goes subsurface and/or dry during late summer.

HYDROMODIFICATION

There is no known hydromodification in this stream.

UNNAMED TRIBUTARIES (27, 28 AND 29)

These streams are grouped together because of their similar characteristics and geographic location.

FISH PASSAGE

All three streams enter the Puget Sound estuary via restrictive bulkheads along the shoreline. These bulkheads effectively restrict access from saltwater for anadromous salmonids.

LAND USE

Land use within this subbasin is a mixture of forest and rural residential. The mouth of each creek has single-family residences nearby.

RIPARIAN CONDITION

The riparian condition is typically a mix of second-growth deciduous and coniferous forest and rural residential. Approximately 60 percent of the stream exists in a shaded condition.

SEDIMENT CONDITION

Overall, the substrate condition of these streams was characterized as 70 percent gravel and 30 percent. Pool-to-riffle ratios are reported as 10:90.

HYDROLOGY

No data was located that indicated changes in stream flows.

HYDROMODIFICATION

No data was located that indicated any hydromodification in these streams.

BATES CREEK (30) (H2)

FISH PASSAGE

There are three private driveway culverts approximately 100 feet upstream of the mouth of the creek that are probable barriers to anadromous fish migration. Cutthroat fingerlings have been observed downstream of these culverts but none were observed upstream.

LAND USE

Land use within this subbasin is a mixture of forest and rural residential

RIPARIAN CONDITION

The riparian condition is typically a mix of second-growth deciduous and coniferous forest and rural residential. Instream structure and complexity is provided by moderate amounts of brush, logs, rootwads and tree limbs.

SEDIMENT CONDITION

Overall, the substrate condition of Bates Creek was characterized as 60 percent gravel, 25 percent sand, and 15 percent mud. Pool-to-riffle ratios are reported as unknown.

HYDROLOGY

No data was located that indicated changes in stream flows.

HYDROMODIFICATION

No data was located that indicated the presence of hydromodifications in this stream.

SEALTH CREEK (32)

FISH PASSAGE

The mouth of Sealth Creek enters the Puget Sound estuary via a bulkhead and is contained within a culvert to a point approximately 200 feet upstream. The bulkhead and associated culvert are barriers and eliminate any marine access to the upper reaches of Sealth Creek by anadromous salmonids.

LAND USE

Land use within this subbasin is a mixture of forest and rural residential. The mouth of the creek is through Girl Scout camp (Camp Sealth).

RIPARIAN CONDITION

The riparian condition is a mix of second-growth deciduous and coniferous forest and in the lower reaches is criss-crossed with trails. Stream channel complexity is provided by moderate amounts of brush and tree limbs while there are sparse amounts of logs. No rootwads were present during the year 2000 survey. Approximately 90 percent of the stream exists in a shaded condition.

SEDIMENT CONDITION

Overall, the substrate condition of Sealth Creek was characterized as 20 percent gravel, 70 percent sand, and 10 percent mud. Pool-to-riffle ratios are reported as 10:90.

HYDROLOGY

No data was located that indicated changes in stream flows.

HYDROMODIFICATION

Hydromodification occurs primarily in the reach associated with Camp Sealth.

S-1 AND S-2 CREEKS (33 AND 35)

These creeks are north and south respectively of Spring Beach Creek and are grouped together here because of similar characteristics and geographic location.

FISH PASSAGE

A sand bar and debris jam at the mouth of S-1 and S-2 eliminates access from marine waters. No salmonids were observed in either creek.

LAND USE

Land use within these creeks is dominated by deciduous and coniferous forests. A boat in only campsite is associated with the mouth of S-2.

RIPARIAN CONDITION

Both creeks originate in the steep ravines of the eastern Vashon Island shore. The riparian condition is typically a mix of second-growth deciduous and coniferous forest. Alder with invasive ivy dominates the riparian corridor of S-2.

Instream complexity is dominated by tree limbs and brush with logs and rootwads being sparse or absent. Approximately 100 percent of S-1 and 90 percent of S-2 exists in a shaded condition.

SEDIMENT CONDITION

Overall, the substrate type of S-1 was characterized as 25 percent gravel, 50 percent sand and 20 percent mud. Substrate type for S-2 was 10 percent gravel, 70 percent sand, and 20 percent mud.

HYDROLOGY

No data was located that indicated changes in stream flows.

HYDROMODIFICATION

No information was located that showed any hydromodification in either stream.

SPRING BEACH CREEK (34)

FISH PASSAGE

No salmonids were observed in this creek during the 2000 surveys. The creek flows into the Puget Sound estuary through a perched bulkhead and then travels upstream for approximately 60 feet through a culvert under Spring Beach Creek Road. These are both impassable barriers to anadromous salmonids.

LAND USE

Land use within this subbasin is a mixture of forest and rural residential.

RIPARIAN CONDITION

The creek flows through the group of houses sometimes referred to as Spring Beach. Riparian conditions are a mix of second-growth deciduous and coniferous forest along with ornamental plantings. Instream complexity is provided by moderate amounts of tree limbs and brush, while logs and rootwads are sparse. Approximately 70 percent of the stream exists in a shaded condition.

SEDIMENT CONDITION

Overall, the substrate condition of Spring Beach Creek was characterized as 35 percent gravel, 40 percent sand, and 25 percent mud.

HYDROLOGY

Stream base and low flow information is shown in table Vashon-2 previously. No data was located that indicated changes in stream flows.

HYDROMODIFICATION

A community water system tank approximately 400 feet upstream of the creek's mouth removes water from the creek. Hydromodification also occurs in the reach upstream of the culvert for approximately 350 feet where the creek is confined to a ditch. Upstream of the community water tank, the stream reverts back to a more natural state.

SLAIGHTERS CREEK (36)

FISH PASSAGE

No salmonids were observed in this creek during year 2000 surveys. Impassable barriers are present from the mouth upstream through a culvert to a series of small ponds and at a three-way standpipe in the vicinity of Pohl Road.

LAND USE

Land use within this subbasin is primarily residential. The mouth of the creek has numerous single-family residences.

RIPARIAN CONDITION

The riparian condition is in the lower reaches is inside a natural ravine that with brush and smaller deciduous trees. After moving upstream out of the ravine the creek channel traverses through residential landscaped lots. At Pohl Road, a three-way standpipe brings the three streams and two seeps together. The mainstream channel upstream of this point again traverses through residential landscaped lots before entering a small ravine with similar riparian vegetation to the lower ravine. The percentage of stream shaded is approximately 50 percent.

SEDIMENT CONDITION

Overall, the substrate condition of Slaighters Creek is characterized as 75 percent gravel, 15 percent sand, and 10 percent mud. The pool-to-riffle ratio is reported as 10:90.

HYDROLOGY

No data was located that indicated changes in stream flows.

HYDROMODIFICATION

Hydromodification occurs throughout in the reaches in the residential areas of Slaighters Creek and Pohl Road.

TAHLEQUAH CREEK (37)

Tahlequah Creek runs from north to south, has a drainage basin of 780 acres, and empties into the Puget Sound estuary at the southern tip of Vashon Island.

FISH PASSAGE

There are no known barriers to anadromous or resident salmonids on the mainstem Tahlequah Creek. A possible barrier exists on the second left bank tributary (B) where it exits a constructed pond (~3/4 acre) via a stand pipe. Coastal cutthroat were observed in this creek and chum utilization is suspected (Williams 1975).

LAND USE

Land use within this subbasin is a mixture of forest and rural residential. The mouth of has numerous single-family residences

RIPARIAN CONDITION

The riparian condition is typically a mix of second-growth deciduous and coniferous forest and rural residential. Stream channel complexity is provided by abundant amounts of brush, moderate amounts of logs and tree limbs and sparse numbers of root wads. Approximately 90 percent of the stream exists in a shaded condition.

After the mainstem creek emerges from the forest upstream of Tahlequah Road, it passes under the road via a large culvert and into a narrow cement trough where it is channelized past several private residences. After passing though a series of small stair-steps and across a rough cement slab the creek enters the Puget Sound estuary.

SEDIMENT CONDITION

Overall, the substrate condition of Tahlequah Creek was characterized as 60 percent gravel, 35 percent sand, and 5 percent concrete. The percentage of the stream channel in pools is approximately 10 percent.

HYDROLOGY

Stream base and low flow information is shown in table Vashon-2 previously. No data was located that indicated changes in stream flows.

HYDROMODIFICATION

Hydromodification occurs primarily in the reach from Tahlequah Road downstream to the where the stream enters the Puget Sound estuary.

SHAWNEE CREEK (40)

FISH PASSAGE

The mouth of the creek consists of a 4-foot-high perched bulkhead upstream of which the stream is channelized through a flume prior to being channelized though landscaped private property. Upstream of the first residence, the stream is contained in 150 feet of a 30-inch PVC culvert that goes underneath a private residence prior to being daylighted for 10 feet before entering another culvert underneath Vashon Highway SW. Individually each of these are barriers to anadromous salmonids migration.

LAND USE

Land use within this subbasin is a mixture of residential and forest.

RIPARIAN CONDITION

Upstream of the single-family residences at the mouth of the creek and in its lower reaches, the creek enters an area of second-growth mixed deciduous and coniferous trees.

SEDIMENT CONDITION

No data was located that indicated overall sediment conditions for Shawnee Creek. Suitable spawning gravels are present in reaches upstream of the piped and channelized reaches.

HYDROLOGY

No data was located that indicated changes in stream flows.

HYDROMODIFICATION

Extensive piping and channelization of the lower stream reaches has eliminated any natural stream channel migration.

FISHER CREEK (41)

The Fisher Creek subbasin drains an area of approximately 1,549 acres. The headwaters are north of Old Mill Road and it flows south until it empties into Quartermaster Harbor along the west shore near the mouth of the harbor. Cutthroat trout, coho salmon and sculpin can be found in its lower reaches.

FISH PASSAGE

There is a potential barrier at 232nd Street. WDNR has listed the stream upstream of 232nd Street as a Type 3 to the headwater pond approximately ¼ mile upstream of the road crossing. The outlet structure of the headwater pond is a stand-pipe that controls water elevation and is also a possible barrier to upstream migration.

LAND USE

Land use within this subbasin is a mixture of forest, agriculture and rural residential.

RIPARIAN CONDITION

Where Fisher Creek leaves saltwater it traverses through a channelized and landscaped reach and then crosses under Vashon Highway SW through a 30-inch culvert. Upstream of the highway the creek traverses through an abandoned blueberry patch before entering a steep walled ravine. This vegetation in this ravine is a mixed coniferous and deciduous second-growth forest with a shrub understory of salmonberry, skunk cabbage, and sword ferns. Only limited information was available that indicated the riparian habitat after the creek exited the ravine. Livestock rearing

occurs in the upper reaches and the headwater pond is a created structure. Approximately 70 percent of the stream is in shaded reaches.

SEDIMENT CONDITION

Overall,, the substrate is condition is approximately 5 percent boulders, 15 percent cobble, 30 percent gravel, 30 percent sands, 10 percent mud, and 10 percent bedrock. The creek has an approximate pool-to-riffle ratio of 40:60.

HYDROLOGY

The Burton Water Company has facilities located on this creek and withdraws water for domestic use. As is the case with most water withdrawal situations, the greatest need for potable water is during low baseflow periods.

HYDROMODIFICATION

The stream channel has been modified in several places as noted previously in the riparian section above.

JUDD CREEK (42)

Judd Creek was not surveyed by Washington Trout as a part of their year 2000 efforts. It is anticipated that a survey will occur during 2001.

Chum, coho, and chinook salmon (WDFW Spawning Ground Survey Database) along with steelhead trout are known to spawn in this stream system. Coastal cutthroat trout juveniles have also been observed in the lower reaches.

Lack of habitat information is a data gap.

TSUGWALLA CREEK (43)

FISH PASSAGE

There are numerous barriers to anadromous or resident salmonids throughout Tsugwalla Creek. At the mouth of the creek is a constructed 8- to 10-foot-high dam with a 16-foot energy dispersion apron and no plunge pool. This dam has no passage facilities and is an effective barrier to all anadromous salmonids.

No salmonids were observed in any stream reaches of Tsugwalla Creek.

LAND USE

Land use within this subbasin is a mixture of forest and agriculture with a few single family residences.

RIPARIAN CONDITION

Upstream of the dam is a 2- to 3-acre impoundment (Pond 1) that is connected by a 50-foot culvert to a second pond that is approximately 1.5 acres in size. An earthen dam separates Pond 2 from Pond 3 (~1.5 acres). Apparently some of the water in Pond 3 is used for irrigation purposes as a pump was present during a site survey on June 1, 2000. Upstream of Pond 3 was an intermittent stream that flows from seeps in a wetland area covered with skunk cabbage.

SEDIMENT CONDITION

The ponds effectively trap fine sediments and any open stream channels are typically dominated by mud.

HYDROLOGY

Hydrology has been extensively modified by the three ponds and water withdrawal.

HYDROMODIFICATION

The three ponds, piping system, dam, and concrete apron are all extensive hydromodifications that eliminate salmonid production.

RAAB'S LAGOON CREEK (44)

Raab's Lagoon Creek originates from Maury Island and flows southerly into Quartermaster Harbor.

FISH PASSAGE

There are no known barriers to anadromous or resident salmonids on Rabb's Lagoon Creek. There is some type of water control structure at the bulkhead at the downstream end of the creek and the exact purpose of this structure is unknown.

LAND USE

Land use within this subbasin is a predominantly agriculture with some single-family rural residences.

RIPARIAN CONDITION

The riparian condition is typically a mix of second-growth deciduous and coniferous forest and rural residential. A small wetland downstream of Dockton Road is fenced to eliminate livestock intrusion. A braided stream channel traverses through a wetland dominated by skunk cabbage and

bullrush. Approximately 60 percent of the stream exists in a shaded condition primarily with streamside associated shrubs.

SEDIMENT CONDITION

The creek is a low gradient system and is dominated by mud (60 percent) and sand (20 percent) with patches of 1-6 inch gavels (20 percent). The amount of the stream in pools is approximately 30 percent.

HYDROLOGY

No data was located that indicated changes in stream flows.

HYDROMODIFICATION

Local culverts limit stream channel migration. Upstream of the Dockton Road, the stream channel resembles a roadside ditch as it parallels the road before the creek turns northwesterly where it originates from a series of diverse seeps.

MILETA CREEK (45)

FISH PASSAGE

Mileta Creek has a drainage basin of approximately 700 acres and drains from Vashon Island into Quartermaster Harbor. Coastal cutthroat have been observed downstream of the culvert at Dockton Road. The culvert at Dockton Road is a 3-foot square box culvert with a 5-½-foot vertical drop and represents a barrier to anadromous fish migration. No salmonids were observed upstream of this point. A small tributary (A) that originates from the right bank has a constructed pond at approximately RM 0.05 with a culvert control structure that represents a barrier to anadromous salmonids.

LAND USE

Land use within this subbasin is a mixture of forest, agriculture and rural residential.

RIPARIAN CONDITION

The riparian condition is typically a mix of second-growth deciduous and a few coniferous trees along with some single family residences. Stream channel complexity is provided by logs, rootwads, tree limbs, and brush. A Volkswagen Beetle (VW Bug) was also present in the stream channel about 200 feet upstream of the crossing at Dockton Road. Approximately 80 percent of the stream exists in a shaded condition.

SEDIMENT CONDITION

Overall, the substrate types of Mileta Creek were characterized as 10 percent cobble, 40 percent gravel, 30 percent sand, and 20 percent mud. Overall, 40 percent of the stream channel was in pools.

HYDROLOGY

Stream base and low flow information is shown in table Vashon-2 previously. No data was located that indicated changes in stream flows.

HYDROMODIFICATION

The northern tributary is channelized inside a culvert for approximately 300 feet in the reach where it parallels 240th Street. The box culvert at Dockton Road detailed above in the Fish Access section is also a detrimental hydromodification.

ELLIS CREEK (62)

Ellis Creek is also referred to as Tramp Harbor Creek by some local residents and in some literature.

FISH PASSAGE

Coastal cutthroat trout were observed at numerous points in this stream. At least two barriers to anadromous fish exist in this creek. A culvert perched 2-feet high at SW Ellisport Road and the Water District #19 water storage basins at approximately RM 0.15.

LAND USE

land use within this subbasin is a mixture of forest, agriculture and rural residential.

RIPARIAN CONDITION

The riparian condition is a mix of second-growth deciduous and coniferous forest and rural residential. Larger alders and conifers dominate the riparian zone upstream of the Water District 19 property. However, there was no flow in this reach during a site visit on June 7, 2000. Stream channel complexity is provided by moderate amounts of logs, tree limbs and brush. Rootwads were not observed during the year 2000 survey. Approximately 60 percent of the stream exists in a shaded condition.

SEDIMENT CONDITION

Overall, the substrate type of Ellis Creek was characterized as 30 percent gravel, 30 percent sand, and 40 percent mud.

HYDROLOGY

Stream base and low flow information is shown in table Vashon-2 previously. No data was located that indicated changes in stream flows.

HYDROMODIFICATION

Hydromodification occurs primarily in the reach along Southwest Ellisport Road where the stream channel parallels the roadway, at the Water District #19 instream water storage ponds, which are contained behind dikes and at the road crossings.

ELLISPORT CREEK (63)

FISH PASSAGE

Coastal cutthroat trout are the only salmonid to have been observed in this stream. There are no known barriers to anadromous or resident salmonids on the mainstem Ellisport Creek.

LAND USE

Land use within this subbasin is predominantly of forest. An abandoned oil storage site is located inside the floodplain of the lower reaches of the creek.

RIPARIAN CONDITION

In the lower reaches, the riparian condition is typically a mix of second-growth deciduous and a few coniferous trees. Once the creek enters the ravine the presence of coniferous trees increases but the riparian zone is still dominated by alders and maples. Instream structure and complexity is supplied by logs from deciduous trees, tree limbs and brush. Very few coniferous tree logs are present in this stream channel.

In a lower reach of the stream a power line parallels the stream channel. The trees (primarily alder and maple) in a 200-foot reach have been cut eliminating any functioning riparian habitat in this reach.

A small mass wasting site is present in ravine that is contributing sediments to downstream reaches. This site is approximately 30 feet by 50 feet in size.

Approximately 70 percent of the stream exists in a shaded condition.

SEDIMENT CONDITION

Overall, the substrate types of Ellisport Creek are characterized as 10 percent boulder, 20 percent cobble, 30 percent gravel, and 35 percent sand. The percent of stream in pools was approximately 30 percent.

In the lower reaches of the stream there are numerous old bricks and debris that either originated from the abandoned oil transfer site or greenhouses that were historically in this location.

HYDROLOGY

No data was located that indicated changes in stream flows. Water District #19 does own property on this stream and historically operated a water storage reservoir that is now abandoned.

HYDROMODIFICATION

Hydromodification occurs primarily where the creek is confined by county roads and at culvert crossings. Water District #19 no longer operates the water storage reservoir in this system.

BEALL CREEK (64)

FISH PASSAGE

Beall Creek has a drainage basin of 211 acres along the eastern shore of Vashon Island. Juvenile coastal cutthroat have been observed utilizing this stream. Water District #19 has a pump station on this creek and the diversion dam associated with this facility is a complete barrier to upstream salmonid migration.

LAND USE

Land use within this subbasin is a mixture of forest and rural residential.

RIPARIAN CONDITION

The riparian condition is typically a mix of second-growth deciduous and coniferous forest and rural residential. Brush is abundant throughout the stream. Logs and tree limbs are termed moderate and rootwads sparse.

SEDIMENT CONDITION

No information on the condition of sediments in this stream was located.

HYDROLOGY

No data was located that indicated changes in stream flows. The Water District #19 pump station is a consumptive use of water in this stream. Water is diverted out of the stream for potable water use.

HYDROMODIFICATION

A water diversion dam and associated pump station are the dominate hydromodifications in this subbasin.

GORSUCH CREEK (65)

FISH PASSAGE

Gorsuch Creek drains from the eastern shoreline of Vashon Island. There are several potential barriers to anadromous or resident salmonids on the mainstem Gorsuch Creek, but coastal cutthroat have been observed upstream as far as approximately RM 0.4. These barriers include natural features (e.g., boulder and cobble cascades) and anthropogenic barriers (e.g., an old washed out bridge). A culvert at approximately RM 0.5 that is perched is a barrier to anadromous salmonid migration. The last fish observed during year 2000 surveys was located a about 150 feet downstream of this barrier.

LAND USE

Land use within this subbasin is a mixture of forest and rural residential. are Single-family residences and an old apple orchard are present at the mouth of the creek.

RIPARIAN CONDITION

The riparian condition is dominated by larger second-growth deciduous trees with smaller numbers of coniferous trees. Stream channel complexity is provided by abundant amounts of logs and tree limbs, while rootwads are sparse. Approximately 70 percent of the stream exists in a shaded condition.

At the mouth of the creek is an old apple orchard and grass meadow. Grass and low shrubs cover the stream upstream of the tidewater beach. The creek then enters an area of shrubs composed of salmonberry, sword fern and nettles. The creek then enters riparian zones composed of larger big leaf maple and alder trees with some Douglas fir and small cedars.

SEDIMENT CONDITION

Overall, the substrate condition of Gorsuch Creek was characterized as 20 percent boulder, 20 percent cobble, 20 percent gravel, 20 percent sand, and 20 percent bedrock. In the lower reaches where the stream drops through a ravine, the stream gradient can be quite high (15 percent). In this reach, the substrate is composed of boulders, clay and cobbles with pockets of gravels. Rock impediments are located in several reaches of the stream but do not appear to be barriers coastal cutthroat were observed upstream.

HYDROLOGY

No data was located that indicated changes in stream flows. A sewage treatment plant is in operation in the upper reaches of Gorsuch Creek. Survey crews from Washington Trout

(Washington Trout In Progress) noted on their June 6, 2000 survey that the effluent from the sewage treatment plant was almost the entire streamflows at the facility discharge point and that the water was quite discolored. The channel was dry upstream of sewage treatment plant.

HYDROMODIFICATION

Hydromodification occurs primarily in the vicinity of culverts at road crossings and at the sewage treatment plant.

DILLWORTH CREEK (66)

FISH PASSAGE

A natural barrier to anadromous or resident salmonids is present approximately 800 feet upstream from the mouth of Dillworth Creek. This barrier is a small bedrock waterfall that has headcut into a layer of clay with debris jams immediately downstream. A wooden bulkhead at the mouth of the creek does not appear to be a barrier as of this date.
A culvert at approximately RM 0.4, upstream of Dillworth Road is undermined and is a probable barrier. A natural waterfall (~3 feet high) at approximately RM 0.15 may be a barrier at some flows. The last fish observed during year 2000 surveys was located in the vicinity of the culvert that crosses underneath Dillworth Road.

LAND USE

Land use within this subbasin is a mixture of forest, agriculture and rural residential.

RIPARIAN CONDITION

The riparian condition is dominated by deciduous trees with smaller numbers of coniferous trees. Stream channel complexity is provided by abundant amounts of logs, rootwads, tree limbs and brush. Approximately 70 percent of the stream exists in a shaded condition.

SEDIMENT CONDITION

Overall, the substrate condition of Dillworth Creek was characterized as 25 percent boulder, 35 percent cobble, 15 percent gravel, and 25 percent bedrock. In the lower reaches where the stream gradient is fairly low (~4 percent), there are numerous small debris jams with cobble and boulders. The creek travels through a seam of clay at approximately 800 feet upstream from its mouth. This seam of clay forms the barrier mentioned above. Upstream of these falls the stream gradient increases before flattening out as it exits the ravine.

HYDROLOGY

No data was located that indicated changes in stream flows.

HYDROMODIFICATION

Hydromodification occurs primarily in the vicinity of culverts at road crossings and at an unfinished diversion just upstream of Dillworth Road.

GLEN ACRES CREEK

FISH PASSAGE

Glen Acres Creek drains from the northeastern shoreline of Vashon Island. A bulkhead at the mouth of the creek is perched approximately 4 feet above the beach and represents a complete barrier to anadromous fish access. No salmonids were observed during a June 8, 2000 survey.

LAND USE

Land use within this subbasin is a mixture of forest and rural residential.

RIPARIAN CONDITION

The riparian condition is dominated by deciduous trees with smaller numbers of coniferous trees. Stream channel complexity is provided by moderate amounts of logs, rootwads, tree limbs and brush. Approximately 80 percent of the stream exists in a shaded condition.

SEDIMENT CONDITION

Overall, the substrate condition of Glen Acres Creek was characterized as 10 percent cobble, 40 percent gravel, 30 percent sand, and 20 percent mud.

HYDROLOGY

No data was located that indicated changes in stream flows.

HYDROMODIFICATION

Hydromodification occurs at the mouth of the creek where a bulkhead is present.

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PART II: FACTORS OF DECLINE/CONDITIONS

4. Summary of Estuary and Nearshore Conditions

4. SUMMARY OF ESTUARY AND NEARSHORE CONDITIONS

INTRODUCTION

The nearshore environment in the WRIA 9 watershed is extremely complex, productive, and provides important habitat structure and functions for the support of salmonids and other fish and wildlife. While historical urbanization and development practices have altered or destroyed much of this habitat, efforts are underway to develop planning and management strategies to reduce ongoing losses and recover habitat processes and ecosystem functions that are vital to the survival of our nearshore natural living resources. Achieving these goals requires an understanding of these processes, functions, and species life history requirements. Unfortunately, while numerous documents describe salmon life history, habitat requirements, and strategies for assessment, recovery, and management, few even mention estuarine and marine ecosystems and life history requirements, even though anadromous salmonids depend heavily upon the nearshore for early survival and spend most of their lives in the marine environment. This lack of scientific knowledge leaves us few alternatives but to develop a conceptual approach to understanding the nearshore ecosystem and how salmonids depend upon and interact with the system.

A conceptual model builds upon existing knowledge of the physical, chemical, and biological processes that form and maintain habitat. In addition, it may use principles of conservation biology and landscape ecology and account for effects of human-induced activities. Conceptual models show how various processes interact to form nearshore habitat and ecological functions important to salmonids. In the absence of adequate levels of quantifiable data, we can use such a model to help us understand how natural processes interact and how alterations or modifications in these processes may affect multiple or individual species. For example, erosion of coastal bluffs that were built from glacial deposits, and the transport of these sediments along the shoreline, are processes that form and maintain our beaches. Rivers and streams also supply sediments to our beaches. Sediment type and distribution determines species composition and use in certain areas. If sediment sources are cut off, or distribution is interrupted, it could change the plant and animal species composition within an area. Indirectly, these changes could affect salmonids if those species happen to be important for refuge or prey items for salmonids. There are numerous examples of how alterations in ecosystem processes, individually and cumulatively, change habitat characteristics and may affect salmonids directly or indirectly. Yet, we know little about many of these individual processes and even less about the ecosystem as a whole.

This chapter begins with a conceptual model of salmonid use of the nearshore, and discusses what is known about salmonid use of the nearshore and the factors that may adversely affect salmonid habitat. Key findings and data gaps are listed at the end of each section. Much of the information in this chapter is drawn from the draft *Reconnaissance-level Assessment of the State of the Nearshore* report (SONR) (Williams, et al. In Prep.). The draft SONR gathers together existing information about selected nearshore and estuarine habitats and species, providing a summary of what is known about the nearshore ecosystem in WRIAs 8 and 9. Because the SONR is still in draft form, all information in this chapter is considered **preliminary and subject to change**. The final report will refine and expand upon the information offered below, and

list recommendations for addressing data gaps and habitat limiting factors in the nearshore environment. Readers are strongly encouraged to refer to the final document, which is scheduled for publication in January 2001.

GEOGRAPHIC SCOPE

This chapter covers the marine and estuarine nearshore environments of WRIA 9, including Vashon and Maury Islands (Figure NS-1). This area encompasses approximately 83 miles of shoreline, of which 49 are on Vashon and Maury Islands. The northern boundary of the WRIA 9 nearshore is West Point, and the southern boundary is just north of Dumas Bay in the City of Federal Way. The Washington Department of Ecology places Vashon and Maury Islands within WRIA 15. However, discussions are underway with Kitsap County, Lead Entity for WRIA 15, on an agreement to include Vashon and Maury Islands in WRIA 9 for planning purposes. Therefore, nearshore and estuarine environments of Vashon and Maury Islands are included in this chapter. While the geographic scope of this chapter is WRIAs 8 and 9, it is important to note that salmonids from other WRIAs utilize the WRIA 9 nearshore as they migrate.

DEFINITION OF THE NEARSHORE

The nearshore environment is strongly linked to both upland habitats and deeper waters, and is the interface between marine and terrestrial environments. For the purposes of this report, the seaward boundary of the nearshore is the outer limit of the photic zone [approximately -30 meters Mean Lower Low Water (MLLW)] (Figure NS-2), or the depth beyond which there is insufficient sunlight penetration for active photosynthesis. The nearshore environment extends landward to include coastal landforms such as bluffs, the backshore, sand spits and coastal wetlands, as well as the riparian zone on or adjacent to any of these areas. In addition, the nearshore environment includes sub-estuaries such as the tidally influenced portions of river and stream mouths (Figure NS-3). Examples of sub-estuaries in WRIA 9 include the mouths of direct drainages to Puget Sound such as the Duwamish River and Miller and Des Moines Creeks.

SALMONID USE OF THE NEARSHORE ENVIRONMENT

Salmonids, particularly chinook, chum, and the anadromous form of cutthroat trout, depend upon the nearshore environment both as juveniles and as adults. The nearshore environment is also vital to numerous aspects of the food web upon which all anadromous salmonids depend. This section presents a conceptual model of salmonid use of the nearshore environment and then discusses salmonid use in detail.

CONCEPTUAL MODEL

The nearshore environment is complex and can be highly productive. It is constructed and maintained by a wide variety of processes. Figure NS-4 is a conceptual model illustrating how these processes interact to form nearshore habitat structures, which provide essential ecological functions to salmonids. The figure also shows the locations where human activities affect this ecosystem.

The geoclimatic setting provides many of the building blocks for the ecosystem. For example, the geologic history of Puget Sound left massive deposits of sediments. The bathymetry and topography of Puget Sound create the basis for shallow, deep, and steep habitats. A wide variety of physical, chemical, and biological processes work with these building blocks to create habitat structure. Erosion and sediment transport processes carry sediments to beaches, spits, and other coastal landforms. Tides bring nutrients, and expose certain areas and inundate others. Fresh water flows into Puget Sound via rivers, streams, and seeps, all of which create complex patterns of salinity.

These ecological processes create a diversity of habitat types that provides essential ecological functions. Where and when these processes operate without interruption, they create connected habitats. The quantity and quality of habitat also are linked to these processes; where they operate naturally, they generate high quality habitat. These processes also contribute to the foodweb through nutrient cycling, tidal flux, introduction of organic litter and insects, and maintenance of highly productive habitats such as eelgrass. The cumulative result of these processes working in concert is a complex landscape composed of a variety of habitat types and functions.

This system is extremely important to salmonids, particularly juveniles. Cederholm et al. (2000) found that one of the most important concepts in understanding how juvenile salmonids use nearshore habitat is that they do not necessarily use individual habitats. Instead, they utilize a "landscape mosaic" of habitats due to changes in tides, freshwater runoff, and life history requirements. Many factors, such as predator/prey distributions, tides, river flows, and genetic structure, affect how juveniles move through the nearshore. However, the distribution and connectivity of critical landscape features such as brackish rearing and tidal freshwater areas may be just as important in providing opportunities for juveniles to use preferred habitats (Cederholm et al. 2000).

However, in many instances human activities have disrupted the processes that create and maintain this landscape mosaic, as well as the habitats themselves. Shoreline development, particularly bank hardening, blocks the natural erosion processes that create beaches and shallow-water habitats. Diversion of rivers, such as the Cedar and White from the Green, reduces freshwater flows and freshets important for maintaining salinity gradients and complex flood plains. Dredging and channelization of rivers, such as the Green/Duwamish, eliminates estuary complexes and flood plains. Filling of lowlands creates new land for development, but destroys marshes, flats, swamps, and other shallow habitats. Although many of these changes were made historically, habitat loss and disruption of processes continues in the nearshore. As a result, the landscape mosaic upon which salmonids depend has been and continues to be altered, degraded, and in some areas, destroyed.

The remainder of this chapter provides more detail about salmonid use of the nearshore environment, and the factors that adversely affect the nearshore landscape, likely limiting salmonid production.

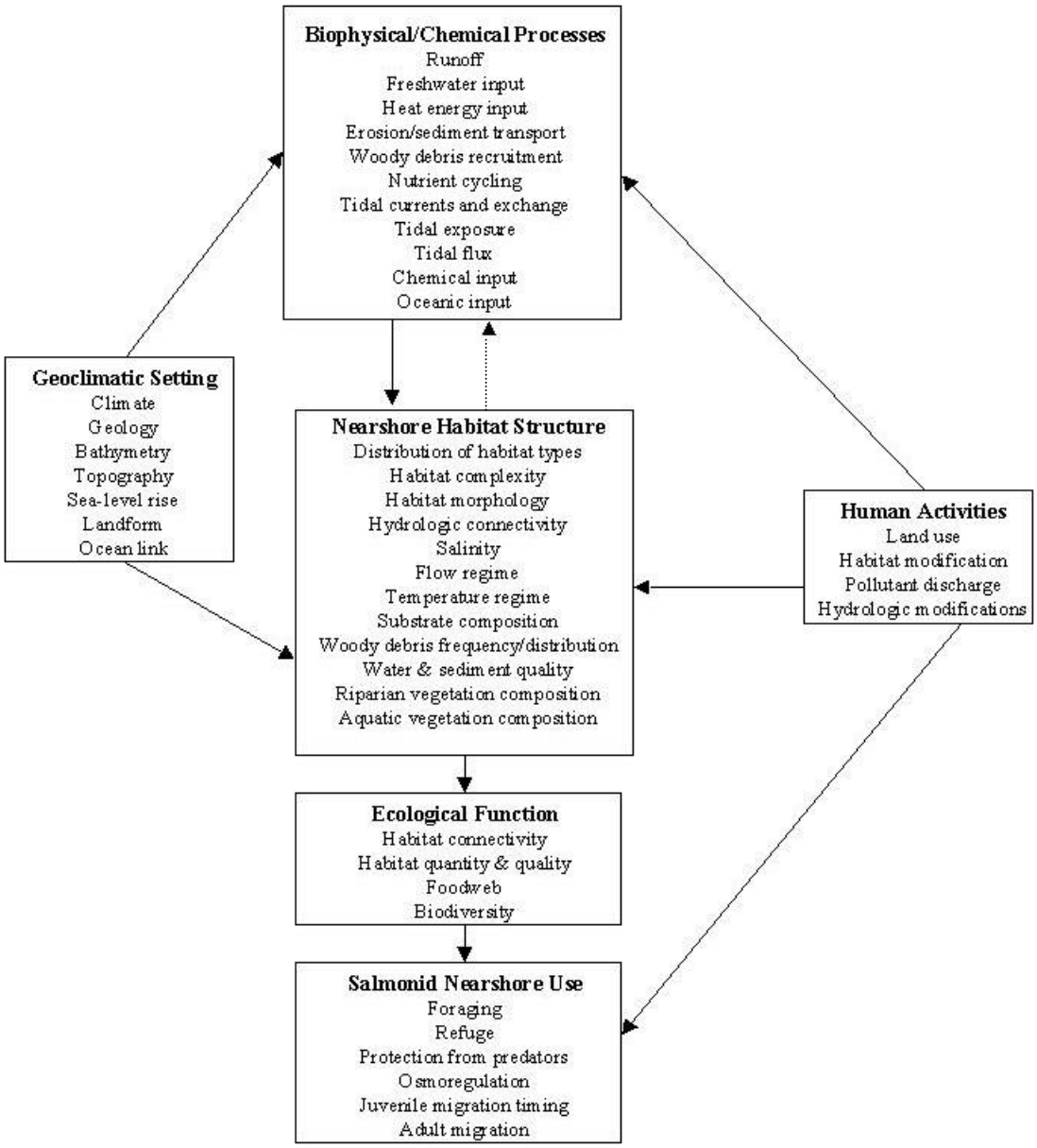

Figure NS-4: Conceptual model of salmonid use of the nearshore environment (after Martin, 1999)

SALMONID USE OF THE NEARSHORE ENVIRONMENT

The landscape mosaic of nearshore habitats provides a number of critical functions for salmonids (Williams and Thom, 2000; Simenstad, 1999; Aitkin, 1998):

- Migratory corridors for both adults and juveniles
- Refuge for both adults and juveniles
- Nursery habitat for juveniles
- Food production and feeding areas for adults and juveniles
- Residence/staging areas for adults
- Physiological transition for adults and juveniles

The following discussion provides an overview of these functions and individual species' use of the nearshore.

NEARSHORE SUPPORT OF JUVENILE SALMONIDS

Studies of juvenile salmonid use of estuaries indicate that early estuarine survival can be a key determinant of adult returns (Simenstad 1999). During this life stage, juvenile salmonids rely on the nearshore for feeding, refuge, and the salinity gradients necessary for the physiological transition from fresh to salt water (Williams and Thom, 2000). Juvenile salmonids depend upon a detritus-based food web for their prey resources. However, the composition of this detritus varies from place to place in the nearshore. Some estuaries depend upon eelgrass more than others, whereas some receive most detritus from rivers, and still others depend more upon phytoplankton and benthic algae (Wissmar and Simenstad, 1998). Studies to determine the relative inputs of detritus have not been conducted in WRIA 9.

Juvenile salmonids depend upon shallow-water habitats, especially in the early stages as they make the physiologically difficult transition from fresh to salt water, avoid predators, and grow rapidly. In particular, tidal marshes and channels, eelgrass beds, and shallow sand and mud flats provide protection from predators and places to rest and forage. As smolts grow larger and begin to move into deeper waters, they rely more heavily on planktonic prey, but some, especially chinook, continue to eat insects that drift out from shore (Simenstad 1999). Juvenile salmonids rely on high quality and diverse habitats as they migrate to the ocean.

NEARSHORE SUPPORT OF ADULT SALMONIDS

Adult salmonids use the nearshore as a place to feed and rest. Returning spawners may remain in the nearshore environment for up to 21 days before entering freshwater streams and rivers. Throughout the adult phase, several types of forage fish, including surf smelt, sand lance and Pacific herring, are primary prey items for some species of salmonids (Williams and Thom, 2000). These forage fish rely on nearshore habitats for meeting a variety of life history requirements, including spawning, refuge, and feeding. Adult salmonids also use nearshore environments to complete their physiological transition from salt to fresh water.

INDIVIDUAL SPECIES' USE OF THE NEARSHORE

Eight species of anadromous salmonids are present in nearshore areas of WRIA 9: chinook, coho, chum, pink, and sockeye salmon, and steelhead, anadromous coastal cutthroat, and native char. Of all salmonid species, juvenile chinook and chum are the most dependent on the near-shore environment (Williams and Thom, 2000; Aitkin, 1998). Juvenile chinook have been documented as staying up to 189 days in sub-estuarine environments such as marshes and river mouths, but there are no published data that define total residence times in coastal nearshore areas. Most juvenile chinook spend only about two weeks in the heavily industrialized Duwamish estuary (Williams et al., In Prep.). Although the peak juvenile out-migration occurs in spring (March-June), juveniles commonly arrive earlier and may be present in the nearshore environment throughout the year if conditions are favorable. For example, recent beach seining studies found juvenile chinook in WRIA 9 nearshore areas through August (pers. comm., (b) (6)) and into November (pers. comm., (b) (6)). Juvenile chum salmon are also highly dependent on nearshore areas for feeding, refuge, and growth for extended periods (Williams and Thom, 2000).

Juvenile pink salmon feed and take refuge in nearshore environments, peaking from March-June, although they may arrive earlier and stay later. Pink salmon juveniles typically move quickly through sub-estuaries and seem to prefer bays and shallow areas, but may be found in estuarine tidal channels for brief periods. Because coho smolts are much larger than other juveniles by the time they reach the nearshore, scientists believe that they prefer deeper habitats than do other anadromous salmonid species. However, they do utilize shallow-water habitats such as eelgrass and flats in the coastal nearshore and tidal channels in sub-estuaries, as seining studies have shown. Several studies also have shown that juvenile coho utilize sub-estuaries, sometimes in high densities (Johnson, 1999). Juvenile sockeye appear to have the shortest residence time in the nearshore of all salmon species, but take refuge and forage in productive habitats there. Coastal cutthroat trout juveniles, subadults, and adults use a variety of nearshore habitats, but congregate near gravel beaches with upland vegetation and shallow nearshore habitats with large woody debris for feeding and migration. Also, since cutthroat rarely spend the winter in marine waters, they utilize tidal freshwater areas of sub-estuaries until conditions are favorable for up-stream migration. Steelhead trout prefer deeper waters and seem to spend very little time in the nearshore. Unfortunately, little is known about native char use of the nearshore environment (Williams and Thom, 2000). However, it is assumed that native char (e.g., bull trout) use the nearshore for feeding and migration. Recent seining efforts have captured native char in the Duwamish River (pers. comm., (b) (6)).

KEY FINDINGS

- Salmonids, especially juveniles, utilize a landscape mosaic, rather than individual habi-tats *per se* in the nearshore. Eight species of anadromous salmonids utilize nearshore habitats in WRIA 9.
- Salmonids produced in other geographic areas also utilize nearshore habitats in WRIA 9.
- A wide variety of physical, chemical, and biological processes create and maintain the diversity and connectivity of nearshore habitats.
- Human activities can interrupt these processes, and alter, degrade, or destroy habitats.

- Early salmonid survival and growth can be an important determinant of adult returns.
- The nearshore environment provides migratory corridors, nursery areas, feeding and prey production areas, refuge, and habitat for the physiological transition from fresh to salt water environments for juveniles of all species of salmonids.
- The nearshore provides migratory corridors, staging and feeding areas, and habitat for the physiological transition from salt to fresh water environments for adult salmonids.
- All anadromous salmonids utilize and depend upon the nearshore. Of the salmonid species, chinook and chum salmon rely most heavily upon the nearshore environment.

DATA GAPS

- Little detailed information is available on the importance of nearshore habitats to the growth and survival of fish. Actual juvenile salmonid use of eelgrass, kelp, flats, tidal marshes, subestuaries, beaches and backshore areas are data gaps.
- There is a general lack of data quantifying the role of nearshore habitats in the development and survival of juvenile salmonids.
- The relative contributions of different sources of detritus to the food web in WRIA 9 are not known.
- There is limited data on the residence time or migration rates and spatial patterns of juvenile salmonids in the nearshore, or on how these times and patterns influence survival.

NEARSHORE AND ESTUARINE HABITAT LIMITING FACTORS

As discussed in the previous section, salmonids rely upon a complex landscape of habitats in the nearshore environment, but human activities have disrupted this landscape. This section provides more information about these activities and details about their effects in WRIA 9. For the purposes of this report, we have grouped these activities into five categories: (1) loss of habitat in the migratory corridor, (2) degradation of water and sediment quality, (3) alteration of processes, (4) loss of riparian functions, and (5) introduction of non-native species. Each of these is discussed below.

LOSS OF HABITAT IN THE MIGRATORY CORRIDOR

Over the past 150 years, substantial amounts of habitats have been altered and/or destroyed in WRIA 9. By far the most striking example of nearshore habitat loss in WRIA 9 occurred in the Duwamish River Estuary and Elliott Bay, beginning as early as 1895. In order to create new land for development and deeper channels for navigation, 97 percent of shallow areas, flats, and marshes in the Duwamish were eliminated by 1986 (Figure NS-5). All (100 percent) of the tidal swamps bordering the Duwamish were filled by 1940 (Williams et al., In Prep.).

Although these habitat losses may be considered historic, habitat loss continues to occur. Lynn (1998) describes several mechanisms for nearshore habitat loss, including the following:

- Shoreline armoring eliminates riparian habitat, leads to beach erosion, interrupts sediment transport, disrupts organisms dependent on those sediments, and displaces and destroys

high intertidal habitat. Vertical bulkheads in lower intertidal zones may slow the migration of juvenile salmonids in migratory corridors (Heiser and Fin, 1970).

- Filling displaces aquatic vegetation, eliminates shallow-water habitats such as marshes and flats, and can cover spawning habitat.
- Dredging kills nearshore organisms during dredging, destroys shallow-water habitats by deepening them, releases toxins into the water column if sediments are contaminated, and removes vegetation that traps sediments.
- In-water structures cast shade, which can kill organisms and seems to prevent juvenile chinook from passing under the structures, interrupting their migration (Williams et al., In Prep.).

Shoreline armoring (i.e., bank hardening) is the placing of structures such as bulkheads, seawalls, and riprap along the shoreline in order to protect upland property from erosion. According to the ShoreZone database recently compiled by the Washington Department of Natural Resources (WDNR), shoreline armoring covers 75% of the shorelines in WRIA 9, and from 50-90% of shorelines in the Duwamish River and Elliott Bay (Williams et al., In Prep.). Therefore, it is reasonable to infer that shoreline armoring has caused a significant amount of nearshore habitat loss and degradation in WRIA 9.

Although the filling of all tidal swamps, and almost all marshes and flats, in the Duwamish River and Elliott Bay are the most dramatic examples of filling in WRIA 9, smaller-scale filling activities continue. Nearshore habitats often are filled to support residential development, especially the installation of shoreline armoring.

Most dredging in WRIA 9 has occurred in the Duwamish River, Elliott Bay, and marinas. Extensive dredging in the Duwamish straightened and widened the channel, eliminated the distributary channels, and created the East and West Waterways. These projects contributed to the near-total loss of flats and marshes in the Duwamish Estuary (Williams et al., In Prep.). Dredging also occurs in marinas and slips in order to maintain navigational safety. In WRIA 9, overwater structures are most prevalent in Elliott Bay and the Duwamish, but residential docks and piers occur along the shorelines of Puget Sound as well (Williams et al., In Prep.).

The combination of these massive, historic habitat losses and the cumulative impacts of smaller, on-going losses has resulted in major changes in the landscape mosaic upon which salmonids depend. However, little is known about the effects of these changes on salmonid use of WRIA 9. Few studies have examined salmonid behavior in developed estuaries versus natural ones, there is no data on possible prey resource limitations in the Duwamish and Elliott Bay, and the effects of shoreline armoring and other development practices on salmonids are poorly understood.

DEGRADATION OF WATER AND SEDIMENT QUALITY

Numerous human activities can lead to degradation of water and sediment quality in the nearshore. Storm water runoff, improperly functioning septic systems, point source discharges, oil spills, agricultural practices, and clearing and grading practices all contribute contaminants to nearshore waters and sediments (Lynn, 1998). Adverse effects of degraded water and sediment quality include smothering of marine plants through excess sedimentation or algal blooms caused

by nutrient enrichment (Lynn 1998), and bioaccumulation in fish, shellfish, and mammals (Williams et al., In Prep.).

Water and sediment quality in Elliott Bay and the Duwamish have been degraded severely. Studies have shown that several organic compounds (such as PCBs and PAHs) and metals (such as mercury, cadmium, and zinc) are present in the sediments of some areas of Elliott Bay and the Duwamish at levels that exceed state standards. The most highly contaminated areas are within the East and West Waterways of the Duwamish and west of Harbor Island, and are Superfund sites.

Although there is much less information about water and sediment quality in the nearshore environment of WRIA 9 outside of Elliott Bay and the Duwamish River, the data that exist indicate that water and sediment quality are acceptable. Subtidal water samples indicate that water quality is generally good (http://dnr.metrokc.gov/wlr/waterres/marine/index95.htm) outside of Elliott Bay and the Duwamish. King County monitors sediment quality at Alki Point and Seahurst Park, and has found that the levels of various contaminants in the sediments are well below those thought to be harmful to benthic organisms (Williams et al., In Prep.).

Adverse effects of degraded water and sediment quality include smothering of marine plants through excess sedimentation or algal blooms caused by nutrient enrichment (Lynn 1998), and death of organisms through poisoning or smothering. These processes damage the landscape mosaic upon which salmonids depend, and can decrease their prey resources. Degraded water and sediment quality also can affect juvenile salmonids directly. Several studies have noted that these chemicals bioaccumulate in fish, shellfish, and mammals collected in the Duwamish River estuary, and have found indications of genetic damage in juvenile salmonids (Williams et al., In Prep.). However, not enough is known about the sublethal effects of these contaminants on salmonids or other species.

ALTERATION OF PROCESSES

As the Conceptual Model (Fig. NS-4) shows, many processes create and maintain habitat in Puget Sound, and are fundamental to the maintenance of the habitat mosiac upon which salmonids depend. Human activities have altered or interrupted many of these, but perhaps the most significant changes in WRIA 9 have been interruption of sediment transport and alteration of freshwater input.

INTERRUPTION OF SEDIMENT TRANSPORT

In Puget Sound, nearshore sediments come primarily from slumping of banks and bluffs, while the remainder comes from rivers and streams. The transport of sediments from the landslides and streams is critical to the maintenance of beaches, spits, flats, eelgrass beds, and other nearshore habitats. Waves and currents provide the bulk of this transport, which is organized into units called drift cells. Drift cells are zones along the coast that act as closed or nearly closed systems with respect to transport of sediments (Johannessen, 1992), and generally begin with an area in which sediment is deposited or eroded, such as bluffs (often called feeder bluffs). Waves and currents then carry this sediment to an area of deposition, such as a beach, headland, or spit. Although daily and seasonal changes in tides and currents can change the direction of drift, over

the long term each drift cell has a direction of net sediment transport (Johannessen, 1992). Figure NS-6 shows the drift cells in WRIA 9.

In WRIA 9, shoreline armoring and other shoreline development have interrupted the natural movement of sediment. Shoreline armoring traps sediment behind and beneath it, preventing waves and currents from picking it up. Armoring also reflects wave energy more strongly than a natural beach does, causing waves and currents to scour beaches and flats in front of seawalls and other structures, further upsetting the natural balance of sediments. Because shoreline armoring prevents nourishment of beaches while erosion continues to occur, beaches in front of shoreline armoring structures may narrow or disappear entirely (Williams and Thom, 2000).

Other shoreline development can alter sediment transport processes as well. Roads, homes, marinas, and other structures built along the shoreline can deprive the nearshore of sediments. Where structures jut into the water, they can inhibit, and in some instances block, the movement of sediment past them.

The ShoreZone mapping program conducted by the Washington Department of Natural Resources indicates that approximately 75% of the 83 miles of WRIA 9 shoreline is armored. Surveys conducted for the Port of Seattle indicate that nearly 100 percent of the shorelines of the Duwamish River Estuary is modified by dikes, levees, or revetments. From river mile (RM) 12 to the Turning Basin, 56 percent of the shoreline had visible riprap armoring and 3 percent had vertical bulkheads in some portion of the intertidal zone. From the Turning Basin to the mouth of the Duwamish, 65.8 percent of the shoreline is riprapped and 5.3 percent has near-vertical bulkheads. Nearly 90 percent of Elliott Bay is riprapped or armored with rubble, and 16.2 percent has vertical bulkheads or seawalls. Along much of the shoreline, bulkheads or seawalls occur in the upper intertidal zone with riprap or rubble in the lower zone (Williams et al., In Prep.). It is reasonable to infer these extensive modifications of the WRIA 9 shoreline alter natural sediment transport processes.

Sediment transport processes are critical to the formation and maintenance of many nearshore habitats that make up the landscape mosaic. In turn, many nearshore plant and animal species rely on particular sediment sizes for spawning, attachment, burrowing, or root development. For example, forage fish, especially surf smelt and sand lance, require certain sediment grain sizes for their spawning grounds (Williams et al., In Prep.). Forage fish are a key prey item for some species of adult salmonids, particularly chinook and coho. Figure NS-7 shows the known distribution of forage fish spawning beaches in WRIA 9, based upon data from the Washington Department of Fish and Wildlife[1]. Significant changes in sediment size caused by the interruption of sediment transport processes could deprive these important fish of their spawning habitat (Williams and Thom, 2000). Increased erosion also can deprive juvenile salmonids of the shallow habitats they require for protection from predators (Williams and Thom, 2000).

Although shoreline armoring and other development have interrupted sediment transport processes around the Sound, few quantitative studies of the effects of shoreline development on

[1] These data are likely incomplete because surveys have not been conducted on all beaches, or in multiple years. The figure also does not show surveyed beaches where forage fish spawn was not recovered.

sediment transport have been done. In turn, few quantitative studies of the effects of interrupted sediment transport on biological communities exist.

ALTERATION OF FRESHWATER INPUT

Freshwater is very important to nearshore habitats. In particular, in estuaries such as the Duwamish, freshwater is necessary to create the gradations in salinity that influence habitats and species. Floods create complex habitats in natural flood plains. Streams and seeps support riparian vegetation.

In WRIA 9, significant alteration of freshwater input has occurred in the Duwamish River estuary. Historically, the Cedar, Black, Green, and White Rivers flowed into the Duwamish River, producing a mean annual flow of between 2500 and 9000 cfs (Williams et al., In Prep.). The White River was diverted in 1911, followed by the Black and Cedar Rivers in 1916, reducing the drainage area of the Duwamish Basin by 70 percent. Two dams on the Green River, a water diversion dam and the Howard Hansen Dam, further restrict flows and flooding in the system. By 1996, the mean annual flow of the Duwamish was about 1700 cfs, a reduction of between 32 and 81 percent (Williams et al., In Prep.)[2].

These alterations have affected the Duwamish Estuary in a number of ways. The severe reduction in drainage area and management of floods has eliminated the large floods that historically created side channels and sloughs, deposited large woody debris, formed deltas, and reworked sediment deposits. The diversion of the White River removed the historic primary source of sediments for the Duwamish. Reductions in the freshwater input, coupled with dredging of the Duwamish Waterway, allows salt water to penetrate further up the estuary than it did historically (Williams et al., In Prep.). These changes have altered dramatically the landscape upon which salmonids in the Green River depend. However, little is known about how these changes affect salmonid behavior or survival.

LOSS OF RIPARIAN FUNCTIONS

Riparian areas are the transition zones between aquatic habitats and upland areas, such as banks and bluffs. Although much is known about the importance of riparian areas in freshwater systems, relatively little research has been conducted on the functions and values of riparian vegetation in marine systems. Brennan and Culverwell (In Preparation) hypothesize that marine riparian areas provide functions similar to freshwater riparian areas and may provide additional functions unique to marine systems. Marine riparian areas may provide numerous functions including wildlife habitat, erosion control, pollution abatement, sediment retention, shade, organic matter, large woody debris, and salmonid prey items (insects) to the nearshore environment. In particular, data exists to show that salmonids benefit directly or indirectly from many of these riparian functions. For example, juvenile salmonids continue to feed on terrestrial insects even when moving to deeper marine waters (Simenstad 1999), and some species of adult salmonids prey upon surf smelt, which spawn in the upper intertidal zone (Williams et al., In Prep.). Surf smelt eggs, deposited during the summer months, experience higher survival on

[2] For more information about hydrologic modifications in the Green/Duwamish section, see Chapter 2.3, Hydromodification.

shaded beaches than on non-shaded beaches in north Puget Sound, suggesting that the shade provided by riparian vegetation is important to the survival of the species (Penttila, 2000).

However, shoreline armoring and other shoreline development have reduced severely the amount of marine riparian vegetation in WRIA 9. When bulkheads or seawalls are constructed, riparian vegetation is removed. Owners of shoreline residences cut down trees and other native vegetation to improve their views, or make room for structures, roads, and landscaping. The Shore-Zone mapping program conducted by the Washington Department of Natural Resources (WDNR) estimated that marine riparian vegetation exists along only 11 percent of the WRIA 9 shoreline. Because WDNR defined marine riparian vegetation as only trees overhanging the intertidal zone, this number likely underestimates the actual amount of marine riparian vegetation in WRIA 9 (Williams et al., In Prep.). However, it is safe to infer that the majority of WRIA 9 shorelines do not have marine riparian corridors that provide effective ecological functions.

NON-NATIVE SPECIES

Non-native species are those species that have been introduced to Puget Sound through a variety of means, including discharges of ballast water from ships, packing materials for seafood shipped from overseas, and intentional or unintentional establishment by the mariculture industry. Non-native species may compete with and/or displace native species, inflicting severe damage on the food web and the nearshore ecosystem.

Very little data exists about non-native species in WRIA 9. The 1998 Puget Sound Expedition identified 39 non-native species in the shallow waters of Puget Sound as a whole (Cohen et al., 1998), but did not indicate which species were found in specific geographic areas. The chapter on non-native species elsewhere in this report contains a comprehensive list of these species.

Non-native species of concern include *Spartina spp.*, salt marsh grasses native to the east coast of the United States that drive out native marsh plants; and *Sargassum muticum*, a seaweed that can smother intertidal species. However, little data exists about these or other organisms' effects on the landscape mosaic upon which salmonids depend, or on salmonids themselves.

KEY FINDINGS

- Massive amounts of habitats critical for juvenile salmonid support in the migratory corridor have been lost. For example, 97 percent of the marshes and flats, and 100 percent of tidal swamps, have been removed from the Duwamish River.
- Shoreline armoring, dredging, filling, and overwater structures have contributed much of this loss of habitat in the migratory corridor.
- Commercial, industrial, and residential development has contributed toxic chemicals and organic compounds to the water and sediments of the nearshore environment in WRIA 9, primarily in Elliott Bay and the Duwamish River.
- Among many others, sediment transport and freshwater input processes are critical for maintenance of important nearshore habitats.
- In WRIA 9, shoreline armoring and development have interrupted sediment processes. Approximately 75 percent of the WRIA 9 shoreline is armored.

- Significant alterations of freshwater input have occurred in WRIA 9, particularly in the Duwamish River basin. These alterations have reduced habitat complexity and sediment loading in the Duwamish.
- Significant amounts of marine riparian vegetation have been lost from WRIA 9 shorelines. The WDNR ShoreZone program estimates that only 11 percent of WRIA 9 shorelines have trees overhanging the intertidal zone.
- Non-native species may be detrimental to salmonid survival in the nearshore in WRIA 9, but more data is necessary to identify specific effects of particular species.

DATA GAPS

- Little is known of the cumulative effects of loss of habitat in the migratory corridor on juvenile salmonids.
- The details of juvenile salmonid use of nearshore habitats are not well understood.
- Complete maps of nearshore habitats do not exist in all areas.
- The carrying capacity of natural and altered nearshore habitat for salmonid support is not fully understood. Similarly, the amount of carrying capacity in the nearshore necessary to support self-sustaining runs of salmonids is not known.
- Sublethal effects of sediment and water contaminants on salmonids and other nearshore organisms are fully understood.
- Very little is known about the cumulative effects of interrupting natural sediment transport processes in the nearshore.
- Although shoreline armoring is very widespread in the nearshore environment, few studies address the effects of armoring on nearshore biota over the long term. Similarly, little is known definitively about the cumulative effects of shoreline armoring on the nearshore environment. More specifically, very few studies have investigated the effects of shoreline armoring on juvenile salmonid feeding, vulnerability to predation, and overall survival.
- Surveys of forage fish spawning areas are incomplete, and stock assessments are absent.
- The effects of the major hydromodification of the Duwamish River on salmonids are not known.
- Very little data on the functions and values of marine riparian vegetation exists.
- Non-native species may be detrimental to salmonid species' survival in WRIA 9, but more data is necessary to identify specific effects of particular species.
- Assessment methods for evaluating habitat quality and for directing mitigation, restoration, preservation, and enhancement efforts are lacking.

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