PART III: SUMMARY

1. Assessment

1. ASSESSMENT

Part III of the Habitat Limiting Factors and Reconnaissance Assessment Report summarizes information presented in the previous limiting factors chapters, and makes some preliminary conclusions based on the information gathered in this report. It is organized in two chapters. Chapter 1: Assessment, includes a description of key findings and data gaps for each of the limiting factors. Chapter 2: Conclusions, includes a description of principles for the watershed, followed by a recommended strategy, and action recommendations to address each of the limiting factors. The key findings and data gaps describe the context and limitations of salmon recovery in WRIA 9. These limitations, combined with the overarching principles for salmon recovery form the basis of the strategy for WRIA 9 recovery. This strategy, in turn, guides the action recommendations.

The following key findings and data gaps are taken from individual chapters in the Habitat Limiting Factors and Reconnaissance Assessment Report.

PART I: CHAPTER 3. CURRENT SALMONID POPULATION CONDITIONS

KEY FINDINGS

GREEN/DUWAMISH WATERSHED-WIDE

- Every species of anadromous salmonids that are native to the North Pacific Region plus one non-native species (Atlantic salmon) have been recently documented to be present in the Green/Duwamish River and tributaries: chinook, coho, chum, sockeye, and pink salmon plus steelhead, coastal cutthroat, and bull trout/Dolly Varden trout.

- The stock status of Green River summer/fall chinook, Crisp Creek fall chum, Green River/Soos Creek coho, and both the summer and winter steelhead stocks are described as healthy by both Washington Department of Fish and Wildlife and the Western Washington Treaty Tribes in their 1994 stock status review. Newaukum Creek coho are described as depressed in that same review. The National Marine Fisheries Service lists the Puget Sound summer/fall chinook Evolutionary Significant Unit (ESU) as Threatened under the Endangered Species Act and the Green River summer/fall chinook stock is a part of that ESU.

- The stock status of Green River fall chum, sockeye, and bull trout is described as unknown.

SUMMER/FALL CHINOOK SALMON

- Escapement for the Green/Duwamish River summer/fall chinook stock from 1986 to 1997 averaged 6,031 and ranged from 2,027 to 10,059.

- Draft run-reconstruction information for the years 1989 – 1997 inclusive indicates approximately 56 percent (range: 25 to 83 percent) of the natural escapement in the main-stem Green River was from hatchery reared and released fish.

- For the same time period, in Newaukum Creek, the origin of adult chinook is approximately 45 percent (range: 15 to 79 percent) of hatchery origin.

- Draft data indicate that the contribution of naturally spawned adults to escapement at the Soos Creek Hatchery is approximately 39 percent (range: 1 to 76 percent).

- The initiation of the "mass marking" of hatchery produced chinook began with brood year 1999. This will provide a tool for fish managers to distinguish all age classes of hatchery produced fish from naturally produced fish on the spawning grounds beginning in 2004. The juvenile chinook are marked by the removal of their adipose fin but are not tagged.

COHO SALMON

- The total natural coho escapement goal for Green River coho stocks is 8,700 fish. That escapement goal has been met only three times in 27 years (1965 to 1992 inclusive) and fluctuates over a wide range.

- Significant differences exist in spawn timing between Newaukum Creek and Green River coho stocks. Coho returning to the Green River typically spawn to mid-November. Newaukum Creek coho may spawn into mid-January.

CHUM SALMON

- Chum salmon returning to the Green River consist of two fall-run stocks: Green River chum and Crisp Creek (also referred to as Keta Creek) chum. The origin of Green River fall-run chum is an East Kitsap/wild remnant mix, while the Keta Creek fall-run stock is of East Kitsap.

PINK SALMON

- Green River pink salmon have been characterized as extinct from this basin. However, pink salmon adults are observed in odd number years during spawning ground surveys in the mainstem Green River and a few tributaries and juvenile pink salmon have been captured in a screw trap on the mainstem Green River.

WINTER STEELHEAD

- The stock status of winter steelhead stocks has been characterized as healthy. An escapement goal was established in 1984/85 of 2,000 fish. Actual escapement of wild fish from run years1976/77 to 1998/99 averaged 1,890 fish. The escapement goal has been met in four of the last five years and water conditions in the other year precluded accurate counts.

SUMMER STEELHEAD

- Green River Basin summer steelhead are the result of non-native (hatchery introduced) origin fish from the North Fork Washougal River (Skamania State Fish Hatchery) summer steelhead stock initially introduced in 1965.
- Escapement goals are not set for this stock.

SOCKEYE

- Sockeye adults and juveniles (Jeanes, 2000) have been documented in the Middle Green River sub-watershed.

ATLANTIC SALMON

- Atlantic salmon adults have been captured by sports fishermen and observed recently in the Green/Duwamish River. These were most likely escapees from commercial net pen operations. There has not been any evidence of successful Atlantic salmon reproduction in the Green/Duwamish River watershed.

NATIVE CHAR (BULL TROUT/DOLLY VARDEN)

- The stock status for bull trout in the basin is unknown.
- One of the first observations of native char in Washington was by Suckey, who first observed native char in the Duwamish River during June 1856. During that same expedition he captured an individual fish approximately 35 miles upstream.
- Investigations have not provided any evidence of bull trout spawning in the Green River watershed.
- Native char have been captured as far as RM 40 in the Green River.
- Native char have not been observed or captured upstream of Howard Hanson Dam as a part of surveys conducted by Plum Creek Timber Company.
- Bull Trout/Dolly Varden have been captured in the lower mainstem Green/Duwamish River on several occasions.

COASTAL CUTTHROAT

- WDFW identifies a distinct stock of coastal cutthroat trout in the Green River watershed.

- NMFS found that the scarcity of information available made risk assessments extremely difficult for coastal cutthroat trout. In their final conclusion they determined that there were two alternative conclusions: "(1) there is not enough evidence to demonstrate that coastal cutthroat trout are *not* at a significant risk of extinction, and (2) there is not enough evidence to demonstrate that coastal cutthroat trout are not at risk." (Johnson 1999).

DATA GAPS

- The Green River mainstem chinook sampling rate was roughly 4 percent due to difficulties in locating samples in the large river and is probably less reliable. Sampling efforts in the mainstem Green River were increased beginning in 1998 but the data have not yet been analyzed.

- Chum salmon escapement information for the Green River basin is sparse.

- No escapement data for Green/Duwamish River watershed origin winter steelhead stocks is available prior to 1978. Escapement estimates are not available for 1997 due to poor water visibility conditions.

- With the exception of one fish, no meristic sampling was conducted on the char captured in the lower Green River basin so it is unclear if they are bull trout or Dolly Varden.

- Data for trends in coastal cutthroat trout abundance in Green River Basin streams is currently not available.

PART I: CHAPTER 4. GENETICS

KEY FINDINGS

FALL CHINOOK

- The Green River has had a fall chinook hatchery program for the last 95 years.

- Green River fall chinook have played an important part in a number of hatchery programs throughout Puget Sound.

- Green River hatchery and Newaukum Creek wild fall chinook populations are genetically indistinguishable.

- The initiation of the "mass marking" of hatchery produced chinook began with brood year 1999. This will provide a tool for fish managers to distinguish all age classes of hatchery produced fish from naturally produced fish on the spawning grounds beginning in 2004. The chinook are marked through the removal of their adipose fin but are not tagged. This will allow for the monitoring of hatchery strays into the Green River and provide a tool to start monitoring any genetic exchange between naturally and hatchery produced fish.

CHUM SALMON

- The Green River has had a chum hatchery program since 1976.
- Green River chum salmon are geographically isolated from other chum salmon populations in Puget Sound.
- Two chum salmon stocks exist within the Green River watershed.

COHO SALMON

- Green River hatchery and Newaukum Creek coho are genetically similar.
- Green River watershed coho are listed as a Candidate for listing under the Endangered Species Act.

WINTER STEELHEAD

- Green River origin winter steelhead are a part of the larger wild Puget Sound winter-run steelhead stocks.

DATA GAPS

- The exact contribution of hatchery fall chinook to mainstem Green River natural escapement is not yet fully known.
- In the Green River watershed, the ramifications of genetic flow between the hatchery and winter steelhead, wild chinook, coho, and chum populations is unknown.
- The extent of chum salmon straying in the Green River watershed is unknown.
- The contribution of hatchery coho to natural escapement is unknown. The reverse is also true.
- The actual extent of any temporal separation in timing between Green River and Newaukum Creek coho is unclear in terms of defining separate stocks.
- In the Green River watershed, the ramifications of genetic flow between the winter steelhead hatchery and wild populations is unknown. Because of timing differences, the genetic flow between these stocks is believed to be low.

PART II: CHAPTER 1.1 LAND USE

KEY FINDINGS

The following key findings were identified when reviewing land use as a factor of decline for salmonids:

- Effects of land use on habitat range from elimination of habitat to degradation of habitat quality to mitigation for environmental damages under existing regulations.

- Historically, local, state, and federal policies have greatly influenced the amount and type of land use that has occurred in WRIA 9:
  - ➢ By the early part of the twentieth century, the region and state planned to develop the Duwamish River and Lower Green into the main industrial area in the county and Puget Sound region
  - ➢ For the first 120 years of settlement, economic development was the predominant driver of growth and development
  - ➢ For the last 30 years, development has occurred under an increasing number of environmental protection policies and growth management policies
  - ➢ Specific actions were taken over many years to enable economic growth and develop natural resource industries
  - ➢ Many policies have been established in the last 30 years that require sound planning and development at both the regional and local level
  - ➢ Meeting multiple objectives for the Growth Management Act, the Endangered Species Act, and other complex regulations creates a challenging, overlapping framework for regulations and protections

- The seven years from 1910 to 1916 saw the most dramatic hydrologic change. During this time period, 70% of the acreage of the Green/Duwamish Watershed was diverted away from the original Green/Duwamish River and a dam was constructed that blocked fish access to 45% of the remainder.

- Growth management is having a significant influence on directing growth to the Urban Growth Area (UGA) and reducing sprawl. However, as population increases, there is a corresponding increase in the amount of developed land:
  - ➢ Growth indicators suggest that the UGA is large enough to accommodate projected growth through 2012
  - ➢ Eighty nine percent of the population of WRIA 9 is concentrated in the UGA
  - ➢ Thirty percent of WRIA 9's land area is within the UGA

- Most of the urban land uses are located in the western third of the WRIA while the middle and upper portions of the WRIA are primarily rural and natural resource lands:
  - ➢ Forestry is the primary designated land use at 99% in the Upper Green River sub-watershed
  - ➢ Residential development (50%), forestry (27%) and agriculture (12%) are the primary land uses in the Middle Green River sub-watershed

- Residential development (50%), industrial development (17%), and commercial development (10%) are the primary uses in the Lower Green River sub-watershed
- Industrial development (43%) and residential development (39%) are the primary designated land uses in the Green/Duwamish Estuary Sub-watershed
- Residential development (68%) and industrial development (10%) are the primary designated land use in the Nearshore Sub-watershed
- Residential development at 92% is the primary designated land use in the Vashon-Maury Island Sub-watershed

- Population growth has been a driving factor for the rapid development rates in the watershed:
  - Before 1996, the majority of jurisdictions in WRIA 9 were experiencing a 1% per year or higher population growth rate
  - Population growth has slowed since 1997 to less than 1% per year overall in King County
  - Every 1% increase in population growth corresponds with a 2% or higher increase in developed land

DATA GAPS

Land use information currently available presents certain challenges. The information is not currently organized by watershed boundaries. Although a great deal has been written regarding land use and its effect on salmonids, there has not yet been a close look at local regulations and the subsequent effects on salmonid habitat. Below are the identified land use data gaps:

- Prepare land development and demographic information for King County by boundaries of the Water Resource Inventory Areas, sub-watersheds, and basins.

- Inventory permitting and regulatory processes (SEPA and Shoreline review, permit review, sensitive area review, ordinance and regulatory review) throughout the WRIA. Assess the biological implications of various land use activities, regulations, and policies.

- Inventory impervious surface areas (location and amount), road densities, and forest cover retention at a sub-watershed or smaller scale.

PART II: CHAPTER 1.2 WATER QUALITY

KEY FINDINGS

The following key findings were identified when reviewing water quality as a factor of decline for salmonids:

- Water quality conditions in the Lower Green and Duwamish River have improved from the poor water quality conditions that existed in the 1960s. This is a result of the reduction of municipal and industrial discharges (including higher levels of wastewater treatment and reduction of combined sewer overflows (CSOs)) and the relocation of the south municipal wastewater treatment plant outfall to Puget Sound.

- There has been a trend towards increasing surface water temperatures in most tributaries in the urban and urbanizing areas of the region over the past 20 years, probably attributable to urbanization and development, including increased runoff from impervious surfaces and loss of riparian vegetation.

- Temperatures in the mainstem during the summer have peaked between 23 and 24 ^{o} C at stations in the Lower and Middle Green River in studies involving continuous monitoring probes, based on available data. In some years, this is probably of concern for adult chinook migration up the Green River in August and early September. Water temperatures in some tributaries of the Mill (Hill) and Springbrook subbasins have been historically high and are probably of concern for salmonid rearing. Water temperatures during spawning and rearing are also of concern for several Soos Creek tributaries. There are insufficient data and information on the distribution of bull trout in the watershed to assess to what extent localized temperature conditions are a concern for bull trout.

- Dissolved oxygen (DO) levels are one of the most significant issues for salmonids in the basin. In the mainstem, DO levels in the Duwamish and Lower Green rivers are of concern for salmonid rearing on some occasions. In the mainstem above RM 24 (where most mainstem spawning occurs), DO levels in the Middle Green River are occasionally of concern during incubation. DO for incubation and rearing is a probable factor of decline for salmonids in several tributaries, particularly Springbrook Creek, Mill (Hill) Creek, Soos Creek, and Newaukum Creek. The most severe documented DO problem in the basin is in Mill Creek (just north of SR-18).

- Turbidity and total suspended solids (TSS) are possible factors of decline in terms of water column impacts for the Duwamish River, Lower Green River, Mill Creek, and Springbrook Creek. However, no data were available for the duration of exposure, so it is difficult to determine the extent to which TSS is of concern. TSS may be a concern in terms of sedimentation in some areas, but this was outside the scope of this study, and would be better characterized by analysis of sediment deposition or embededness.

- Based on the King County Streams water quality data evaluated from 1996 to 1999, pH, ammonia, and metals are unlikely to be factors of decline for salmonids at the locations analyzed. Ammonia may be a factor of decline in the Mill Creek basin based on data collected between 1990 and 1991 by King County. Metals (cadmium, chromium, copper, mercury, and zinc) may be of concern in Springbrook Creek based on sampling carried out by Ecology and King County (Metro) between 1984 and 1990 that led to its listing on the 303(d) list. It is possible that there are localized areas near stormwater outfalls to smaller tributaries where metals could also be of concern.

- No data were available to assess to what extent organic chemicals such as pesticides, polycyclic aromatic hydrocarbons (PAHs), and phthalates are a factor of decline for salmonids.

- In the Duwamish Estuary, risks to water column dwelling organisms are minimal. However, there are potential risks to benthic organisms from several chemicals in the sediments, most notably bis(2-ethylhexyl)phthalate, 1,4-dichlorobenzene, mercury, polycyclic aromatic hydrocarbons (PAHs), PCBs, and tributyltin (TBT) (King County, 1999). Risks to the benthic community can potentially translate to risks to salmonids via food-chain transfer (bioaccumulation in prey), reduction in function of immune systems, or from potential toxicity to prey organisms (reduction in available food).

- Biological monitoring of macroinvertebrates in the Soos Creek basin (1995-98) found highly variable conditions. Five of eight stations monitored had benthic index of biotic integrity (B-IBI) scores in the fair range, two were in the poor range and one station was in the very poor range. Seven stations monitored in 1999, located throughout the mainstem of the Green River all had B-IBI scores in the fair range. Mill (Kent) and Meridian Valley creeks had B-IBI scores in the very poor range.

- Although aluminum concentrations often exceed the EPA national criterion throughout the watershed, this does not necessarily indicate aluminum is a factor of decline. Measurements of total aluminum include several forms, such as aluminum that is occluded in minerals, clay and sand or is strongly sorbed to particulate matter, that are not toxic, or are not likely to become toxic under natural conditions (U.S. EPA 1988). Therefore, this criterion may be overprotective when based on the total recoverable method because the digestion procedure dissolves some aluminum that is not toxic and cannot be converted to a toxic form under natural conditions (U.S. EPA 1988).

DATA GAPS

- The spatial availability of water quality data are highly variable across the watershed. There is a paucity of sampling locations for the mainstem of the Green River, with only four sampling stations between the Duwamish River (RM 11) and the Tacoma diversion dam (RM 61). Conversely, some tributaries such as Newaukum and Soos creeks have a dense spatial representation, with 18 and 17 sampling stations, respectively. Such sparse coverage in some subbasins could potentially overlook some areas with impaired water quality in the Green River, and result in greater uncertainty in this assessment.

- There is a lack of continuous temperature data for the mainstem and several tributaries. Continuous data are necessary to determine maximum daily temperatures and the duration of temperature exceedences that have the greatest potential to impact salmonids. For example, temperature conditions in Crisp Creek were determined to be unlikely as a factor of decline based on routine monthly monitoring. However, examination of continuous temperature data indicated somewhat frequent small exceedences of the proposed rearing and spawning standards leading to a possible factor of decline determination.

- Data are lacking for many of the water quality parameters that may adversely affect salmon. Available TSS data do not include any information on the duration of exposure, which is needed to evaluate accurately potential effects on salmonids. In an urban watershed with extensive commercial and industrial development characteristic of the Lower Green River and Duwamish River segments, other parameters that could be of concern include metals, pesticides and herbicides, PAHs, and phthalate esters. There is a shortage of data available for these parameters in the water column. Most of the existing data are for sediments.

- The majority of the ambient metals data in the Green River watershed were collected as part of the stormwater monitoring program; therefore, baseflow metals concentrations are generally unknown. Furthermore, between 1996 and 1999, metals data were available in only seven locations in the watershed. Therefore, the subbasins are not well characterized for metals with the current data.

- There is insufficient information on the combined effects of toxicants, such as metals or organic chemicals, on salmonids. Additivity is the characteristic property of a mixture of toxicants that exhibits a total toxic effect equal to the arithmetic sum of the effects of the individual toxicants (U.S. EPA 1991). Synergism is the characteristic property of a mixture of toxicants that exhibits a greater-than-additive total toxic effect (U.S. EPA 1991).

- Unlike chemical data that yield a snapshot of aquatic conditions at the time of sampling, aquatic insects provide an integrated view of overall water quality conditions at a given location. Unfortunately, the only available aquatic insect data (as measured by B-IBI) in the Green River basin was for the Soos Creek subbasin from 1995, 1997, and 1998, and from selected stations on the Green and two tributaries in 1999. Thus, this is a data gap for the basin as a whole.

- There is a need to define closer links between water quality data and site conditions with the historic, current, and potential future distribution of salmonids. It is likely that water quality conditions limited salmonid distribution in the past, even without extensive human activities. For instance, DO and temperature conditions in areas with extensive open water wetlands may not be compatible with fish presence. Also, the DO and temperature requirements for salmonid migration, rearing, and spawning/incubation vary considerably.

- There is an interest in having reference sites based on different geomorphic systems to define background water quality conditions. Without reference sites, it is difficult to define the relative contribution of anthropogenic activities to degraded water quality conditions.

PART II: CHAPTER 2.1 HYDROLOGY

KEY FINDINGS

The following key findings were identified when reviewing hydrology as a factor of decline for salmonids:

UPPER GREEN RIVER

Upstream migration

- The Howard Hanson and Tacoma dams that alter the mainstem hydrology also are blocking the upstream migration of anadromous salmonids. See Passage Chapter of this report for details.

Spawning and Incubation

- One model suggests that timber harvest related disturbances are extensive enough to cause peak flow increases capable of modifying channel conditions (USFS 1996) and mainstem reaches just upstream of the Lester Watershed Administrative Unit (WAU) have recently experienced scour to a depth sufficient to cause redd mortality during high flows (Plum Creek 1996).

- The inundation of up to 7.7 miles of mainstem and tributary habitat will result in lower water velocities, decreased oxygen levels, and increased sediment loads in the redd environment, which can result in embryo and larval mortality. The associated decrease in temperature with the increase in water depth can result in a delay of egg maturation.

- The dams have resulted in the inaccessibility of over 100 miles of combined mainstem, tributary, and side channel spawning habitat to anadromous salmon.

Juvenile Rearing

- The construction of HHD has resulted in a net loss of 7.7 miles of mainstem and tributary rearing habitat (side channel habitat undetermined) due to inundation when operated at full pool. This area has been converted into rearing habitat that fluctuates unnaturally from a lake to free flowing depending on flood control responsibilities.

Downstream Migration

- Downstream migrating salmonid smolts, especially chinook, are delayed within the reservoir behind HHD and subject to increased mortality in the reservoir and through the dam bypass pipe and gates.

MIDDLE GREEN RIVER

Upstream Migration

- Since 1913 the Tacoma water withdrawals at the headworks have severely lowered the natural summer low flows in the mainstem. Howard Hanson dam summer low flow augmentation (since 1962) has helped to increased these flows but not to natural, pre-diversion levels. These low flows in the late summer have only met instream flow requirements in 9 out of the last 30 years (30%) and delay upstream migration of adult chinook salmon. Tacoma's First Diversion Water Right Claim (FDWRC) of 113 cfs is not constrained by these minimum instream flow requirements.

- The lack of freshets, especially during the spring reservoir refill period, may delay salmon (e.g., steelhead) upstream migration.

- Late summer low flows and associated shallow water over many riffles increase the energy expenditure of upstream migrating adult chinook.

- Summer low flows increase the difficulty adult chinook have in moving from the Green River into major spawning tributaries such as Newaukum Creek.

Spawning and Incubation

- Alterations in the natural flow regime during HHD refill operations may adversely impact spring spawning and incubation success in off-channel habitats that become disconnected.

- The dam flood flow manipulations result in an increase in the duration of flows that scour spawning gravel from the streambed.

- Late summer flows downstream of the Tacoma Headworks (1911) compel many chinook to spawn towards the thalweg rather than the margins, increasing the probability of egg loss due to streambed scour during higher winter flows.

- Late summer low flows and associated shallow water can reduce the number of chinook that spawn in the downstream ends of side channels.

Juvenile Rearing

- Low summer flows reduce the amount of rearing habitat and exacerbate high summer water temperatures.

- Refill operations at HHD have reduced the frequency of side-channel connectivity, which increases the probability that juvenile salmonids may become stranded in side channels that become disconnected from the mainstem. Juvenile chinook have been observed utilizing side channel habitats in the mainstem during the spring (Jeanes and Hilgert 1998).

Downstream Migration

- Refill operations at HHD have reduced flows and prevented spring freshets, which prolong downstream migration of juvenile salmonids. This makes juvenile salmonids more susceptible to predators and adverse water quality conditions. Green River Hatchery chinook smolt releases have higher survival to the Duwamish with increasing flow: only

40% survived at approximately 650 cfs at Auburn while survival rates between 70 and 100% were observed at flows higher than 2,000 cfs (Wetherall 1971).

LOWER GREEN RIVER

Upstream Migration

- The diversions of the White River and Cedar/Black Rivers altered the migration routes of upstream migrating salmonids.

- The combined diversion of the White River and Cedar/Black Rivers reduced the drainage area of the Green River watershed by almost 60 percent. The diversion of the White River reduced summer flows in the lower Green River by roughly 50 percent. The combined diversions results in the loss of physical habitat area such as size of pools, depth of riffles, and an increase in temperature that could delay migration and harm fish.

Spawning and Incubation

- Alterations in the natural flow regime during HHD refill operations may adversely impact spring spawning and incubation success by disconnecting off-channel habitats.

Juvenile Rearing

- Low summer flows adversely impact the amount of rearing habitat and increase high summer water temperatures.

- Juvenile chinook, coho, steelhead, chum, and cutthroat salmonids have been observed utilizing side channel habitats in the mainstem during the spring (Jeanes and Hilgert 2000). Refill operations at HHD have reduced the frequency of side-channel connectivity, which increases the probability that juvenile salmonids may become stranded in side channels that become disconnected from the mainstem.

- The diversion of the White and Cedar/Black Rivers and the construction of revetments reduced the channel width and caused the Green River to form a new, lower floodplain, cutting off access to former off-channel rearing habitats.

- The amount of urbanization increases the frequency, magnitude, and duration of stormwater runoff that adversely impacts salmonid rearing habitat.

MAJOR TRIBUTARIES

Upstream Migration

- The affects of urbanization and groundwater withdrawals have reduced summer low flows, which may delay the upstream migration of adult chinook salmon in Newaukum and Soos Creeks.

Spawning and Incubation

- Impervious surfaces resulting from urbanization increases the volume of stormwater discharged into a stream for a given storm event. This action increases the height of peak flows and creates new peaks where none previously existed, potentially increasing the frequency of scouring and deposition. This further reduces egg and alevin survival.

Juvenile Rearing

- Increases in urbanization and groundwater withdrawals have reduced summer low flows, reducing the amount of available salmonid rearing habitat and exacerbating increases in summer water temperatures (water quality degradation).

- As urbanization increases, the volume of stormwater discharged into a stream for a given storm event also increases. This action increases the height of peaks and creates new peaks where none previously existed, potentially increasing the downstream displacement of emergent fry and reducing quality of overwintering habitat.

PART II: CHAPTER 2.1 ADDENDUM. NATURAL FLOW ANALYSIS

KEY FINDINGS

- Several trends are evident in flow conditions shaped by the Howard Hanson Dam and Tacoma projects. These include an overall decrease in median flow values, and an overall downward shift in flow distributions. These effects no doubt result from the diversion of up to 113 cfs from the river by the Tacoma project and a reduction in flood peaks due to HHD.

- Although one of the original purposes for Howard Hanson Dam was low flow augmentation, it is clear from the analysis that this flow augmentation does not fully overcome the flow reduction effects of the Tacoma diversion during low flow periods. The low flow conditions in the river last longer than they would without the projects in place and the annual minimum flow tends to occur two weeks earlier than without the projects.

- Flood flows have been greatly reduced. Simulated peak flows ranged up to 29,000 cfs under without-projects conditions and 16 percent of annual peaks were greater than 11,000 cfs at Palmer. With the projects in place, none have exceeded 11,000 cfs. The dam has resulted in the managed flood peaks lasting for substantially longer periods of time, albeit at greatly reduced levels.

DATA GAPS

- The natural flow analysis appears to have merit for evaluating hydrologic changes in the Green River and for identifying possible impacts on salmon stocks. Several improvements to the analysis could make it even more useful. The analysis should be updated to reflect changes in HHD operations that have occurred in recent years, especially during the spring refill period. Actual withdrawal records for Tacoma's diversion should be investigated as well. The analysis also could be improved to better simulate short-term high and low flow rates, so that 1- and 3-day annual minima and maxima can be better analyzed.

PART II: CHAPTER 2.2 SEDIMENT TRANSPORT

KEY FINDINGS

The following key findings were identified when reviewing sediment as a factor of decline for salmonids:

UPPER GREEN RIVER

Spawning and Incubation

- Road related sediment yields exceeded 50 percent of background yields in several subbasins in the Lester Watershed Administrative Unit (WAU). In addition, the volumetric proportion of fine sediment was elevated in potential spawning gravels collected from various sites throughout the Lester WAU. High levels of fine sediment smother or trap incubating eggs and alevins and could limit the reproductive success of salmonids. The exact sediment concentrations are being compared to threshold values known to impact the reproductive success of salmonids.

- The Howard Hanson dam is reducing river flow velocities, resulting in sedimentation detrimental to salmonid egg incubation in at least 7.2 miles of river channel.

- Landslides and mass wasting associated with logging practices have led to coarse and fine sediment inputs that fill pools and dramatically increase width-to-depth ratios in streams and rivers, reducing the area of habitat available for juvenile salmonid rearing. Landslides have negatively impacted juvenile salmonid rearing habitat in 2.6 of the 4.7 miles of stream surveyed in the Lester WAU.

MIDDLE GREEN RIVER

Spawning and Incubation

- The upper basin formerly supplied over 90 percent of the alluvial gravel (6,500 to 19,700 tons of gravel per year) to downstream reaches prior to construction of HHD. This gravel is now deposited upstream of the dam (USACE 1998). Entrapment of this sediment behind HHD has resulted in a reduction of suitable spawning gravels in the Middle Green River sub-watershed.

- Howard Hanson Dam operations have increased the frequency and duration of flows between 3,500 and 9,100 cfs, and this increase, in combination with the limited supply of sediment below HHD, may have increased the annual sediment transport capacity by as much as 30% (Dunne and Dietrich 1978).

- The increase in sediment transport capacity has resulted in sediment being carried downstream without being replenished. The channel has incised and an armor layer formed. As of 1993, the armor layer was believed to have moved downstream to RM 40.0, which is near the upstream end of the most valuable spawning area of the Green River. The incision is continuing to move at a rate of approximately 700 to 900 feet per year (Perkins, 1993). As armor layer formation progresses downstream, spawning habitat is lost and channel incision may reduce the amount of available rearing habitat. Rearing habitat is lost by increasing the amount of time that side channels or other off-channel habitats are disconnected from the mainstem.

- Large amounts of fine sediments are released from slides in this sub-watershed and their downstream deposition is detrimental to the successful spawning and incubation of salmonid eggs and alevins. One such slide, near RM 43, was reactivated by a major flood in 1996 (Cropp 1999). This slide is estimated to have delivered up to 50,000 cubic yards of sediment to the channel (Perkins 1998). This slide has been linked to pool filling and degradation of spawning gravels for at least a mile downstream (Cropp 1999).

Juvenile Rearing

- The reduced coarse sediment supply has led to river channel incision. This could reduce the connectivity of important off-channel salmon spawning and juvenile rearing habitat such as side channels, groundwater fed channels, and tributaries.

- Increased fine sediment inputs have been observed to fill pools and the interstitial spaces within substrates near RM 43. This reduces the amount and quality of habitat (i.e., disturbs benthic invertebrate food supply, reduces benthic cover) available for rearing juvenile salmonids and is to be expected downstream of other slide zones in this reach.

LOWER GREEN RIVER

Spawning and Incubation

- The diversion of the White River to the Puyallup River in 1906 reduced the delivery of coarse sediment to the lower Green River by 75 percent. This loss of coarse sediment reduced the availability of suitable anadromous salmonid spawning habitat.

- Increased deposition of fine sediments are filling pools and substrate interstitial spaces, reducing the amount and quality of habitat available for rearing juvenile salmonids.

Juvenile Rearing

- Since the diversion of the White River and the Cedar/Black River, the channel downstream of RM 32 has narrowed by forming a new floodplain within the old channel (Perkins 1993). The new floodplain surface is at least seven feet lower than the former floodplain (Dunne and Dietrich 1978).

- This lowering has disconnected off channel juvenile salmonid rearing habitat. This change has been compounded further and masked by the construction of levees.

MAJOR TRIBUTARIES

Upstream Migration

- The increased sediment delivery to alluvial fans and low gradient reaches of the Green River, in combination with the decrease in low flows, impedes adult chinook attempting to migrate upstream into tributaries.

Spawning and Incubation

- Newaukum Creek represents an important source of coarse sediment to the Middle Green River (Perkins 1993). In contrast, most of the coarse sediment transported by Soos Creek settles out in low gradient reaches prior to reaching the Green River (King County 1989).

- Increased fine sediment delivery and deposition into low gradient reaches of the tributaries reduces salmonid reproductive success. High levels of fine sediment can smother or trap incubating salmonid eggs and alevins.

Juvenile Rearing

- The increase of fine sediment inputs may fill pools and the interstitial spaces within substrate. This results in a reduction of the amount and quality of habitat (e.g., disturbed benthic invertebrate production, reduced benthic cover) available for rearing juvenile salmonids.

DATA GAPS

- Watershed-wide sediment contribution information at the sub-watershed scale was not available.

- The downstream progression of the armor layer on the mainstem has not been estimated for almost ten years.

PART II: CHAPTER 2.3 HYDROMODIFICATION

KEY FINDINGS

The following key findings were identified when reviewing hydromodification as a factor of decline for salmonids:

UPPER GREEN RIVER

- High sediment supply has transformed portions of the mainstem Floodplain channel type from pool-riffle to braided morphology. Braided channels experience frequent scour of a depth sufficient to damage or destroy chinook redds and have low pool frequencies, reducing the amount of juvenile rearing and adult holding habitat.

- Inundation by Howard Hanson Reservoir has transformed 4.5 miles of former Floodplain channel type (18% of total in Upper Green River sub-watershed) to periodic Lacustrine habitat and has resulted in the loss of 10,000 linear feet of side channel habitat.

- Armoring of channel banks to protect transportation corridors (roads and railroads) has reduced the complexity and quality of rearing habitat in approximately 6.3 miles (26%) of the remaining Floodplain channel type in the Upper Green River sub-watershed.

- Large woody debris (LWD) loadings in the Upper Green River sub-watershed are currently rated as "not properly functioning" or "fair" to "poor" according to criteria developed by the National Marine Fisheries Service (NMFS) (NMFS 1999) and Washington Department of Natural Resources (DNR) (WFPB 1997). LWD that contributes to "fair" rating is generally small and does not include "key" pieces. The low LWD frequencies correspond with low pool frequencies, indicating that the lack of LWD in Floodplain channels known to be responsive to LWD has degraded rearing and adult holding habitats required by chinook, coho, and steelhead salmonids.

- Large pieces of LWD (up to 90 feet long) were previously mobilized and transported downstream through Floodplain channels in the Upper Green River sub-watershed. Downstream transport of LWD has been interrupted by HHD since 1964.

MIDDLE GREEN RIVER

- The total length of Floodplain channel type between RM 58 and RM 61 has declined by approximately 0.5 miles (15%) as a result of road/railroad construction and flood control by HHD. This has resulted in a loss of habitat used by adult chinook and steelhead for spawning, rearing, and adult holding. Coho, cutthroat, and probably chum would use this area for rearing and possibly some spawning.

- Bank armoring to protect transportation corridors has reduced the complexity and rearing habitat value over 1.6 miles (26%) of the Large Contained channel between RM 61 and 64.5. Channel constraints in this segment generally affect only one bank, and have not substantially reduced the ability of this channel to form side or off-channel habitats due to the naturally high confinement (valley width <2 times channel width) of this channel type.

- Construction of levees and revetments to prevent bank erosion and control flood levels has reduced the complexity and rearing habitat value over approximately 5.6 miles (40%) of the Middle Green Floodplain segment between RM 31 and RM 45. Levees and revetments generally affect only one bank in this segment, and thus have not altered the overall channel type.

- The length of channel characterized by a braided morphology between RM 31 and RM 45 declined from 10.4 miles to less than 4 miles from 1936 to 1992 (60% reduction). Reduced area of braided morphology represents an improvement in the stability of spawning habitat, as braided channels typically experience extensive scour on an annual basis.

- The area of active gravel bars in Floodplain segments of the Middle Green River has declined as a result of flood control by Howard Hanson Dam. All 10 acres of formerly active bar surface between RM 56 and RM 61 now support riparian forest communities. Bar area in the Floodplain channel segment between RM 31 and RM 45 declined from 236 to 78 acres (67% reduction) between 1936 and 1992. The loss or stabilization of bar surfaces corresponds with a reduction in shallow marginal habitat and suggests that creation of new side channel habitats and riparian forest stands has been slowed or halted.

- LWD is currently scarce in Floodplain channel types known to be responsive to LWD. No LWD was observed in the Floodplain channel segment between RM 58 and RM 61 on aerial photographs from 1953 and 1987. LWD in the Middle Green Floodplain segment (RM 31 to RM 45) currently averages only 32.6 pieces per mile, even with LWD placement undertaken in recent restoration projects. NMFS criteria for "properly functioning habitat require at least 80 pieces per mile. The lack of LWD corresponds with a scarcity in large pools, which numbered less than 0.12 pools per channel width based on evaluation of air photos from 1992 (Fuerstenberg et al. 1996). The scarcity of LWD and pools indicates that the quality and quantity of mainstem rearing and adult holding habitat has declined in Floodplain channel types.

- The length of side channel habitats in the Floodplain segments of the Middle Green River has declined by over 70 percent as the result of the disconnection of 1.7 miles of side channel between RM 58 and RM 61 from 1953 and 1987, and the loss of 13.8 miles of side channels between RM 31 and RM 45 from 1906 to 1992.

- Decreased flood flows, road and railroad construction, and levees and revetments are believed to have reduced the area of floodplain inundated on a regular basis (by 2-year return interval flood). Available data are insufficient to quantify the magnitude of the reduction.

LOWER GREEN RIVER

- Six miles of Floodplain channel type and 14 miles of Palustrine channel type have been channelized. Both Palustrine and Floodplain channel types typically have complex plan-forms and dissipate flood energy by overbank flows. Consequently, channelization has presumably resulted in the loss of almost all mainstem winter rearing habitat and a reduction in the quality of summer rearing and adult holding habitat in these segments.

- All 36 acres of gravel bars (100%) in the former Floodplain channel segment (RM 25 to RM 31) have been lost. These sites formerly provided shallow marginal habitat, increased channel complexity, and sites suitable for colonization by riparian hardwood forests.

GREEN/DUWAMISH ESTUARY

- Diversion of the White and Cedar/Black Rivers from the Green/Duwamish River has reduced the freshwater inflow to the estuary by about two-thirds and has led to profound changes in the nature of the Duwamish River channel and adjacent floodplain.

- Creation of the Duwamish Waterway resulted in replacement of about 9.3 miles of meandering river with 5.3 miles of straightened channel.

- Approximately 98 percent (2.2 mi^2) of the Duwamish River's historic floodplain marshes and intertidal mudflats have been replaced with fill, overwater structures, commercial and industrial facilities, and other development.

- A large proportion of the shoreline downstream of RM 5.3 and around Elliott Bay has been armored in some way and much of this shoreline also is altered by the presence of overwater piers and wharves.

- Despite the straightening of the river and loss of intertidal habitat, the Duwamish River and Elliott Bay still have some areas of mudflats that provide important estuarine rearing functions for juvenile salmon.

- Recent habitat management policies and restoration projects, as well implementation of requirements for mitigation for any new losses of habitat, have begun to address the degraded conditions along the Duwamish River.

MAJOR TRIBUTARIES

- 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.

DATA GAPS

- No quantitative data on the extent or quality of side channel habitat exist for the Upper Green River sub-watershed. SSHIAP recently mapped side in the Upper Green sub-watershed using 1:12,000 aerial photos from 1995/1996, but these data have not been field verified. Data should be available soon.

- Available data are insufficient to assess the reduction in floodplain area throughout the WRIA.

- There are no existing data on the quality of off-channel habitat.

- No quantitative field data on pool frequency, channel morphology, substrate, or bank condition in the mainstem (with the exception of the Upper Green River sub-watershed) exists. Changes from historic conditions are speculative and based on general characteristics of the various channel types.

- No data on LWD in the lower Green River (RM 11 to RM 25) or Green River gorge (RM 45 to RM 31) exists.

- Limited data are available on hydromodifications or habitat in Soos and Newaukum Creeks. SSHIAP is in the process of conducting a hydromodification assessment that will include all tributaries mapped on the 1:24,000 DNR hydrography. The assessment will quantify the stream length affected by artificial confinement (levees, bank armoring, adjacent roads/railroads, etc.) and ditching (channelization, straightening, etc.).

PART II: CHAPTER 2.4 RIPARIAN FUNCTION

KEY FINDINGS

Riparian condition was assessed based on vegetation type, size, and density, generally corresponding with methodologies from the Salmon and Steelhead Inventory and Assessment Program (SSHIAP) and the Washington Forest Practices Board Manual (WFPB 1997). In areas where no existing riparian data were located, an original assessment was conducted specifically for this report. The original methodology is described in the chapter text. The following key findings were identified when reviewing riparian functions as a habitat factor of decline for salmonids:

UPPER GREEN RIVER

- At least 33 percent of the riparian zone has conditions that would be expected to result in poor bank stability. Bank stability may be further compromised by increased sediment delivery and in-channel storage.

- Almost 50 percent of the channel length is currently bordered by a riparian zone that is classified as providing poor shade. None of the riparian zone along the mainstem Green River is sufficient to provide good shade conditions.

- The ability to supply organic matter and filter sediments is rated poor along approximately 35 percent of the channel.

- Large woody debris recruitment is currently rated poor along almost 50 percent of the river and is not considered to be good anywhere along the mainstem Green River in the Upper Green River sub-watershed.

- Seasonal inundation by Howard Hanson Dam reservoir and the permanent presence of roads and railroads within the riparian zone will hinder recovery of riparian functions along approximately 12 miles of the mainstem Green River.

MIDDLE GREEN RIVER

- Almost 25 percent of the riparian zone has conditions that would be expected to result in poor bank stability.

- Almost 30 percent of the channel length currently is bordered by a riparian zone that is classified as providing poor shade. Sixty-five percent of the riparian zone classified as having good shade conditions is located within the Green River gorge.

- The ability to supply organic matter and filter sediments is rated poor along approximately 27 percent of the channel.

- Large woody debris recruitment is currently rated poor along almost 38 percent of the river. The 22.6 miles of riparian zone considered to have good LWD recruitment are located almost entirely within the Green River gorge.

LOWER GREEN RIVER

- Levees and revetments have fixed the channel in place and effectively prevent bank erosion where channel migration would occur naturally. This stops an important mechanism of LWD recruitment to the river.

- Over 80 percent of the riparian zone currently is considered to provide poor shade, organic matter recruitment, and sediment filtration.

- Ninety-seven percent of the riparian zone is considered to have poor LWD recruitment potential and microclimate conditions. None of the riparian zone along the lower Green River is considered to have good LWD recruitment potential.

- Almost 50 percent of the riparian zone is comprised of forbs and grass, or shrubs, many of which are non-native.

- Pavement and bare ground account for approximately 33 percent of the total area within 300 feet of the river in this sub-watershed.

GREEN/DUWAMISH ESTUARY

- The majority of the upper intertidal zones in both the estuary and in Elliott Bay are supplanted with riprap, seawalls, and overwater structures.
- The upper estuary between RM 5.3 to RM 11.0 supports the largest proportion of riparian vegetation, although these stands are not wide enough to provide high quality riparian functions.
- Riparian vegetation is sparse in the lower estuary (RM 5.3 to the mouth).
- Functional riparian stands on Elliott Bay are limited to Magnolia Bluff and represent less than 14 percent of the bay shoreline.
- The remaining riparian areas of the lower estuary and bay are dominated by overwater and inwater structures.

MAJOR TRIBUTARIES

- Sections of intact riparian zone that currently support small- to medium-sized deciduous and mixed conifer and deciduous trees are concentrated in the canyon section of Newaukum Creek from RM 0 to 3 and on Soos Creek from RM 1.5 to 2.8.
- Bank stability, shade, and organic matter recruitment are considered poor along approximately 65% to 80% of Soos Creek and 53 % of Newaukum Creek.
- None of the riparian zone along Soos Creek is currently considered to provide good LWD recruitment.
- Sixty percent of the riparian zone along Newaukum Creek currently provides poor LWD recruitment. The remaining 40% of the riparian zone analyzed currently has fair LWD recruitment and may develop good conditions if left undisturbed.
- Impacts to riparian functions along mainstem Soos Creek from RM 0.0 to 13.0 occur primarily as a result of urban (including powerline corridors and roads) or residential development adjacent to the stream.
- Impacts to riparian functions along mainstem Newaukum Creek from RM 0.0 to 10.0 occur primarily as a result of agricultural or residential development adjacent to the stream.

DATA GAPS

- A field reconnaissance of riparian conditions using a consistent methodology designed for application at the appropriate stream/river scales has not been conducted for most of the watershed.

PART II: CHAPTER 2.5 FISH PASSAGE

KEY FINDINGS

The following key findings were identified when reviewing fish passage as a factor of decline for salmonids:

- There are no known <u>natural</u> impassable barriers in the mainstem Green River up to RM 93. The historic upstream extent of anadromous salmonid use is presumed to have been around RM 93 based on an analysis of river gradient and a series of mapped cascades.

- The earliest documented anthropogenic barrier on the mainstem Green River was a wooden weir erected annually from 1904 to 1924 on the mainstem Green River at the confluence of Soos Creek to allow capture of adult chinook in the mainstem.

- The Tacoma Headworks, which began construction in 1911 and was finished in 1913, was the first permanently constructed barrier to adult salmon and steelhead in the Green River. This dam has blocked anadromous salmonids from natural migration and reproduction in the Upper Green River sub-watershed for nearly 90 years.

- Salmonids that are not naturally produced (e.g., hatchery planted juveniles), juveniles from adult steelhead that were transported upstream of the dams, or resident trout may migrate downstream past Tacoma's existing Headworks. Most pass over the dam spillway, where there is a potential for fish to be injured. The second avenue of passage available at the Headworks is the pipeline intake. The existing Headworks intake screens do not meet NMFS or State screen criteria (1/4" mesh size from center strand to center strand, with 5/32" openings) and juvenile salmonids can potentially be impinged on the intake and killed; very small juvenile salmonids could pass through the existing screens.

- Howard Hanson Dam completed construction in 1962 at RM 64.5 and represents another complete barrier to the upstream passage of anadromous and resident fish.

- There are two main concerns regarding downstream fish passage associated with Howard Hanson Dam: (1) passage through the dam, and (2) passage through the reservoir:

  (1) The low survival rate of fish passing through Howard Hanson Dam is primarily a function of two factors: 1) the spring refill operation strategy, which influences the ability of fish to locate the outlets; and 2) the low survival of juveniles passing

through the bypass outlet pipe. Current annual survival of juvenile salmon and steelhead migrating through HHD outlets is estimated to be between 5 and 25 percent based on a fish passage model and on-site monitoring data (Dilley and Wunderlich 1992, 1993). Out-migrant studies indicate that there is little or no injury to juvenile fish using the radial gates (Seiler and Neuhauser 1985; Dilley and Wunderlich 1992; 1993), but injury rates through the bypass pipe range from 3 to almost 90 percent, depending on species and environmental conditions.

(2) Aitkin et al. (1996) found that migration of juvenile coho salmon through Howard Hanson Reservoir took a significantly longer time at both mid- and high-pool elevations. Travel times for both coho and steelhead smolts were longest at mid-pool. Travel time was more closely related to refill rate than pool level, increasing as refill rate increased. Survival of fish passing through the reservoir has been identified as a concern, but cannot be assessed using existing data.

- Recent high levels of coarse sediment inputs upstream of HHD and alterations in the flow regime downstream of HHD have transformed sections of floodplain channel types from essentially a single-thread pool riffle channel morphology to a braided morphology consisting of numerous shallow flow paths. These shallow paths are most likely to adversely affect juvenile coho and steelhead rearing in the mainstem and adult chinook salmon moving upstream in August and September when flows are generally lowest. Mainstem low flow concerns have been documented in the middle Green River between RM 31 and RM 45 and in the upper Green River near RM 83.

- Low flow concerns have been identified at the mouths of several of the Green River's tributaries, including Newaukum Creek and a number of streams in the upper watershed. This is largely due to the porous nature of alluvial fans. Water flowing across these fans is rapidly lost to seepage, and flows may disappear before reaching the foot of the fan (Levin 1981). An increase in channel sediment from logging in the Upper Green River sub-watershed, lower flows in the Middle Green River, and low levels of LWD in both reaches have exacerbated low flow concerns and may impede passage of adult salmonids.

- Subsurface flows have been observed in the North Fork Green River during late summer (Noble 1969; Hickey 2000b), and could prevent salmonids from entering the river or moving upstream. Operation of the North Fork well-field by Tacoma could reduce flows in the North Fork, although there currently are insufficient data on the extent of this potential impact.

- Water quality degradation can pose significant barriers to salmonid migration. Temperatures that exceed the optimum range identified by NMFS have been observed throughout the watershed from the upstream end of Howard Hanson Reservoir to the estuary. Temperatures exceeding potentially lethal limits have been measured in the lower Green River and Green/Duwamish estuary. As late as 1985, kills of adult chinook were reported in the Green/Duwamish estuary presumably from inadequate water quality parameter(s) that are not specified in this report

- In 1958, an earthen dam was constructed on the Black River, 1000 feet upstream from the Green River. Besides impeding salmonid migration into the Springbrook Creek system, this dam blocked flows from the Green River from backwatering into the remnant Black River, which could have provided some refuge habitat for salmonids during high flows. In 1972, the US Soil Conservation Service replaced the dam with the Black River Pumping Station (BRPS), which currently is operated by King County. Although it is equipped with upstream and downstream fish passage facilities, the BRPS can act as a barrier to migration of juvenile and adult salmonids due to inadequate screening, fishway design, and operation schedule.

- Adult salmonids cannot pass downstream via the downstream fish passage facility at the BRPS. Chinook salmon have been known to move upstream and become trapped in the Springbrook Creek system, where there is little if any suitable chinook spawning habitat.

- Streamside recreation or fish viewing activities have been observed to reduce the rate of upstream coho migration in the middle and lower Green River (Malcom 1996). In-water activities such canoeing have also been observed to displace adult coho salmon downstream (Malcom 1996). In addition to direct disturbances, mammalian odors, such as those arising from dogs and people, have been observed to temporarily disrupt and slow the upstream migration rate of adult coho and chinook salmon. Salmon will expend energy as they are displaced downstream and then, must again expend energy to move back upstream. In portions of the river with elevated temperatures, the energy loss and stress have the potential to increase pre-spawn mortality and reduce reproductive success. Displacement of salmon from redds may result in incomplete redd construction, selection of less preferred redd sites, and incomplete spawning.

DATA GAPS

- There is limited information on the location of natural barriers or historical fish distribution, particularly for the Upper Green River sub-watershed

- There is little information available to assess the historic impacts of operation of Tacoma's North Fork well field on fish passage in the North Fork Green River.

- The available information is inadequate to assess survival through Howard Hanson Reservoir.

- The rate of injury or mortality (if any) for fish passing the existing Tacoma Headworks is unknown.

- Data on fish passage barriers and other physical habitat in Newaukum and Soos Creeks is incomplete. This lack of physical habitat information is a WRIA-wide data gap for all tributary and mainstem reaches.

PART II: CHAPTER 2.6 NON-NATIVE SPECIES

KEY FINDINGS

The key findings on exotic plants and animals in the Green/Duwamish estuary, mainstem Green River, and major tributaries are listed below:

- Although adult Atlantic salmon, which have escaped from the commercial net pen industry, occasionally swim into the estuary and up the Green River, no juvenile Atlantic salmon have been observed in the system.

- Exotic warmwater fish are known to be present in lakes that drain to the mainstem Green River, but observations of these fish in the river are limited.

- Nutria and bullfrogs are the only exotic aquatic animal species other than fish observed in the Green River watershed upstream of the tidally influenced zone.

- In the Green/Duwamish Estuary, three exotic benthic invertebrates are known to occur - the amphipod *Grandidierella japonica*, the tanaid *Sinelobus stanfordi*, and the cumacean *Nippoleucon hinumensis.*

- Some riparian areas are dominated by dense colonies of exotic vegetation, such as blackberry, reed canary grass, and Japanese knotweed.

DATA GAPS

- No program exists that routinely monitors for or documents the presence and location of exotic species in the Green River watershed.

- The overall implications of non-native species invasions are not well understood.

PART II: CHAPTER 3. TRIBUTARIES WRIA-WIDE

KEY FINDINGS

- There is a general lack of physical habitat information for tributary streams.

- Most of the tributary streams downstream of Newaukum Creek are undergoing a conversion from forest and rural to a more urbanized environment.

- The riparian buffer of most tributary streams downstream of HHD is insufficient and is limiting natural salmonid production.

- There is a general lack of LWD throughout the tributary streams.

- High winter flows in streams in urbanized settings limit the reproductive success of salmonids because of scour and bedload movement and lack of refugia.

- Channelization of many stream reaches has eliminated stream channel complexity and limits natural production of salmonids.

- Summer low flow discharges are decreasing in some subbasins, which limits salmonid production of those species that have life history rearing trajectories that require over-summer rearing.

- In spite of the habitat degradation of most of the tributary streams, they are still important contributors to salmonid production.

DATA GAPS (H2)

- Information on numerous tributaries was not located or made available during the course of this investigation.

- There is a general lack of physical habitat information for tributary streams.

- Comprehensive barrier surveys need to be completed throughout the watershed.

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

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

- While LWD is generally lacking throughout the tributary streams, the amount and type of LWD that is present is not well documented.

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

- The quality of the sediments in the tributary streams is not fully known.

PART II: CHAPTER 4. ESTUARY AND NEARSHORE CONDITIONS

The information below is a summary of preliminary findings on salmonid factors of decline as determined in the draft *Reconnaissance-level Assessment of the State of the Nearshore Report* (SONR). 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 WRIA 9. Because the SONR is still in draft form, all information below is considered **preliminary and subject to change**. Readers are strongly encouraged to refer to the final document, which is scheduled for publication in January 2001.

KEY FINDINGS

- Early salmonid survival and growth can be an important determinant of adult returns. This is the life stage that the nearshore environment supports.
- 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.
- A wide variety of habitats in the nearshore are important to salmonids, including but not limited to eelgrass beds, kelp forests, flats, tidal marshes, subestuaries, beaches and backshores, and marine riparian vegetation.
- Sediment transport processes are critical for maintenance of important nearshore habitats.
- In WRIA 9, shoreline armoring and shoreline development have interrupted these processes. Approximately 75 percent of the WRIA 9 shoreline is armored.
- Eelgrass, kelp, marsh, flat, subestuary, beach and backshore habitats, and riparian vegetation, critical for juvenile salmonid support in the migratory corridor, have been lost. For example, 98 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 to much of this loss of habitat in the migratory corridor.
- Significant amounts of marine riparian vegetation have been lost from WRIA 9 shorelines. The Washington state Department of Natural Resources ShoreZone program estimates that only 11 percent of WRIA 9 shorelines have trees overhanging the intertidal zone. This loss may indicate a significant loss of critical functions that support salmonid habitat.
- Commercial, industrial, and residential development have contributed toxic sediments, chemicals and organic compounds to the water and sediments of the nearshore environment in WRIA 9. The Duwamish River is the most heavily contaminated portion of the WRIA 9 nearshore.

- Non-native species may be detrimental to salmonid survival in the nearshore in WRIA 9, but more data are necessary to identify specific effects of particular species.

DATA GAPS

- There is very limited data on the residence time or migration rates of juvenile salmonids in the nearshore.

- While scientists agree that juvenile salmonids use a variety of habitats in the nearshore, little detailed information is available. Actual juvenile salmonid use of eelgrass, kelp, flats, tidal marshes, subestuaries, beaches and backshore areas, are major data gaps.

- The complete functions and values of marine riparian vegetation are not fully understood.

- The carrying capacity of natural and altered nearshore habitat for salmonid support is not 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.

- Surveys of forage fish spawning areas are incomplete and stock assessments are absent.

- 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.

- Very little data on the functions and values of marine riparian vegetation exists.

- Sublethal effects of sediment and water contaminants on salmonids and other nearshore organisms are not known.

- Non-native species may be detrimental to salmonid species' survival in WRIA 9, but more data are 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.