4.1 INTRODUCTION

The scientific foundation for the Habitat Plan for the Green/Duwamish and Central Puget Sound Watershed (Water Resource Inventory Area 9 [WRIA 9]) is built upon knowledge of Chinook salmon, other salmonids, and habitat conditions within the watershed. This information is summarized in the WRIA 9 Strategic Assessment Report (King County Department of Natural Resources and Parks et al. 2004), which represents the scientific information used to support development of policies and actions in the WRIA 9 Habitat Plan to address salmonid habitat needs. This chapter of the Habitat Plan summarizes the key components of the Strategic Assessment relevant to the Plan.

The approach and guiding principles used to carry out the scientific work in the Strategic Assessment were influenced by several previous decisions by the WRIA 9 Steering Committee, including use of the viable salmonid population (VSP) framework, the Habitat Plan substantive scope and approach, and the Puget Sound Technical Recovery Team (TRT) technical guidance documents. The scientific foundation includes information regarding historical and current habitat conditions, salmonid population conditions, and water quantity and quality. Specific information is available on fish utilization, including juvenile migration and rearing patterns, habitat usage, and habitat limiting factors and factors of decline. This information was used to examine the functional linkages between habitat conditions and populations and help guide the development of conservation hypotheses and habitat-planning actions. (Functional linkages are the qualitative and quantitative relationships between habitat quantity and quality and the four VSP parameters of abundance, productivity, diversity, and spatial structure.) The Strategic Assessment report provides recommendations regarding necessary future conditions to support a viable population of Chinook salmon, as well as necessary future habitat conditions by subwatershed. The necessary future conditions, themselves, are also essentially hypotheses about what is thought to be necessary habitat to recover the Green River Chinook population. The conservation hypotheses and necessary future conditions were then used to develop habitat management strategies by subwatershed (see Chapter 5) to guide the development of policies and actions (see Chapter 7) included in this WRIA 9 Habitat Plan.

See Figure 4-3 for a visual presentation of the logic train that includes the elements described above.

4.2 GUIDING PRINCIPLES FOR THE SCIENTIFIC FOUNDATION

The guiding principles for the scientific foundation included the following:

- Viable salmonid population (VSP) parameter framework (McElhany et al. 2000);
- Habitat Plan Substantive Scope and Approach, approved by the WRIA 9 Steering Committee in 2002; and
- Technical guidance document developed by the Puget Sound Technical Recovery Team (2003) for integrated recovery planning.

Viable Salmonid Populations (VSP) in WRIA 9

The viable salmonid population (VSP) guidance (McElhany et al. 2000) was developed by NOAA Fisheries to guide conservation and recovery efforts. The VSP approach is intended to help establish delisting goals and the specific delisting criteria for the Puget Sound Evolutionarily Significant Unit. NOAA Fisheries will use this information to determine how many and which populations are necessary for a viable Evolutionarily Significant Unit. WRIA 9 technical work will help inform this determination. The VSP document contains guidelines for each parameter that a salmonid population must demonstrate in order to be considered viable. At the heart of the VSP concept are four parameters that describe a viable salmonid population:

- **Abundance**: defined simply as population size or numbers of fish at all life stages;
- **Productivity**: defined as how well the population is "performing" in its habitat, or the growth rate of the population;
- **Diversity**: defined as differences within and among populations in genetic and behavioral traits (e.g., life history trajectories); and
- **Spatial Structure**: defined as both the geographic distribution of fish in a watershed and the physical processes that lead to that distribution.

Coho (top) and Chinook (bottom) outmigrating juveniles sampled in the Duwamish transition zone. May 2005 photo.

Information about these VSP parameters were used to help guide research efforts, develop conservation hypotheses, and determine hypothesized necessary future conditions to support viable salmonid populations.

Habitat Planning Approach

The WRIA 9 Steering Committee approved an overall approach to habitat planning in 2002. The Committee specified the following:

- The Plan will use an ecosystem approach to watershed management, with a focus on federally-listed species. The process will include evaluation of ecosystem interactions, and the Plan recommendations will emphasize restoration of ecosystem processes where possible. This approach is expected to produce conditions that benefit all native aquatic species. Management of non-listed species will focus on preventing future listings and ensuring that protection of non-listed species is not put at risk;
- Because the Plan will use an ecosystem approach, the geographic area of focus will be the aquatic ecosystems within WRIA 9 and the landscape-level processes that affect these aquatic ecosystems. Where actions address listed species (Chinook and bull trout), the geographic area of focus would be the nearshore, mainstem river, and tributaries where listed species exist or could occur in the future; and
- In conducting research and studies to fill in information and data gaps, research focused on listed species following the viable salmonid population (VSP) guidelines, but information was also collected on other salmonid species when feasible and within budget constraints.

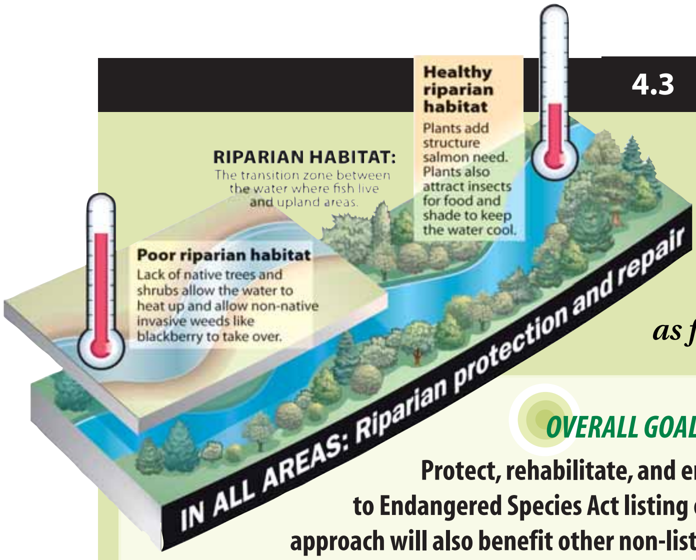
Puget Sound Regional Recovery Plan and Technical Guidance

The Shared Strategy for Puget Sound is a regional effort focused on the development of a collaborative recovery plan for Puget Sound Chinook and other listed species. The group represents federal, tribal, state, and local governments working towards common objectives, as follows (Shared Strategy 2001):

- The recovery and maintenance of an abundance of naturally spawning salmon at self-sustaining, harvestable levels;
- The broad distribution of naturally spawning salmon across the Puget Sound region; and
- Genetic diversity of salmon at levels consistent with natural evolutionary patterns.

The Shared Strategy effort is supported by the Puget Sound Technical Recovery Team (TRT). The TRT is an independent scientific body convened by NOAA Fisheries to develop technical delisting criteria and guidance for salmon recovery planning in Puget Sound. The TRT serves as science advisors to groups such as WRIA 9 charged with developing measures to achieve recovery goals. Specifically, the TRT developed technical guidance for watershed groups in Puget Sound regarding integrated recovery planning for listed salmon (Puget Sound Technical Recovery Team 2003). The document describes the biological content of a recovery plan to fulfill Endangered Species Act requirements and address broader recovery goals. It also specifies that the approach to recovery planning should address the concept of a viable salmonid population (VSP), including the four parameters: abundance, productivity, diversity and spatial structure. Shared Strategy will present its plan to NOAA Fisheries, which will ultimately provide the official regional recovery plan for Chinook salmon.

4.3 HABITAT PLAN GOALS AND OBJECTIVES



Habitat Plan goals and objectives were also established by the Steering Committee to guide the planning efforts. These included an overall goal, four specific goals and associated objectives, as follows:

OVERALL GOAL:

Protect, rehabilitate, and enhance habitat to support viable salmonid populations in response to Endangered Species Act listing of Chinook salmon and bull trout using an ecosystem approach. This approach will also benefit other non-listed aquatic species.

GOAL:

Protect and restore physical, chemical, and biological processes and the freshwater, estuarine, and marine nearshore habitats on which salmonids depend.

Objectives:

- *Protect and restore natural ecosystem processes; where restoration is not possible, consider sustainable engineered solutions;*
- *Protect currently functioning habitat;*
- *Protect and restore headwater areas, streams, and wetlands where feasible;*
- *Encourage management of flows to support habitat-forming processes; and*
- *Encourage management of land use changes and development standards to minimize impacts.*

GOAL:

Protect and restore habitat connectivity where feasible.

Objectives:

- *Encourage maintenance and protection of corridors that link habitats and (re) connect freshwater, estuarine, and saltwater habitats and their associated zones, as required by salmonids during all life stages;*
- *Connect side channels and floodplain areas to the mainstem where feasible; and*
- *Restore fish access where limited by dams, culverts, revetments and other barriers, where feasible.*

GOAL:

Protect and improve water quality and quantity conditions to support healthy salmonid populations.

Objectives:

- *Reduce processes and inputs that degrade water quality where possible;*
- *Enhance riparian vegetation to improve water quality conditions where possible; and*
- *Encourage management of water withdrawals and groundwater recharge to maintain cool water inputs in key areas.*

GOAL:

Provide an implementable plan that supports salmon recovery.

Objectives:

- *Promote informed, sustained commitment of key watershed interests;*
- *Implement an adaptive management approach to respond to changes and to ensure continued effectiveness;*
- *Develop a strategy to secure adequate funding for implementation;*
- *Obtain support of WRIA 9 interlocal agreement member jurisdictions, federal and state agencies, Tribes, the agricultural community, and the business community in their recovery efforts;*
- *Provide public outreach and education, and engage the public in stewardship, restoration, and enhancement activities;*
- *Coordinate with other WRIA 9 planning activities; and*
- *Provide management actions that are doable, practical, and effective.*

4.4 SALMONID ECOLOGY AND ECOSYSTEM MANAGEMENT

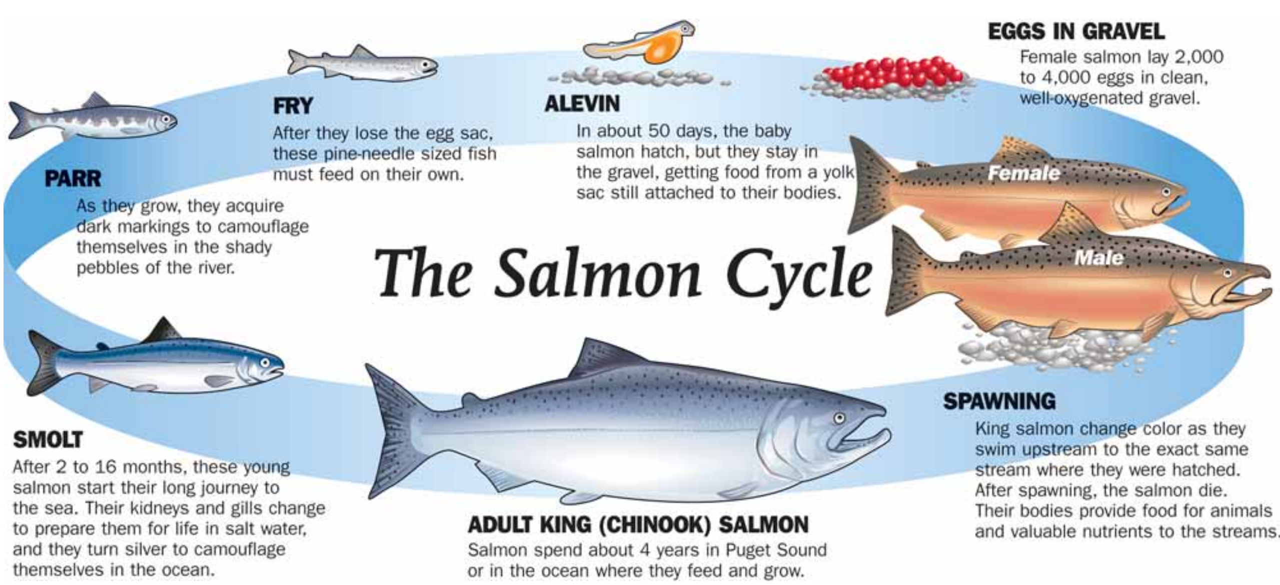
Chinook salmon and other salmonids (including bull trout) require use of and access to distinct aquatic habitats for each phase of their life cycle: adult maturation and migration, spawning, incubation of embryos and alevins, emergence of fry, juvenile rearing, and smolt migration. To protect and restore habitat for salmonids, the natural processes that produce the features and characteristics of aquatic habitats must be maintained or restored. The contribution of habitat loss and modification on the current status of salmonid populations is documented in Spence et al. (1996). Intrinsic to this philosophy is that a holistic watershed and ecosystem approach is essential for preventing further habitat degradation, maintaining habitats that are relatively intact, aiding in the recovery of species at risk of extinction, and benefiting many other aquatic organisms.

Understanding the aquatic habitat needs of Chinook salmon requires a solid understanding of salmonid population biology and how salmonids utilize habitat. A conceptual model of natural Green River Chinook salmon is included in Ruggerone et al. (2004). The conceptual model includes information on life history diversity such as (1) migration and spawn timing of returning adults, (2) the age composition of adults, and (3) the residence time and body size of juveniles in different parts of the watershed (e.g., river, estuary, marine nearshore habitats). The bulk of the information available in WRIA 9 covers adult spawning (location, timing, number of redds [spawning egg nests]) and juvenile rearing (diet and growth, out-migration timing, aggregations of juveniles). More limited information is available on habitat capacity (spawning or rearing), predation, and egg-to-fry survival.

The Green/Duwamish River is used by bull trout for foraging, but no spawning populations have been detected. Bull trout have been observed on the mainstem up to Newaukum Creek and it is presumed that bull trout utilize the Green River up to the Tacoma Headworks at river mile 61 (Lakey 2004).

The ecosystem management philosophy of the Habitat Plan includes eight components:

1) It seeks to be sustainable by virtue of maintaining the ecosystem structures and processes necessary to provide the habitat needs of Chinook salmon and other salmonids (versus solely focusing on single-species management).
2) It contains clearly defined goals and desired future conditions necessary for sustainability (see Section 4.5).
3) It is founded on sound ecological principles and based on the best science and models currently available, taking into account the characteristics and challenges of the watershed.



4) The complexity and connections of watershed processes are a major factor in determining the number, characteristics, and geographic distribution of the current and historical salmonid populations and, therefore, in making habitat management decisions.
5) It seeks to increase ecological capacities, not a particular state, over the long term in recognition of environmental change and evolution. This management approach supports conservation and recovery of anadromous salmonids throughout Puget Sound because connectivity among habitats is maintained, allowing the invasion of vacant habitats, sufficient genetic diversity to allow successful colonization of these habitats, and refugia from which dispersal can occur.
6) Both spatial and temporal scales were taken into consideration when evaluating the ecosystem processes of the watershed. This allows an understanding of the behaviors of the processes at a given location due to management actions and other human-induced perturbations.

The seventh and eighth components of the ecosystem management approach are related to implementation.

7) The Habitat Plan recognizes that humans are part of the watershed's ecosystem, as well as its source of most significant challenges to sustainability. It takes into account social and economic systems of the watershed.
8) It acknowledges that the scientific understanding of the ecosystem will continue to grow and current models and paradigms of ecosystem function and structure will be refined as more is learned. Adapting to new information as it becomes available and acknowledging limits to scientific understanding are central to the ecosystem management construct of this Plan.

4.5 SCIENTIFIC FOUNDATION

The WRIA 9 Habitat Plan is based on scientific research and analysis of the salmonid population and habitat conditions in the watershed. This section describes the scientific foundation that underlies the Plan, the research that was conducted in order to prepare the Plan, and the rationale underlying the hypothesized necessary future conditions to support a viable salmonid population of Chinook. Although the WRIA 9 Technical Committee had a reasonable amount of information about salmon habitat at its disposal when it began the Strategic Assessment, more information was necessary, especially concerning the Green River Chinook salmon population. Research focused primarily on Chinook following the viable salmonid population (VSP) guidelines. Information pertaining to other salmonid species was collected when feasible and within budget (requiring 20-30% more effort than that expended on Chinook only).

Ecological Synthesis Approach (Salmonid Ecology and Current Versus Historical Habitat Approach)

In carrying out the Strategic Assessment, the Technical Committee needed to develop an approach for linking the quantity and quality of habitat to salmon population parameters in a spatially explicit manner. Phase 1 of what was termed the "functional linkages evaluation" included reviewing and comparing a number of analytical models and tools for carrying out this task. Some of the tools are built on statistical relationships among parameters and some are scientific models built from a general understanding of how ecosystem processes work and the interaction between variables. Seven approaches were selected for review and comparison based on their stated purpose, history of use, and potential for use in WRIA 9: Ecosystem Diagnosis and Treatment (EDT), EDT-Light, SHIRAZ (a salmon habitat and life-cycle model), Qualitative Habitat Assessment (QHA), Salmonid Watershed Assessment Model (SWAM), Cumulative Risk Initiative (CRI), and a synthesis of available science related to salmon ecology and historical versus current habitat, which was named the "Ecological Synthesis Approach."

The Phase 1 report (Anchor Environmental and Natural Resources Consultants 2003), concluded there is no obvious choice, nor a choice upon which WRIA 9 should depend exclusively. However, two options were recommended for further consideration: SHIRAZ by itself or coupled with other statistical tools such as Cumulative Risk Initiative (CRI), or the Ecological Synthesis Approach. The Technical Committee reviewed the Phase 1 report and chose the Ecological Synthesis Approach. The ability to provide information that would be useful in the development of habitat management strategies and actions for the Habitat Plan was an important consideration in this decision. The Technical Committee concluded that the Ecological Synthesis Approach, in concert with adaptive management and monitoring plans could meet the needs of WRIA 9.

The Ecological Synthesis Approach does not use a single model, but relies on information from as many sources as possible, including information on current and historical habitat quantity and quality and fish use, habitat limiting factors analyses, statistical models, and scientific models as available. It provides a series of conservation hypotheses to guide the development of habitat management strategies and actions. In contrast to the other models reviewed, the Ecological Synthesis Approach is a less structured approach that does not have an underlying framework or a series of *assumed* functional relationships upon which decisions are made. Instead, it is a practical approach based on empirical observations of how Chinook salmon currently use habitats in WRIA 9 in the context of current versus historical habitat. Conservation hypotheses about fish use and habitat, based on available science, will be tested through quantitative monitoring projects.

Overview of Key Components of the Strategic Assessment

The Strategic Assessment Report is a summary of the technical work carried out in support of the WRIA 9 habitat planning effort. It is available online at http://dnr.metrokc.gov/Wrias/9/StratAssess.htm. This chapter presents information from the Strategic Assessment by subwatershed instead of by topic. This is done to make it easier for the reader to track the available information and focus on a particular geographic area of interest. For purposes of providing an overview of the Strategic Assessment and laying out the sections that follow, this section provides a brief overview of the components of the Strategic Assessment (King County Department of Natural Resources and Parks et al. 2004).

Section 2 of the Strategic Assessment report summarizes the **historical habitat and salmon population conditions** in WRIA 9. An effort to compile and analyze historical salmonid population conditions was undertaken to gain an understanding of Chinook and other salmonid species and to assist with estimating historical abundance, life cycle productivity, life history and genetic diversity, and spatial distribution. By examining how the river, floodplain, and estuary functioned historically, insight was gained on how the Green River salmonid species adapted to their habitat and how historical habitat conditions supported a viable population. In addition, a historical reconstruction of riverine and estuarine environments of the Upper Green River, Middle Green River, Lower Green River, and Duwamish Estuary was created. This information served as a benchmark or template for defining hypothesized necessary future conditions that support long-term viability of Green River Chinook salmon. The findings of these analyses are presented in Collins and Sheikh 2004, Bergeron 2004, and King County Department of Natural Resources and Parks and WRIA 9 2004 (See Chapter 10 for full references).

Section 3 of the Strategic Assessment report summarizes the findings on **current conditions, with an emphasis on aquatic habitat, water quantity, water quality, and salmonid population conditions**. This information is drawn from the Habitat Limiting Factors and Reconnaissance Assessment Report (Kerwin and Nelson [Eds.] 2000) and numerous Strategic Assessment reports (Anchor Environmental 2004a, Anchor Environmental 2004b, Herrera Environmental et al. 2004, King County Department of Natural Resources and Parks 2004a, King County Department of Natural Resources and Parks 2004b, R2 Resource Consultants 2002, Taylor Associates and King County Department of Natural Resources and Parks 2004, and TerraLogic and Landau 2004). Some information is focused on the Green/Duwamish River mainstem, such as the aquatic habitat reports, and some information is more watershed-wide, such as water quality conditions. Because of time and resource constraints, information on nearshore habitat conditions and water quantity conditions is incomplete. Information on current conditions was used to compare with historical conditions, and it also serves as a baseline for monitoring changes over time as the Habitat Plan and related actions are implemented.

Section 4 of the Strategic Assessment report summarizes the analysis **comparing historical and current habitat conditions**. This comparison was used to identify and quantify how aquatic habitats have changed over time and provide information to support development of necessary future habitat conditions. The focus for the aquatic habitat included mainstem and tributary channels and in-channel wood for the Upper Green River, Middle Green River, Lower Green River, and Duwamish Estuary Subwatersheds. These findings also were used to support the development of conservation hypotheses, establish necessary future habitat conditions targets, and guide habitat restoration efforts. The findings are presented in full in the Comparison of Historical and Current Habitat Conditions in WRIA 9 (King County Department of Natural Resources and Parks and WRIA 9 2004).

Section 5 of the Strategic Assessment report summarizes the findings of numerous independent salmonid studies carried out over the past four years and synthesizes and connects important information related to **salmonid ecology** in WRIA 9. Studies carried out during or after 2000 differed from past studies because a program was initiated in that year to mass mark juvenile Chinook released from the Soos Creek hatchery. Mass marking made it possible to distinguish hatchery Chinook from natural Chinook, allowing interactions between hatchery and naturally spawned fish to be studied. Most recent studies focus on Chinook migration timing and relative abundance and growth, which can be used to indirectly assess WRIA-wide habitat use. In addition, similar baseline data were concurrently collected for other non-target salmonid species, including coho and chum salmon.

Numerous studies and key findings that contribute the understanding of salmon ecology in WRIA 9 are summarized below, including: Anchor Environmental and Ruggerone et al. 2004, Berge and Mavros 2001, Brennan et al. 2004, City of Seattle Salmon Team 2003, Goetz et al. 2003, Goetz and Jeanes 2004, Hahn and Cropp 2003, Malcom 2002, Ruggerone et al. 2004, Nelson et al. 2004, R2 Resource Consultants 2001, Ruggerone and Jeanes 2004, Seiler et al. 2002, Sobocinski 2003, Toft et al. 2004, Weitkamp et al. 2000, and Brennan (Ed.) 2001. A description of the current knowledge regarding Chinook life cycle use of habitat in WRIA 9 is contained in the Conceptual Model of the WRIA 9 Research Framework (Ruggerone et al. 2004). The conceptual model is a tool to assist recovery planning and provides guidance for developing research questions. Most of the information used in the model was from WRIA 9 studies, but information from other watersheds also was used to support assumptions regarding Chinook ecology when WRIA 9 watershed information was lacking. The model discusses Chinook life history for different stages (adult, egg, juvenile) and alternative juvenile life history trajectories.

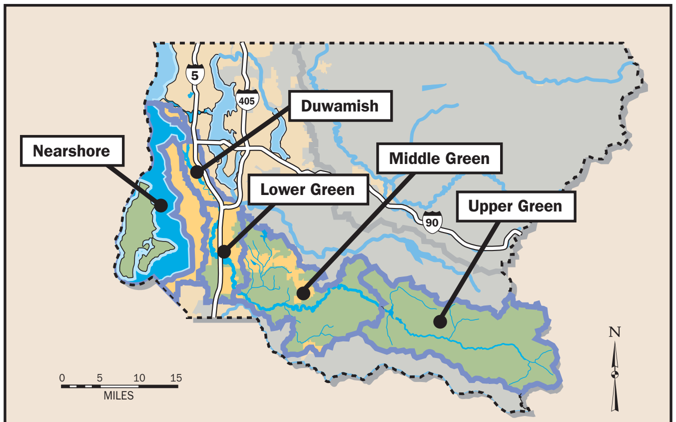
Section 6 of the Strategic Assessment report summarizes the **functional linkages evaluation** examining the relationships between habitat conditions and salmonid populations. Functional linkages are defined here as qualitative and quantitative relationships between habitat quantity and quality and the four viable salmonid population parameters. The evaluation leads to the development of conservation hypotheses that provide a basis for habitat management strategies and management actions. The Ecological Synthesis Approach provides a way to link quantity and quality of habitat to salmon population parameters in a spatially explicit way. The functional linkages evaluation is a synthesizing step in the sequence of technical tasks that support habitat planning in WRIA 9.

Section 6 also includes conservation hypotheses. A **conservation hypothesis** is an estimate of how improvements in habitat conditions and habitat-forming processes will lead to changes in the four viable salmonid population (VSP) parameters. As more information becomes available during Plan implementation, these hypotheses will be tested and refined to reflect improved understanding of habitat conditions and population response. A total of 34 conservation hypotheses in seven *categories* — the five subwatersheds, watershed-wide, and non-habitat hypotheses — were developed that will be tested through a monitoring and evaluation program (see Appendix E). These conservation hypotheses were evaluated based on seven criteria: viable salmonid population (VSP) parameters, overall population viability, salmonid life stages affected, magnitude of effect, hypothesized necessary future conditions, certainty, and habitat factors of decline.

This evaluation resulted in prioritization into three tiers for purposes of identifying relative importance (see Appendix D). Tier 1 conservation hypotheses are relatively more important than Tier 2 conservation hypotheses, which are relatively more important than Tier 3 conservation hypotheses.

Section 7 of the Strategic Assessment report summarizes the **necessary future conditions** to support a viable salmonid population in WRIA 9 with a focus on Chinook salmon (WRIA 9 and King County Department of Natural Resources and Parks 2004). Using scientific guidance for population recovery developed by the Puget Sound Technical Recovery Team, NOAA Fisheries, and Shared Strategy, viable salmonid population (VSP) goals and objectives were established for the Green River Chinook population. Using ecosystem and habitat guidance from many sources, the VSP goals were translated into more explicit ecosystem and habitat goals that form the basis for strategies and actions in the Green/Duwamish River and WRIA 9. Using information from historical and current habitat and population conditions, including data on salmonid utilization of habitats, the necessary future conditions are targets from management strategies and actions can be developed. As mentioned at the beginning of this chapter, the necessary future conditions are themselves hypotheses.

Finally, Section 8 of the Strategic Assessment report summarizes key findings from the Strategic Assessment and addresses key questions linking the conservation hypotheses developed in the functional linkages work to the viable salmonid population and habitat goals identified in the necessary future conditions work. This section summarizes the overall scientific foundation for the WRIA 9 Habitat Plan.



King County WRIA 9 Subwatersheds

The sub-sections below are organized by subwatershed and present information on historical and current habitat conditions, changes in habitat conditions, fish utilization, conservation hypotheses and necessary future conditions. Also included is information on water quantity and water quality and the watershed Chinook salmon population.

The Green/Duwamish and Central Puget Sound Watershed (WRIA 9)

Historical Conditions

Prior to European influence, the greater Duwamish watershed was approximately 4,077 km^2 and included the White River, Black River, Cedar River, Green River, Duwamish River, Sammamish River, and Lakes Washington and Sammamish, as well as numerous other salmon spawning tributaries. The historical watershed contained approximately 3,060 km of streams accessible to fish (U.S. Army Corps of Engineers and King County 2000). By 1916, the historical watershed had been reduced by 70% and accessible streams reduced by 93% (U.S. Army Corps of Engineers and King County 2000). The White and Cedar rivers were reengineered and diverted in the early 1900s and the Duwamish River was straightened in 1906. The construction of the Ship Canal in 1916 lowered water levels in Lake Washington that lead to the dewatering of the Black River and blocked migration of salmonids to Lake Washington and Lake Sammamish via the Duwamish River.

Of the major drainages listed above, the WRIA 9 watershed today consists only of the Green/Duwamish River watershed. For analytical purposes, present-day WRIA 9 is divided into the five subwatersheds described below. In addition, 13 assessment segments were identified for analyzing the Green/Duwamish River mainstem aquatic habitat (Table 4-1). The following subsection is a summary of water quantity and quality conditions in the watershed.

Water Quantity and Water Quality

Water quantity conditions, including instream flows, groundwater, habitat-forming flows, and out-of-stream water use affect the quality and quantity of habitat available for different salmonid life stages. Historical changes combined to have a profound effect on water quantity conditions, including the diversion of the White River in 1906, the Cedar/Black River in 1913, the construction of the Tacoma Headworks (diversion dam) in 1911-1913, and construction of the Howard Hanson Dam for flood control in 1962. In addition, there were extensive land use changes that converted forests to urban, industrial, and agricultural uses, as well as numerous smaller water diversions and groundwater withdrawals that affected water quantity conditions. Diversion of the White River in particular reduced summer low flows because of the loss of glacial meltwater. Tacoma Public Utilities continuously diverts up to 113 cubic feet per second (cfs) from the mainstem. As a result of the Howard Hanson Dam, floods greater than 12,000 cfs (formerly the two-year event at the U.S. Geological Survey Auburn stream gage) have been prevented, while the duration of moderate flows (3,000 to 5,000 cfs) has increased due to metered release of floodwaters stored behind the dam.[1]

Urban development in the Duwamish Estuary, Lower Green River, and Middle Green River Subwatersheds

TABLE 4-1: Assessment Segments of the Green/Duwamish River Used To Analyze Aquatic Habitat Change

River Mile*	Segment ID	Assessment Description	Subwatershed	Historical Channel Type	Current Channel Type	Slope (%)
0–1.5	1	Tidal Delta	Duwamish	Estuarine	Artificial Constrained	0.09
1.5–11	2	Duwamish Valley	Duwamish	Estuarine	Artificial Constrained	0.003
11–31.3	3	Lower Green Valley	Lower Green	Palustrine (river mile 25 to 11); Floodplain	Artificial Constrained	0.05
31.3-45.3	4	Middle Green Valley	Middle Green	Unconfined Floodplain	Unconfined Floodplain	0.23
45.3–57.6	5	Green Rive Gorge	Middle Green	Large Contained	Large Contained	0.85
57.6-60.5	6	Boulder Zone	Middle Green	Unconfined Floodplain	Unconfined Floodplain	0.60
60.5-64.4	7	Eagle Gorge	Middle Green	Large Contained	Large Contained	0.75
64.4-72.7	8	Reservoir Plus	Upper Green	Unconfined Floodplain	Seasonally Inundated	0.55
72.7-77.0	9	Smay Valley	Upper Green	Unconfined Floodplain	Unconfined Floodplain	0.72
77.0-77.9	10	Mile Canyon	Upper Green	Large Contained	Large Contained	0.02
77.9-84.1	11	Lester	Upper Green	Unconfined Floodplain	Unconfined Floodplain	0.83
84.1–88.3	12	Intake Valley	Upper Green	Unconfined Floodplain	Unconfined Floodplain	1.50
88.3-93.6	13	Headwaters	Upper Green	High Gradient Confined	High Gradient Confined	11.30

** River miles are estimated from Williams et al 1975*

1. For much of this chapter, metric measurements are used in keeping with scientific practice and the information in the Strategic Assessment and other scientific reports. However, English measurements are used for locations along the river [river miles] and flow [cubic feet per second].)

has resulted in substantial increases in stormwater runoff from small tributary streams and subbasins. This in turn has contributed to larger and more frequent peak flows during the winter and reduced recharge of shallow aquifers that formerly sustained flows during the late summer and fall. Water withdrawals and diversion of springs or other surface water sources also serve numerous cities and water districts in the Lower and Middle Green River Subwatersheds. These withdrawals, together with exempt wells further reduce the water available to streams and the mainstem. An analysis of natural flow conditions, conducted as part of the Reconnaissance Assessment (Kerwin and Nelson [Eds.] 2000), revealed the following findings:

- Flows less than 302 cubic feet per second occurred 49% more often and summertime means and annual minimum extremes were consistently longer. This flow regime:
  - Reduces spatial habitat for rearing, decreases water depth in riffles, glides, and pools and may constrain upstream adult Chinook migration;
  - Reduces water velocity, potentially constraining downstream juvenile movement; and
  - May decrease wetted width of river available for spawning, forcing Chinook to spawn closer to the thalweg (deepest part of the river), where scour potential is generally greater.

- The annual minimum flow occurred two weeks earlier, in late August rather than mid-September. This timing of low flow:
  - May affect timing of upstream adult migration; and
  - May create warmer, more stressful instream conditions where temperatures already can exceed salmon preferences.

- Flood peaks were reduced, with no flood flows above 11,000 cubic feet per second at the Palmer gage below the Tacoma Headworks (compared to one day flows ranging up to 18,000 cubic feet per second (and peak flows even higher) and exceeding 11,000 cubic feet per second in one out of every six years). This reduction in peak flows:
  - May mean the river has less ability to create new side channel habitat, reducing habitat for salmon as well as recruitment of gravel from the floodplain; and
  - May mean the river has less ability to maintain existing side channels and recruit wood into the channel, reducing overall habitat quality.

- Durations of moderate flood flows (greater than 5,900 cubic feet per second) were longer by 39%. This increased duration of flows:
  - May increase frequency or duration of scour of riverbed gravel. Effects are compounded as fewer side channels (where scour would be less) are being created so more of the population spawns in the mainstem.
- Water quality conditions in the watershed are summarized from recent water quality reports (Kerwin and Nelson [Eds.] 2000, Taylor Associates and King County 2004, Herrera Environmental et al. 2004). Data were compared to Washington State water quality standards (WAC 173 201A), U.S. Environmental Protection Agency water quality criteria and appropriate toxicity screening thresholds to assess potential for biological significance. Temperature and dissolved oxygen are the parameters of greatest concern to salmonids. The following represent some key findings of the temperature assessment (Taylor Associates and King County Department of Natural Resources and Parks 2004):
  - All 17 mainstem locations exceeded the 2003 State water quality temperature standards for 10 or more days during the 2001, 2002, and/or 2003 water years, with average exceedances ranging from 0.4 to 3.5°C;
  - Temperature data for 52 of the 86 monitoring stations violated the applicable 2003 State temperature standard on some or frequent occasions;
  - Station TM-7 (Meridian Valley Creek) had the highest temperature exceedance with an average exceedance of 23.1°C which can be lethal for salmonids. Stations CO1 (Covington Creek) and GRT02 (Springbrook Creek) had average exceedances of 21.5°C and 21.4°C, respectively, which have the potential for migration blockage; and

- An additional 29 stations had average exceedances between 18 and 21°C (potential for impairment), with four sites greater than 20°C.

Adult migration is a key life history stage affected by current temperature exceedances. Exceedances during adult migration may also indicate inadequate early fall cooling required to support adequate spawning, incubation, and rearing temperatures. Coho and steelhead subyearlings and steelhead yearlings that remain in freshwater throughout the summer after emergence are another key life stage affected by temperature exceedances.

Dissolved oxygen is an important water quality parameter for salmonids and other aquatic life. Washington State standards require that dissolved oxygen concentrations exceed 9.5 milligrams per liter (mg/L) in freshwaters designated for core salmonid rearing and 8.0 mg/L in freshwaters designated for noncore salmonid rearing (WAC 173 201A). Dissolved oxygen is a 303(d) listed parameter for each of the four major streams (Springbrook, Mill, Soos, and Newaukum Creeks). Among all sites monitored, dissolved oxygen concentrations ranged from 3.0 to 13.7 mg/L during baseflow and from 1.5 to 14.3 mg/L during storm flow. Among the four major stream sites, the dissolved oxygen standard was exceeded with the greatest frequency in Springbrook Creek. The dissolved oxygen standard was never exceeded at the Soos and Newaukum Creek mouths, although few samples were collected during summer base flow when the lowest dissolved oxygen concentrations would be expected.

For most salmonid life stages (juvenile rearing and migration and adult migration), slight, moderate, and severe production impairment occur at 6 mg/L, 5 mg/L, and 4 mg/L, respectively (U.S. Environmental Protection Agency 1986). Acute mortality occurs at 3 mg/L. The minimum values observed at four sites during baseflow (Springbrook Creek, Black River, Mill Creek tributary to Springbrook, and Soosette Creek) and one site during storm flow (Newaukum Creek tributary) were 4 mg/L or below, leading to potential severe impairment to salmonids.

Watershed-Wide Conservation Hypotheses

Based on the results of the habitat and population analyses, six conservation hypotheses were developed that are potentially applicable to all subwatersheds in WRIA 9. Three of these were rated as Tier 1 hypotheses and three were rated as Tier 2 hypotheses:

All–2 (Tier 1): Protecting and improving riparian conditions by adding native riparian vegetation and controlling invasive species will enhance habitat quality by improving water quality, stabilizing streambanks, providing overhanging vegetation and large woody debris, and contributing organic matter, nutrients, and terrestrial prey items, thereby leading to greater juvenile salmon growth and higher survival;

All–4 (Tier 1): Allowing natural flows (including low flows and habitat-forming flows) in a relatively unconstrained river channel will enhance habitat diversity and provide habitats that can support spawning and rearing salmon at a greater variety of flow conditions, thereby leading to expanded salmon spatial distribution, greater juvenile salmon growth, and higher survival. [Note: May be less applicable to the marine nearshore.];

All–6 (Tier 1): Preventing new bank/shoreline armoring and fill and removing existing armoring, fill, and other impediments (e.g., levees) will enhance habitat quality and quantity and lead to improved juvenile salmon survival, spatial distribution, and diversity;

All–1 (Tier 2): Protecting and improving water quality (e.g., temperature, dissolved oxygen, turbidity, and chemical contamination conditions) by addressing point and nonpoint (specifically stormwater runoff and agricultural drainage) pollution sources will enhance habitat quality and lead to greater juvenile salmon growth, disease resistance, and survival. Improved water quality will also enhance survival of adult salmon, incubating salmon eggs, and salmon prey resources, such as forage fish;

All–3 (Tier 2): Protecting and improving access to tributaries will increase the quantity of available habitat, particularly for juvenile Chinook and coho salmon, and lead to expanded salmon spatial distribution, greater juvenile salmon growth, and higher survival; and

All–5 (Tier 2): Preserving and protecting against watershed and upland impacts by implementing low impact development techniques, including minimizing impervious surfaces, will maintain habitat quality by helping maintain flow and reduce sedimentation, thereby leading to greater salmon survival.

Watershed-Wide Priorities

As an initial approach to developing watershed-wide guidelines, the Science Panel[2] considered how alternative population models and structures, along with selected habitat limiting factors, might be used as a basis for making decisions about watershed-wide priorities (Anchor Environmental and Grette Associates 2005a). Several assumptions have been considered that influence the relative importance of certain geographic areas and types of habitat management actions over others. Assumptions include the basis of different life history trajectories (genetic vs. environmental) and the potential existence of "limiting habitats" that limit the effectiveness of habitat actions that improve survival upstream. Four limiting habitats were considered, including:

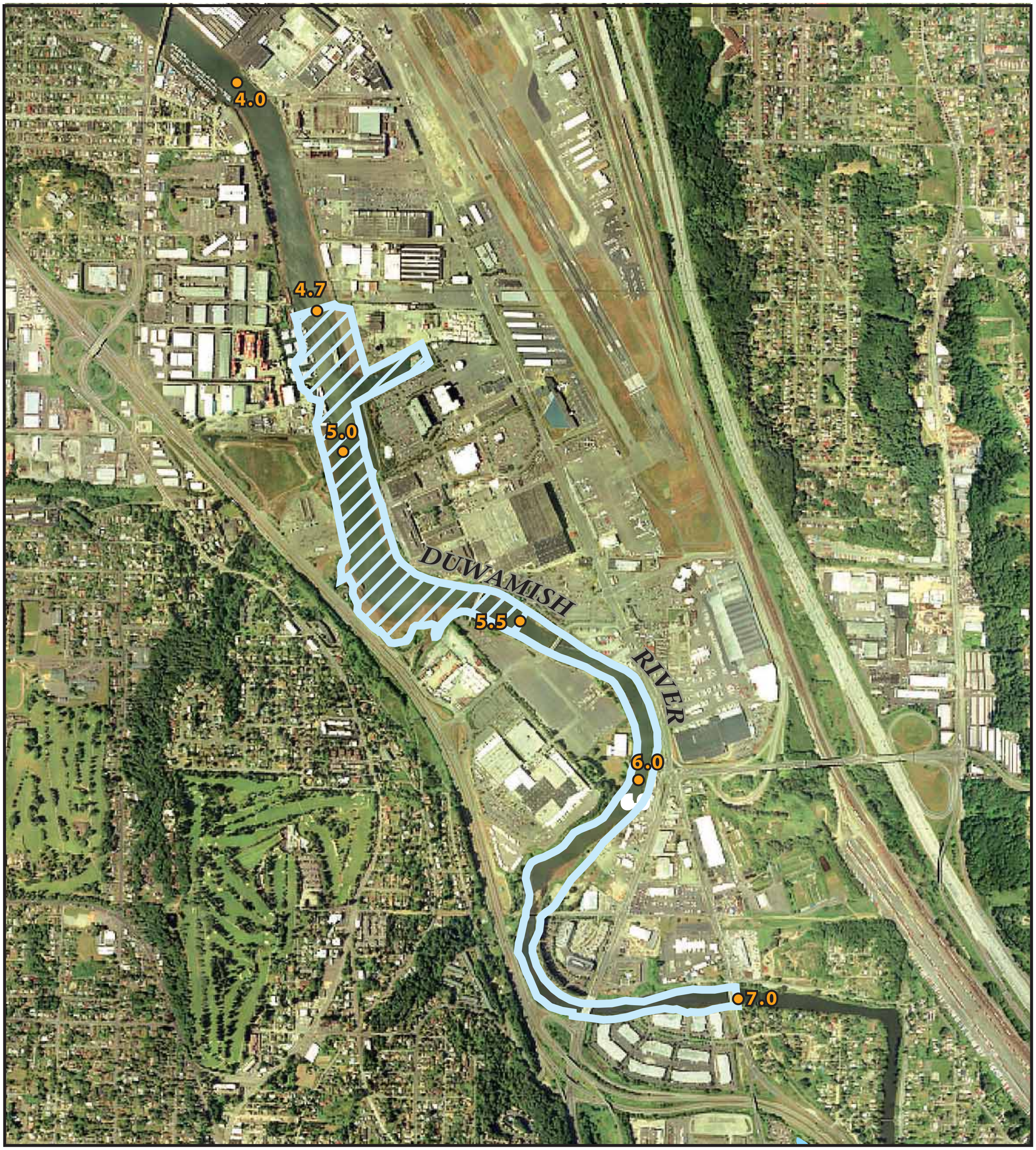
- Duwamish Estuary transition zone habitat;
- Middle Green and upper Lower Green River spawning habitat;
- Middle Green River, Lower Green River, Duwamish Estuary, and marine nearshore rearing habitat; and
- Howard Hanson Dam, which impedes salmon migration and affects downstream habitat formation (e.g., gravel transport, altered flow regime).

In making decisions about watershed-wide priorities it is important to recognize that increasing productivity of the Chinook population is a key short-term (i.e. 10 year) priority (see Chapter 5), while over the long term (i.e. 50 years or more), lack of spatial structure is most threatening the viability of the Chinook population. With improvements to spatial structure, greater diversity will also follow. While developing spatial structure is a longer-term process, it is recognized that it needs to begin now.

Solving the fish passage, gravel, and large woody debris transport issues at Howard Hanson Dam (and fish passage at the Tacoma Headworks) is a significant opportunity for expanding spatial structure and diversity. However, it was recognized that these issues are being addressed by U.S. Army Corp of Engineers and Tacoma Public Utilities projects in the near-term timeframe of the Habitat Plan, and thus they were not considered further in this prioritization. Review of the evidence supporting the other three potential limiting habitats indicated that a compelling case could not be made that any one limiting habitat is more important than the others, or should be singled out as <u>the</u> most important factor.

On May 12, 2005, the Steering Committee adopted the three priority geographically-specific limiting habitats noted above and supported the slight prioritization of the transition zone habitat over the other areas for project implementation within the first 10 years of the Habitat Plan (see Policy MS1 in Chapter 5). Specifically, the Duwamish Estuary transition habitat will have a 40% weighting in terms of overall action funding, while the other two areas (spawning and rearing habitats) will have 30% weightings each. An adaptive management approach will be taken so that relative weights and geographic specificity can be altered in accordance with changing conditions and scientific discoveries. (See Figure 4-1 for the estimated location of the Duwamish transition zone.)

2. A group of scientists convened in late 2004 to develop a process and review proposed habitat actions in WRIA 9 for technical merit.



Map produced by: King County Department of Natural Resources and Parks, WLR Visual Communications & Web Unit **File:** 0508_W9HP_DuwTzone.ai lpre

FIGURE 4-1

Documented Duwamish Transition Zone

GREEN / DUWAMISH AND CENTRAL PUGET SOUND WATERSHED

N

0 1/4 1/2 Mile

August 2005

● 1.0 **River Mile and Number**
(Estimated from "Catalog of Washington Streams and Salmon Utilization", (Williams, et al. 1975).

Duwamish Transition Zone
(Rm 7.0-5.5, according to data in Strategic Assessment)

Additional Likely Transition Zone
(According to preliminary data in 2005)

Upper Green River over Segment 9 (river miles 72.7-77), looking west. December 2003 photo.

Upper Green River Subwatershed

Historical Conditions

Historically, the Upper Green River Subwatershed provided extensive spawning and rearing habitat for salmon and trout. There were approximately 7,735 km of mapped stream channels, including 267 km of fish-bearing streams (U.S. Forest Service 1996). It is assumed that the upper watershed supported mostly spring Chinook (adult Chinook that begin spawning migration in the spring), coho, winter and summer steelhead, and resident trout, although the lower reach may have supported fall Chinook (adult Chinook that begin spawning migration in the fall) as well. Important overwintering habitat and refugia for these species included areas with reduced water velocities, relatively constant year-round temperatures, and protection from predators. According to Cutler (2000), the presumed upstream extent of use by Chinook, steelhead, and coho was estimated to be approximately river mile 91.8, where the stream gradient steepens substantially (see Figure 7-1 for location of river miles). Historically, large woody debris in the streams may have ranged from 240 to 2,080 pieces per kilometer (Cedarholm et al. 1989; Fox 2001). These quantities would have provided a critical structure and habitat complexity.

Current Conditions

Current habitat information on the Upper Green River is limited to aquatic and riparian habitat conditions in the mainstem. Channel characteristics vary by reach and were calculated from the 1998 mapped channel location (King County Department of Natural Resources and Parks 2004b). There are five assessment segments within the Upper Green River from river mile (RM) 64.5 to 88.3. Segment 8 (RM 64.5 to 72.7) is the lowest segment of the Upper Green River, including those areas between RM 64.5 – 69 that are completely inundated or seasonally inundated by Howard Hanson reservoir. The North Fork Green River is a major tributary within this segment. The channel is constrained along approximately 22% of the channel length from railroad lines and logging roads that prevent lateral channel migration. Segment 9 (RM 72.7 to 77) is unconfined and flows through a low gradient, broad alluvial valley and floodplain and contains one core area for spawning as predicted by Martin et al. (2004). Segment 10 (RM 77 to 77.9) is a confined (V-shaped valley with little to no floodplain) segment that flows through a steep, gradient (0.6%) floodplain. This reach appears to be effectively transporting sediment and channel width has decreased over time. Segment 11 (RM 77.9 to 84.1) is located within glacial alpine deposits and the channel is unconfined within the valley bottom, with a gradient of 0.8% and contains one core area for spawning as predicted by Martin et al. (2004). Segment 12 (RM 84.1 to 88.3) is a confined segment with inclusions of lower gradient, broad alluvial valley portions and contain two core areas for spawning as predicted by Martin et al. (2004). Railroads and forest roads constrain the mainstem channel in several segments.

Change in Habitat Conditions

In the Upper Green River, the interaction between sediment supply and transport capacity has influenced the change in channel pattern. The mainstem substantially increased between 1901 and 1997 in active channel width and channel area in Segments 8, 9, and 11. In Segment 8, the increase in channel width and area appears to be a function of sediment deposition in channel bars due to the reduction in transport capacity at, and upstream of, the reservoir low-water stage. In Segments 9 and 11, excess sediment from Smay Creek and road-related failures (Faulkner (Ed.) 1997), and sediment from Sunday and Twin Camp creek (Toth et al. 1996), respectively, appear to be the primary cause of channel widening. These analyses showed substantial increase in sediment load. Segment 8 (river mile 64.5–67.8) is now seasonally inundated by Howard Hanson reservoir. The primary change in channel edge over time has been the construction and maintenance of logging roads and the railroad (the modern-day BNSF

Railway). Revetments constructed of riprap were placed along the channel edge to protect the road and railroad grade from channel erosion. Between river miles 61.5 and 88, over 22% of the channel edge is impacted by these revetments.

Fish Utilization

At present, Chinook adults are not placed upstream of the Howard Hanson Dam, so natural production does not occur in the Upper Green River Subwatershed. The Muckleshoot Indian Tribe plants about 400,000 marked Chinook fry in the upper watershed in late March (Anchor Environmental and National Research Council 2004). The survival rate of these fish is thought to be very low because of downstream passage problems posed by passage through Howard Hanson Dam, as well as high river flow during the spring outmigration season, which coincides with reservoir refill (Kerwin and Nelson [Eds.] 2000). Some marked hatchery subyearling Chinook were captured in spring 2000 at the screw trap at river mile 34.5 (Seiler et al. 2002). Larger hatchery Chinook juveniles have been observed moving downstream through Howard Hanson Dam during the late fall and early winter when the reservoir level is dropped to "run of the river" conditions in preparation for storage of winter flows (Anchor Environmental and Natural Resources Consultants 2004). Bull trout surveys were carried out in the Upper Green River Subwatershed by Plum Creek fisheries biologists in the mid-1990s (Watson et al. 1997) and King County in 2000 (Berge and Mavros 2001), but no bull trout were observed.

Conservation Hypotheses

Based on the results of the habitat and population analyses, four conservation hypotheses were developed for the Upper Green River Subwatershed. Two of them were rated as Tier 1 hypotheses and two as Tier 2 hypotheses:

UG–1 (Tier 1): Establishing/restoring Chinook salmon access above Howard Hanson Dam by providing passage upstream (trap and haul) beyond Howard Hanson Dam and the reservoir for natural origin Chinook and downstream passage for the progeny as well as first generation hatchery fry will increase habitat quantity and expand salmon spatial structure. (Alternative Hypotheses: (1) Augmenting restoration of salmon populations above Howard Hanson Dam by introducing out-of-basin spring Chinook from a neighboring river system (possibly White River) to replace the extirpated Green River spring Chinook will expand Chinook distribution, diversity, and enhance abundance in the river; (2) Restoring salmon above Howard Hanson Dam without the use of hatchery outplants or returning hatchery adults will recover Chinook without bypassing important evolutionary processes (i.e. the selection of the fittest adults for spawning, and juveniles for incubation). [*Note: The alternative hypotheses were not scored and tiered. Final decisions on which fish to pass upstream are dependent upon NOAA Fisheries, U.S. Fish and Wildlife Service, and the co-managers (Washington State Department of Fish and Wildlife and Muckleshoot Indian Tribe). A June 8, 2004, letter from NOAA Fisheries to Tacoma Public Utilities advised that their preliminary recommendation is to pass upstream of Howard Hanson Dam all natural and hatchery-origin Chinook, as well as other salmonids, with the exception of summer run steelhead and Atlantic salmon. Also, the Hatchery Scientific Review Group recommendations for the Green River population propose the continued management of the population as an integrated stock* (Hatchery Scientific Review Group 2004).]

UG–4 (Tier 1): Protecting and restoring natural sediment recruitment process by reducing the amount of slides and road-borne sediment from forest roads will enhance salmon migration, spawning success, and juvenile rearing.

UG–2 (Tier 2): Protecting and restoring/enhancing habitat (e.g., side channels, pools) along the Upper Green River mainstem and major tributaries (e.g., North Fork, Smay Creek) by restoring the riparian corridor will enhance habitat quality and lead to greater residence time and survival (after the establishment of populations above Howard Hanson Dam).

UG–3 (Tier 2): Establish a bull trout population above Howard Hanson Dam by providing passage upstream (trap and haul) beyond Howard Hanson Dam and the reservoir for returning adults and downstream passage for the progeny increase habitat quantity and expand spatial structure.). [*Note: Final decisions on which fish to pass upstream are dependent upon NOAA Fisheries, U.S. Fish and Wildlife Service, and the co-managers (Washington State Department of Fish and Wildlife and Muckleshoot Indian Tribe)*]

Necessary Future Conditions

There are five assessment segments within the Upper Green River Subwatershed. They are *Reservoir Plus* (Segment 8, river mile 64.5 – 72.7), *Smay Valley* (Segment 9, RM 72.7–77.0), *Mile Canyon* (Segment 10, RM 77.0 –77.9), *Lester* (Segment 11, RM 77.9–84.1) and *Intake Valley* (Segment 12, RM 84.1–88.3). The hypothesized necessary future habitat conditions identified for the Upper Green River Subwatershed follow:

- Core areas (Martin et al. 2004) predicted as likely to provide source population structure are targeted as refugia for both adult and juvenile Chinook (Segments 9, 11, and 12);
- Natural rates of lateral channel migration are reestablished to create and maintain functioning aquatic habitats that represent about 65% of historical levels at any given time (Segments 8, 9, 11, and 12);[3]
- Hydrologic connection to floodplain and side channel habitats are restored to achieve access to about 65% of historical habitat areas at any given time (Segments 9, 10, 11 and, 12);
- Natural rates of sediment recruitment are reestablished to increase productivity of spawning areas and to maintain and develop habitat. Large woody debris quantity and distribution are increased after the channel begins to return to equilibrium conditions (Segments 8, 9, 11, and 12);
- Water quality meets State standards to increase productivity of spawning areas (e.g., increase egg-to-fry and spawner-to-spawner productivity) and to increase juvenile life stage productivity. Stream temperatures comply with water quality standards for rearing and migration for Sunday Creek (Segments 8, 9, 11, and 12);
- Mainstem, off channel, and tributary habitats are improved to increase juvenile rearing, life stage diversity, and productivity (increase egg-to-fry and fry-to-fingerling survival rates). Habitats include braided channels, side channels, shallow channel edges, large woody debris jams, and in-channel pools. Targets are functioning habitats representing 65% of historical habitat area at any give time (Segments 8, 9, 11, and 12); and
- The riparian zone is functioning and effective buffer widths are established to provide all riparian functions (shade, bank stabilization, sediment control, organic litter, large woody debris, nutrients, and microclimate) (Segments 8, 9, 10, 11, and 12).

Middle Green River Subwatershed

Looking west over the Middle Green River Subwatershed, showing the mix of forests and farms along the river between river miles 45 and 32. July 2004 photo.

Historical Conditions

The Middle Green River Subwatershed historically provided excellent spawning and rearing habitat that supported multiple salmonid species. From river mile 32 to 45 (see Figure 7-2 for location of river miles), the historical channel incised (downcut) through the wide alluvial valley bottom while migrating throughout. This channel migration created a sinuous and braided channel, with significant amounts of off channel habitat that was used for juvenile rearing. The mainstem channel edge habitat was abundant and pools were large and frequent. There was potentially 50 km of mainstem channel edge habitat (Collins and Sheikh, 2004). There were approximately 29 hectares of side channels in the Middle Green River, providing potentially 52 km of channel edge habitat and the necessary refuge to escape high velocity flows that can result from the steep valley bottom of this section of

3. For the Upper and Middle Green River Subwatersheds, the hypothesized necessary future conditions identified refer to targeting 65% of historical habitat at any given time. This target emanates from work by Reeves et al. indicating that at any given time about a third of river habitat is of sufficiently high quality to support source areas of the population, another third is of moderate quality and may exhibit sporadic spawning, and the remaining third is of low quality and does not support spawning at all. Applying this to the Green/Duwamish watershed, it would be desirable to have two-thirds (about 65%) of the potential habitat patches in a river segment available, with suitable to moderately suitable habitat at any given time (King County Department of Natural Resources and Parks et al. 2004).

the river. The mainstem channel also provided juvenile rearing habitat in shallow areas along the channel edge and within large woody debris jams. The vegetation along the river and tributaries was dense and overhanging the low-water line as described in the mid-1860s General Land Office notes (Collins and Sheikh 2004). These tree species would have contributed to large woody debris within the river system and provided the habitat complexity needed to support a viable population.

Current Conditions

Middle Green channel characteristics vary by reach and were monitored as part of surveys performed in late summer 2001 (R2 Resource Consultants 2002). There are four assessment segments from river mile 31.3 to 64.5. Key habitat attributes were monitored in six reaches of the Middle Green River (RM 32 to 64.5) including bankfull width, canopy cover, pool habitat (location and dimensions), large woody debris, and riffle particle size distribution. The bankfull width ranged from 33 to 45 meters in the Middle Green River. Canopy cover was generally about 15%, except in Segment 5 (Green River Gorge, RM 45.1 to 57.6) where it averaged 26%. Pool spacing ranged from nine channel widths per pool in Segment 5 to 34 channel widths per pool in portions of Segment 4 (Middle Green Valley, RM 32 to 45.1). Pools represented about 18 to 27% of the total habitat area. Large woody debris was most common in the lower reaches of Segment 4 (RM 32 to 40), which contained several log jams composed of more than 100 pieces of large woody debris. Gravel was abundant between RM 32 and 45, where dominant riffle particle size was 42 to 69 mm. Substantial amounts of gravel were present in pool tailouts, small point bars and along channel margins downstream of a large landslide near RM 49. Upstream of RM 49, gravel was scarce, consisting mostly of cobbles due to the loss of gravel recruitment from above Howard Hanson Dam over the past 40 years. In Segments 6 and 7 (RM 57.6 to 64.4), gravel deposits at pool tailouts were rare and several low gradient riffles were largely devoid of gravel.

Change in Habitat Conditions

In the Middle Green River Subwatershed, a valley bottom change analysis was performed for Segment 4 (river mile 32 to 45.3), because of the availability of historical habitat conditions. The forest that once covered the valley bottom has become fragmented, and today only about 40% of the valley bottom is forested. The King County Agricultural Production District comprises 74% of the valley and more than half of the forested valley bottom (636 hectares) has been converted to agriculture. The river no longer migrates freely throughout the valley due to 27 levees and revetments (totaling 8.7 km) and regulated flows. The current 100-year floodplain is 52% of the historical floodplain and is now a mosaic of forest and agricultural lands. Accessible floodplain forests have been reduced by 72%.

All four assessment segments in the Middle Green River had a reduction in total channel area. Channel area for Segments 4 and 7 is about 34% less than historical conditions; Segment 6 is about 29% less. This reduction in channel area is likely a result of bank armoring and reduction of flood flows. In Segment 5, the channel area and width stayed relatively constant due to confinement of the Gorge. The levees that protect roads, a railroad, and private property constrict the channel and prevent the river from meandering. The levees also change the flow dynamics, often increasing velocity and reducing the ability of the river to dissipate energy and sediments.

An analysis of changes to tributaries, focusing on channel edge, was completed for the valley bottom of Segment 4. Overall, tributary channel edge decreased by 19%; however, Unnamed Creek 0098/0099 decreased by about 45%. All of the losses occurred in headwaters that are completely contained within the floodplain. Historically, the headwater of Unnamed Creek 0098 appears to have connected to the mainstem and was likely maintained through frequent flooding. This remnant side channel still exists, but is no longer connected to the mainstem. Juvenile Chinook likely utilized this side channel during high flow events and reared in the creek. Historically, side channels were the dominant type of channel edge creating an extensive network that exited and entered the mainstem. Most of the side channels were north of the river and were likely created by overbank flows branching through alluvial deposits of the valley bottom. Historically, there was about 54 km of side channel, compared with 13.4 km today (a 75% reduction), a significant loss of habitat resulting from flood control efforts and land use changes.

Fish Utilization

One of the few studies aimed at assessing juvenile salmonid habitat use was carried out by the U.S. Army Corps of Engineers in the Middle Green River Subwatershed. The purpose of this study, conducted between 1998 and 2000, was to elucidate life history characteristics and salmonid habitat use of the Middle Green River and help Howard Hanson Dam managers identify strategies to minimize flow manipulation effects upon salmonids (R2 Resource Consultants 2001). Sampling focused on shallow mainstem lateral habitats, defined as mainstem and off channel habitats with water depths less than 1.5 meters. Chinook fry were found to use mainstem habitats much more than off channel habitats. Moreover, Chinook preferred shallow, low-velocity stream edge areas with ample structural cover. There was a tendency for the smaller, younger, Chinook fry (less than 50 mm in length) to initially use shallow areas and gradually shift into deeper water as they grew. By late March, fry were found in slow-velocity (below 2.0 feet per second) habitat created by deep scour pools formed by boulders and mats of woody debris. Chinook were also found in off channel habitats (areas separated from the mainstem by a vegetated island or abandoned floodplain such as wall base channels or old oxbows).

The Washington State Department of Fish and Wildlife screw trap has provided valuable information about juvenile salmon migration. May 2005 photo.

However, many of these habitats became disconnected from the mainstem at flows of less than 850 cubic feet per second.

Juvenile outmigration has been studied by Washington State Department of Fish and Wildlife and King County since 2000 at river mile 34.5 using a screw trap. Seiler et al. (2002) found a strongly bimodal pattern of juvenile Chinook outmigration, with one large peak of fry (35-45 mm) from January to March, and a second smaller peak of fingerlings (70-80 mm) from May through June. This bimodal pattern was also observed with varying ratios of fry/fingerling abundance in 2001-2003 (Nelson et. al 2004). Flows appear to influence the fry/fingerling ratio in any given year, with more fry captured during periods of high winter and early spring flows, when downstream migration is likely to be passive rather than volitional. Nelson et al. (2004) also observed fry movement during moderate flow, which suggests that active migration could also be occurring. The larger natural fingerlings are thought to be more physiologically prepared to enter marine waters and thus tend to spend less time rearing in the lower river and estuary prior to marine residence.

Data from spawning surveys conducted from 1997 to 2002 were used to map redd (spawning egg nest) density and it was determined that about 80% of Chinook redds occurred in the Middle Green River mainstem. These redds were from a mix of hatchery and naturally produced adults, with about 60% attributed to adults from the Soos Creek Hatchery and Icy Creek Ponds (Anchor Environmental and Natural Resources Consultants 2004). The subwatershed has two larger tributaries and several smaller tributaries that also provide spawning habitat and rearing habitat for salmonids. The Soos Creek and Newaukum Creek subbasins currently provide significant spawning habitat and some rearing habitat for Chinook salmon. Other documented tributaries used by salmonids are Unnamed Creek 0098/0099, Burns, Crisp, and O'Grady creeks.

Although there are no recent studies of bull trout habitat use in WRIA 9, several captures of adult bull trout have occurred near the mouth of Newaukum Creek, one as recently as February 2004 (Berge and Mavros 2001; Goetz and Jeanes 2004). A sport fisherman also captured two adult bull trout in October 2001 at river mile 33.8 (personal communication with Hans Berge, King County).

Conservation Hypotheses

Based on the results of the habitat and population analyses, six conservation hypotheses were developed for the Middle Green River Subwatershed. Three of them were rated as Tier 1 hypotheses, two as Tier 2 hypotheses, and one as a Tier 3 hypothesis:

MG–1 (Tier 1): Protecting and creating/restoring habitat that provides refugia (particularly side channels, off channels, and tributary access), habitat complexity (particularly pools) for salmon over a range of flow conditions and at a variety of locations (e.g., mainstem channel edge, river bends, and tributary mouths) will enhance habitat quality and quantity and lead to greater salmon residence time, greater growth, and higher survival.

MG–3 (Tier 1): Protecting and restoring natural sediment recruitment (particularly spawning gravels) by reconnecting sediment sources to the river will help maintain spawning, adult holding, and juvenile rearing habitat.

MG–4 (Tier 1): Preserving and restoring spawning and rearing habitat in lower Newaukum and Soos Creeks will increase habitat quality and quantity, thereby increasing productivity and spatial structure of Green River Chinook salmon.

MG–2 (Tier 2): Protecting against watershed and upland impacts by implementing low impact development techniques (also see conservation hypothesis All-5) will be particularly beneficial in the sub-watersheds of tributaries that provide spawning (e.g., Newaukum and Soos Creeks) and/or rearing habitat (e.g., Jenkins and Covington Creeks) will increase habitat quality and quantity and promote utilization of non-mainstem habitats and prevent creating additional stressors that limit survival.

MG–5 (Tier 2): Maintaining regional groundwater recharge and base flows to the mainstem Green River through forest retention and low impact development will maintain spawning and rearing habitat.

MG–6 (Tier 3): Restoring Chinook salmon access between the Tacoma Headworks and Howard Hanson Dam by providing passage upstream and downstream at the Tacoma Headworks for natural origin Chinook will increase habitat quantity and expand spatial structure. [Note: see notes for conservation hypothesis UG-1 above regarding species recommended for upstream passage.]

Necessary Future Conditions

There are four assessment segments within the Middle Green River Subwatershed. They are *Middle Green Valley* (Segment 4, river mile 31.3–45.3), *Green River Gorge* (Segment 5, RM 45.3–57.6), *Boulder Zone* (Segment 6, RM 57.6–60.5), and *Eagle Gorge* (Segment 7, RM 60.5 – 64.4). The hypothesized necessary future habitat conditions identified for the Middle Green River Subwatershed follow:

- Refugia are established that provide habitat to support both juvenile and adult Chinook (Segment 4);
- Water quality and quantity meet State and instream flow standards to increase productivity of spawning areas (e.g., increase egg-to-fry and spawner-to-spawner productivity) and to increase juvenile life stage productivity (Segments 4, 5, 6, and 7);
- Sediment recruitment and transport rates approach natural rates to increase productivity of spawning areas and to maintain and develop habitat (e.g., pool tail outs, spawning riffles, shallow channel edge) for improving life history productivity. Sediment target with suitable gravel size is 6,300 cubic yards/year to support spawning habitat (Segments 4, 5, 6, and 7);
- Natural rates of lateral channel migration are reestablished to create and maintain functioning aquatic habitats that represent about 65% of historical levels at any given time (Segments 4 and 6);[4]
- Natural disturbance events are less restrained to support the creation of new habitats and to recruit sediment and large woody debris (Segments 4 and 6);
- Mainstem, off channel, and tributary habitats are improved to increase juvenile rearing, life stage diversity, and productivity (increase egg-to-fry and fry-to-fingerling survival rates). Targets are functioning habitats representing about 65% of historical habitat area at any given time. Habitats include braided channels, side channels (target = 16 km in Segment 4), shallow channel edges, large woody debris jams (target = 50 pieces/km), and in-channel pools (target = 6 channel widths/pool) (Segments 4 and 6);
- Hydrologic connections to floodplain and side channel habitats are restored to achieve access to

4. For the Upper and Middle Green River Subwatersheds, the hypothesized necessary future conditions identified refer to targeting 65% of historical habitat at any given time. This target emanates from work by Reeves et al. indicating that at any given time about a third of river habitat is of sufficiently high quality to support source areas of the population, another third is of moderate quality and may exhibit sporadic spawning, and the remaining third is of low quality and does not support spawning at all. Applying this to the Green/Duwamish watershed, it would be desirable to have two-thirds (about 65%) of the potential habitat patches in a river segment available, with suitable to moderately suitable habitat at any given time (King County DNRP et al. 2004).

about 65% of historical habitat areas at any given time (Segments 4 and 6);

- The riparian zone is functioning and effective buffer widths are established to provide all riparian functions (shade, bank stabilization, sediment control, organic litter, large woody debris, nutrients, and microclimate) (Segments 4, 5, 6, and 7);
- Sub-populations of natural origin recruits in Newaukum Creek and Soos Creek are maintained to protect against catastrophic risk and the maintenance of spatial structure within the population (Segment 4);
- Sources of cool, clean water from surface and ground water are maintained (Segment 5); and
- Provide access to additional spawning areas between river miles 61.1 and 64.4 to increase productivity and abundance by expanding spatial structure (Segment 7).

Lower Green River Subwatershed

The Lower Green River, shown here at river mile 17.5 in Kent, is mostly leveed, lacking in native trees, and overrun by non-native weeds such as Himalayan blackberry. April 2005 photo.

Historical Conditions

The wide, low-gradient valley bottom of the Lower Green River was historically a mosaic of floodplain forest and wetlands. The Black, White, and Green rivers were all tributaries of the lower Green River, resulting in frequent floods. During flood events, the Lower Green River overflowed its banks creating a network of ephemeral streams that fed the wetlands and tributaries within the valley. It is likely that some juvenile salmon were carried along in the floodwaters and eventually ended up in the tributaries, wetlands, and side channels, providing refuge during flood events and serving as rearing habitat. The majority of the floodwaters flowed to the east and fed the Springbrook Creek drainage complex and re-entered the system through the Black River. Floodwaters from the historical White River fed the Mill Creek drainage complex. Sand and gravel bars were common (totaling 15 hectares) in the reach between river miles 25 and 32 (see Figure 7-3 for location of river miles) directly downstream of the White River confluence (U.S. Army Corps of Engineers 1907). These gravel bars and large woody debris created shallow habitat for juveniles and suitable spawning habitat that still persists today.

At approximately river mile 18, Hilbert et al. (Eds.) (2001) describes the Indian village of Stook that means “a big jam of logs.” In the mid-1860s, the mainstem channel was wide (about 72 meters) and covered about 316 hectares. Historically, the river migrated throughout the floodplain, leaving behind oxbows and wetlands. Tributaries provided important habitat and accounted for approximately one-third of total channel area and 62% of channel edge. There were approximately 1,700 hectares of wetlands and black cottonwood was the most abundant tree species (Collins and Sheikh 2004).

Current Conditions

There is one assessment segment in the Lower Green River, which encompasses the entire length of the Green River in this subwatershed. Key habitat attributes were monitored in sample four reaches. Monitored attributes included bankfull width, bank conditions, canopy cover, riparian vegetation, pool habitat, large woody debris, and riffle particle size distribution. In general, the observed habitat conditions reflect extensive alterations to the river and floodplain from dam operations, and urban and agricultural development. Key findings of the survey (Anchor Environmental 2004b) were:

- Instream habitat quality and quantity for juvenile and adult salmonids is significantly impaired;
- The channel is confined throughout the Lower Green River, with extensive riprap bank armoring;
- Habitat types are generally homogenous and off channel habitat is limited;
- The dominant pool forming factors are manmade structures, such as riprap and bridge abutments;

- Spawning size gravels occur only in the upper third (river mile 25-32) of the segment;
- The connectivity between the riparian zone and instream habitats is limited by levees;
- The riparian zone is dominated by invasive species and lacks native vegetation; and
- Numerous stormwater and tributary outfalls discharge to the river.

Anchor Environmental (2004b) summarized conditions by noting that gradual channelization of the river in the last century has resulted in substantial losses in the quality and quantity of mainstem spawning, winter and summer rearing, and adult holding habitat. Encroachment of land use, roads, trails, and levees to the river margins has greatly reduced the extent of existing or potential riparian habitat. Bank tree cover is sparse, and existing non-native vegetation provides little cover for fish. The average ordinary high water mark width ranged from 26 to 39 meters in the Lower Green River. Median canopy cover varied from 34 to 44%. Large pool (width greater than 50% of the ordinary high water mark width) spacing ranged from 16 channel widths per pool from river mile 27 to 32 to 254 channel widths per pool from river mile 11 to 16. Large pools represented 10-16% of the total habitat area from river mile 16 to 32, but less than 1% from river mile 11 to 16. The dominant pool-forming factor throughout most of the river was riprap. Total wood pieces (logs and rootwads) ranged from 11 pieces/km between river miles 27 and 32, and 43 pieces/km between river miles 16 and 19. Log jams were only found between river miles 19 and 27, with two observed.

Change in Habitat Conditions

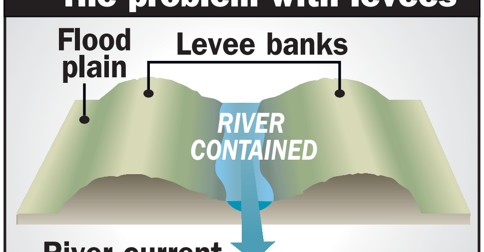
The Lower Green River valley bottom has been dramatically altered from a once densely-forested floodplain with numerous large "swampy" wetlands scattered throughout. The most obvious and significant land cover change has been urban development. It is estimated that about 60% of the valley bottom is either high density (100% impervious) or low density (50% impervious) development. Road density is 8.1 km/km^2 and there are 69 road crossings of the river. This development has resulted in clearing of the floodplain forest (about 87%) and filling of wetlands (about 40%). Historically, there were several large wetlands located in the major tributary drainages and numerous smaller wetlands were scattered throughout the valley. The total area of historical wetlands was estimated at 1,495 hectares, compared to 927 hectares today (Collins and Sheikh 2004; U.S. Fish and Wildlife Service 1990). In the present Southcenter Mall area, there was a large wetland (159 hectares), but it has been completely filled except for a small area. There was also a 109 hectares wetland further south on the west side of the river that was described as a "cranberry marsh" by the General Land Office. This wetland was unique because it was symbolized on the General Land Office plat map with numerous springs. Today, this area remains largely undeveloped and is drained by Johnson Creek, but it is slated for development as part of a large project planned for the area.

Historically, tributaries were the dominant type of channel edge in the Lower Green River because of the geologic and glacial processes that formed the river. Flooding was common, creating a network of flood channels that fed the tributaries and wetlands. Tributaries provided important habitat and accounted for approximately one-third of total channel area and 62% of channel edge (Collins and Sheikh 2004). Side channels contributed about 6.5 km of channel edge habitat. Today, the tributaries are heavily altered due to development of the floodplain and are rarely fed by floodwater. Approximately 20% of Springbrook Creek is contained in drainage ditches and its confluence is upstream of the Black River Pump Station, a partial fish passage barrier.

Fish Utilization

Nelson et al. (2004) studied juvenile Chinook in the Lower Green River during 2001-2003, focusing on timing, growth rates, and relative abundance of hatchery and naturally-produced Chinook. Natural Chinook passed through the Lower Green River quickly (hours to days) from late winter to late summer with peaks for fry and fingerling migration coinciding closely with the Middle Green. Flows seem to play an important role in the residence time within this reach.

The problem with levees



Levees help reduce flooding. But during peak river flows, a faster current can scour away gravel and structure needed by salmon.

Flood control facilities (e.g., levees) have severely limited the ability of Chinook to find refuge during high flows, resulting in juveniles being prematurely flushed downstream to the estuary. River flows in 2001 were unusually low during the winter and early spring, and it appears that a higher proportion of fry may have reared in the Middle and Lower Green River compared to the proportions of fish that reared there during 2002 and 2003 (Nelson et al. 2004). In recent years, about 3.5 million hatchery Chinook fingerlings were released annually in WRIA 9. These fish typically travel through the Lower Green River at a time when smaller and much less abundant natural fingerlings are present, thus the more abundant and larger hatchery fish may prematurely force natural fish to the estuary. As a result of such interactions, hatchery fish likely have a competitive advantage (at a minimum, due to fat reserves) over their natural conspecifics if the food supply is limited.

Conservation Hypotheses

Based on the results of the habitat and population analyses, four conservation hypotheses were developed for the Lower Green River Subwatershed. One was rated as a Tier 1 hypothesis, one as a Tier 2 hypothesis, and two as Tier 3 hypotheses:

LG–1 (Tier 1): Protecting and creating/restoring habitat that provides refuge (particularly side channels, off channels, and tributary access) and habitat complexity (particularly pools) for juvenile salmon over a range of flow conditions and at a variety of locations (e.g., mainstem channel edge, river bends, and tributary mouths) will enhance habitat quality and quantity and lead to greater juvenile salmon residence time, greater growth, and higher survival.

LG–2 (Tier 2): Restoring and enhancing sediment recruitment (particularly spawning gravels) by reconnecting sediment sources to the river will reduce channel downcutting, increase shallow habitats, improve access to tributaries, and improve spawning habitat, thereby leading to greater juvenile salmon residence time, greater growth, and higher survival.

LG–3 (Tier 3): Preserving and maintaining groundwater inflow from the historical White River channel will contribute to maintaining river flows and good water quality, thereby leading to greater juvenile and adult salmon survival.

LG–4 (Tier 3): Modifying the Black River Pump Station to improve fish passage will increase habitat quantity and lead to greater juvenile salmon residence time and growth.

Necessary Future Conditions

There is one assessment segment within this subwatershed: *Lower Green Valley* (Segment 3, river mile 11.0 - 31.3[5]). The hypothesized necessary future habitat conditions identified for the Lower Green Subwatershed follow:

- Water quality and quantity meets State and instream flow standards to increase productivity of spawning areas (e.g., increase egg-to-fry and spawner-to-spawner productivity) and to increase juvenile life stage productivity;
- Sediment processes and transport rates that produce spawning gravel (river mile 25 to 32) are reestablished and improved to increase productivity in spawning areas, increase spatial structure, and maintain and develop habitats (e.g., pool tail outs, spawning riffles, shallow channel edge) that will increase life history productivity. Spawning habitat target with suitable gravel size is about 45% of historical levels (5,000 cubic yards/year[6]) for viability of population;
- Mainstem, tributary, and off channel habitats are improved to increase juvenile rearing, life stage diversity and productivity (increase egg-to-fry and fry-to-fingerling survival rates). Targets are functioning habitats representing about 45%[7] of historical habitat area. Habitats include side channels (target = 4.5 km), wetlands (target = 763 hectares), tributaries within the valley bottom (target = 36 km), ponds (target = 13 hectares), shallow channel edges, large woody debris jams, and in-channel pools;

5. The boundary for this segment is at the historical confluence of the Green River with the White River, just downstream of the boundary between the Lower and Middle Green River Subwatersheds.

6. Estimated from general guidance by Perkins (2000).

7. Loss of historical watershed area, and by rough extension the loss of flow, was used to determine the target habitat percentage. Above the historical confluence of the White and Green rivers, approximately 55% of the contributing area was in the White River drainage area; therefore a target of 45% of the historical habitat of the Lower Green River was established as the reference condition, which is equivalent to the remaining contributing area after diversion of the White River.

- Hydrologic connections to floodplain, tributaries and historical off channel habitats are restored to achieve access to about 45% of historical habitat area; and
- The riparian zone is functioning and effective buffer widths are established to provide all riparian functions (shade, bank stabilization, sediment control, organic litter, large woody debris, nutrients, and microclimate).

Duwamish Estuary Subwatershed

Historical Conditions

The historical Duwamish River estuary was small relative to other estuaries in Puget Sound due to its unique topography (Collins and Sheikh 2004). The narrow floodplain in the upper part of the Duwamish River valley likely funneled the floodwater from the watershed and resulted in overbank flooding and the creation of "swampy marshes" (freshwater wetlands). Similar to conditions in the Lower Green River Subwatershed, these floodwaters likely carried with them juvenile salmonids that used these wetlands as rearing habitat. At the lower end of the river where it becomes tidally influenced, there were several types of tidal marshes that contained different plant communities. Collins and Sheikh (2004) classified them as riverine-tidal marshes and they totaled approximately 166 hectares in the mid-1860s. There were approximately 175 hectares of estuarine wetlands in the mid-1860s, primarily downstream of present day Kellogg Island. Blind tidal estuarine channels (i.e. "dead-end" channel connected at only one end) provided the most channel edge on the Duwamish with the mainstem providing the next largest amount of channel edge habitat (Collins and Sheikh 2004). Information from other estuaries in the Northwest (Simenstad et al. 1982, Levings et al. 1986, Healey 1991) suggests that it was likely an important rearing habitat for multiple life histories of Chinook salmon. Numerous small channels in the estuary were bordered by key dense marsh vegetation that contributed to the production of salmon prey.

The banks of the Lower Duwamish, shown here looking downstream at river mile 2.0, are intensively used for industry and commerce. September 2002 photo.

Current Conditions

Channel characteristics in the Duwamish River vary by reach and were monitored as part of surveys performed in 2003 and 2004 (TerraLogic and Landau 2004, Anchor Environmental 2004a). Habitat attributes included riparian vegetation, invasive species, overwater structures, bank armoring, large woody debris, and pilings. In general, observed habitat conditions reflect extensive alterations to the upper (RM 5.7 to 11) and lower (RM 0 to 5.7) Duwamish River (see Figure 7-4 for location of river miles). The average width of the channel was 50 meters in the upper river. There are three large pools with a spacing of one pool per 59 channel widths. Over 90% of the lower Duwamish is armored (60% with riprap; 24% with steel or concrete bulkheads). About 48% of the shoreline has no vegetation; 30% is Himalayan blackberry; nearly 10% is landscaped; 6% is other invasive shrubs; and 3% is immature deciduous vegetation. Approximately 87% of the shoreline has greater than 75% impervious surface in the area adjacent to the river. There are 56 piling groups, 49 pieces of large woody debris, including two large accumulations, and 14 occurrences of Japanese knotweed. Kellogg Island and the Turning Basin are two of the areas that have little or no armoring and are higher in habitat quality. A number of investigations within the Duwamish River have documented sediment contamination with polychlorinated biphenyl (PCBs), polycyclic aromatic hydrocarbons (PAHs), phthalates, inorganics, and organotins. In 1997, the natural resource trustees for the Duwamish River initiated an investigation to evaluate the extent and severity of PCBs in the sediments of the waterway. The major findings indicated that almost 71 of the 350 acres sampled, or just under 20% of the waterway, were estimated to have PCB levels that exceed the state standards.

Change in Habitat Conditions

The valley bottom of the Duwamish differs in the lower valley versus the upper valley (see river miles noted above). Historically, the upper valley resembled the lower Green River with natural levees depositing along the riverbanks, whereas the lower valley riverbanks are lower in elevation than the rest of the valley bottom. Today, armoring and levees have mostly altered the natural riverbanks. Historically, this area was prone to flooding and these floodwaters supported about 200 hectares of freshwater wetlands that have been decreased to about 7 hectares In addition, historically there were riverine-tidal forested and scrub-shrub wetlands but these are completely gone (Blomberg et al. 1988; U.S. Fish and Wildlife Service 1990).

Estuarine habitats were extensive historically but are currently found only in small patches. Historical estimates of estuarine mudflats were 900 hectares and estuarine wetlands were 174 hectares. Filling of wetland and marsh habitats began in 1895. Today there are only about 1% of mudflats and 11% of tidal marshes remaining. The filling of the mudflats and the straightening and widening of the former channel completely altered the estuarine habitat. A healthy estuary provides transition zone habitats that aid juvenile salmon in osmoregulation (adapting to saltwater), growth, and survival. The transition zone is characterized by a mixing of fresh and saltwater. This mixing creates brackish water that supports a unique ecology. A much greater expanse of this transition zone habitat was historically available closer to and within Elliott Bay prior to regular dredging, reduced freshwater flow from river diversions, and extensive filling of historical intertidal areas in the Duwamish River and Elliott Bay. The freshwater-salt water mixing zone has been vastly reduced in size and moved upstream to its current location. The Strategic Assessment defines the current location of the transition zone between river miles 7.0 and 5.5. Additional data generated in 2005 suggest the location during the outmigration of juvenile salmonids may be between river miles 6.5 and 4.7 or 4.8 (Figure 4-1). The final results of this study will be used to help determine the location of projects intended to rehabilitate/substitute transition zone habitat. Dredging for maintenance of navigation now leaves only a thin margin of tide flats along the shoreline with an artificially deepened central channel from about river mile 5.0 to Elliott Bay. The one exception to these narrow slices of intertidal habitat is at Kellogg Island (river miles 1.1-1.4).

Fish Utilization

Several year classes of Chinook (fry, yearlings, and possibly two-year-old fish) were found in the Duwamish Estuary between January and September in 2002 and 2003 (Nelson et al. 2004, Goetz et al. 2003, Ruggerone and Jeanes 2004). Two peaks in abundance occurred in the estuary: the first, composed of fry, was observed from late February to early March, and the second for fingerlings occurred between mid-May and mid-June. Subyearlings were consistently captured at river mile 5.5 and 6.5, which has been postulated to be a critical estuarine transition zone where the river and salt wedge initially mix. This transition zone is also where the river widens, velocities decrease, and estuarine mudflats begin to appear. The boundaries of the existing transition zone are being refined at the time of publication. Chinook salmon utilize estuaries to acclimate to marine water and to grow in a relatively food-rich environment where predators are often less abundant. In general, smaller salmon (e.g., fry) are likely to rear in estuaries for longer periods, before moving into marine nearshore areas.

Natural origin fry (marked at lower Soos Creek in winter 2003) were found in the transition zone within one to 31 days (53% of the fry were found within 1-4 days) after release (Nelson et al. 2004) and may rear in this area to fingerling size before migrating out to Elliott Bay during the outmigration peak in June. This scenario, if confirmed, would amount to an estuarine residence of up to five months, much longer than commonly believed. From observing peak catch data in 2002 and 2003, most natural fingerlings arrived in the estuary in May to acclimate and feed for several weeks, before departing to marine waters. Nelson et al. (2004) reported that Chinook growth rates in the Duwamish estuary in 2003 were initially steady, but increased to rates between 0.44 and 0.54 mm/day from April through June, except for three weeks from mid May to early June, when hatchery Chinook occupied the area. During this time of hatchery fish residence, growth rates dropped 75% to 0.13 mm/day, indicating the existence of a juvenile density-dependent depression in growth.

In addition to reduced growth rates, natural origin Chinook fingerlings may have been physically displaced as well. This phenomenon was apparent in the transition zone (Nelson et. al 2004), and in restored off channel estuarine habitats (Ruggerone and Jeanes 2004). These results suggest that there is a shortage of available food and habitat capacity as a result of competition between hatchery and natural Chinook in the estuary, especially in the transition zone. Ruggerone and Jeanes (2004) demonstrated that restoration of large amounts of off channel habitat is necessary to have a measurable effect. This finding is based on an estimate that only 0.16% of the three million hatchery Chinook, and 0.16 to 0.33% of the natural subyearling Chinook population used the five off channel restoration sites these authors sampled in the Duwamish estuary in 2003.

Since 2000, nine sub-adult (mean size 290 mm) and one adult (585 mm) bull trout have been captured in the Duwamish River. The large adult was captured in May 2003 near Kellogg Island (river mile 1.0); the sub-adults were captured in the transition zone (river mile 5.5) in August and September 2000 and September 2001 (Goetz and Jeanes 2004).

Conservation Hypotheses

Based on the results of the habitat and population analyses, six conservation hypotheses were developed for the Duwamish Estuary Subwatershed. Three were rated as Tier 1 hypotheses, two as Tier 2 hypotheses, and one as a Tier 3 hypothesis:

Duw–1 (Tier 1): Expanding and enhancing the Duwamish estuary, particularly vegetated shallow subtidal and intertidal habitats and brackish marshes, by restoring dredged, armored, and filled areas, will enhance habitat quantity and quality and lead to greater juvenile salmon residence time, greater growth, and higher survival.

Duw–3 (Tier 1): Enlarging the Duwamish River estuarine transition zone habitat by expanding the shallow water and slow water areas will enhance habitat quantity and quality of this key Chinook salmon rearing area, leading to greater juvenile salmon residence time, greater growth, and higher survival.

Duw–5 (Tier 1): Protecting and restoring natural sediment process (supply-transport-delivery) will increase the quantity and quality of available juvenile salmon rearing habitat, including salmon prey production;

Duw–4 (Tier 2): Protecting, creating, and restoring habitat that provides refugia (particularly side channels, off channels, and tributary access) and habitat complexity (particularly pools) for juvenile salmon over a range of flow conditions and at a variety of locations (e.g., mainstem channel edge, river bends, and tributary mouths) will enhance habitat quality and quantity and lead to greater juvenile salmon residence time, greater growth, and higher survival.

Duw–6 (Tier 2): Protecting and improving water quality (e.g., temperature, dissolved oxygen, metals and organics) by addressing point and nonpoint (specifically stormwater runoff) pollution sources will enhance habitat quality and lead to greater juvenile salmon growth, disease resistance, and survival. Improved water quality will also enhance survival of adult salmon, and salmon prey resources.

Duw–2 (Tier 3): Protecting and improving sediment quality will enhance habitat quality and lead to greater juvenile salmon growth, disease resistance, and higher survival.

Necessary Future Conditions

The Duwamish Estuary Subwatershed contains two assessment segments *Tidal Delta* (Segment 1, river mile 0.0–1.5) and–*Duwamish Valley* (Segment 2, river mile 1.5-11.0). However, they are being treated as one segment for the necessary future conditions since their goals and targets are similar. The hypothesized necessary future habitat conditions identified for the Duwamish Estuary Subwatershed follow:

- Water quality meets State standards to prevent recontamination of sediments and provide cool, clean water required for healthy salmonid habitat, including juvenile and adult migration;
- Sediment recruitment and transport rates approach natural rates to improve and maintain existing habitat and support habitat development (estuarine and riverine mudflats and marshes) that will increase life stage productivity;
- Sediment quality meets State sediment management standards and achieves conditions consistent with the State/Federal cleanup process to improve life stage productivity;
- Impediments (e.g., overwater structures) to Chinook and salmonid migration are reduced;
- Mainstem, off channel, and tributary habitats are improved to increase juvenile rearing, life stage diversity, and productivity (increase egg-to-fry and

fry-to-fingerling survival rates). Targets are functioning habitats representing about 30%[8] of historical habitat area. Habitats include shallow channel edge, Palustrine and Riverine-tidal wetlands (target = 108 hectares), and off channel habitat (target = 2 hectares);

- Estuarine habitat (transition zone area, where juveniles adjust to hyperosmotic conditions) is expanded to encompass about 30% of historical habitat area (target is about 70 hectares) and habitat quality is functioning to improve juvenile growth and survival rate; and
- Riparian zone is functioning and effective buffer widths are established to provide all riparian functions (shade, bank stabilization, sediment control, organic litter, large woody debris, nutrients, and microclimate).

Marine Nearshore Subwatershed

Historical Conditions

While a complete WRIA 9 marine nearshore historical habitat analysis has not yet been completed, a section from Elliott Bay to West Point was reconstructed (Collins and Sheikh 2004). There were three small tidal marsh complexes: West Point, Smith Cove, and the present-day Occidental Square area of Seattle. Smith Cove was the largest and protected at the mouth by a

The marine nearshore includes the completely developed central Seattle waterfront. July 2004 photo.

About half of the shoreline of Vashon/Maury Island, shown here at Piner Point on Maury Island, is unarmored. July 2004 photo.

sand spit. The northern portion was a salt marsh (about 18.9 hectares) fed by a large tidal network that entered on the western side of the cove. Undeveloped shorelines along the marine nearshore of Puget Sound supported a diversity of shoreline habitats including mud flats, eelgrass meadows, sand spits, estuaries, beaches, and riparian areas. In general, shallow water marine nearshore habitat was more prevalent, and sub-estuaries were more numerous and in a more natural state (e.g., Smith Cove in Elliott Bay, Raab's Lagoon on Maury Island), providing a high level of habitat diversity for different life stages of Chinook (e.g., fry migrants). There are limited data on the historical distribution of submerged aquatic vegetation (e.g., eelgrass and kelp).

Current Conditions

Information on current aquatic and riparian habitat conditions in the marine nearshore is summarized from the Marine Shoreline Inventory Report (Anchor Environmental 2004b) and the Reconnaissance Assessment of the State of the Nearshore Ecosystem (Brennan (Ed.) 2001). The attributes mapped included: substrate, marsh habitat, aquaculture and shellfish harvest areas, energy, sedimentation (net shore drift), freshwater inputs, marine riparian vegetation (MRV), large woody debris, shoreline armoring, impervious surfaces, overwater structures and marinas, boat ramps, jetties, breakwaters and groins, and marine rails. A total of 151 km of marine shoreline was inven-

8. Loss of historical watershed area, and by rough extension the loss of flow, was used to determine the target habitat percentage. Above the historical confluence of the Black and present-day Green rivers, approximately 70% of the contributing area was in the Black and White River drainage areas; therefore a target of 30% of the historical habitat of the Duwamish River was established as the reference condition, which is equivalent to the remaining contributing area after diversion of the White and Black rivers.

toried. Approximately 59% of the MRV consisted of trees, 28% was grass/landscaped and 10% had no vegetation. There was marsh habitat along 8% of the shoreline, with 6% patchy dune grasses, and only 1.5% native high marsh habitat. Large woody debris and drift logs were present along 14.7 and 21% of the shoreline, respectively. No wood was present along 64% of the shoreline. Armoring was present along 63% of the shoreline. There were 250 identified overwater structures, 122 boat ramps, and 142 jetties, groins, or breakwaters. Vashon/Maury Island and Federal Way had the greatest extent of MRV as trees with 73 and 69%, respectively. The greatest extent of shoreline armoring occurred in Seattle (90%) and the least amount of armoring occurred in Federal Way (42%) and on Vashon/Maury Island (50%).

Change in Habitat Conditions

Historically, Elliott Bay provided vital habitat for both juvenile and adult salmonids. It was recorded that in the 1860s, this area was abundant with salmon (Bagley 1929). It provided approximately 350 hectares of tideflats and three small tidal marshes. These marshes have been filled and highly altered, as have most of the tideflats. Some of the northern portion of Elliott Bay retains some unarmored shoreline, mostly along bluffs of the Magnolia neighborhood. In addition, the western side of Elliott Bay (West Seattle) has lost much of the middle to high intertidal habitat due to bank armoring and urban development; some tidal flats still exist at lower elevations. A more complete analysis of changes in habitat conditions for the marine nearshore is pending the outcome of the Puget Sound Nearshore Ecosystem Restoration Project assessment of historical conditions and changes in habitat conditions and a WRIA 9 study examining changes in sediment sources, erosion, and accretion along the marine nearshore.

Fish Utilization

Beach seine surveys were conducted in 2001-2002 along marine shorelines in WRIA 9 to fill data gaps and characterize juvenile Chinook utilization of the marine nearshore (Brennan et al. 2004). Juvenile Chinook were captured throughout the study area, and there were no significant differences in catch rates between the mainland and Vashon/Maury Island. There were also no significant differences at various tidal elevations, indicating that juveniles move up and down along the shoreline with the tide, primarily using shallow water habitats. In 2003, natural-origin Chinook were also surveyed along Elliott Bay shorelines and at the mouth of the Duwamish Estuary (Nelson et al. 2004). After early February, the juvenile (fry) catch declined before peaking again from mid-May to late June, coinciding with the fingerling outmigration from the river. The use of shallow water habitats was also observed in a study conducted by Toft et al. (2004). Based on these studies and previous assessments (e.g., Brennan (Ed.) 2001), Chinook salmon appear to occupy the marine nearshore nearly year round.

Although juvenile Chinook appear to be shoreline oriented, they are quite broadly distributed, and readily cross the open waters of Puget Sound. Furthermore, juvenile Chinook do not simply leave the river and head north through Puget Sound to the open sea. Based on recaptures of coded wire tagged fish, Green River Chinook appeared to disperse into Puget Sound around mid-June, at the same time coded wire tagged fish from other river systems increased in the catch (Nelson et al. 2004). Outside of Elliott Bay, Green River Chinook were found in higher numbers south of Elliott Bay, compared to northern sampling sites. This suggests that oceanographic influences (e.g., winds, surface currents) may play a significant role in distribution within nearshore areas. In addition, coded wire tagged juvenile salmonids recaptured in WRIA 9 originated from 16 different hatcheries in nine WRIAs, illustrating the potential importance of the WRIA 9 marine nearshore to multiple stocks of Chinook.

Stomach content surveys of juvenile salmonids revealed their food sources. September 2001 photo.

A detailed examination of juvenile Chinook feeding habits along marine shorelines (Brennan et al. 2004) revealed a large component of terrestrial insects in their diet (50% numerically overall), with an even higher seasonal component (about 80%) by weight for one size category. Similar results were found by Toft et al. (2004) along Seattle's marine shoreline. Over the course of the year, juvenile Chinook diets are composed of diverse prey that are of benthic, pelagic, and terrestrial origin. The prey composition varies seasonally and with fish size, with smaller fish feeding primarily on epibenthic and pelagic organisms and the largest size category of fish (>150 mm) feeding primarily on other fishes (e.g., herring and sand lance).

Toft et al. (2004) investigated the abundance and behavior of juvenile salmon at sites with different shoreline modifications (e.g., bank armoring, overwater structures) along Seattle's marine shoreline in 2003. The study found that substrate type and slope are the most influential factors for fish densities when shoreline modifications extend into the upper intertidal zone. However, shoreline modifications extending into subtidal areas have the largest effect on fish densities and behaviors by truncating the shallow water zone. In the absence of shallow water habitat, Toft et al. (2004) observed that juvenile salmonids were forced into occupying deep water areas and exhibit a higher amount of schooling behavior. In addition, juvenile salmon avoided areas under overwater structures.

Given the temporal and spatial use of the marine nearshore and apparent consumption of the same types of food resources (Brennan et al. 2004), it is apparent that hatchery and wild fish compete for the same resources. While little is known about resource limitations, partitioning, or potential behavioral changes resulting from these interactions, it is likely that wild juvenile Chinook are at a disadvantage. In studies by Brennan et al. (2004) and Nelson et al. (2004), wild Chinook were smaller in size, occurred in significantly lower numbers, and apparently competed for the same spatial and dietary resources as their hatchery counterparts during the same time periods.

A recently draft report on bull trout ecology in the nearshore (Goetz and Jeanes 2004) states that "[B]ull trout in the Puget Sound can undertake rapid, directed migrations that may exceed 250 km using the nearshore marine shorelines as pathways." The only direct data in this report regarding the utilization of WRIA 9 by bull trout was a single fish captured at Lincoln Park in West Seattle in April 1998. However, due to the highly migratory behavior of these fish, many important inferences for WRIA 9 can be drawn from data collected in other nearshore areas. Especially important are the bull trout diet studies that show a prevalence of bull trout prey species (e.g., smelt, herring, sandlance, and shiner perch) that depend on the marine nearshore for spawning habitat.

Conservation Hypotheses

Based on the results of the habitat and population analyses, five conservation hypotheses were developed for the Marine Nearshore Subwatershed. Two were rated as Tier 1 hypotheses, one as a Tier 2 hypothesis, and two as Tier 3 hypotheses:

Near–2 (Tier 1): Protecting and increasing the availability of vegetated shallow nearshore and marsh habitats will enhance habitat quantity and quality and lead to greater juvenile salmon residence time, greater growth, and higher survival.

Near–3 (Tier 1): Protecting and restoring nearshore sediment transport processes by reconnecting sediment sources and removing shoreline armoring that impacts sediment transport will lead to greater prey production, greater juvenile salmon growth, and higher survival.

Near–5 (Tier 2): Protecting and enhancing pocket estuaries (i.e. smaller non-natal estuaries, lagoons, and spits) and salmon-bearing and non-salmon bearing tributary mouths by maintaining/ restoring tributary mouths will increase quantity of key habitat and lead to greater juvenile salmon growth and survival.

Near–1 (Tier 3): Protecting and improving sediment quality, particularly in Elliott Bay, will enhance habitat quality and lead to greater juvenile salmon growth and higher survival.

Near–4 (Tier 3): Protecting and expanding forage fish spawning areas by maintaining/ increasing high intertidal zone access and maintaining/increasing availability of suitable substrate sizes will lead to greater juvenile salmon growth and higher survival.

Necessary Future Conditions

There are nine assessment segments in the Marine Nearshore Subwatershed: five assessment segments on the mainland and four assessment segments on the islands. The hypothesized necessary future habitat conditions identified for the Marine Nearshore Subwatershed follow:

- Water quality of tributaries meets State standards to increase productivity of pocket estuaries and marine nearshore areas to increase juvenile and adult life stage productivity;

- Marine sediment recruitment and transport rates approach natural rates to maintain existing habitat and support habitat development to increase life stage productivity;
- Sources of cool, clean water from groundwater supporting marine nearshore springs and seeps are maintained;
- Impediments (e.g., overwater structures) to Chinook and salmonid migration are reduced;
- Marine nearshore habitats are improved to increase juvenile rearing, life stage diversity, and productivity. Marine nearshore habitats include salt marshes, beaches and backshore, pocket estuaries, and shallow water habitat; and
- Marine riparian zone is functioning and effective buffer widths are established to provide all riparian functions.

Chinook Salmon Populations

Historical Conditions

The following section summarizes information from Historical and Current Salmonid Population Conditions in WRIA 9 (King County Department of Natural Resources and Parks and WRIA 9 2004). Historical **abundance** estimates for independent populations such as the Green River Chinook salmon are difficult to determine since available data from the early 1900s is on fish catch or pack data for Puget Sound as a whole. Myers et al. (1998) reviewed fish canning data from the early 1900s and observed a peak harvest in 1908 that resulted in 95,210 cases of Chinook salmon, corresponding to a peak Chinook run size of approximately 690,000. Based on this historical peak catch, an estimate of historical abundance for the Green/Duwamish watershed was made using comparative watershed size (and flow), resulting in an estimate of maximum run size of 37,700 Chinook and a minimum run size of 9,000 to 11,000. A different method used by NOAA Fisheries estimated potential historical Chinook spawner capacity for the Green River at 45,200 (Sanderson et al. 2004).

No reliable historical information is available on **productivity**, in terms of recruits per spawner for Puget Sound Chinook. The best information available that can be used for representing historical productivity are the Chinook spawner abundance planning targets and ranges for the Puget Sound Region provided by the Puget Sound Technical Recovery Team (Shared Strategy 2002). Target maximum population growth rates have been identified that range from 2.3 to 3.8 recruits per spawner for various Puget Sound river systems.

The greater Duwamish watershed included the White, Black, Cedar, Green, Duwamish, and Sammamish rivers, as well as numerous other salmon spawning tributaries. By 1916, the watershed was reduced to 30% of its former size, thus greatly altering **spatial structure** and affecting other viable salmonid population (VSP) parameters, including genetic and life history diversity, abundance, and productivity. Historically, the spatial distribution for Chinook spawning in the Green River ranged from river mile 24 to river mile 91.3, including reaches within the Lower, Middle, and Upper Green River Subwatersheds. Before construction of the Tacoma Headworks in 1911, it is believed that Green River spring Chinook and possibly summer/fall Chinook used the Upper Green River for spawning and rearing. Without historical spawning data, assumptions of spawning distribution in the Upper Green River are based on the spawning patches (core areas) predicted by Martin et al. (2004). The historical spatial structure of rearing habitat for Green/Duwamish Chinook has not been documented, but juvenile salmonids likely utilized most of the watershed. As discussed previously, the aquatic habitats of the Green/Duwamish system included hundreds of hectares of tidal wetlands and intertidal flats, hundreds of kilometers and a dense network of tributaries and side channels, and a dynamic mainstem (Blomberg et al., 1988; Collins and Sheikh 2004; Kerwin and Nelson, 2000). Depending on the life history trajectory, the length of residence by juvenile salmonids in these aquatic habitats varied.

Chinook salmon display the greatest **diversity** in life history patterns of the Pacific salmonids. Since there is virtually no reliable historical data or information on the life history of Green River Chinook, a conceptual model was developed for historical diversity using assumptions based on current knowledge, hatchery records, and historical habitat conditions that likely existed prior to 1900. The Green River is believed to have historically supported two independent populations of Chinook salmon, a stream-type and ocean-type (Nehlsen et al. 1991; Washington Department of Fish and Wildlife and Western Washington Treaty Indian Tribes 1993; Puget Sound Technical Recovery Team 2003). Stream-type Chinook salmon, commonly referred to as spring stocks, return to their natal river principally in spring and early summer, several months prior to spawning. Ocean-type, commonly referred to as summer/fall stocks, principally enter freshwater during the late summer and fall, just a few days or weeks before spawning. In addition to the two Green River populations, there were probably a minimum of three other independent Chinook populations within the greater Duwamish basin, including those in the Cedar River, White River, and North Lake Washington (King County Department of Natural Resources and Parks 2004, Puget Sound Technical Recovery Team 2004).

For adults, variations in return and spawn timing are behavioral patterns that help to differentiate ocean-type from stream-type Chinook salmon, as well as create greater diversity within a population that can reduce its risk of extinction due to natural disaster. It is difficult to know for certain the historical return and spawn timing, but estimates are summarized from Historical and Current Salmonid Population Conditions in WRIA 9 (King County Department of Natural Resources and Parks and WRIA 9 2004). Lacking specific data on the historical life history diversity of Green River juvenile Chinook, it is assumed that all the current five juvenile life histories would have been present historically in the Green River, with some trajectories being more common than they are today. Information on historical populations of other salmonids can be found in Historical and Current Salmonid Population Conditions in WRIA 9 (King County Department of Natural Resources and Parks and WRIA 9 2004). Section 7 of the Strategic Assessment summarizes the findings related to Chinook viable salmonid population parameters in WRIA 9 and presents goals and rationale on these parameters to support a viable population in the future.

Current Conditions

The abundance and productivity analyses carried out for the Green River population by the Puget Sound Technical Recovery Team and the WRIA 9 Technical Committee revealed several interesting and sometimes ambiguous outcomes:

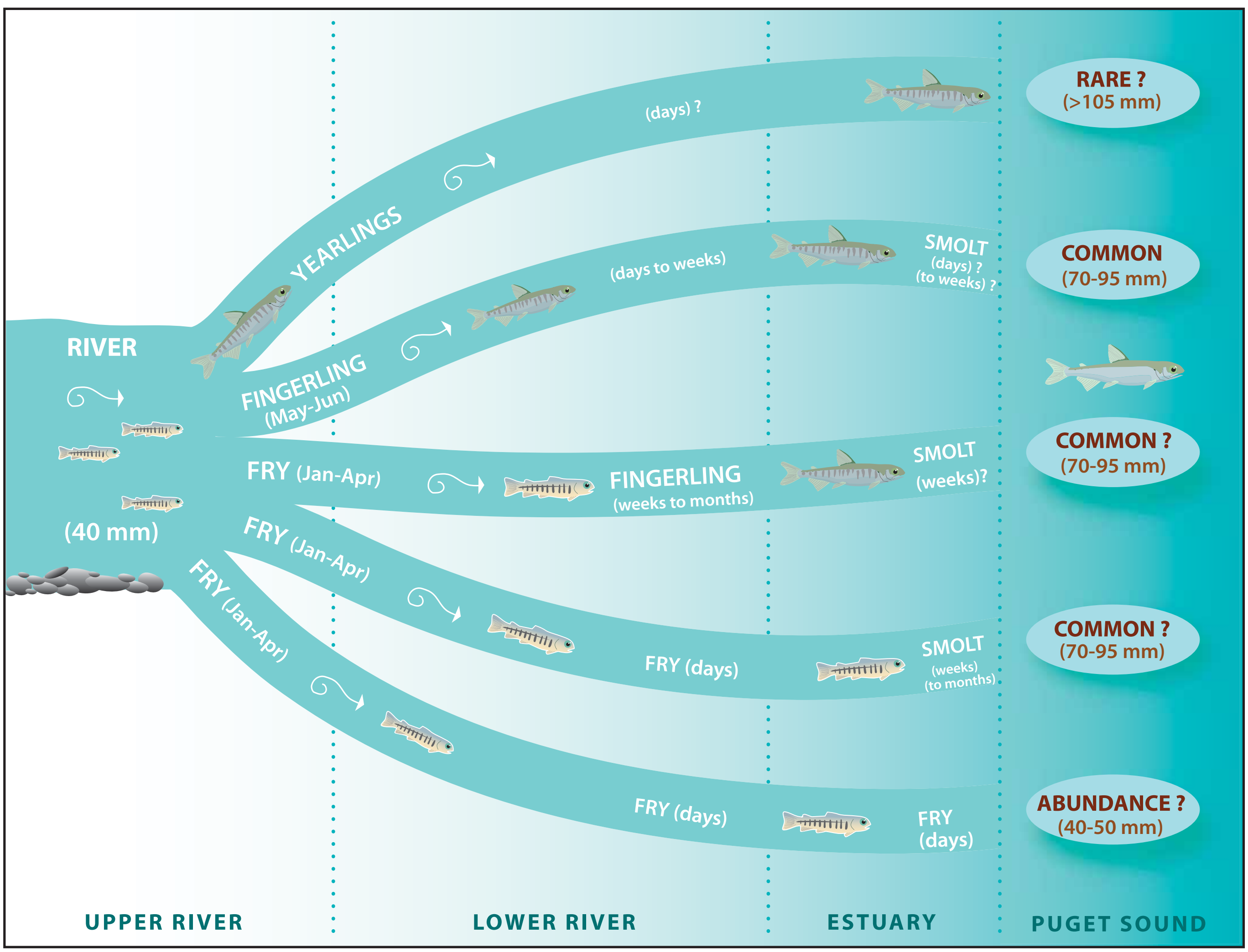
- The population of the Green River is greatly affected by hatchery origin fish; the number of hatchery origin fish spawning naturally varies considerably – from about 30% to over 70% in a given year;
- Estimates of historical population size are quite variable but independent methods put the historical maximum run size at approximately 37,700;
- Current mean natural origin run-size estimates vary between 11,200 (Puget Sound Technical Recovery Team 2004) and 14,700 (Weitkamp et al. 2000) (Note: these numbers include escapement plus all harvest of natural origin Chinook);
- It has been estimated that annually an average of 5,700 Chinook have returned to the river to spawn naturally and 8,200 have returned to the hatcheries from 1968-1997 (Kerwin and Nelson [Eds.] 2000);
- Natural origin recruit spawner estimates vary as well but the Technical Recovery Team calculated the mean of natural origin recruit spawners from 1993 to 2002 at 1,737; and
- Productivity estimates are also variable with a cohort replacement ratio as calculated by the Technical Recovery Team showing a recruit/spawner ratio of natural origin recruits that varies between .02 and 23 with a negative trend.

The spatial distribution of Chinook spawning in the Green River was altered as a result of construction of the Tacoma Headworks. Mainstem spawning is limited to downstream of river mile 61.1, compared to approximately river mile 88 historically. The control of flow and flood events combined with flood control levees/revetments has resulted in the mainstem being narrower, with reduced spawning substrate, and thus spawning habitat patches are likely smaller. The diversion of the White River and Cedar River and the dewatering of the Black River have fragmented the historical spatial structure. The diversion of the White River eliminated the replenishment of spawning gravels at its historical confluence, affecting spawning downstream of river mile 31.3. The current spawning distribution is a continuum of spawning throughout the Green River from river mile 25.4 to 60.8 with patches of very high density, as compared to the expected spatial arrangement of discrete patches separated by long stretches of no spawning. Chinook spawning also occurs in the lower reaches of Newaukum and Soos Creeks. Hatchery practices have altered spawning distribution of the Green River Chinook population by contributing hatchery origin recruits to natural spawning areas, including high density spawning near Soos Creek and the Icy Creek rearing ponds. Though the Green River Chinook population has not experienced the same decline in naturally spawning adults that has occurred in other Puget Sound rivers, these numbers are masked by the high hatchery stray rate onto the spawning grounds.

The dams have blocked upstream migration of adults and limit juvenile rearing distribution in the Upper Green. Significant habitat loss has occurred in the Middle Green River limiting available refuge and rearing habitat and reducing residence time and spatial structure. A total of fourteen types of catastrophic events (natural and/or anthropogenic) were identified when evaluating extinction risk to the Green River Chinook (see WRIA 9 and King County Department of Natural Resources and Parks 2004). Spatial and temporal characteristics for each catastrophe along with their effects on the population were examined. High probability catastrophes include chemical or oil spills, landslides, major floods, and disease outbreak. The current spatial distribution of spawning subjects the Chinook population to a high degree of risk since the majority of spawning (82%) is contained within the mainstem from river mile 61.1 to 33.0. Dam failure, landslides, and chemical/oil spills all pose threats to the spawning and rearing population within this segment of river.

Spring Chinook salmon have been extirpated from the Green/Duwamish watershed and only the fall stock remains. A shift in return time has occurred that is largely attributed to hatchery practices. The mean peak return timing to the hatchery racks is October 4 compared to two-weeks later in the mid-1940s and historical estimates of natural return peak occurring in the third week of October. Five juvenile life history trajectories have been identified (Figure 4-2); however, only two of those trajectories, *estuarine-reared fry* and *marine-direct fingerling*, are common today. A *yearling* life history trajectory continues to be present, but it is

FIGURE 4-2: Green/Duwamish River Juvenile Chinook Salmon Rearing Trajectories



now rare; it is believed that this trajectory may have been common in the past since a spring stock was likely present. *Lower river-reared fry* and *marine-direct fry* appear to be uncommon today, although historically they may have been more abundant because of greater genetic diversity and habitat complexity.

Significant loss of habitat in the estuary and lower river has likely had a negative impact on habitat capacity, growth rate, residence time, and survival, especially among trajectories or life history types that rear in freshwater or the estuary for longer periods. These changes have likely reduced or eliminated behavioral variation by forcing juveniles to move through the river faster as they searched for adequate rearing habitat and food while avoiding predators. Major riverine diversions within the historical Greater Duwamish watershed have reduced the number of independent Chinook populations from five to one, with the Green River fall Chinook population the only one remaining. Straying and gene flow among the five populations have been severely reduced due to human actions that have isolated the populations. A significant amount of genetic interchange between natural and hatchery origin Chinook has occurred through constant intermingling on the spawning grounds during the past century.

4.6 NECESSARY FUTURE CHINOOK SALMON POPULATION CONDITIONS

This subsection summarizes the necessary future viable salmonid population goals and rationale to support a viable population in WRIA 9 (WRIA 9 and King County Department of Natural Resources and Parks 2004). In the absence of Puget Sound Technical Recovery Team goals for **abundance** for the Green River population, a precautionary approach was used based on the historical run size estimates. This was coupled with the population viability calculations from the Technical Recovery Team (approximately 17,000 for most independent populations of Puget Sound Chinook) to establish a range for population viability, with a lower bound of 17,000 adults and an upper bound near 37,700. Since there is always considerable measurement and model error in these calculations, a reasonable target for the population might lie near the midpoint of these estimates at about 27,000 adults. When historical and current capacity estimates are made, and the results of the habitat modeling exercise by the Muckleshoot Indian Tribe is finalized and released, a more confident estimate of target equilibrium run size can be made. The following is a brief summary of abundance goals:

- In the near term (over the next 10 years), a more critical target should be the number of natural origin recruit spawners in the system. In the Green River, the number of natural origin recruits is small and could become smaller with increasing hatchery influence. From 1993 to 2002, the Technical Recovery Team calculated the mean of natural origin recruit spawner escapement to be 1,737. The population appears to be very near the "critical population threshold" and should be increased to the upper values suggested in the viable salmonid population guidelines — 1,000 to 4,200/year; and
- A concomitant effect of low population size is the loss of distinct spawning aggregations (DSA) as population numbers fall. Given the low numbers of natural origin recruits (NORs), it is likely that many once-distinct aggregations have been lost. The number of DSAs may have fallen by a factor of 10 or more based only on the historical population size. The current number should rise as the number of NORs is increased and the DSAs should disperse throughout the available habitat.

To a large extent, the overwhelming presence of hatchery origin recruits (HORs) on the spawning ground may mask a decline in productivity of natural origin recruits (NORs). Calculations by the Puget Sound Technical Recovery Team for long and short-term productivity show considerable variation depending on the assumption used for hatchery origin recruit reproductive success. If hatchery origin recruits are assumed to be as effective as natural origin recruits, then both short- and long-term trends in median growth rate (lambda) are considerably less than 1. The actual value of hatchery origin recruit effectiveness probably lies between 0 and 1, and both short- and long-term trends would then be closer to and just below 1. This short-term trend is disturbing and should be adjusted upward. The importance of productivity is mirrored by the emphasis it received from the WRIA 9 Technical Committee, placing productivity at the top when ranking viable salmonid population parameters for effect on population viability in the Green River. The following is a brief summary of productivity goals:

- Given the estimated value of natural origin recruit breeders, the short term decline in productivity becomes problematic. If the target of 1,000 as an effective population size for natural origin recruits is used, then the rate of growth to achieve this target in 15 years is approximately 1.05. Given the error in estimating lamda and the error in hatchery origin recruit effectiveness, a growth rate of 1.05 should be considered a minimum value;

- Consistent with the expansion of spawning aggregations for natural origin recruits (NORs), the number of suitable habitat patches for spawning should be higher as well. The case could be made that the number of suitable patches for NORs must at least quadruple to achieve the natural origin recruit abundance target. If replacement of hatchery origin recruit spawners with natural origin recruit spawners is factored in, an increase in the number of natural origin recruit occupied patches of at least 50% seems warranted; and
- The reoccupation of patches and the reduction in the effect of hatchery origin recruits on natural origin recruit productivity can only be accomplished if the number of hatchery origin recruits on the spawning ground is reduced. Following the recommendations of Technical Discussion Paper #1 (Hatchery Scientific Review Group et al. 2004), the goal for an integrated hatchery program (the current approach for the Green River Chinook population) is to reduce the hatchery origin recruit escapement to the spawning grounds to 30% or less of the naturally spawning population in any given year.

Spatial structure is important for at least three reasons: (1) the distribution of sub-population units throughout suitable habitats (spawning and rearing) reduces the risk posed by catastrophic events; (2) the wide distribution allows normal rates of demographic processes—immigration, emigration, gene flow—to occur between population sub-units; and (3) spatial structure within a population can lead to increased diversity of life history trajectories. The following is a brief summary of spatial structure goals:

- A significant contribution to population viability can be achieved by recovering spatial structure of spawning and rearing salmon above the dams;
- Recovery of spatial structure below the dams is warranted also. This would bring occupied patches into closer proximity and allow interactions among more numerous local aggregations of Chinook. These patch recovery goals should focus on providing suitable rearing habitat for juveniles;
- Soos and Newaukum Creeks are occupied by Chinook and have become established spawning aggregations. Since occupied patches were lost in the mainstem, these tributaries have become new elements in the spatial structure of the population. These areas should be protected as aggregations, reducing the risk from catastrophes affecting the mainstem; and
- Refugia are areas within a watershed that provide persistent habitat conditions that support the population during environmental perturbations. In the Green River, capturing multiple aggregations of the spawning and rearing population into refugia in the Upper and Middle Green mainstem, the Duwamish Estuary, and the marine nearshore would assist in the maintenance of spatial structure within the population.

Diversity, a result of local adaptation, is often considered to be the hallmark of salmon populations. Diversity encompasses population and sub-population differentiation: variation within a population related to size, fecundity, age structure, life history types and trajectories, and genetic variation. By most accounts, an early (spring-type) run of Chinook once occupied the Green River upstream of the Green River Gorge and the dams, but it is now considered to be extinct by the Puget Sound Technical Recovery Team. In addition, the expression of life history types and trajectories has been reduced as habitats throughout the river (including the estuary and nearshore) have been modified and lost. The following is a brief summary of diversity goals:

- Since the existing life history types are the basic material for future adaptation of the species, the existing life history trajectories must be conserved;
- The opportunity for the expression of historical life history trajectories should be enhanced. This would require the recovery of historical habitat types and some proportion of their quantity in several areas of the river: Upper, Middle, and Lower Green, Duwamish Estuary, and marine nearshore;
- Increase variability in age structure for the population. This includes an increase in the proportion of 5- and 6-year old spawners and an increase in yearling outmigrants;

- The recovery of an early run life history type in the Upper Green River should be considered to expand both life history types and trajectories in the Green River. This could also provide significant conservation value to the Puget Sound Evolutionarily Significant Unit and the South Sound geographic area;
- Expand the run and spawn timing for the existing fall Chinook population to more appropriately mirror the historical timing; and
- Other components of diversity are not as well studied as age structure and life history trajectories. These other components (e.g., size, fecundity, age at migration) should be studied for negative trends over time as part of an adaptive management program.

The WRIA 9 Technical Committee agreed that it is necessary to look at both short-term and long-term needs in evaluating the viable salmonid population parameters that most threaten viability. They determined, using information from the Strategic Assessment, that the short-term concern is productivity of natural origin recruit spawners and that both spawning and rearing habitat quantity and quality will need to be addressed. Over the long-term, spatial structure was identified as the viable salmonid population parameter most threatening the viability of the Green River Chinook population.

Non-Habitat Conservation Hypotheses

Based on the results of the population analyses, three conservation hypotheses were developed to address non-habitat conditions (e.g., hatchery, harvest of salmonids, and harvest of prey species). Two were rated as Tier 1 hypotheses and one was rated a Tier 3 hypothesis:

Non-habitat–1 (Tier 1): Employing live capture techniques to harvest hatchery salmon (marked) and release natural salmon will reduce mortality of naturally-produced salmon while providing the opportunity to harvest a greater percentage of hatchery fish and thereby reducing straying of hatchery fish to the spawning grounds. [Note: Ranking of this hypothesis is based on the presumption of a segregated stock. Chinook in the Green/Duwamish, however, currently are managed as an integrated stock.]

Non-habitat–2 (Tier 1): Modifying hatchery practices (e.g., more natural rearing conditions, smaller releases, release timing and location, genetic management, etc.) and improving the attractiveness of hatcheries to returning hatchery adults will lead to reduced interactions between hatchery origin and natural origin Chinook salmon, and enhance production of natural origin Chinook.

Non-habitat–3 (Tier 3): Reducing harvest of non-salmonid commercially and recreationally important species (e.g., Dungeness crab, and forage fish) will lead to greater prey availability for juvenile and adult salmonids.

4.7 RELATIONSHIP TO HABITAT MANAGEMENT STRATEGIES AND ACTIONS

Chapter 4 has summarized the scientific foundation for development of the WRIA 9 Habitat Plan. In particular, the information on historical and current habitat and salmonid population conditions, fish utilization, water quantity, and water quality was used to develop the conservation hypotheses and hypothesized necessary future conditions for WRIA 9. These priority conservation hypotheses and hypothesized necessary future conditions were then used to develop habitat management strategies by subwatershed (Chapter 5) and habitat actions (Chapter 7) as part of the logic train for developing the recommendations of this Habitat Plan (Figure 4-3).

FIGURE 4-3: Logic Train Showing the Relationship of the Hypothesized Necessary Future Conditions and Conservation Hypotheses with the Habitat Management Strategies and Actions