SEATTLE'S SCIENTIFIC METHODOLOGY

Overview

The freshwater, estuary, and nearshore areas located within the city of Seattle provide important habitat for two federally listed fish species, chinook salmon and bull trout, as well as many other salmonid species. Of the two listed species, chinook salmon are most dependent upon the habitat conditions present in Seattle's aquatic environments, since chinook use them for adult upstream migration, juvenile rearing, and juvenile outmigration.

Bull trout use these aquatic environments principally for opportunistic foraging by sub-adult and adult fish. Because of the greater importance of these areas to chinook, this species is the main focus of the Urban Blueprint.

City Council Resolution 30272 commits the City to base its actions to protect and restore salmon habitat on sound science. The identification, analysis, and implementation of future protection and restoration actions is thus dependent upon a sound scientific understanding of the relationships among 1) chinook salmon life stages present in the city, 2) habitat requirements for those life-stages, and 3) the landscape processes which form and maintain these habitats.

The development of this scientific understanding, and the subsequent prioritization of chinook salmon protection and restoration actions to contribute to recovery based upon this knowledge, will be challenging for a number of reasons:

1. **The city of Seattle contains a number of unique aquatic habitats which are present within the two major waterways passing though the city: the Duwamish River and Cedar River/Lake Washington system.** Historic modifications for navigation and flood control in the early 1900s (see Figure 1) have significantly altered the habitats within the lower reaches of these rivers from natural conditions.

   Major federal engineering projects which greatly altered salmon habitat include the diversion of the White River from the Green River drainage to the Puyallup River drainage in 1906, the diversion of the Cedar River from the Black River (Duwamish drainage) to Lake Washington in 1912, and the construction of the Ship Canal and lowering of Lake Washington in 1916. As a result of these historical modifications, the hydrology and geomorphology of the Duwamish River and Lake Washington systems are vastly different from pre-development conditions. On the Cedar River/Lake Washington system, chinook salmon that once migrated to the Sound through the Duwamish must now migrate through atypical habitats including a large lake, a manmade ship canal, and navigation locks.

   Moreover, the intensive urban development which has occurred within the city since the late 1800s has resulted in major modifications to smaller stream drainages and extensive alterations to the shoreline areas of the Duwamish River, Lake Washington, Lake Union, and nearshore areas including Elliott Bay (Figure 2). As a consequence of this development, very few stream reaches or shoreline areas present within the city remain in natural condition.

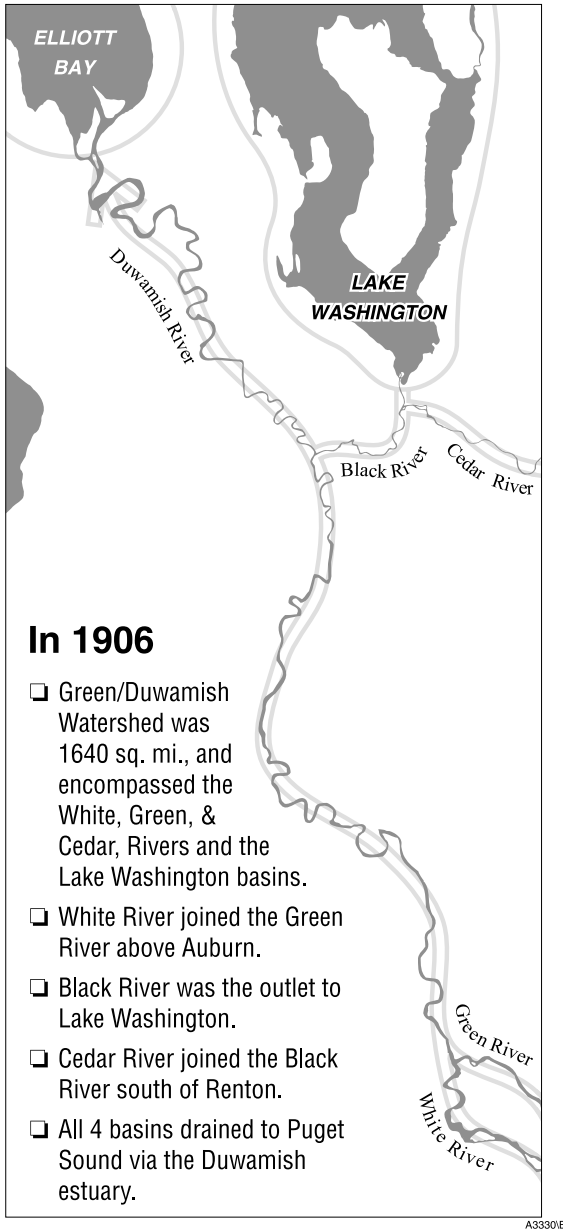
   Even though major constraints have been imposed on the aquatic habitats located within the city by historic waterway modifications and land development, the City recognizes that the urban landscape continues to provide important habitat functions to chinook salmon.

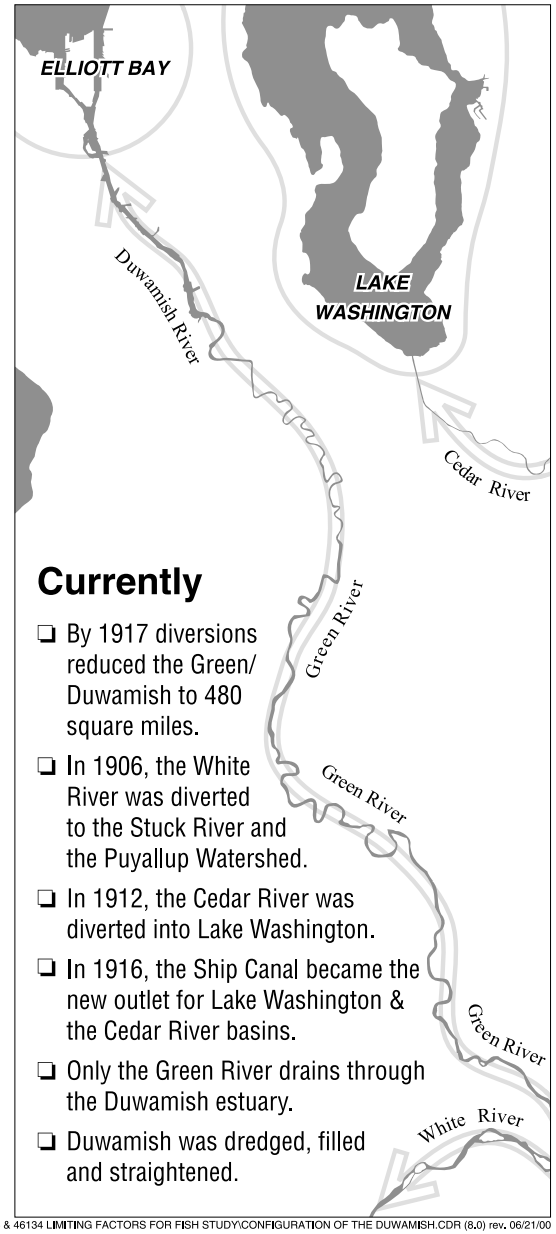
   Indeed, the two major waterways present within the city of Seattle (Duwamish River and Lake Washington system) provide at least two major roles in the life-cycle of chinook

Figure 1

HISTORICAL RIVER DIVERSIONS AFFECTING THE GREEN/DUWAMISH and CEDAR/ LAKE WASHINGTON WATERSHEDS

(Redrawn from Dunne and Dietrich 1978)





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populations in those basins. First, these waterways are the sole migration corridors for adults migrating upstream to the spawning areas located in the upper regions of these two watersheds. Second, they provide foraging and refuge habitat for outmigrating juvenile chinook salmon during the spring. The spatial distribution and diversity of invertebrate food resources and refuge habitat areas may have an important influence on the growth and survival of juvenile chinook salmon migrating through Seattle.

2. **Relatively little is known regarding the life history, ecology, and habitat requirements of chinook salmon in these lower river systems and built-out urban areas compared to the less-developed and undeveloped forested areas of the upper watersheds.** There is also very little research to date on the relative success of alternative restoration methods and techniques in urban areas for improving chinook salmon habitat.

   The City recognizes this presents challenges to the development of effective restoration efforts which provide biologically meaningful, long-term benefits to salmon. For this reason, the City has implemented a research program involving the cooperation of municipal, state, federal, tribal, and university scientists with the goal of better understanding the biology of chinook salmon in the urban environment.

   The objective of this research program is to continue to refine our understanding so we may better target our actions to improve chinook survival and productivity. Through monitoring we hope to validate the expected biological response. Continuing research and monitoring will allow the City and others to adapt actions over time to maximize positive biological responses.

3. **Finally, the results of the in-city analysis of priorities for chinook salmon protection and restoration must be placed in the broader context of the Cedar/Lake Washington and Green/Duwamish watersheds.** Long term prioritization of actions and efficient allocation of resources requires a watershed analysis and prioritization process, and ultimately an ESU-wide analysis. Committees representing governing bodies and major stakeholders are currently working on these analyses for each watershed in the Puget Sound ESU. For example, they are developing analyses that will define the most important factors limiting increased productivity of chinook and other species in each watershed. These analyses will then form the basis for evaluating protective and restorative actions to increase habitat productivity and lead to recovery.

   Complementing and hopefully incorporating the watershed action plans, the National Marine Fisheries Service will provide a federal recovery plan that proposes the population levels necessary to achieve and sustain recovery. The recommendations will cover actions in harvest, hatchery, hydro, and habitat management necessary to achieve recovery at the ESU geographic scale.

   The City, in developing the Urban Blueprint, has sought to utilize information and research results developed in these other planning efforts and to coordinate our work with them. This coordination is vital to the long-term optimization of limited research and project resources to ensure maximum improvements in salmon productivity.

General Approach

Given the need to place our actions in the broader watershed context, the City of Seattle's approach to habitat protection and restoration includes two levels of scientific analysis to define and prioritize recovery actions.

1) Within the ***urban area***, the City will use the framework described below to develop protection and restoration actions to improve habitats used by chinook. The central objective of this approach is to use our current knowledge of salmon needs within the city along with expert judgment to determine the most significant habitat requirements of chinook within Seatle and to direct our efforts to protecting and restoring this key habitat.

   The urban approach involves virtually all members of the City's Salmon Team, including environmental planners, fish biologists, and aquatic ecologists within Seattle Public Utilities, Seattle City Light, the Department of Design, Coonstruction and Land Use,

SeaTrans, the Strategic Planning Office, and the Department of Parks and Recreation.

2) At the ***watershed level***, the City is actively involved in protecting and restoring chinook salmon at the watershed or population scale through participation in watershed planning groups. The primary goal of this approach is to identify the habitat areas or functions that limit the production and diversity of chinook salmon within a river basin (i.e., "population bottlenecks"), and to protect and restore these critical and key habitats in order improve the size and viability of the population.

   Work under this approach requires the combined efforts of scientists and environmental planners affiliated with municipal, state, and federal governments, tribes, and non-governmental organizations.

   The City of Seattle's involvement through this watershed planning process is primarily through watershed coordinators dedicated to each of the two watershed resource inventory areas (WRIAs) within which the city is located (WRIA 8, Cedar River / Lake Washington basin and WRIA 9, Green/Duwamish River basin). In addition the City is active in those WRIAs where it has major utility projects (WRIA 7, Snohomish River Basin and WRIA 3/4, Skagit River basin).

Developing a Scientific Framework

The City's scientific framework involves a number of sequential steps. These are:

❑ **Identify what is known regarding chinook salmon within the urban environment based upon the best available scientific information.**

The Built Environment Study (BES) was completed in 2000 to provide a comprehensive review and assessment of chinook salmon research studies conducted to date within the city of Seattle and surrounding areas. Since its publication City staff have continued to closely track the developing research on chinook and other species in the urban area. Staff are members of and have actively participated in the technical committees for WRIAs 3&4, 7, 8, and 9 as well as the Nearshore Technical Committee. In addition, leading researchers have been invited to present their ongoing work to the City's Science Team.

❑ **Identify and acknowledge key data gaps regarding salmon in the urban environment.**

The BES also provides a comprehensive assessment of data gaps and research needs regarding the life history, ecology, and habitat requirements of chinook salmon within the city of Seattle. This document provides a solid scientific foundation and starting point for identifying and prioritizing chinook salmon research needs within the city. The City Science Team has continued to refine these needs in consultation with agency and university researchers.

❑ **Develop and track research to fill these data gaps.**

The City is currently tracking ongoing research activities in the riverine, estuary, lake, and nearshore habitat areas within the Green/Duwamish basin and Cedar/Lake Washington basin. In addition, the City is currently developing a database of research reports, data, biological assessments and biological opinions, and other documents related to chinook salmon and bull trout to allow quick and easy access to available scientific information to all City staff.

The City is also currently funding research projects in Lake Washington, the Ship Canal and locks, and nearshore areas to fill some of the major information gaps in these areas regarding the migratory behavior, predator impacts, and habitat utilization of chinook and other salmonids. These research projects are being conducted in cooperation with University of Washington, the Washington Dept. of Fish and Wildlife, and the U.S. Fish and Wildlife Service. The City has also funded the marking of all hatchery chinook in these watersheds to aid this research.

❑ **Develop a scientific framework based on current knowledge and expert judgment to describe our current understanding of the linkages between salmon needs, the habitat that must provide for those needs, and the landscape processes that form that habitat.**

The City of Seattle's scientific framework is based upon developing a sound hierarchical understanding of:

- The habitat requirements of those life-stages of chinook salmon migrating through and using the urban environment, and
- Key linkages between the chinook salmon life-stages which are present in the city, the habitat required by these life-stages, and landscape processes which form and maintain this habitat (Figure 3).

Given the challenges discussed above, we start with the needs of the fish to help focus our effort. This "bottom-up" approach allows us to better identify, prioritize, and implement protection and restoration actions that will directly address those critical habitat characteristics having the greatest impacts on salmon within the urban environment. This approach also allows us to better identify those ecosystem and habitat-forming processes which directly link salmon populations to habitat, and habitat to the urban landscape.

This scientific approach recognizes that the city of Seattle contains a number of geographically and ecologically unique areas with respect to chinook salmon. For analytical purposes, the city has been separated into six distinct aquatic environments as part of the scientific framework. These areas are:

1. Lake Washington;
2. Lake Union and the Ship Canal;
3. Duwamish Estuary;
4. Ballard Locks;
5. Marine Nearshore areas including Elliott Bay and Shilshole Bay; and
6. Urban Streams

Although the City's scientific approach will initially focus on each of these areas on a separate basis, we recognize that all of these areas with the exception of urban streams provide important habitat functions to chinook salmon during their migration through Seattle. Consequently, these areas are intrinsically linked by their complementary roles in the life cycle of this species. The City will evaluate the linkages among these areas when developing an inte-

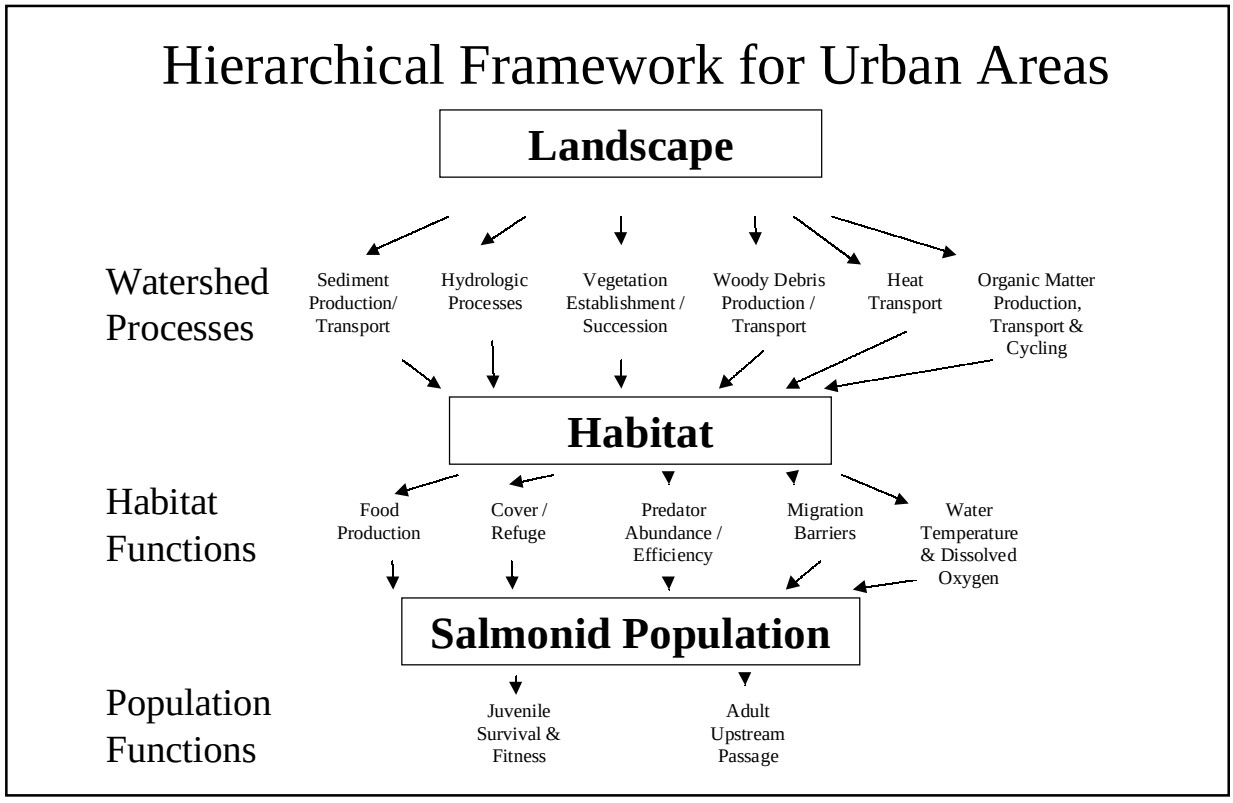

Figure 3. *Hierarchical framework used by Seattle to identify linkages between fish populations, habitat functions, and watershed processes.*

grated set of protection and restoration actions for chinook salmon.

To date, research does not indicate that Seattle's urban streams provide significant habitat for chinook. However, chinook have been observed to congregate at the mouths of some creeks, indicating the importance of continued assessment of the creeks' water quality and food contribution to receiving bodies. The appendix to this report provides an overview of the City's assessment methodology for urban streams. For more detailed information regarding City work affecting creeks, please see the Urban Creeks Legacy Home Page **(http://www.ci.seattle.wa.us/util/urbancreeks/)**.

Finally, it is also important to note that the models described in the Urban Blueprint are based on current scientific knowledge and will be updated as new information becomes available.

The next step within the City's scientific framework is to define how fish use the urban landscape. This includes:

- ❑ Identify the life stages that each area supports; and
- ❑ Determine the habitat requirements that fish need to successfully carry out these life history functions within each area.

Life History Stages

The best available scientific information to date suggests that the City is principally used by two life-stages of chinook salmon:

- ❑ ***Adult up-migration***. Adult chinook salmon migrate through Seattle towards spawning areas located in the upper watershed. This life stage is found within the city for a relatively short time. For example, research suggests that adults rapidly migrate through Lake Washington towards spawning grounds found in the Cedar River, Bear Creek, Issaquah Creek, Kelsey Creek, and other large streams within this basin.

  The main habitat function provided by the city for this life stage is a migration corridor. The use of areas within the city by spawning chinook salmon is assumed to be very limited both historically and currently. A few spawners of hatchery-origin have been observed in recent years within Thornton Creek, a stream located within the boundaries of the city.

- ❑ ***Juvenile outmigration.*** The native chinook salmon populations present within city of Seattle (WRIAs 8 and 9) have an "ocean-type" juvenile life history strategy, meaning that juvenile fish migrate to the ocean a short time (several days to several weeks) after emerging from spawning gravels located in major tributaries. This is in contrast to the "stream-type" life history strategy found in many river systems, in which juveniles spend at least one year in their natal stream prior to migrating to the ocean.

  Due to their ocean-type life history, juvenile chinook salmon are present in the city for a relatively short period from late winter to early summer. Considering this, the primary habitat functions provided by the waterways located within the city are assumed to be: 1) refuge habitat from fast currents (high flow periods) and predators (e.g., largemouth bass and northern pikeminnow); and 2) foraging habitat. We recognize that the best habitat areas for juvenile chinook salmon are probably those which provide both of these functions.

Key Habitat Types and Characteristics

We have identified key habitat types and characteristics that are needed to support these life stages within each geographical area. For example, current research suggests that shallow shoreline areas with fine substrates are important for migrating chinook juveniles in Lake Washington.. Once identified, these habitat types and characteristics help to define inventory needs within each aquatic environment.

The City of Seattle is currently developing a strategy for an inventory of habitat types within the saltwater nearshore areas, and the shoreline areas of Lake Union, Lake Washington, and the Duwamish River. The inventory will provide a detailed description (e.g., area and distribution) of the habitat types potentially available to chinook salmon within the city. This inventory data will be complemented by

research on juvenile chinook salmon habitat use in Lake Washington and Lake Union and the nearshore, currently being funded or planned by the City and other agencies.

A major goal of the scientific framework will be to use the habitat availability data yielded by the inventory and the habitat preference information provided by research to delineate the quantity and distribution of high quality habitat types for juvenile chinook salmon within each geographic area.

Finally in this step, we will identify the landscape processes (watershed functions) that form and maintain chinook salmon habitat within the city. We will give a high priority to those restoration opportunities that are consistent with or mimic natural processes, since they have the greatest potential for long-term success.

However, we also realize that engineered restoration solutions will be required in many areas within the city which have been highly altered by historic river diversions, shoreline modifications, and intensive land development. The engineered solutions may be important for preventing further declines in salmon populations. We recognize that these solutions must be mindful of and consistent with natural processes or they are likely to be undermined.

We recognize the reluctance of many to use engineered solutions rather than restoration of natural processes. We agree with this basic reluctance. The City does face, however, such significantly altered aquatic environments that there is little choice but to intelligently seek to restore needed habitat conditions through cautious human intervention. Our experience indicates that intervention based on a thorough understanding of the ecosystem in which one is working can be very effective (e.g., the Skagit River system).

Our research suggests that this intervention should be done carefully, through pilot projects. Projects must be monitored to verify that restoration efforts are achieving expected biological results. Restorative efforts will be broadened as our knowledge confirms that our efforts are providing positive biological responses.

- ❑ **Identify major constraints to landscape processes.**

  Natural watershed (ecosystem) processes are present in urban landscapes, but some of these processes are highly constrained. For example, in the past, flooding of the Duwamish helped to form valuable complex habitat for juvenile rearing. This process is now constrained by loss of a significant portion of the watershed to diversions, the construction of a dam on the Green River that regulates downstream flows, and significant diking and development in the riparian corridor.

  As part of our scientific approach, we will identify the major constraints to landscape processes present within each of the five geographic areas identified previously. For example, the historic bulkheading and armoring of shoreline areas along Lake Washington, Lake Union, the Duwamish River, and the nearshore environment represents one of the major constraints to landscape processes within the city of Seattle. Where feasible, we will work to develop methods that reduce or overcome these constraints.

- ❑ **Develop methods to directly measure improvements to fish survival and fitness of juvenile salmon migrating through the urban environment.**

  Recognizing that our knowledge of chinook and their interaction with the urban environment is incomplete, we will attempt to develop sampling methods and techniques that can be used to measure the survival, growth, and condition of juvenile chinook salmon directly as they migrate through the Seattle. Our goal is to develop a much stronger link between habitat improvements and fish benefits.

  A number of methods are currently being investigated for this purpose by research studies funded by the City, including a PIT (passive inductive transmitter) tagging program, mark-and-recapture techniques using dyes, and radio tracking. We are also using non-injurious methods for determining the growth, condition, and diet of juvenile chinook salmon as they pass through the city.

The Larger Context

While the approach described above will direct our efforts to focus on the most important factors within Seattle, it will not tell us the relative importance of those efforts within the Cedar/Lake Washington and Green/Duwamish watersheds as a whole. Nor does it tell us about the role of any particular watershed in the recovery of the ESU. For these reasons, we are actively participating in watershed planning efforts in all watersheds where the City has an interest or presence.

At the watershed level we are striving for a more comprehensive understanding of limiting factors and critical habitat needs through quantitative modeling and assessment processes. We are also actively participating in the Puget Sound Shared Strategy to stay connected with the overall recovery planning efforts in the ESU.

Long term biological and habitat goals for the City will be developed in concert with these larger planning efforts. In the short term, however, the scientific approach described above will ensure that the actions we take inside Seattle are scientifically sound and will likely contribute meaningfully to chinook recovery.

Actions Based on Science

In summary, the intent of this scientific effort is to enhance the City's environmental stewardship and, in a targeted way, assist in the recovery of chinook salmon. The City affects land and water through numerous decisions and actions, including regulation of private development and redevelopment, management of its park land, maintenance and operations city streets, management and operations of water quality and water supply programs, and the design and construction of public infrastructure. Through its scientific research on salmon recovery, the city is developing the knowledge of how to adjust its own management practices, design better public infrastructure projects and systems, impose better regulatory conditions on private development, and invest directly in order to protect and restore needed salmon habitat.

The strategy is designed to accumulate knowledge over time and to continuously improve actions with targeted investments and actions that are most effective in achieving improved salmon productivity. This incremental, adaptive management strategy is necessary in a highly developed urban environment such as Seattle, since the risks of unproductive restorative action can be great and the costs of restoration in urban environments are high. One example of such risks is in Lake Washington where some restorative actions could result in aiding predators of chinook more than chinook. Thus, it is vitally important that the City:

- **Continue research to answer key questions arising from the framework and monitoring.**

  We recognize that ongoing research will generate a number of new questions which will need to be answered in order to assure the success of the City's protection and restoration actions in achieving the goal of improving chinook salmon populations. This will require a continuing research effort by the City and its partners in salmon recovery.

- **Prioritize and implement actions which, based on the results of the scientific framework analysis and pilot projects, and watershed level of analysis, best address factors limiting fish production within the city, and within each basin.**

  We will prioritize those restoration actions which provide the greatest improvements to the survival and growth of chinook salmon passing through the city. We recognize that the major limitations (population "bottlenecks") to the production of chinook salmon may be located upstream of the boundaries of Seattle (for example, scarcity of spawning gravels in middle sections of Green River). These population bottlenecks will be addressed through the City's participation in the watershed (WRIA) planning processes.

  The City has been funding restoration and protection projects outside of the city with the objective of protecting and restoring those areas in the ESU which are critical to the health of salmon populations. Examples of these investments include funding estuary restoration projects in the Skagit River basin, and habitat restoration projects in the Snohomish River basin.

- **Modify regulatory codes and conditions based on scientific findings and continuing research.**

  The city, through the Department of Design, Construction and Land Use, updates its codes and regulatory conditions on a continuous basis. Its regulatory regime acts as a comprehensive approach to protecting and, through gradual redevelopment, restoring habitat. Because the city is largely built-out, and redevelopment occurs at a very slow rate, regulatory codes and conditions will have a salutary effect over a longer period of time than direct public investment in restorative action. Nevertheless, the City is paying attention to continuous incorporation of scientific knowledge into regulatory codes. A later section of this report describes the kind of action that the City is taking to adjust its regulatory regime to achieve greater protection of salmon.

- **Monitor results using appropriate indicators for each level of analysis within the framework (salmon population, habitat, and landscape).**

  Habitat types and characteristics will be tracked on a long-term basis and compared to existing baseline conditions to document trends and improvements in habitat conditions. Wherever possible we will seek out direct measures of increased salmon survival or fitness improvements.

- **Modify actions based upon adaptive management principles**

  Adaptive management is an approach to natural resource management that recognizes the uncertainty inherent in designing management actions to achieve specific biological objectives within ecosystems. As Kai Lee, a well known theorist on adaptive management, states, "Adaptive management does not postpone action until "enough" is known but acknowledges that time and resources are too short to defer some action, particularly action to address urgent problems such as…declines in the abundance of valued biota."

  In short, adaptive management is a commitment to learn by doing. An adaptive approach calls for taking action in the face of uncertainty, but taking action in a way that allows for systematically improving understanding of how ecosystems function and how human actions affect them. It calls for decision-makers to formulate actions and policies as hypotheses, and to use monitoring to test them vigorously. When monitoring produces unexpected results, then decision makers can adapt their course of action.

  Adaptive management will be an important part of Seattle's salmon recovery efforts. Although scientific understanding of chinook salmon in urban environments has grown markedly in recent years, there are many questions still unanswered. Some of these questions concern how chinook behave as they migrate through urban waterways, while others concern the likely effectiveness of different habitat protection and improvement strategies in increasing salmonid survival.

  Although there is substantial uncertainty, the declining abundance of chinook runs and the 1998 listing of chinook as a threatened species under ESA make near term action essential. This blueprint identifies potential focal areas for habitat improvement in each of the city's five aquatic environments, based on the best available science and professional judgement. We need to begin looking for opportunities to make progress in these areas, even though there are many scientific questions remaining.

  Having a well coordinated and well managed adaptive management process will be the key to ensuring that we learn as we make investments in habitat protection and improvement within our city limits. It will ensure that when investments are made, they become an opportunity to develop better scientific understanding of the efficacy of different approaches. Monitoring will show whether the outcomes of specific investments – either at the project or the program scale – are achieving their intended results. This will in turn enable us to adapt and refine our habitat improvement strategies.

  Adaptive management produces a cyclical process that moves through different phases, each managed by different actors and institutions. Typically there are five phases in an adaptive management process:

1. Assess the resource and/or the problem
2. Decide on goals, policies and actions, and develop hypotheses that need testing
3. Implement actions, and conduct monitoring
4. Evaluate scientific results
5. Decide on policy adaptations and adjustments

Seattle is in the process of designing an approach to adaptive management that will describe how these steps will occur in the context of the City's policy making processes and operations. This strategy will be presented to the City Council in June, 2001.