EVALUATING WATERSHED RESPONSE TO LAND MANAGEMENT AND RESTORATION ACTIONS:

INTENSIVELY MONITORED WATERSHEDS (IMW) PROGRESS REPORT

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Prepared by

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EXECUTIVE SUMMARY

Millions of dollars have been dedicated to the restoration of freshwater habitat since the listing of many populations of salmon in the Pacific Northwest in the 1990s. Little is known about the efficacy of these efforts. The most effective means of determining the contribution of restoration projects to salmon recovery is to implement experimental, watershed-scale evaluations. This document describes a series of intensively monitored watersheds (IMW) being established in Washington expressly to measure the effect of habitat restoration on salmon and trout productivity.

The IMW effort in western Washington is split between three sets of smaller, paired watersheds (complexes) focusing on coho salmon, and steelhead and cutthroat trout and the Skagit River estuary focused on ocean type chinook. The sole eastern Washington IMW is a BPA-funded effort on the Wenatchee River being coordinated by NOAA Fisheries. Restoration and monitoring objectives vary among the IMWs according to current condition, land use, and restoration potential and are described in the document.

The basic premise of the IMW project is that the complex relationships controlling salmon response to habitat conditions can best be understood by concentrating monitoring and research efforts at a few locations. We have begun implementing a monitoring framework that includes water quantity, water quality, habitat, summer juvenile fish abundance, and smolt production and are identifying specific restoration actions for the purpose of better understanding how salmon and trout respond to current approaches to restore habitat.

We are developing a landscape classification approach with NOAA Fisheries that will aid in applying the information (regarding fish response to habitat restoration) gained from these IMW complexes to more efficiently directing salmon restoration efforts across the state.

We have ranked watersheds statewide according to the potential use as IMWs. Ranking criteria included: the feasibility of obtaining quantitative estimates of smolt production, the record of smolt monitoring, fish species present, and influence of hatchery-produced fish. This list may be used to direct other IMW efforts as needed.

INTRODUCTION

Intensive, watershed-scale research and monitoring efforts have generated results that have been very influential in the development of environmental management strategies in North America. Some of the earliest intensive monitoring efforts were instituted by the U.S. Forest Service in the 1950s to better understand hydrologic responses to logging. Efforts at these sites expanded over time to encompass chemical and biological responses as well. Changes in land use practices nationwide have been based on studies conducted at experimental watersheds like the H.J. Andrews Experimental Forest in Oregon, the Hubbard Brook Experimental Forest in New Hampshire and the Coweeta Experimental Forest in North Carolina. The success of these efforts spawned a number of intensive, watershed-level research efforts in the Pacific Northwest to evaluate the response of salmon to forest practices. The Alsea Watershed Study, which was initiated in the 1960s, evaluated the response of coho salmon and cutthroat trout to various logging methods in a series of small watersheds on the Oregon coast. Results from this study provided much of the technical rationale for the measures to protect aquatic habitat incorporated into the forest practice regulations of Oregon and Washington in the early 1970s. In the 1970s an ambitious watershed-level project was initiated at Carnation Creek on Vancouver Island, British Columbia that evaluated the response of coho and chum salmon to the logging of a previously unlogged watershed. The results of this study led to a revision of the forestry code for B.C. and also influenced revisions to forest practice rules in other areas of the Pacific Northwest. Intensive, watershed-level studies such as these form the foundation of our knowledge about the freshwater habitat requirements of salmonid fishes

Millions of dollars have been dedicated to the restoration of freshwater habitat since the listing of many populations of salmon in the Pacific Northwest in the 1990s. Little is known about the efficacy of these efforts. The most effective means of determining the contribution of restoration projects to salmon recovery is to implement experimental, watershed-scale evaluations. Several organizations in the Pacific Northwest have begun to establish such projects. This document describes a series of intensively monitored watersheds being established in Washington for the purpose of better understanding how salmon and trout respond to current approaches to restore habitat

INTENSIVELY MONITORED WATERSHEDS (IMW) – GENERAL CONCEPT

The basic premise of the IMW project is that the complex relationships controlling salmon response to habitat conditions can best be understood by concentrating monitoring and research efforts at a few locations. The type of data required to evaluate the response of fish populations to management actions that affect habitat quality or quantity are difficult and expensive to collect. Focusing efforts on a relatively few locations enables enough data on physical and biological attributes of a system to be collected to develop a comprehensive understanding of the factors affecting salmon production in freshwater.

IWM is an efficient method of achieving the level of sampling intensity necessary to determine the response of salmon to a set of management actions. Evaluating biological responses is complicated, requiring an understanding of how various management actions interact to affect habitat conditions and how system biology responds to these habitat changes. The response of the fish is dependent on the relative availability of the habitat types it requires, which change through the period of freshwater rearing (Table 1), and the manner in which these habitat types are influenced by application of a management action. Further complicating the issue is the fact that the relative importance of each habitat type in determining fish survival changes from year-to-year due to variations in weather and flow, the abundance of fish spawning within the watershed and other factors. For example, smolt production can be dictated by spawning habitat availability and quality during years when flood flows occur during incubation and greatly decrease egg survival (Seiler et al. 2002a). However, during years of more benign flow conditions during egg incubation, population performance may be more influenced by the availability of food during spring and summer or adequate winter habitat. Untangling the various factors that determine performance of salmon and how these factors respond to land use actions or restoration efforts can only be accomplished with an intensive monitoring approach.

Table 1. Habitat requirements of coho salmon during freshwater rearing. The changing requirements of the fish stress the need to develop monitoring designs that evaluate responses at a spatial scale large enough to encompass the full range of habitat types required by the fish to complete freshwater rearing.

Life History Stage	Habitat
Spawning and egg incubation	Gravel bedded riffles and pool tail outs in proximity of cover suitable for adult spawners (e.g., deep pools, undercut banks, debris jams)
Early fry rearing	Low velocity areas with cover in close proximity to food source. Typically associated with shallow, channel margin habitat with cover from wood and overhanging vegetation
Summer rearing	Pool habitat with cover in close proximity to food source. Typically found in low gradient channels with a pool/riffle morphology
Winter rearing	Low velocity areas with cover. Often associated with off-channel habitat on floodplains including low gradient tributaries, secondary channels and ponds

The ultimate objective of nearly all efforts intended to improve salmon habitat is to increase the abundance, size and/or survival of fish. Therefore, the most meaningful measurements of effectiveness are those related to the performance of the fish during their period of freshwater residency; from adult spawning through smolting of their offspring. Because salmon use multiple habitat types during freshwater rearing, the spatial scale at which an evaluation is conducted should be large enough to encompass all the habitats required for the salmon to complete this phase of their life history. The size of the area required to capture the full range of habitats needed to complete freshwater rearing will vary by species. The basins selected are of sufficient size to encompass the habitat requirements for coho salmon, steelhead and anadromous cutthroat trout.

Experimental Design

Multiple experimental designs will be utilized in the IMW watersheds, depending upon the question being addressed and the scale at which the assessment must be conducted. Regression analysis has been used to investigate the relationship between stream flow and smolt production and this approach will also be used in the IMW investigations. Many of the objectives of the IMW project can be addressed by a before-after/control-impact (BACI) experimental design. This type of design enhances the ability to differentiate treatment responses from responses due to variations in weather or other factors not directly affected by the treatments.

All approaches will benefit from the evaluation of two or more basins in each study complex. At least one watershed will serve as a reference site where no experimental treatments are implemented during the study. A calibration period prior to applying treatments is required to determine how the reference and treatment watershed compare in the key response variables prior to any habitat manipulation. The length of time required to develop this baseline will vary among watersheds. The calibration period for sites with existing information on spawner abundance and smolt output would be much shorter than for watersheds where these data have not been collected.

Treated and untreated sites can be paired at a multiple spatial scales within the IWM design, the scale dependent on the question being addressed. In fact, reference sites for some reach-level projects could be within the basin designated for treatment. These reference sites would consist of portions of the basin comparable in initial condition to the location where a restoration action is applied but where no habitat manipulation would occur during the period of evaluation. Questions that can be addressed at this finer scale include life-history specific biological responses or physical habitat responses to management actions. For evaluations of effects at the scale of the entire basin, a comparison with a nearby basin that is not undergoing treatment is required. Therefore, the IMW approach does require sufficient management discipline to ensure that reference sites remain untreated through the duration of the study. This does not imply that any management activities in the reference watershed will compromise the integrity of the study. The validity of the study design will be maintained provided that the management activities not directly related to the restoration actions being evaluated are comparable at the reference and treated locations. For example, the effectiveness of restoration actions can be evaluated in watersheds being actively managed for wood production provided that the type and intensity of forest management activities in the treated and reference watersheds are comparable.

Experimental treatments applied in the treated watersheds will vary depending upon the initial condition of the watersheds, the perceived factors limiting fish production, and the feasibility of applying treatments. The identification of the most effective treatments will be based on an assessment of current conditions. Many of the selected watersheds have had some type of watershed assessment already conducted (limiting factors analysis, Washington State watershed analysis, EDT). These analyses will be used in conjunction with supplemental information collected as part of the IMW project to identify the suite of habitat restoration efforts most likely to positively influence the salmon and trout production. The identified projects will be applied in conjunction with local lead entities or citizen enhancement groups.

Focus on Coho, Steelhead, and Cutthroat

Most of the IMW effort in western Washington is currently being conducted on three groups of relatively small watersheds (Figure 1). The three watershed complexes include ten total watersheds; three located along the northern side of the Olympic Peninsula, four on the western side of the Kitsap Peninsula and three on the north shore of the lower Columbia River. The individual watersheds range in area from 12 km^2 to 75 km^2. Watersheds of this size are sufficiently large to provide all the habitat conditions required for coho salmon, steelhead and cutthroat to complete freshwater rearing. We recognize the need to also assess the response of other species, especially chinook salmon, to restoration efforts. However, we have focused more heavily on coho, steelhead and cutthroat in initial the IMW effort for four reasons:

1) These species spend more time in freshwater (1-3years) than most other species of anadromous salmonids. Thus, they should be more responsive to changes in the quality and quantity of freshwater habitat than species which only reside in streams and rivers for a short period of time (e.g. ocean-type chinook, chum, pink).
2) In order to cause a change in smolt production, a fairly substantial change in freshwater habitat conditions across a watershed will need to occur. The relatively small size of the watersheds within which coho, steelhead and cutthroat complete their freshwater rearing will make it much more practicable to alter enough freshwater habitat to affect smolt production. Response to the treatments also should be detectable in a shorter period of time than would be the case with species requiring much larger watersheds to support their freshwater rearing requirements.
3) Many of the restoration projects and land use regulations that have been implemented in the region have been based on the habitat requirements of coho salmon. Therefore, this species should be the most likely to respond to many of the restoration activities that are being funded.
4) Because these species complete freshwater rearing in a small watershed, fish responses to management actions can be assessed using a before-after/control impact design. Use of this type of design should make the responses by the fish easier to detect. Such a design would not be possible with species requiring a much more extensive area to complete rearing.

The initial focus on these three species is intended as a “proof-of-concept”. We believe meaningful results can be obtained from these systems in a shorter period of time than would be possible for species requiring much larger watersheds to complete freshwater rearing, like chinook. However, due to interest in chinook salmon recovery, we have incorporated this species into the IMW project. This aspect of the IMW effort is described later in this section.

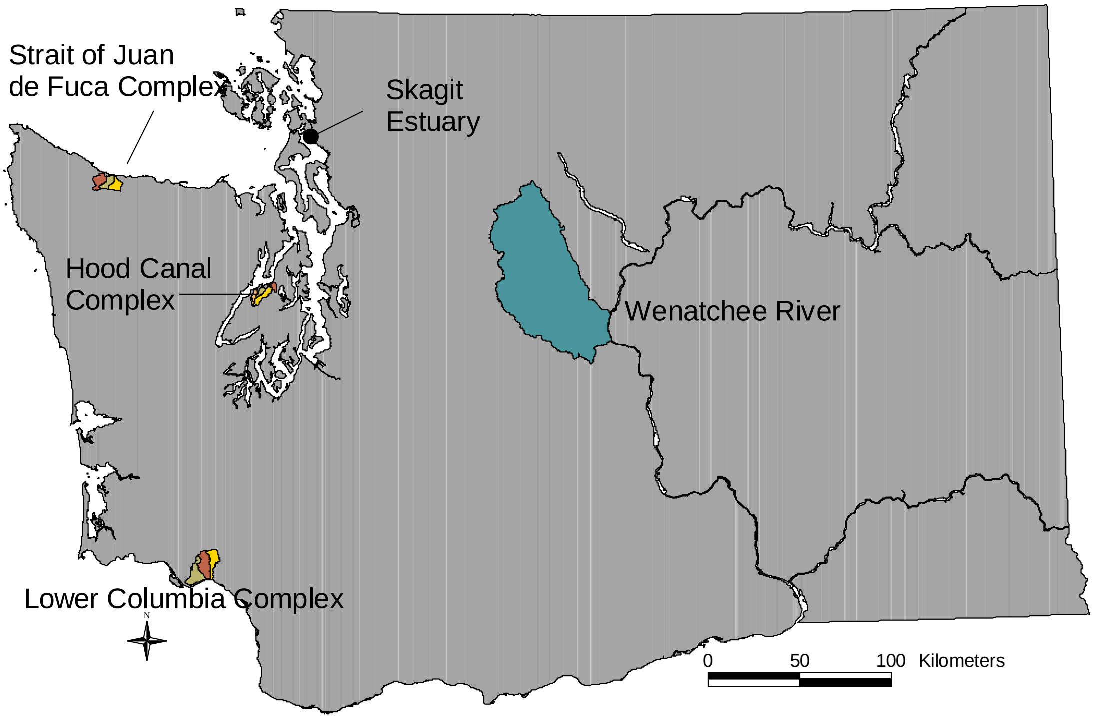

Figure 1. Locations of the three IMW basin complexes, Straits Juan de Fuca (SJF), Hook Canal, and Lower Columbia, and two chinook salmon IMW's, Skagit Estuary and Wenatchee basin.

The coho, steelhead, cutthroat watersheds described below were selected based on the following criteria:

- Watersheds small enough that habitat may be effectively treated and monitored but large enough to encompass all freshwater life stages of coho salmon, steelhead, and cutthroat trout.
- Current monitoring provides a reliable estimate of smolt production for the entire basin above the trap.
- Estimates of returning adults are available or feasible with additional effort.
- There is one or more watersheds in close proximity with similar physical characteristics.
- Sites with longer records of smolt production were preferred.

Variables Measured

The specific parameters measured in each watershed will vary depending on the questions being addressed and the types of treatments being applied. However, a basic set of data will be collected at all of the watersheds (Table 2). These common measures are of attributes that reflect the impact restoration actions are having on a watershed scale or of factors provide context for interpretation of response to treatments. These measures include measures of water quantity and quality, habitat characteristics and characteristics of the fish populations.

Table 2. Variables measured in all coho, steelhead, and cutthroat watersheds.

	Frequency	Data collection
Water/climate		
Flow	Continuous	Begin June 2004
Climate	Continuous	Begin August 2004
Water temperature	Continuous	Begin July 2004
Water chemistry	Monthly	Begin October 2004
Habitat		
Hankin & Reeves survey	Annual	July-August
Probabilistic sampling	Annual (Hood Canal and SJF only)	July-August
Fish		
Smolt production	Annual	March-June
Juvenile abundance	Annual	July-August
Spawners	Annual	(varies by species)

Water Quantity and Quality

Continuous stage height recorders will be installed near the mouth of each stream and flows estimated using the relationship between stage height and flow. Water will be collected monthly at the gauge site and analyzed for temperature, dissolved oxygen, pH, specific conductivity, total nitrogen, nitrate+nitrite-N, ammonia-N, total phosphorus, soluble reactive phosphorus, suspended sediment, and dissolved organic carbon. Wind speed and direction, air temperature, relative humidity, and precipitation will be measured at one location in each basin complex. In situ water temperature loggers will be deployed throughout each basin at selected locations to record changes in water temperature from headwaters to the mouth.

Habitat Conditions

The spatial extent and temporal duration of the IMW studies lend themselves to the use of two methods of collecting habitat data; a spatially continuous, temporally infrequent survey based on the basinwide methods developed by Hankin and Reeves (H-R) (Hankin 1984, Hankin and Reeves 1988) and a spatially discontinuous, temporally frequent survey based on methods developed by the U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP) (Kaufmann et al. 1999, Peck et al. 2001). The H-R-based approach uses visual estimates of habitat types (e.g., , Bisson et al. 1982) and coarse measures or counts of habitat attributes (e.g., large wood, Gregory et al. 2003) to provide estimates of habitat abundance and distribution (Hankin and Reeves 1988). During such surveys the entire stream network in an IMW watershed can be surveyed. The H-R approach provides a more complete view of stream conditions by identifying rare habitat types and attributes that may be missed using traditional sampling approaches (Dolloff et al. 1993, 1997). However, rapid estimation approaches may provide low measurement precision (Simonson et al. 1994, Roper and Scarnecchia 1995, Peterson and Wollrab 1999) that hinders statistical assessment of temporal change (Kincaid et al. *In press*). H-R-based surveys will be conducted infrequently, with the goal of identifying the habitat effects of infrequent, but severe events such as large floods. Such watershed- or stream-specific information may prove crucial to properly interpreting species-habitat relationships (Dunham et al. 2002).

The EMAP-based approach uses precise measurements and/or visual estimates of habitat attributes using transects and variable-length samples (Simonson et al. 1994, Angermeier and Smogor 1995) based on stream size (Kaufmann et al. 1999, Peck et al. 2001). These methods have been selected to ensure precise, repeatable measurements because low measurement precision substantially limits the ability to detect spatial differences and temporal trends in habitat attributes (Peterson and Wollrab 1999, Larsen et al. 2004). Sample sites are randomly selected, but sites are selected to maintain spatial balance (Stevens and Olsen 2004) and allow generalization to the entire watershed. A minimum sample size of 30 per watershed per year should provide a reasonable compromise between the spatial independence of samples, statistical power to detect a temporal trend, and logistical feasibility.

The EMAP sampling approach attempts to allocate sampling effort in a manner that balances the objectives of describing spatial variability in environmental conditions and detecting trends over time. Spatial variation is best captured by maximizing the number of sites sampled while evaluating temporal trends requires re-sampling of sites (Larsen et al. 2001). Because detecting temporal trends and differences in trends among locations is an important component of IMW studies, a relatively large proportion of sites will be re-sampled each year, rather than adding new sample locations (Urquhart et al. 1998, Roper et al. 2003). Samples will be collected from each watershed every year for the duration of the IMW study and sample locations will be determined using the EMAP protocol (Dr. Anthony Olsen, USEPA, personal communication). The duration of the study and temporal periodicity of sampling are the primary determinanats of the ability to detect trends in habitat conditions (Larsen et al. 2004), and therefore to assess correlations between changes in habitat conditions and salmon abundance, distribution and production. Field methods will closely follow those developed in the Western EMAP Pilot Study (see Peck et al. 2001) to ensure a consistent methodology (Beard et al. 1999).

In the Hood Canal IMW Complex remotely sensed (e.g., aerial photography) and geographic information system data will also be collected regularly (i.e., annually or semiannually) to track changes in the ultimate factors of importance; human land and water use. Water availability during summer low flow has been identified as a factor potentially limiting salmon survival and production. Hydrogeology data (e.g., well drilling records and seep location and elevation) will be collected in the Hood Canal complex to assess the effects of water availability on salmon habitat abundance and quality. Such data will be used in combination with gauge station and temporal variability in pool depth and area information to build a multidimensional model of water flow. This model will provide valuable information regarding the location of water gains and losses for individual stream reaches. This information will be used to help identify the type and location of restoration projects.

The spatial distribution and abundance of salmon at various stages of their life cycle must be monitored to meet the goals of the IMW projects. It is imperative that fish sampling be coordinated with habitat sampling to make efficient use of the data and to allow inference to the effects of changes in habitat to fish distribution, abundance and production. Therefore, data collected on fish distribution at various life stages will be closely coordinated with the habitat sampling plan. Counts and locations of spawners and redds plus locations of juvenile salmon and trout abundance estimates will be georeferenced to enable subsequent evaluation of species-habitat associations and inferences to causal mechanisms responsible for changes in their distribution and abundance. Information collected in the H-R surveys will be useful for georeferencing the fish and habitat data. Recommended measurements and the metrics calculated in the EMAP sampling are listed in Table 3.

Table 3. Habitat measurements and calculated metrics procured using the EMAP sampling protocol.

Measurements	Metrics
bankfull width	width-depth ratio
wetted width	channel confinement
valley width	average pool depth
cross-section depth	residual pool depths
channel type	Substrate size distribution
substrate size counts	bank stability
bank angle	bank cover
riparian cover proportions	Shading
canopy cover	woody debris size distribution
embededness	channel slope
channel slope	channel sinuosity
channel bearing	water flow profile
woody debris talley	
thalweg profile	
bar width	
pool-forming process	
backwater talley	
fish cover proportions	
Human influence proportions	
incised height	
water flow	

Fish Populations

Information on number of spawning adult salmon and steelhead, abundance of parr and number of emigrating smolts will be collected at all watersheds. Spawning fish numbers will be estimated from counts of spawning fish (coho) or redd counts (steelhead) at randomly selected stream reaches in most of the watersheds. One watershed (Big Beef Creek) has an adult collection fence that captures all returning fish. Parr abundance will be determined during summer. Fish will be enumerated at randomly selected reaches in each watershed, where habitat information also will be collected. Fish will be collected by one-pass electroshocking. The catch per unit effort (time) will be used to provide a relative indication of parr distribution and an estimate of cutthroat and age 0 trout abundance. Total watershed abundance of coho and age 1 steelhead parr will be estimated by mark-recapture. The adipose fin will be removed from all coho and age 1 steelhead parr captured. Marks will be noted during smolt trapping the following spring and a total estimate of summer parr abundance calculated based on the proportion of marked to unmarked smolts and the survival of marked fish from summer through smolting. Smolts will be collected with a fence on seven of the ten IMW streams, providing a complete count of emigrating fish. On three of the streams, partial traps (screw traps) are used due to the size of these systems. These traps are calibrated frequently to determine catch efficiency.

OBJECTIVES FOR WATERSHED COMPLEXES

The three IMW watershed complexes vary in physical characteristics, land use patterns, climate and relative abundance of the focal species (Table 4). The variation in conditions will enhance our ability to extend our results to other watersheds. The variation in conditions also provides an opportunity to address a wider range of factors contributing to habitat degradation than would be the case if all watersheds were similar.

The smaller watersheds initially included in the IMW project support few chinook salmon. Because many populations of chinook salmon are ESA listed, there is interest in initiating evaluations of there response to restorations. An approach for including evaluations of chinook salmon in the IMW effort is described in this section.

Straits of Juan de Fuca

The watersheds in this complex (West Twin Creek, East Twin Creek, and Deep Creek) have been logged since early in the 20th century. As a result, much of the wood that historically created pools and regulated the movement of sediment and organic matter in these watersheds had been depleted. Wood loss contributed to channel incision at some sites, isolating the floodplain and reducing access to off-channel habitats. The primary treatment for this watershed complex will be the addition of wood to a large proportion of the channel accessible to anadromous fishes in Deep Creek and West Twin Creek. In addition, off-channel habitats will be developed at several locations. No treatments will be applied in East Twin Creek during the period of our evaluation.

Of all the watershed complexes, this location offers the best opportunity for maintaining the integrity of control and treatment watersheds. The watersheds are almost completely owned by USFS and one private forestry company. We have the full cooperation of both organizations. Relatively little timber harvest or road construction will occur in these watersheds over the next decade. Therefore, interpreting any responses of the fish to the restoration treatments at the watershed scale will not be complicated by other activities that might affect habitat condition.

Hood Canal

Land use in the four watersheds in this complex range from urban and residential in Little Anderson Creek to almost entirely forestry in Stavis Creek. We plan to implement restoration treatments in all the watersheds except Stavis Creek. The types of treatments applied will vary by watershed depending on the factors perceived to be limiting fish production. In Little Anderson Creek, lack of wood and off-channel habitat has been identified as likely factors constraining fish production. We are currently planning several restoration projects that will address these concerns. Seabeck Creek displays evidence of channel incision in some locations and significant amounts of sediment deposition in other channel segments. The incision in this watershed may actually be contributing to low summer flows by reducing groundwater storage. We are currently conducting a hydrologic assessment of this watershed to determine the potential for increasing summer flow by reducing incision in key reaches. Big Beef Creek has a small impoundment that impacts water temperature downstream and provides habitat for various warm water fishes that may prey on coho and steelhead smolts. As the factors most likely to be limiting fish production become evident, appropriate restoration actions will be applied and the fish response compared with Stavis Creek, where no restoration applications will be applied.

The watersheds in this complex offer us the best opportunity to evaluate the impact of urban and residential development on our ability to increase salmon production with restoration efforts. These watersheds also offer the advantage of being quite small making it possible to treat a significant proportion of the channel network relatively easily.

Lower Columbia

The available data for the watersheds in the Lower Columbia complex are not as complete as for the other complexes. Land use in the three watersheds is dominated by commercial forestry. Of the three complexes, these watersheds provide the best opportunity to assess the effect of commercial forest management on aquatic habitat and fish. Lack of large wood in the channels, reduction in off-channel habitat and alterations in sediment delivery and transport are likely to be factors that have influenced habitat conditions in these watersheds. Because the currently available habitat data is relatively incomplete, we have not yet determined which of the three watersheds would be most appropriate as a reference site nor have we begun to identify potential restoration projects. Activities during 2004 have been focused on obtaining the data necessary to complete the experimental design for this complex.

One potential positive aspect of these watersheds is the presence of populations of chinook and chum salmon, possibly providing us with an opportunity to evaluate the response of these species to restoration actions. However, there is some speculation that the chinook populations are supported primarily by hatchery strays, confounding any responses that might be generated by alterations in habitat condition. The extent to which chum salmon spawn in these watersheds is not clear and further assessment of their population would be required to determine the feasibility monitoring the response of this species.

Table 4. Characteristics of the three watershed complexes in western Washington.

	Straits of Juan De Fuca	Hood Canal	Lower Columbia
Watersheds	West Twin East Twin Deep	Stavis Little Anderson Seabeck Big Beef	Germany Abernathy Mill
Focal Species	coho steelhead cutthroat	coho cutthroat steelhead	coho steelhead cutthroat (chum, chinook)
Land Use	forestry – private, state, and federal	urban, rural residential, forestry – private and state	forestry - private and state
Total Area	111 km^2	75 km^2	206 km^2
Geology	mixed sedimentary and metamorphic	glacial till	flow basalt w/ interbedded sandstone
Precipitation	190 cm	105 cm	160 cm

Chinook Salmon

Chinook salmon require a substantially larger watershed to complete their freshwater rearing than coho, steelhead and cutthroat. The larger area required by this species makes it very difficult to use a treatment-reference comparison at the level of an entire watershed, as we are doing for the other species. However, because many stocks of chinook are listed under the ESA and they are an important commercial and sport species, there is considerable interest in understanding how this species responds to the application of various restoration measures. We have expanded the IMW effort to include watersheds that support large populations of the chinook using two approaches:

1. We are in the process of integrating two existing projects assessing the response of chinook salmon to restoration measures into the IMW effort. One of these projects, is a BPA-funded, watershed-scale evaluation of restoration efforts in the Wenatchee River. The Wenatchee River watershed includes both listed stream-type chinook and steelhead. We also have begun discussions with researchers conducting an ongoing monitoring effort on the Skagit River to evaluate the response of ocean-type chinook to restoration measures. Bringing the Skagit monitoring effort into the IMW project would cover the two, primary life history types of chinook in the region. Integration of these projects into the IMW effort will help ensure that data are collected in a compatible manner and information is shared.
2. In addition, the IMW project is identifying watersheds where investigations on ocean-type chinook would be feasible. The screening process we used for identifying appropriate watersheds is described later in this document.

IMW WATERSHED COMPLEXES

Strait of Juan de Fuca Complex

Description

The Deep Creek and East Twin and West Twin Rivers watersheds are located on the northwestern Olympic Peninsula and covers a combined area of approximately 132 km^2 (Figure 2). The Deep Creek, West Twin River, and East Twin River watersheds are of comparable size, 45 km^2, 33 km^2,and 35 km^2, respectively. These watersheds drain directly into the Strait of Juan de Fuca. The headwaters of the stream systems initiate in the Olympic Mountains and flow into gradually broadening river valleys. Stream channels generally flow in a northeasterly direction in the upper watershed areas and then turn northerly to the Strait of Juan de Fuca. Elevations in the watershed range from sea level to 1,142 meters atop Mt. Muller in the headwaters of the East Twin and West Twin rivers.

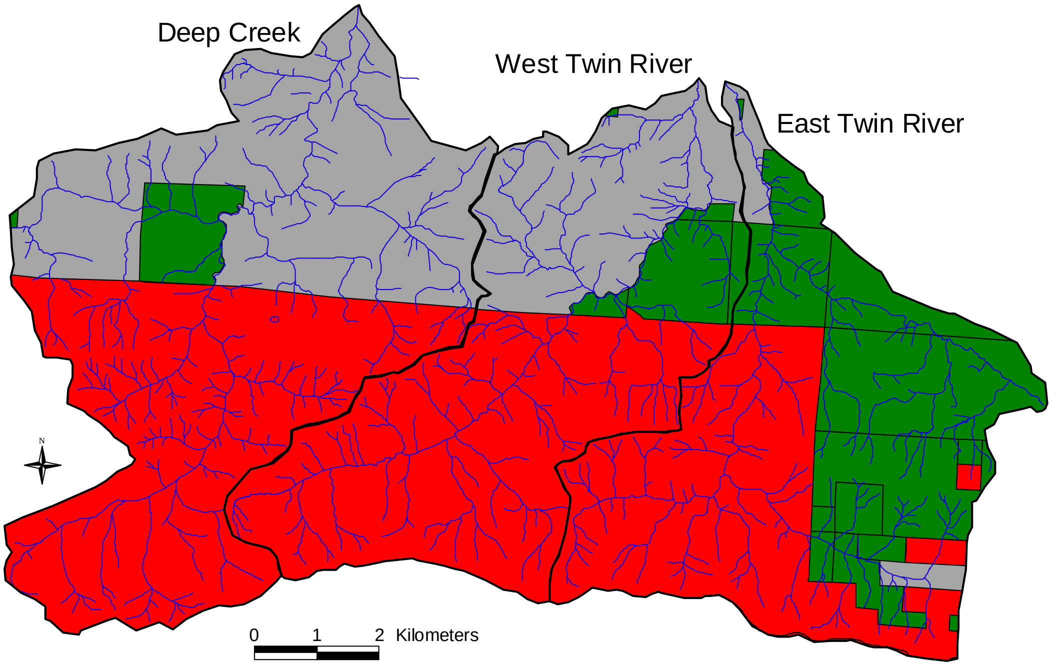

Figure 2. **Deep Creek and Twin Rivers watersheds. USFS land is shown in red, Washington Department of Natural Resources in green, and other in gray.**

Average annual precipitation for the Twin/Deep Creek watersheds is approximately 190 cm. Most precipitation occurs during the autumn and winter months (October through March) with monthly averages ranging from a low of 4 cm in July to a high of around 36 cm in January. Precipitation intensity varies with elevation and some of the higher, headwater areas in these watersheds receive over 250 cm annually. Snowfall typically occurs from November through March and is greatest in December and January. Fog condensation contributes moisture, but the amount of water available for runoff from this process is unknown.

Geology

These watersheds are underlain by volcanic rocks of the Crescent Formation, marine sedimentary rocks, and glacial deposits. The oldest rocks (the Crescent Formation) are at higher elevations, while the youngest the marine sedimentary rocks, are at the lower end of the watershed. Glacial deposits occupy lower valley margins and valley floors toward the upper part of the watershed, and throughout broad terrace areas in the lower parts of the watershed. Recent alluvium (stream deposits) is found locally adjacent to higher-order channels, especially at the lower end of the watershed. The area of the watershed underlain by the Crescent Formation is steep and dissected with generally shallow soils. Landslides and resulting debris torrents are most common in this area of the three watersheds. The marine sedimentary rocks include a mixture of siltstones, sandstones, mudstones and conglomerates. Most mass wasting on this geology is associated with steep converging topography and oversteepened channel margin slopes. The typically low strength, combined with the fine-grained nature of these rocks, contributes to the generation of fine sediment in these watersheds. Glacial deposits occupy valley bottoms, toe slope areas, and terraces in the lower part of the watershed. Typically they are relatively thick deposits on gentle slopes and not particularly susceptible to erosion. Exceptions are where streams have incised deeply into these deposits, leaving high banks (of relatively weak materials) and may form small inner gorge structures that are susceptible to, and in part created through, erosion and/or mass wasting. Glaciolacustrine clay (glacial lakebed deposits) overlying dense glacial till is found in some areas along the lower Deep Creek inner gorge and the upper part of the East Fork of the East Twin River, a condition susceptible to deep-seated mass wasting. (Neal and Buss 1992).

Vegetation

Three vegetation zones occupy the watershed. The Sitka spruce zone is found in the lower valley bottoms, where fog moving inland off the Strait of Juan de Fuca creates mild, moist conditions that allow spruce to compete effectively. This zone occupies about 11.5 percent of the watershed. The western hemlock zone occupies about 77.9 percent of the watershed, in the low to mid elevations throughout the watershed. The silver fir zone occupies about 10.6 percent of the watershed largely in the upper elevations across the southern headwaters of the watershed along the ridge of Kloshe Nanitch/Mt. Mueller.

Early successional stages occupy 27.3 percent of the watershed, mostly on private land while mid successional stages cover 60.8 percent of the watershed. Late successional stands cover 11.0 percent of the watershed, mostly on National Forest land. Only 0.8 percent of the watershed is not forested, primarily wetlands and waterbodies, There are a few residences in the three watersheds but essentially no agricultural or urban development.

Land Use

Fires and floods were the primary disturbance mechanisms affecting these watersheds prior to arrival of European-Americans. The pre-European fire regime in these watersheds was characterized by infrequent, intense, large, stand-replacing fires. Large fires that occurred in 1308, 1508 and 1701 likely spread over most of the three watersheds. However, these fires initiated under climatic conditions that were drier and warmer than those that have existed over the last 200 years. Timber harvest began in these watersheds in the 1890s. Introduction of timber harvest and land clearing in the late 19th and early 20th increased fire frequency. The largest fire events during this period occurred in 1895 and 1939. Private and state lands in the watershed were harvested extensively by 1929. Timber harvest on lands administered by the US Forest Service took place from the 1940s to the 1990s. Second-rotation harvest on State and private lands has been initiated in recent years. Impacts to the streams have also resulted from road runoff, failures, and surface erosion. Disturbances associated with logging and road construction have led to an increase in the amount of coarse and fine sediment delivery to fish-bearing streams in the Deep/Twins Watershed. Riparian timber harvest has depleted the recruitment source for large woody debris (LWD) and very few large conifer trees are present in the channels of these watersheds today. Increased sediment loading and reduction in LWD size and volume has caused a decline in pool size and frequency and reduced the amount of rearing habitat for juvenile salmonids.

Stream channel characteristics

There is a total of 230 km of stream channels in the Deep Creek (36.8%), West Twin River (32.4%), and East Twin River (30.7%) watersheds (Table 5). Drainage density within the watersheds averages around 2.8 km/km^2. Nearly 80% of the total channel length is relatively steep (>8%). Moderate-gradient (2-4%) and low-gradient (<2%) channel segments accounted for 12.5 percent and 8.6 percent of the channel length, respectively.

Table 5. Length of channel segments by gradient and confinement categories.

Gradient Category (percent)	Length by Confinement Category (m)		Total Length (m)	Percent of Watershed Total
	Confined	Unconfined		
< 1	0	5440	5400	2.3
1 – 2	1620	13,160	14,780	6.3
2 – 4	12,140	3320	15,460	6.6
4 – 8	13,820	0	13,820	5.9
8 – 20	47,030	0	47,030	20.3
> 20	136,370	0	136,370	58.6
All	**210,980**	**21,920**	**232,900**	**100**

Discharge patterns closely follow seasonal precipitation patterns. Lowest flows typically occur in late summer and highest flows during the winter. A US Geological Survey discharge station in the East Twin River collected streamflow data from 1963 though 1978 (USGS gauging station 12043430 - East Twin River near Pysht, Washington). These data indicate the large seasonal differences in discharge. Lowest average monthly discharge was recorded in August (0.15 m^3/s) and highest flows occurred in December (4.5 m^3/s). Mean annual flow is 1.8 m^3/s.

Flows were compared among rivers on the Olympic Peninsula by Amerman and Orsborn (1987). They utilized hydrologic models to estimate the seven-day, two-year low flows; average annual flows; and one-day, two-year flood flows in relationship to drainage area for 20 gauging stations on the peninsula. Results showed that the East Twin River was among the stations with the lowest discharge for seven-day two-year low flows; average annual flows; and one-day, two-year floods.

Fish Communities

Populations of fall chum (*Oncorhynchus keta*), fall coho salmon (*Oncorhynchus kisutch*), winter steelhead (*Oncorhynchus mykiss*), and resident and anadromous cutthroat trout (*Oncorhynchus clarki*) utilize the Deep Creek and Twin Rivers watersheds. Pacific lamprey (*Lampetra tridentata*) and sculpins *(Cottus sp.)* also are present in each drainage. Historical accounts mention chinook salmon (*Oncorhynchus tshawytscha*) in these watersheds but it is unclear if these were the results of hatchery outplants that occurred in the 1970's. Chinook salmon have not been observed in recent years.

Historically, Native Americans harvested salmon and steelhead in the Deep/Twins Watershed, as evidenced by a number of archaeological sites around the Pysht River and Deep Creek. Due to chronically low escapements, no terminal salmon fisheries are currently conducted in the watersheds. Tribal fisheries for winter steelhead have been closed in Deep/Twins since 1990. The East Twin River is currently closed to sport steelhead fishing, and all wild steelhead must be released by anglers on Deep Creek and the West Twin River. The status of salmon and steelhead stocks based upon two recent stock reviews is summarized in Table 6 and below.

Table 6. Status of salmonid stocks in the Deep/Twins Watershed.

Species	Race	Production	Stock origin	Stock status (WDF et al. 1993)	Stock status (McHenry et al. 1996)
Chum	Fall	Wild	Native	Healthy	Critical
Coho	Fall	Wild	Mixed	Depressed	Stable
Steelhead	Winter	Wild	Unresolved	Healthy	Depressed

Chum Salmon

Deep Creek was historically the major chum producer in the watershed complex. The East Twin and West Twin river escapements are currently very small, with a peak 1980s count of 36 fish, though historic data are limited. Entry timing for the watershed is early November, with spawning occurring through December. Escapement estimates for Deep Creek are available from 1968 to the present, though the most reliable data begins in 1984. A substantial decline in chum escapement occurred between 1989 and 1991, coinciding with significant mass wasting associated with storms in 1990. Prior to this event, which introduced huge volumes of fine sediment to spawning areas, the population exhibited cyclic trends, with peaks occurring every third to fourth brood cycle. Escapement levels increased briefly after 1991 but have again dropped dramatically, and the population teeters on extirpation (Figure 3).

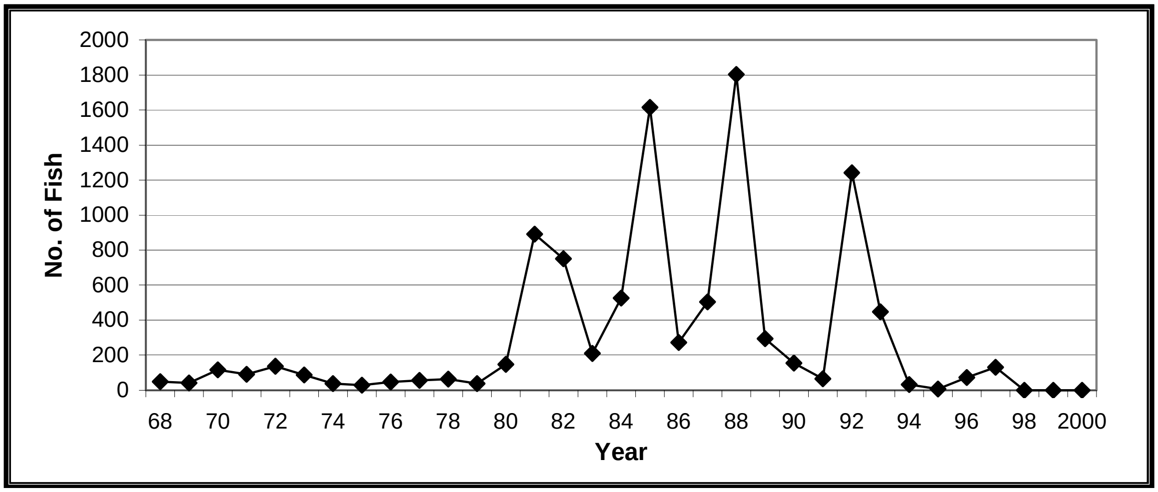

Figure 3. Escapement of chum salmon to Deep Creek, 1968-2003.

Fall Coho Salmon
Although a comprehensive genetic analysis of Strait of Juan de Fuca coho stocks has not been completed, fall coho from the Deep Creek and East and West Twin rivers have been grouped with adjacent Pysht River coho as a distinct stock based upon their geographic proximity (WDF et al. 1993).

Historic hatchery outplants of fry and fingerlings were made mainly from Dungeness and Elwha River stocks. Between 1981 and 1985, between 50,000 and 139,000 fry and fingerlings were planted in the East and West Twin rivers and between 85,000 and 147,000 fry and fingerlings were planted in Deep Creek. (PFMC 1997). No hatchery outplanting has occurred in the last decade.

Strait of Juan de Fuca stocks of coho salmon have been depressed for several decades and likely declined to their all-time lowest levels in the early to mid-1990s. The Pacific Fisheries Management Council reviewed the status of coho populations in the Strait of Juan de Fuca region and concluded that none of the 48 independent drainages in this region supported healthy coho stocks (Krause et al. 1997). The study concluded that SJF coho populations as a whole are negatively impacted by low freshwater survival, low marine survival rates and high marine interception rates.

Sporadic spawning ground surveys by WDFW in Deep Creek between 1950-1970 reported counts as high as 206 fish/mile (330 fish/km). Repeatable surveys of index areas have been conducted in Deep Creek and Sadie Creek (E Twin tributary) since 1984 by WDFW. These index areas provide an indication of trends, but cannot be reliably expanded into an estimate of watershed-level spawner abundance. The Deep Creek index reach, river mile 0.0-1.3 (km 0.0-2.1), is primarily a chum salmon survey and its utility in evaluating coho trends in Deep Creek is unclear. However, these data indicate a decline in fall coho populations in Deep Creek since 1989. Populations in Sadie Creek have varied cyclically with relatively low numbers of spawners (Figure 4).

Significant efforts have been made since 1997 to improve estimates of spawning salmon abundance in Deep Creek and East and West Twin rivers. A habitat based system of spawning ground surveys was initiated in 1997 involving WDFW and the Makah and Lower Elwha Klallam Tribes. A random stratified sampling system of available habitat types was instituted. This new system enables estimation of individual watershed escapement. Using this system coho escapement to the Deep/Twins watershed is depicted in Figure 5. Escapement to each individual watershed has been consistent in four of the five years with Deep Creek supporting the highest number of spawning coho followed by West Twin then the East Twin River.

Winter Steelhead

Little information is available regarding the genetic composition of the winter steelhead stock in Deep Creek, East and West Twin River. However, like fall coho, the steelhead are grouped with Pysht River population as a single stock based upon geographic proximity (WDFW et al. 1993). Although the status of this stock was considered healthy in the early 1990's (as a result of higher escapement to the Pysht River), more recent information indicates Deep and Twin River steelhead are in decline (Figure 6). Formal steelhead escapement surveys were only initiated in 1995, limiting the ability to determine long-term trends in watershed escapement.

The stock is currently managed for wild production and no hatchery outplants have been released in the Deep/Twin complex since the early 1980's. Winter steelhead adults enter the watershed beginning in December and continue through May. Spawning occurs in February through early June.

Smolt Enumeration

The Elwha Klallam Tribe installed smolt traps in Deep Creek in 1998 and in the East and West Twin Rivers in 2001. Traps, consisting of a fence weir and live box, capture the entire population of emigrating smolts. Trapping begins in late April and continues through mid-June. Peak outmigration occurs in late May. Data collected to date suggest that steelhead smolt production has declined in all three watersheds (Figure 7), while no apparent trend in coho production (Figure 8) has occurred over the relatively short period of record.

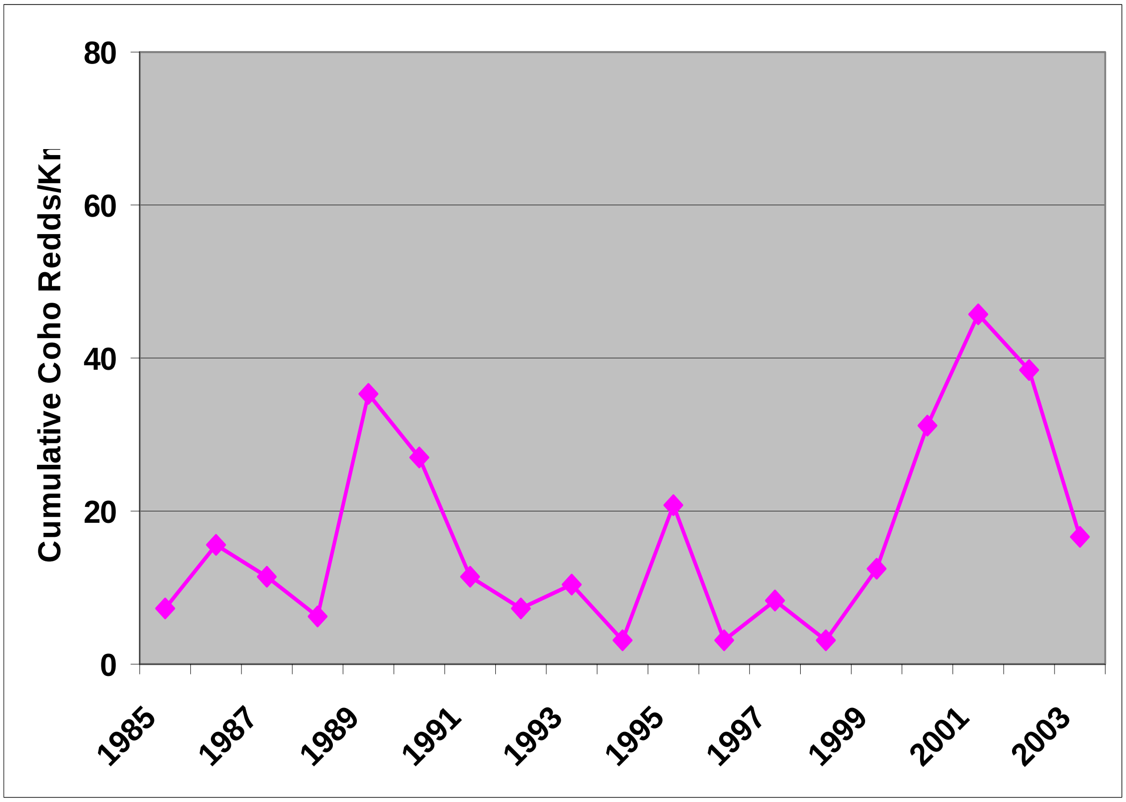

Figure 4. Coho salmon escapement (redds/km) to WDFW index area on Sadie, Creek (1984-2003).

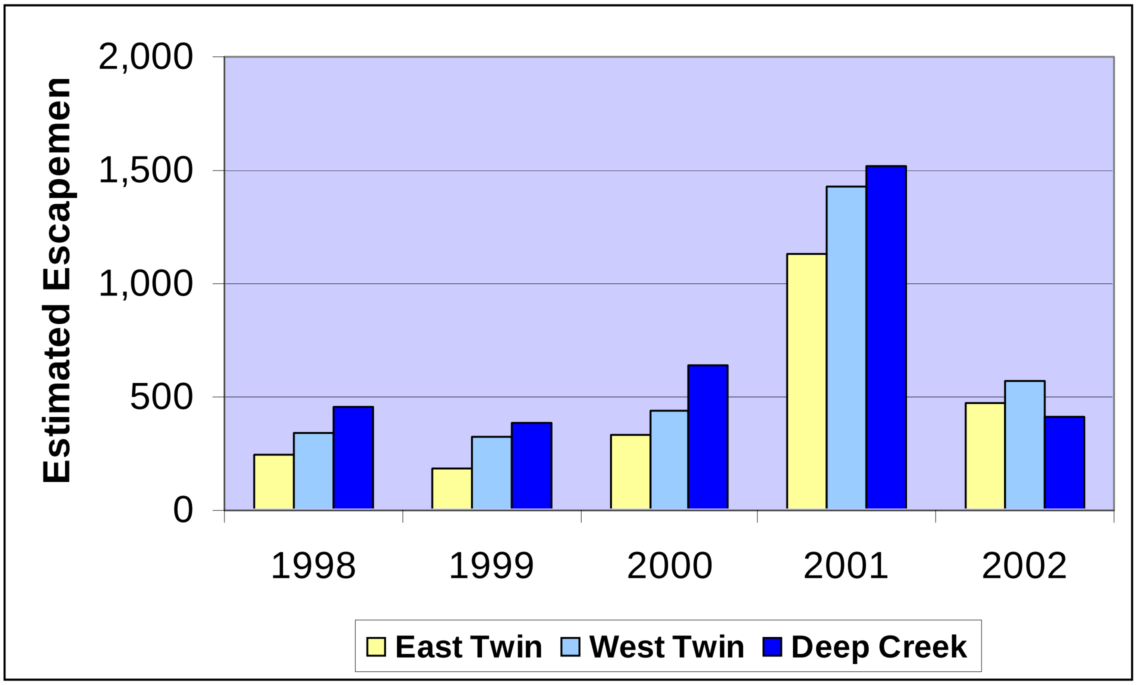

Figure 5. Coho salmon escapement to Deep Creek and East Twin and West Twin Rivers, 1998-2002.

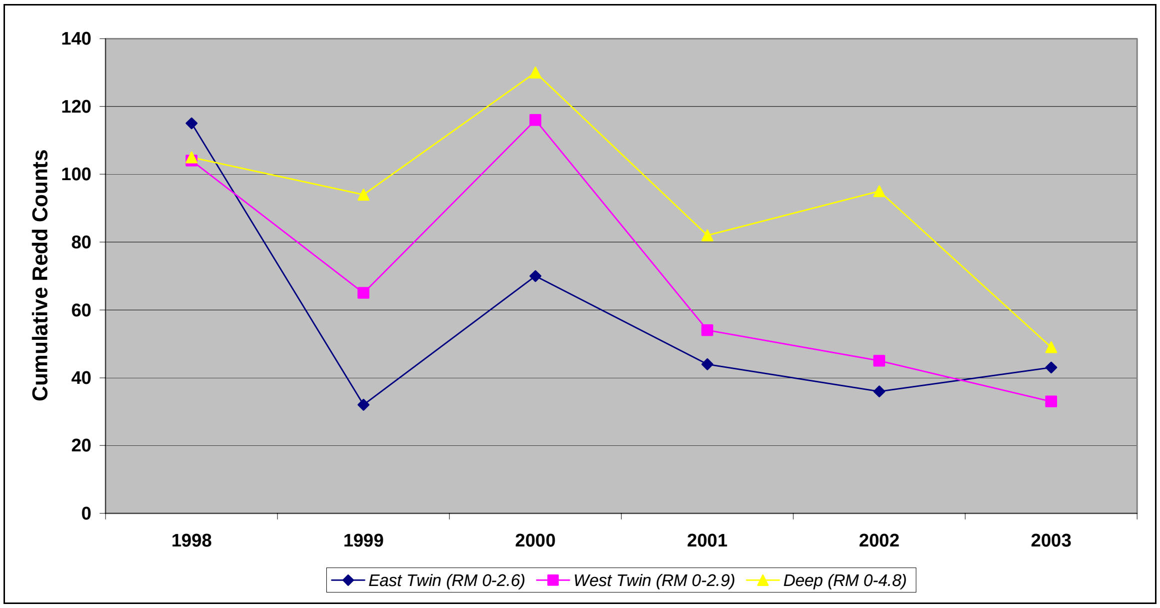

Figure 6. Steelhead escapement to Deep/Twin Rivers, 1995-2004.

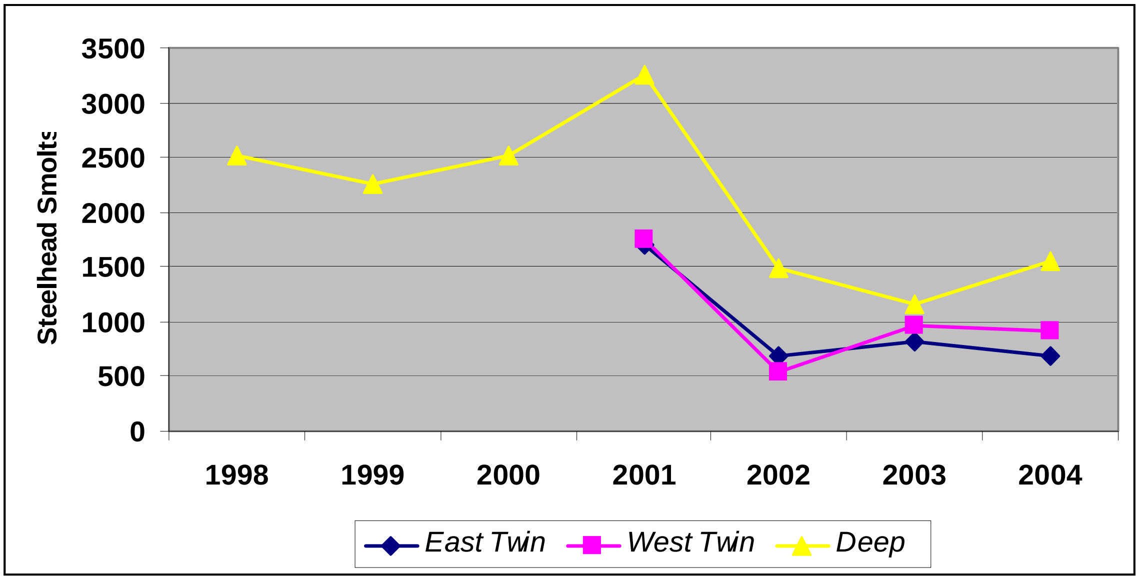

Figure 7. Steelhead smolt production from Deep/Twin Rivers, 1998-2004.

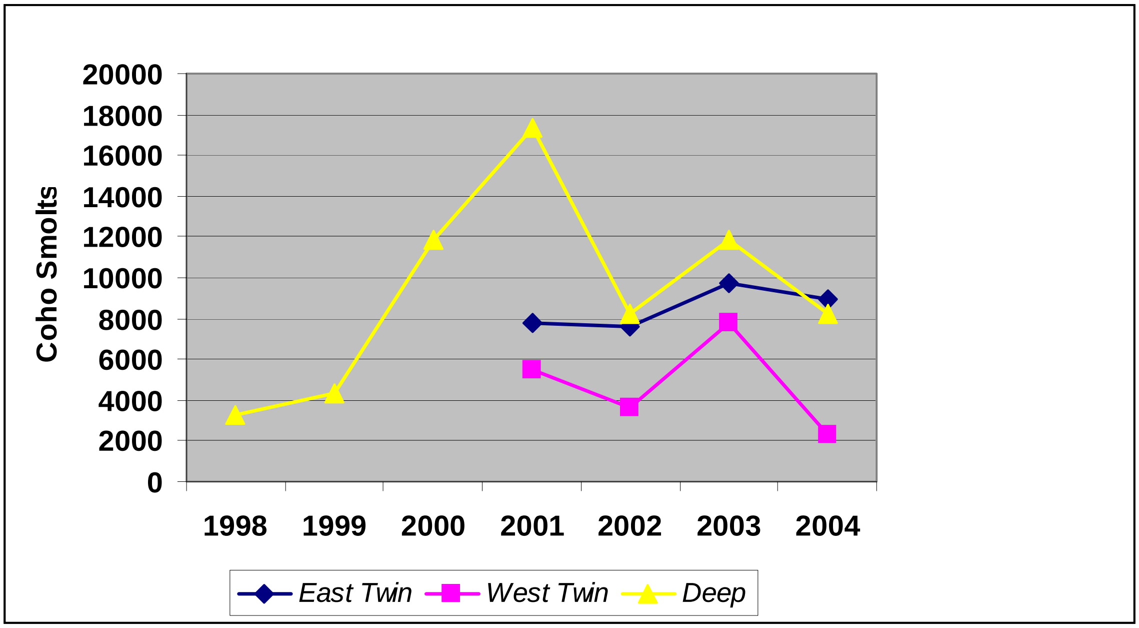

Figure 8. Coho smolt oumgration from Deep/Twin Rivers, 1998-2004.

<u>Implementation of Restoration and Monitoring</u>

Deep Creek

A number of habitat conditions in the Deep Creek watersheds were identified as having been impacted by past human activities during analyses conducted in the 1990s, primarily timber harvest and road construction (Table 7). Compromised conditions varied among reaches but generally included alterations in temperature, sediment, large wood and channel stability.

Table 7. Factors Limiting Smolt Production in SJF complex

Factors limiting smolt production
Excess sediment due to elevated rates of mass wasting
Lack of wood in channels and elevated temperatures due to reduction in conifer trees in riparian areas
Loss of off-channel, floodplain habitats (side-channels, alcoves, associated wetlands)

In response to declines in both habitat quality and populations of native anadromous fish, the Elwha Klallam Tribe has been actively attempting to restore fish populations within Deep Creek.). A restoration strategy was developed with the goal of reestablishing the dominant physical processes that controlled the identified limiting factors. This strategy is outlined in McHenry et al. (1995) and includes the following:

- Reduction in the rate of mass wasting to historical background rates
- Reestablishment of late successional, conifer-dominated riparian forests.
- Reintroduction of functional, high quality in-channel LWD.
- Re-creation of off-channel habitats.

Restoration efforts in Deep Creek were initiated in 1997 by the Elwha Klallam Tribe and have continued through 2004. Tribal efforts have focused upon the latter three categories. Increased rate of mass wasting in Deep Creek has been caused by poorly constructed roads and is being addressed by the US Forest Service. In 1999-2001, road maintenance and abandonment were conducted on hazardous road segments within the watershed. Additional activities are planned in 2004-2005, including a NEPA analysis of the entire 3040 road system, which has generated dozens of landslides not only to Deep Creek but also to the East Twin and West Twin rivers. It is possible that significant portions of this mid-slope road system will be abandoned.

To date, 3.0 miles of Deep Creek and 0.5 mile of Gibson Creek have received in-stream restoration treatments (Table 8), while riparian improvements have been conducted on 2.5 miles of riparian forest. An additional four off-channel habitat projects have been implemented.

Channel restoration activities have focused on using LWD to accomplish specific goals, depending upon the dominant impact at the reach level. For example, above RM 1.3, the 1990 dam-break flood resulted in severe scour of the bed and the almost complete loss of in-channel LWD. Conversely, below RM 1.3, the impacts were primarily associated with sediment aggradation (pool filling, widening). Because of the inherent channel instability observed below RM 1.3, restoration activities were initiated above this point (RM 1.0 to 4.0). LWD was placed in an attempt to convert this plane-bed reach into a forced pool-riffle reach. Over 1,000 individual pieces of LWD have been used in the following configurations: log revetments (2), engineered log jams (2), rock weirs (17), constructed log jams (59), deflectors (19), log weirs (13), and rock/log structures (12). In 2004 restoration activities will focus on the lower reaches of Deep Creek (RM 0 to 1.8) and 17 locations have been identified for installation of large, complex logjams.

Table 8. Summary of in-channel restoration activities conducted on Deep Creek, 1997 to 2000.

Year Constructed	River Mile	Number of Structures	Entity
1997	1.0-1.8	40	Elwha Klallam Tribe
1998	2.5-3.7	53	Elwha Klallam Tribe
1998	3.7-4.0	7	Clallam Conservation District
2000	2.1-3.5	25	Elwha Klallam Tribe
2002	1.3-2.5	25	Elwha Klallam Tribe
2004	0.0-1.8	17	Elwha Klallam Tribe

During December of 1999, the north Olympic Peninsula was struck by an intense rainstorm that generated a 120-year flood on the nearby Hoko River. This flood was of a magnitude sufficient to thoroughly test the effectiveness of the restoration effort at Deep Creek. Of the 100 structures constructed through 1999, only 14 failed. These failures were all located in the upper treatment area in the vicinity of the West Fork Deep Creek, where the channel is severely confined by its valley. Additionally, fully half of the structures that failed were built by hand crews in reaches inaccessible to heavy equipment.

East & West Twin Rivers

A watershed analysis (USFS 2002) conducted in the 1990s identified the same suite of factors affecting habitat condition in East and West Twin rivers as Deep Creek. However, recent logging related disturbances have been less severe in the Twin Rivers than Deep Creek.

No restoration will be conducted in West Twin River. This watershed will serve as a reference watershed and habitat conditions and fish populations will be compared over time to Deep Creek and East Twin River where active restoration is underway. Restoration goals for East Twin River are similar to those established for Deep Creek.

Restoration efforts in the East Twin River were initiated in 1998, when an off-channel rearing pond was constructed on private property near river mile 1.0 (km 1.6). Large scale LWD reintroductions were initiated in 2002 by the Elwha Klallam Tribe when a Salmon Funding Recovery Board awarded a restoration grant to fund these efforts. In the summer of 2002 over 450 metric tons of large LWD was placed with a helicopter into Sadie Creek at forty sites in river mile 0-2.0 (km 0.0-3.2) and at 30 sites in the East Twin River in river mile 2.0-3.0 (km 3.2-4.8). These efforts were followed in 2003 with ground-based placement at an additional 35 sites in the East Twin at river mile 1.2-2.0 (km 2.0 and 3.2). An estimated 50 year flood occurred in October of 2003, resulting in significant habitat response to restoration.

The Elwha Klallam Tribe has monitored the effects of the habitat restoration efforts in Deep Creek. Prior to beginning the restoration effort (1990), the entire channel was mapped and extensive habitat measurements were made. Fifty permanent cross-sections have been established throughout the treatment area to measure changes in channel bed form and to serve as photo reference points. An extensive summer stream temperature database has been collected in Deep Creek. Annual salmon escapement counts are made throughout the subwatershed, and the Tribe has conducted smolt trapping in the spring since 1997. In addition, each structure placed under the restoration effort has been mapped, tagged, and monitored for effect. Repeat surveys of habitat conditions have been conducted in 1992, 1995, 1997, and 2003).

Similar data are being collected on the East Twin River by the Tribe. In addition, a fish movement study is being conducted using PIT-tagging techniques in cooperation with scientists from NOAA Fisheries. In 2003, 1500 juvenile fish were tagged and marked with acrylic paint. The relationship between habitat condition and fish movement and survival will be evaluated. Evaluation efforts in all watersheds will be expanded under the IMW project. Discharge stations have been established in each stream and a weather station is being established in the lower, East Twin River watershed. Juvenile salmon and steelhead abundance will be estimated in mid summer each year.

Hood Canal Complex

Complex Description

These four basins, on the west side of the Kitsap Peninsula, comprise a large portion of the West Kitsap WAU. This WAU is within the Puget Sound trough which has experienced considerable glacial activity and, as a result, generally has a gently rolling upland of glacial till with steep-sided ravines leading down to the river floodplains (Figure 9). The glacial till of the uplands is fairly resistant to erosion but the loose sandy soil and layers of fine textured material comprising the ravine sideslopes are much more prone to erosion. In addition, layers of clay in the ravine walls can transport water laterally and where this intersects a road cut, ground water often flows onto the road.

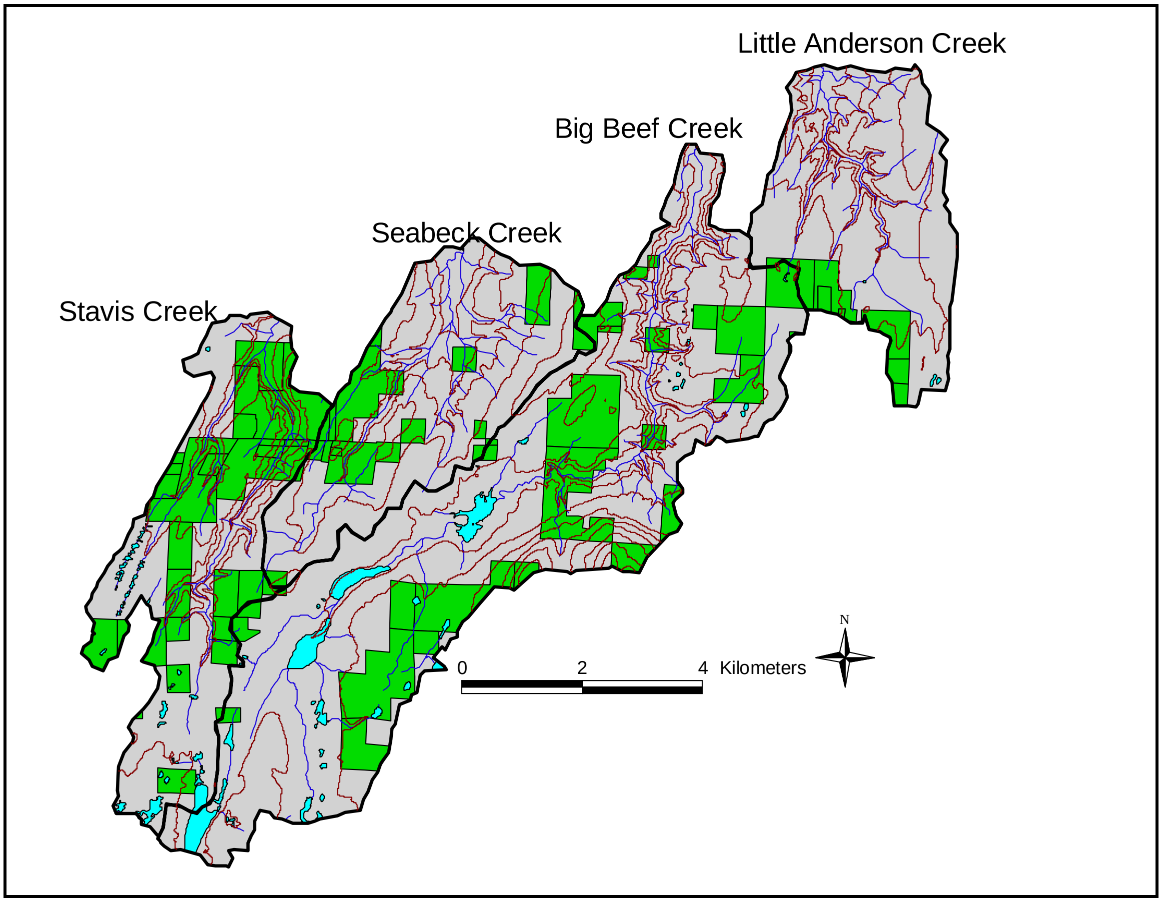

Figure 9. Hood Canal IMW Complex. Washington Department of Natural Resources land is green. Lakes and wetlands are blue. Contour intervals are 100m.

Commercial logging of lowland areas was underway by 1870 with the establishment of large sawmills. Extensive logging of the uplands began in the 1920s when a railroad network was built to transport the timber and continued into the 1940s until few merchantable trees were left. Although forest practices have improved markedly, legacy effects may exist. Based on early 1990's satellite imagery, over 80% of each basin is forested and the proportion developed is low (Table 9). However, rural residential development has increased markedly since the

1970's and is likely degrading habitat through riparian vegetation removal, stormwater runoff, fish passage barriers, and high sediment loads (WA DNR 1995; Seiler et al. 2002b).

Table 9. Land cover, land management, and ownership percentages for each trap basin are shown below. Land cover is based on satellite imagery from the early 1990s. HCP area is based on 2001 maps provided by U.S. Fish and Wildlife Service. The land under Forest and Fish rules (FFR) is based on a map compiled for DNR and does not include small forest landowners. Public ownership was based on the Major Public Lands map.

Smolt trap	Basin area (acres)	Land cover (%)		Land mgt (%)		Ownership (%)	
		Forested	Developed	FFR	HCP	Public	Private
L. Anderson Cr	3173	87	8	6	4	12	88
Big Beef Cr	9044	90	3	43	24	31	69
Seabeck Cr	3471	91	2	25	20	21	79
Stavis Cr	3872	83	2	37	39	45	55

Naturally produced salmonids from the Hood Canal Complex include coho salmon, fall chum salmon, cutthroat trout, and a small population of steelhead. Efforts are being made to establish a naturally-produced population of summer chum in Big Beef Creek. The University of Washington maintains an artificial production facility on Big Beef Creek, where summer chum and chinook are reared. All chinook returning to the creek are sorted at a weir located at the mouth and precluded from migrating upstream to spawn in the wild. All of the releases from this facility occur downstream of the weir and, therefore, do not effect the wild juvenile downstream migrant counts at Big Beef Creek. Hatchery fish are not released in any of the other Hood Canal Complex streams.

Smolt counts began in Big Beef Creek in 1978 and 1992 or 93 in the other streams (Table 10). Wild coho salmon from Big Beef Creek have been coded wire tagged since 1976. Historically, a substantial portion of the harvest occurred in outside fisheries (i.e., Vancouver Island Troll Fishery, Washington Troll & Sport Fisheries). As these fisheries became increasingly constrained by weak-stock management and ESA, terminal harvests in the Hood Canal Net Fishery have made up the bulk of the fishing impact on this stock. The terminal Area 12 fishery is centered around Big Beef Creek and runs as far north as Lone Rock and as far south as Stavis Bay. Sampling over the last two years indicated catch rates can be highly variable. In 2002, we estimated a 68% total exploitation rate on tagged wild Big Beef coho with 98% of the impact occurring in the Area 12 beach seine fishery. Yet in 2003, very few fish were harvested in this fishery as the bulk of the effort was centered in the Areas to the south.

Table 10. Period of record and data collected at each smolt trap.

Smolt trap	Watershed analysis?	Juveniles		Adults	
		Since	Species	Since	Species
Anderson Cr	Yes, 1998	1992	coho	-	
Big Beef Cr	Yes, 1998	1978	coho, cutthroat, steelhead	1976	chinook, chum, coho
Seabeck Cr	Yes, 1998	1993	coho	-	
Stavis Cr	Yes, 1998	1993	coho	-	

Big Beef Creek, Little Anderson Creek, Seabeck Creek, and Stavis Creek have been well studied over the years. We have drawn upon the following data sources in developing our hypotheses of production constraints in these basins:

- 26-years of smolt and adult escapement counts at the Big Beef Creek weir (WDFW);
- Stream discharge has been measured near the mouth of Big Beef Creek by the USGS since 1969 (http://nwis.waterdata.usgs.gov/wa/nwis/discharge/?site_no=12069550) and above Lake Symington by the Department of Ecology since 2000 (http://www.ecy.wa.gov/apps/watersheds/flows/station.asp?sta=15F150) ;
- 11 to 12 years of smolt counts in the other three streams (WDFW);
- Sporadic coho and chum spawning ground surveys in all four basins (WDFW);
- Habitat surveys in all four streams conducted by Point No Point Treaty Council and US Fish & Wildlife Service in 1993 (USFWS, 1993);
- 1998 Ecosystem Diagnosis and Treatment analysis of Big Beef Creek;
- West Kitsap Watershed Analysis (1995);
- Habitat surveys conducted on all four streams by WDFW in 2000-2002;
- The West Kitsap Limiting Factors Analysis (Kuttel 2003);
- Salmon Index Watershed Monitoring (Seiler et al. 2002b); and
- The Kitsap Salmon Refugia Report (May and Peterson 2003).

These data sources were used to develop descriptions for each watershed and analyzed to formulate hypotheses regarding factors constraining salmonid production in each basin. Most of the discussion on production constraints will focus on coho salmon. Cutthroat utilize habitats similar to those preferred by coho. Steelhead typically utilize larger, higher gradient channels. Production of this species in these basins is very low, reflecting the small size and low gradient of channels in these watersheds.

Little Anderson Creek

Little Anderson Creek is an independent tributary to Hood Canal located approximately 2-km east of Big Beef Creek in the adjacent watershed. The Little Anderson Creek watershed has an area of approximately 12-km^2 and is the smallest of the Hood Canal IMWs (Figure 10). It is bordered on the east by the City of Silverdale and a part of the watershed is within the urban growth boundary of the city. Little Anderson Creek is primarily used by coho, chum, and cutthroat. A few steelhead also spawn in the stream each year. Hypothesized constraints to coho production are listed in Table 11 and discussed below.

Table 11. Factors limiting coho smolt production in Little Anderson Creek.

Factors limiting smolt production
Preferred habitat is limited to the lowest 2.0-km of the mainstem. (Steep tributaries with little flow provide little habitat.)
Main channel lacks LWD to control bed movement and create rearing habitat
Steep hillslopes, high channel gradients, and altered hydrology combine to degrade stream channels upstream of river kilometer (RK) 2.0 and scour and/or bury redds below this point
Fisheries may exert a higher-than-sustainable impact on Little Anderson Creek coho given its current productivity

Figure 10. Orthophoto of the Little Anderson Creek watershed; the horizontal line indicates the upstream extent of preferred coho and steelhead spawning and rearing habitat.

Most of Little Anderson Creek and its tributaries are deeply incised. Stream gradient within the fish-bearing portions of Little Anderson Creek is high averaging 3.1% (WDFW unpublished data). The most suitable habitat is found in the lower 2.0 km of the mainstem, where channel gradient is less than 2% (Figure 10). Upstream of this point, flow is evenly divided between the main channel and the right-bank tributary and the channel steepens to 3-5%. The increased gradient and decreased flow limits use of the stream above this point by anadromous fishes.

Although stream banks are largely intact within the Little Anderson Creek watershed, with area of exposed bank averaging less than 0.3-m^2 per meter of stream length, bed scour has resulted in the transport of large amounts of sediment downstream. Large quantities of sediment were deposited in the lower reaches of Little Anderson Creek in 1994 as a result of a storm and an undersized culvert on Anderson Hill Road. This incident released large amounts of sediment accumulated above the culvert and resulted in a braided channel below the culvert. Although the culvert was removed and a bridge was installed in its place in 2002, damage to the channel as a result of the 1994 storm is still very evident. Low to moderate levels of LWD are available to retain gravel and create pools resulting in little spawning and rearing habitat (WDFW unpublished data).

Little Anderson Creek produces the fewest coho smolts of the four Hood Canal IMWs. Annual coho production has ranged from 45 to 833 smolts while cutthroat production has been much higher than coho in all but two of the ten years of record (Figure 11). In low gradient stream systems, coho smolt production is typically one or more orders of magnitude higher than cutthroat (Seiler et al. 2003). Coho may be sensitive to peak winter stream flows as their eggs are in the gravel through the winter and thus subject to redd scour and sediment deposition (Figure 12). Cutthroat trout do not spawn until spring and avoid negative impacts associated with winter high flows. Summer low flow, an indicator for the amount of summer rearing habitat available, may also limit Little Anderson Creek coho production (Figure 13). Both winter high flows and low flow in summer may be exacerbated in Little Anderson Creek by the increases in development and impervious surfaces over the last decade. The relationships shown in Figures 12 and 13 were made using Big Beef Creek flow data, the nearest stream gauge. Given its close proximity, it is expected that precipitation in the Big Beef drainage is similar to the other Hood Canal IMWs.

The outlier in Figure 13 is for the brood year 1993 coho production which was twice as high as measured in any year before or since. In 1994, when these coho were fry, only 61 cutthroat smolts emigrated from Little Anderson Creek, which was the lowest production on record. The second lowest cutthroat production was 566, nearly 10 times greater. The record high coho production measured from the 1993 brood may indicate substantial predation on coho fry by cutthroat pre-smolts in most years.

Another potential impact is the terminal Area 12 fishery. It is likely that Little Anderson coho, which are not tagged, experience exploitation rates similar to Big Beef coho. Given their low productivity, harvest rates on Little Anderson Creek coho may not be sustainable in some years. The low coho production observed in Little Anderson Creek may, in part, be due to low escapements. Weekly spawner and redd counts will be conducted during the coho spawning season to estimate escapement and spawner distribution.

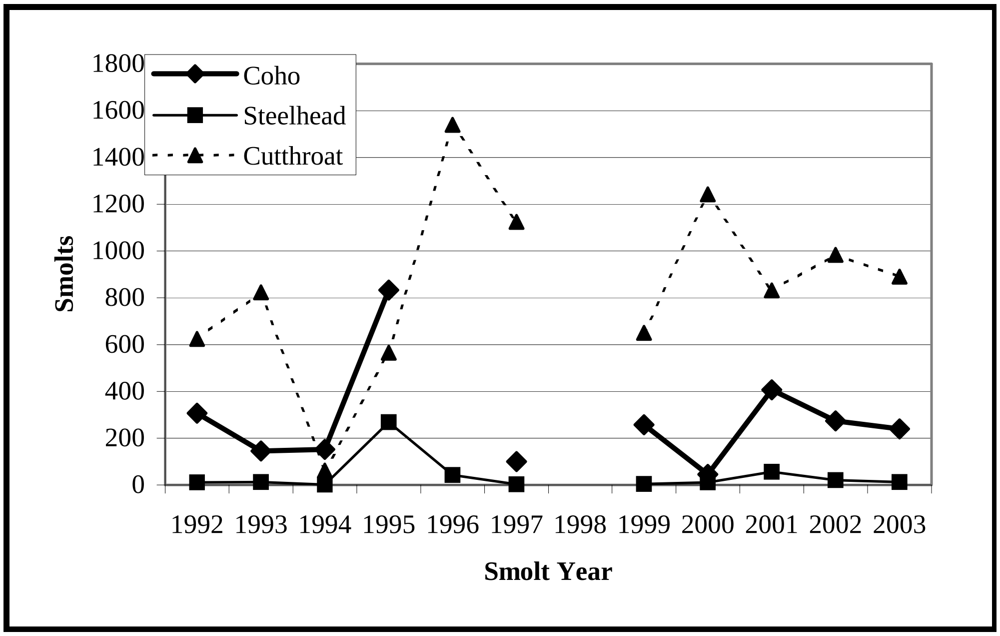

Figure 11. Annual production of coho, steelhead, and cutthroat smolts from Little Anderson Creek.

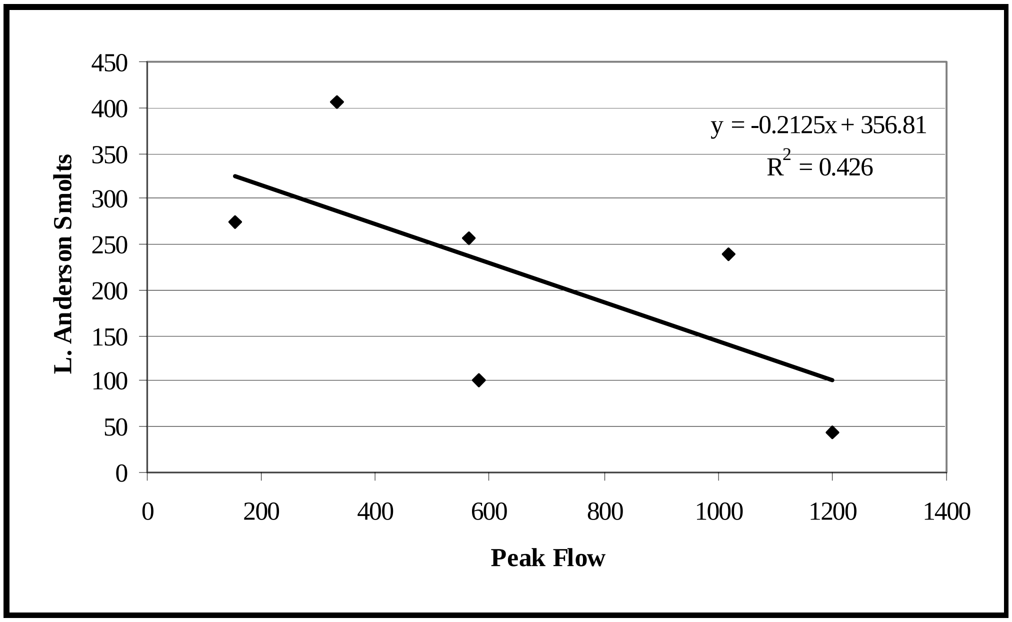

Figure12. Little Anderson Creek coho production as a function of peak December to March discharge in Big Beef Creek.

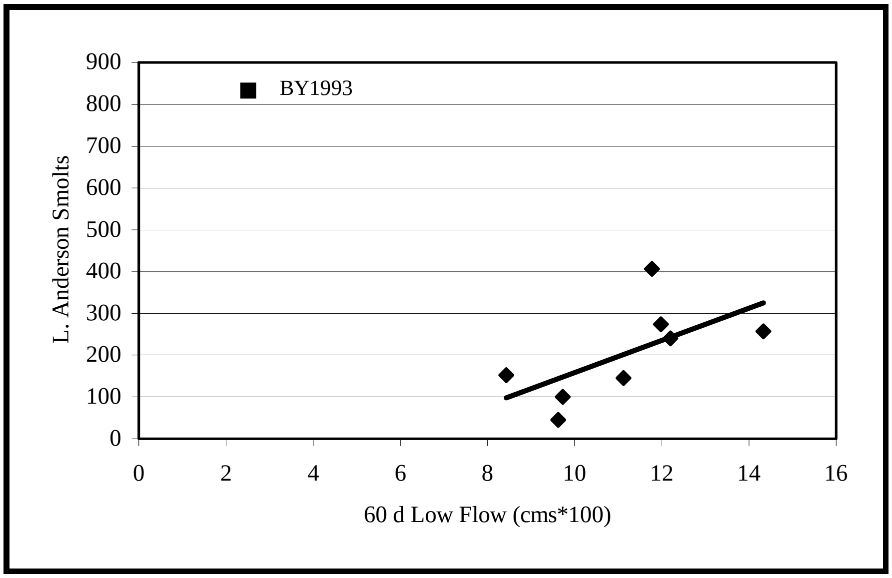

Figure 13. Little Anderson coho production as a function of the lowest 60-day mean flow in Big Beef Creek.

Big Beef Creek

Of the four Hood Canal streams, Big Beef Creek is the largest, draining a 36-km^2 basin. Big Beef Creek flows through a number of depressional wetlands in its upper watershed (Figure 14). Wetland habitats are also found in the headwaters of Seabeck and Stavis Creeks, but represent a much less prominent feature in these watersheds compared to Big Beef Creek.

Big Beef Creek is unique in that it flows through Lake Symington, a shallow, man-made impoundment surrounded by a housing development. A fishway provides passage for adult and juvenile coho, steelhead, and cutthroat above the dam. Downstream of the reservoir, Big Beef Creek cuts down through a canyon to reach Hood Canal. The stream is highly confined in this section, but it develops a wider floodplain in the lower three kilometers. The swampy upper watershed, Lake Symington, the lower canyon, unconfined valley, and estuary represent distinct sections of the watershed that are affected by different processes. Chum salmon spawn downstream of the dam while the wetlands above the lake are important for coho, steelhead, and cutthroat.

The University of Washington Big Beef Creek Research Station is located at the mouth of the stream. The facility includes a weir, where WDFW built and currently operates an upstream/downstream trapping facility to count adult escapement and the subsequent production of downstream-migrating juveniles. The trapping facility has been operating since 1976. Downstream of the trapping facility the Seabeck Hwy bridge, approximately 200-m wide, was replaced with a narrower 12-m wide bridge and causeway in the 1970's. Much of the estuary has filled with sediment since the constriction. Formerly abundant low tide habitat has largely been reduced to the Big Beef channel meandering across a mudflat.

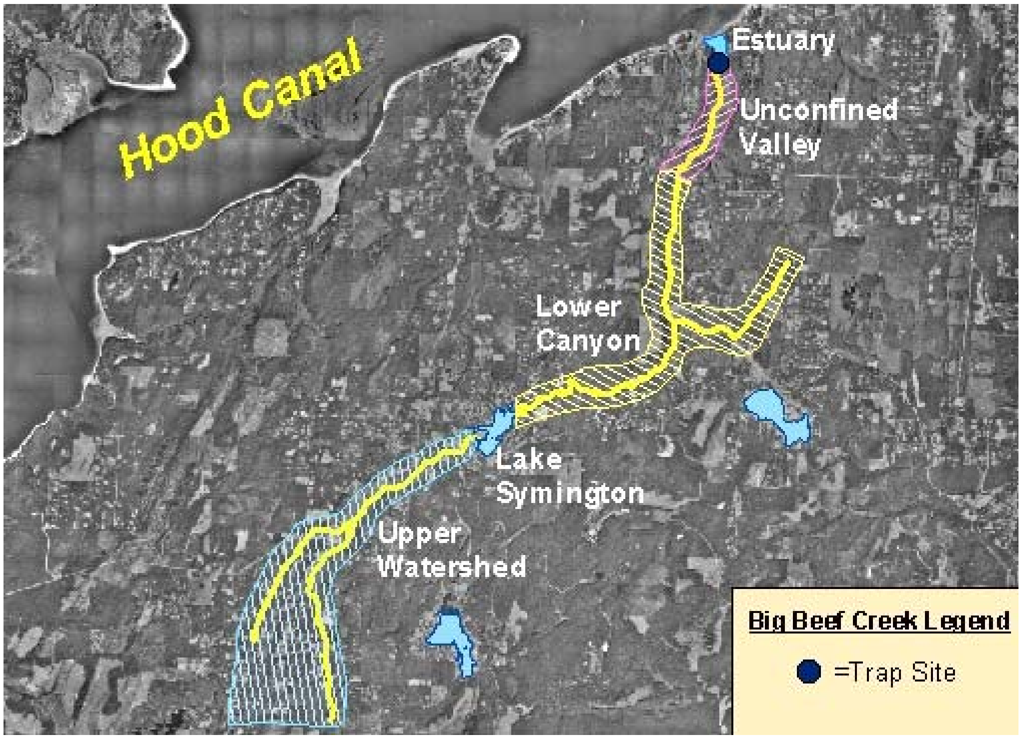

Figure 14. Primary habitat forming features in the Big Beef Creek watershed.

Big Beef Creek is the most productive of the Hood Canal IMWs. Coho smolt production has ranged from 11,500 to 47,000, and averages over 25,000. Over the 26 years trapped (1978 – 2003), coho salmon production has exhibited three short-term trends. Production between 1978 and 1986 showed a lot of inter-annual variation, but little trend, with an average production of 29,000 smolts (Figure 15). Coho production decreased between 1987 and 1996, averaging just over 19,000 smolts. Since 1997, production has returned to the pre-1987 level, averaging 30,000 smolts. Steelhead and cutthroat production are an order of magnitude lower than coho production in Big Beef Creek. Production for both species has been trending slightly upward over the monitoring period. Hypothesized constraints to coho production are listed in Table 13 and discussed below.

The majority of coho spawning occurs above Lake Symington. Channels in the upper watershed are low gradient and are often unconfined. Data indicate that coho smolt production directly varies with the magnitude of peak November flow event (Figure 16) suggesting that higher fall flows enable spawners to penetrate further upstream accessing more spawning and rearing habitat. Peak November flows were available for only nine of the 27 years of coho smolt production measurements. However, a similar relationship was found using the maximum 3-day November precipitation measured at Bremerton as a surrogate for peak flow (Figure 17).

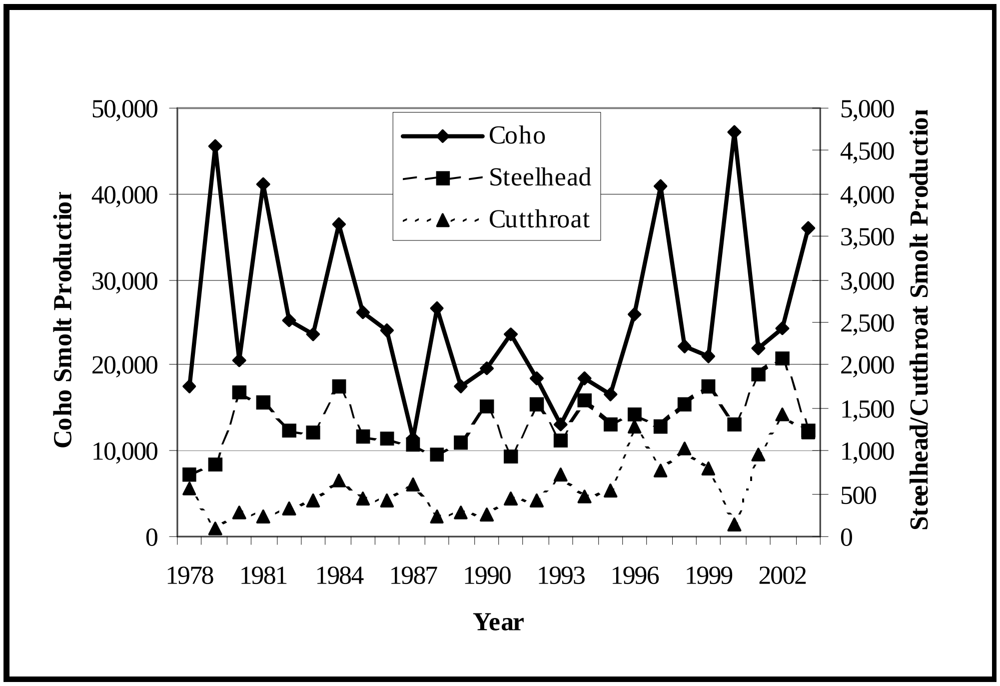

Figure 15. Big Beef Creek coho, steelhead, and cutthroat smolt production.

Table 13. Factors limiting coho smolt production in Little Anderson Creek.

Factors limiting smolt production
Extremely low summer base-flow limits the availability of summer rearing habitat in the lower and unconfined valley
Low fall flows limit access to spawning habitat in the upper watershed
Predation by largemouth bass and other exotics on coho salmon over-wintering in or migrating through Lake Symington reduces the survival of offspring produced above the lake
High summer water temperatures reduce available rearing habitat in Lake Symington and a portion of the canyon below the lake
Land use actions have greatly increased coarse sediment inputs from adjacent hill slopes and tributaries in the lower canyon filling pools and widening channels in the lower canyon and unconfined valley sections, thereby reducing rearing habitat and channel stability
Removal of large cedar debris in the lower canyon and unconfined valley in the 1980s has destabilized the channel and reduced rearing habitat

A similar positive relationship was found between smolt production and summer base flow (60 day average flow) (Figure 18). The outlier in the plot coincided with very low November spawning flows, suggesting that limitation on access to spawning habitat may have limited production for this year. Given the magnitude of habitat loss associated with changes in summer base flow and the potential for reduced summer flows as the basin is developed, this issue needs to be further addressed.

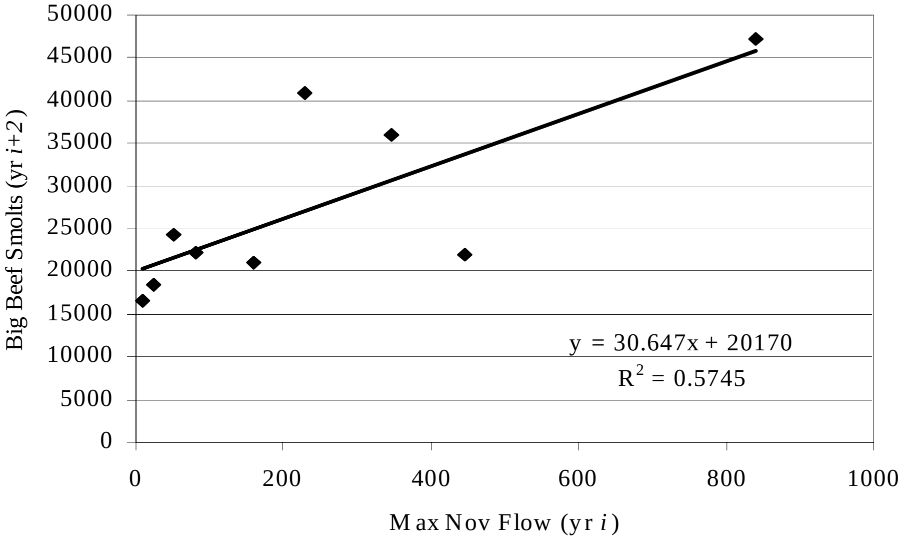

Figure 16. Big Beef Creek coho production as a function of peak November spawner flows.

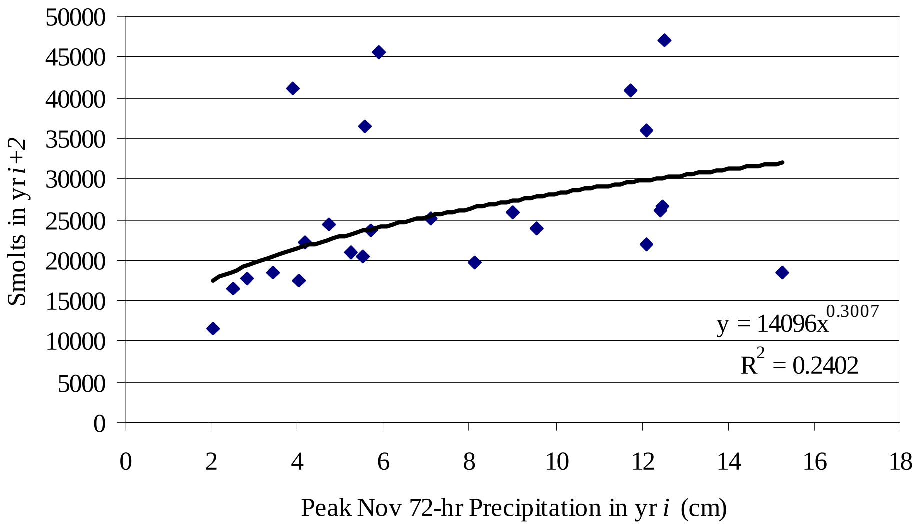

Figure 17. Big Beef Creek coho production as a function of peak November 72-hr precipitation during the parent spawner migration.

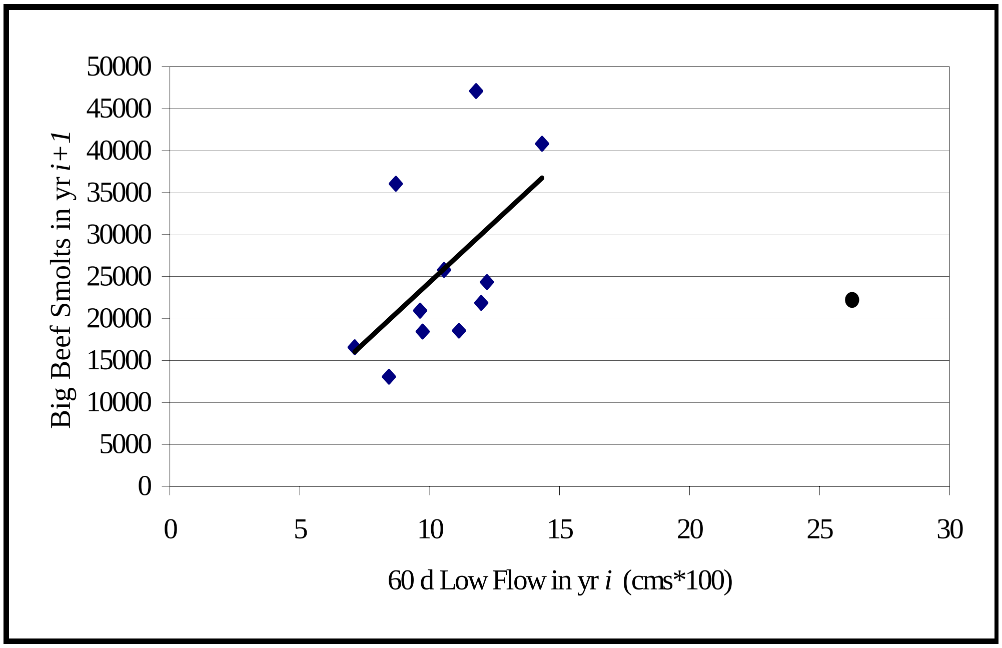

Figure 18. Big Beef Creek coho smolt production as a function of the lowest 60-day mean flow.

Coho smolt production is also predicated on the size of the parent brood escapement or number of eggs deposited in the gravel, particularly when escapements (egg deposition) are low (Figure 19). The flow relationships described above combine to influence the capacity of the system (Figure 20). Line "A" is fitted to data from years where the peak three-day November rainfall totals and minimum 60-day mean summer flows were above their respective median values (diamonds). Line "C" is fitted to data from years when both were below their respective median values (triangles) and "B" is fitted to data from years when one was above and the other was below the medians (circles). These relationships suggest that flow is important in determining coho production from Big Beef Creek.

Smolts produced from above Lake Symington must pass through the lake to reach saltwater. Based on an unpublished two-year study by the WDFW, largemouth bass predation was estimated to have caused a loss of 4 and 8% of the total coho smolt production from the watershed. These rates likely vary with the relative annual abundance of juvenile salmonids and piscivorous bass, water temperature, water clarity, and other factors but the data indicate that a substantial predation impact is occurring in the reservoir.

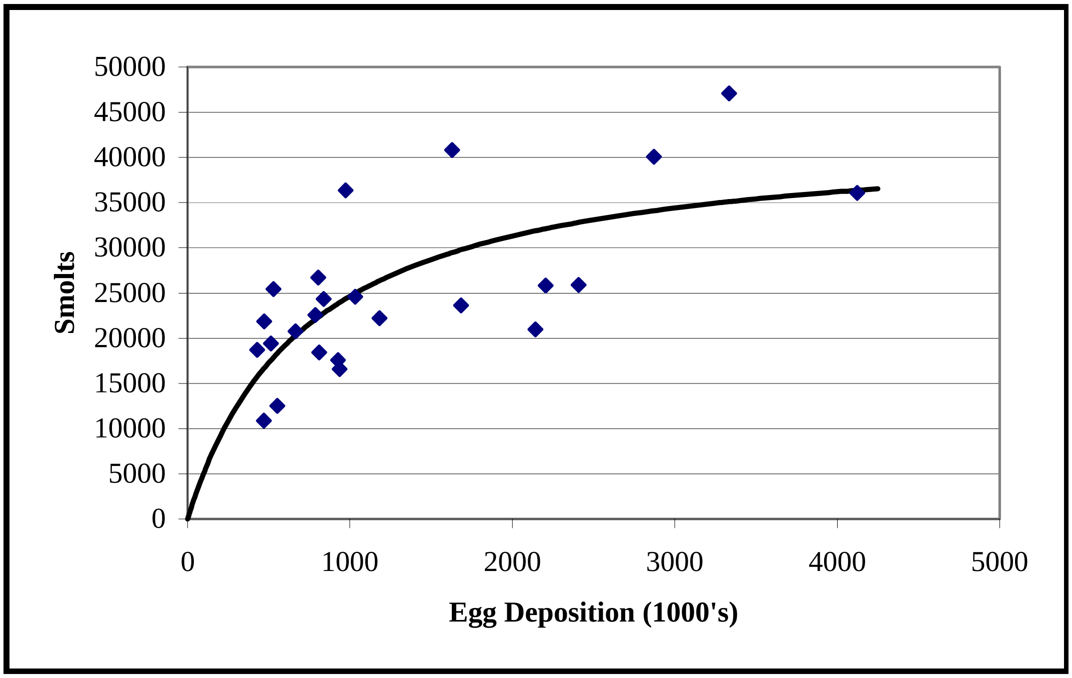

Figure 19. Beverton-Holt production function fitted to coho egg deposition and subsequent smolt production in Big Beef Creek.

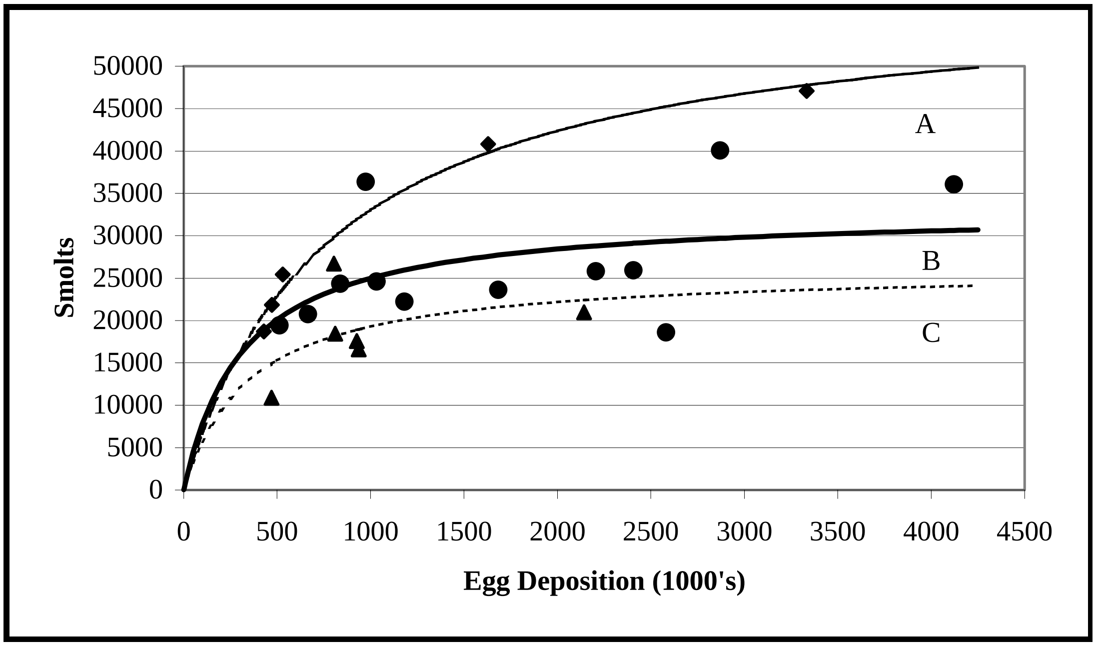

Figure 20. Beverton-Holt coho production functions expressing changes in capacity with changing November and summer flow conditions in Big Beef Creek.

Another impact associated with Lake Symington is its effect on summer stream temperatures (Figure 21). Stream temperatures just below Lake Symington exceeded 16C continuously from May to September 2001 (Seiler et al. 2002b). Temperatures exceeded the lethal limit for coho and chum salmon of 25.5ºC for brief periods and were well above the preferred range of approximately 12.5º to 14.5º C throughout the summer. Measurement stations above the lake and near the mouth rarely exceeded 16ºC, and then only for brief periods. Temperature impacts from Lake Symington continue downstream for some distance and negatively effect summer rearing habitat available to coho, steelhead and cutthroat but it is unclear how far downstream high temperatures extend. Temperature effects of the lake likely also limit the distribution of adult summer chum in the creek, which migrate and spawn beginning in September. As this temperature barrier exists in the center of the watershed, it fragments summer rearing habitat within the basin, which may further effect survival and/or fitness.

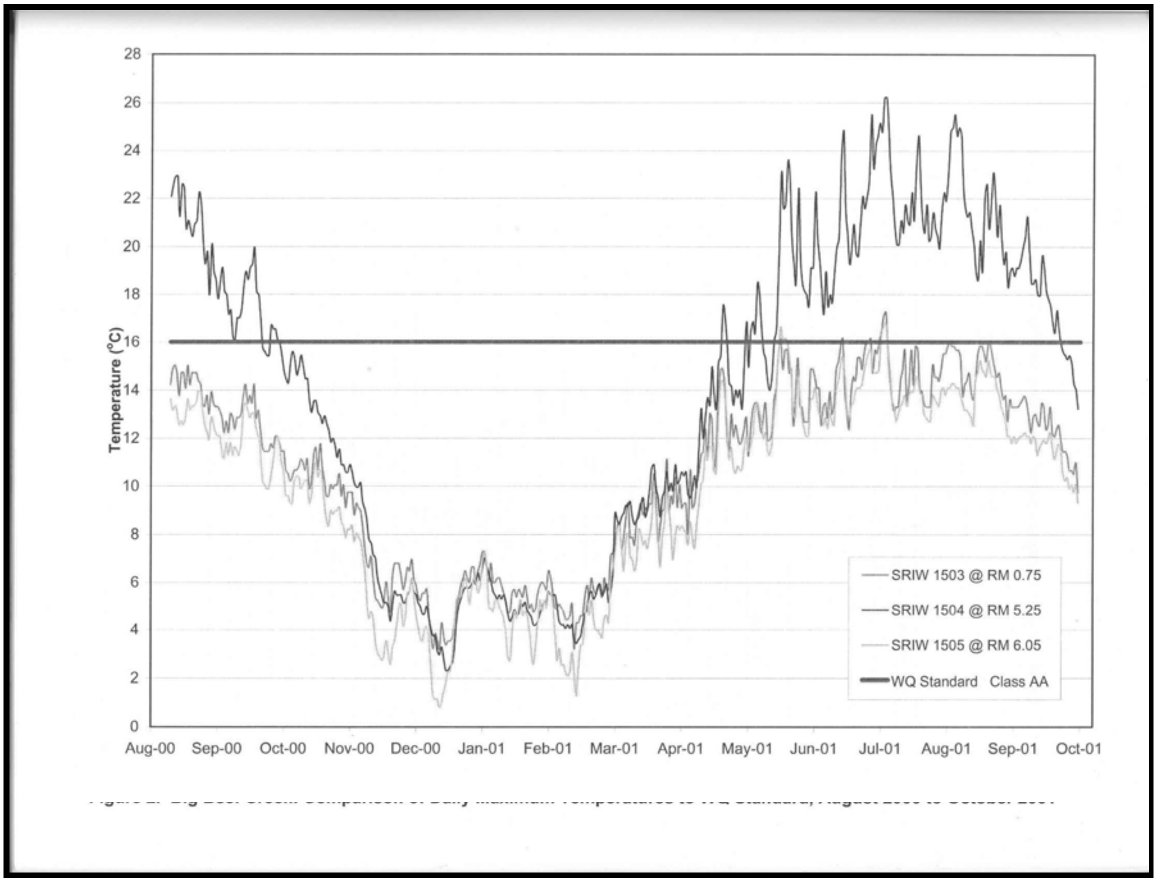

Figure 21. Big Beef Creek stream temperatures measured at the inlet and outlet to Lake Symington, and near the smolt weir.

In the lower canyon, Big Beef Creek flows through an inner gorge. Valley walls are comprised of a mixture of glacially deposited sediments. Some are very erodible while others are more resistant. A number of small tributaries enter Big Beef Creek in this section. Erosion of the inner gorge and tributary stream banks has contributed a tremendous amount of coarse and fine sediments to Big Beef Creek. Land-use activities have intensified sediment contribution rates. The most striking example is along Kid Haven Road. The road was constructed along a small tributary of Big Beef Creek. Material from the road cut was pushed into the stream forcing it laterally so that the stream continually eroded the toe of the far bank . Based on the erosion that is currently evident, it appears that thousands of cubic meters of material have entered Big Beef Creek as a result. Other tributaries are also large contributors of sediment. As a result, Big Beef Creek moves a large amount of sediment each year, which may influence egg-to-fry survival in this section of the stream. The sediment has also filled pools and reduced rearing habitat, resulting in simplified plane-bed channel morphology in the upper half of the lower canyon section.

The removal of large cedar logs from the stream in the early 1980's has contributed to the loss of habitat in the lower canyon and unconfined valley reach. These large logs were responsible for stabilizing accumulations of wood in the channel, providing pool habitat and cover, and retaining spawning gravel. Following their removal, much of the remaining, smaller wood was flushed from the system in a few years. This may partially explain the reduction in coho smolt production observed from 1987 to 1996. More recently, habitat complexity has been increasing in lower Big Beef Creek with the formation of many log jams below Kid Haven Road. Currently, over 30 jams, composed mainly of alder, have been counted downstream of this point. These are trapping sediment and creating pools and may be partially responsible for the increase in coho production observed since 1997. The recruitment of wood into Big Beef Creek may be in response to channel widening with the input of sediment in the lower canyon. The longevity of these jams may be short given the rapid decay rate for hardwood in the stream. Fewer jams exist between the Kid Haven Road crossing and Lake Symington.

Seabeck Creek

Seabeck Creek is a 13.3-km^2 watershed located approximately 4-km west of Big Beef Creek. The fish-bearing portion of the mainstem is approximately 6.2-km long with the lower 3-km flowing through an unconfined or moderately confined valley (Figure 22). In the upper 3-km, the channel is more confined and is incised within the steep surrounding hills. In addition to the mainstem, Seabeck Creek has two right-bank fish bearing tributaries (WDFW unpublished data). The smaller of these, Trib 1, enters Seabeck Creek approximately 150-m upstream of the mouth, whereas the larger, Trib 5, enters the creek approximately 1,600-m upstream of the mouth.

Of the four Hood Canal IMWs, Seabeck Creek has the second lowest smolt production. Since trapping began in 1993, production has averaged approximately 1,400 coho, 300 cutthroat, and fewer than 30 steelhead smolts per year (Figure 23). No trends in production are evident for any species over this eleven-year period. Hypothesized constraints to coho production are listed in Table 14 and discussed below.

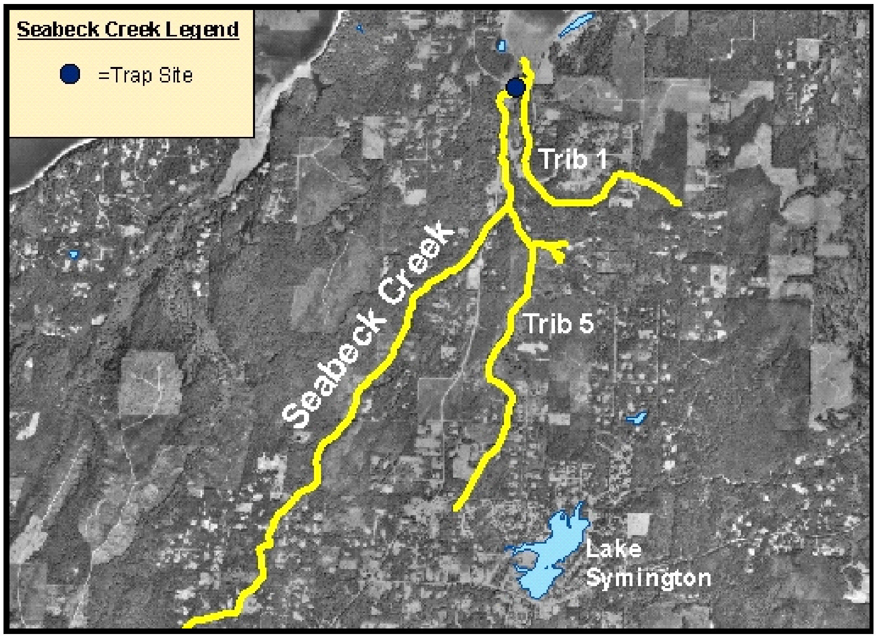

Figure 22. Anadromous fish streams within the Seabeck Creek watershed

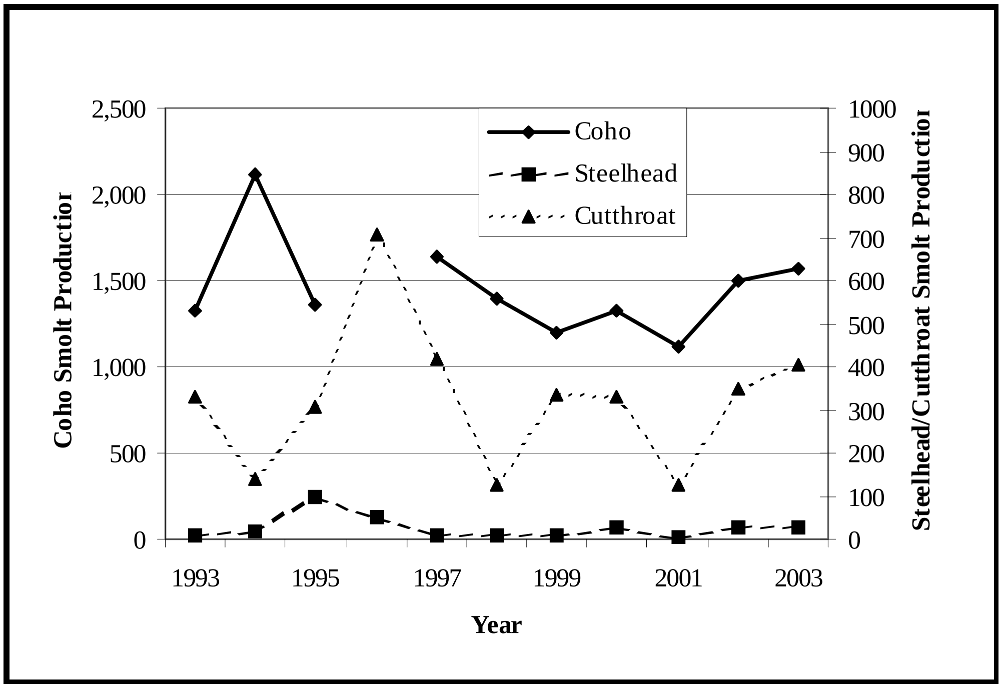

Figure 23. Wild coho, steelhead, and cutthroat smolt production from Seabeck Creek.

Table 14. Factors that are likely limiting coho smolt production in Seabeck Creek.

Factors limiting smolt production
Extremely low summer flows combined with sediment deposition cause much of the accessible habitat to become dry, greatly reducing available summer rearing habitat and fragments much of what remains
Bed erosion in Trib 5 has disconnected the stream and floodplain and degraded habitat downstream in the mainstem.
LWD is scarce in the lower mainstem and Trib 5 reducing rearing habitat

Spawning ground surveys have indicated that approximately 9.6 kilometers of stream habitat are accessible to adult coho salmon. Yet only 2.4 kilometers are contiguous with saltwater in the summer and another 2.3 kilometers are wetted, but separated from the mouth of the stream by dry reaches. The dry reaches previously flowed year around (Neuhauser pers. comm.).

Dry reaches occur at low-gradient reaches downstream of a major sediment source, suggesting coarse sediment deposition may cause the stream to go sub-surface in these reaches. One such reach occurs upstream of the Seabeck-Holly Road crossing where the channel gradient decreases downstream of two eroding banks. Downstream of this point, the stream gradient increases and surface flow returns. The road culvert may be a hydraulic control that causes coarse sediment to accumulate above this point .

The loss of summer rearing habitat resulting from this reduction of surface flow may be the principal factor influencing coho, cutthroat, and steelhead production in Seabeck Creek. Furthermore, the fragmentation of habitat causes population segments upstream of dry sections to be less able to avoid or escape perturbations. Factors causing the extreme low flow conditions observed in Seabeck Creek and Big Beef Creek will be a principal area of investigation in the near future.

Trib 5 exhibits severe bed erosion, with an average of over 4 m^2 of eroded bank per meter of stream in one 100 m stretch. The streambed was down cut 2 m or more along this section and banks were eroding in response to the change in bed elevation . An undersized culvert on a forest road may have contributed to the erosion at this site. Bed and bank erosion continues downstream for approximately 1.7 kilometers becoming less severe farther downstream. As a result, the channel is highly entrenched and disconnected from its floodplain.

Sediment from the bed erosion has deposited in the mainstem Seabeck Creek. This is especially evident where the stream crosses under the Misery Point Road. The bed is currently approximately 0.6 meters below the bottom of the road bridge.   Anecdotal reports have indicated that the bed used to be much lower historically (Neuhauser pers. comm.). It appears that the bridge abutments may constrict flow, possibly resulting in additional deposition upstream of the bridge. Deposition is evidenced by the many live cedars in this reach with the base of their trunks buried in the bed sediments.. As a result, salmonid spawning areas in the lower mainstem and Trib 5 may be more susceptible to scour and sediment deposition than in other portions of the watershed.

Habitat surveys have found functioning LWD to be at very low levels in lower Seabeck Creek and in Trib 5. Consequently, simplified pool-riffle and plane-bed channel morphologies exists in the lower mainstem and Trib 5, respectively; and provide less habitat than would more LWD-rich, complex channel forms. The lack of wood also contributes to bed instability which exacerbates the potential for redd scour and suffocation described previously.

Stavis Creek

Stavis Creek is a 13.1-km^2 watershed located approximately 2.4 km west of Seabeck Creek (Figure 24). During summer fish occupy nearly 8 km on the mainstem, 2 km on the South Fork Stavis Creek, and 0.4 km on an unnamed left bank tributary to the mainstem (WDFW unpublished data).

Stavis Creek was selected as a reference watershed for the Hood Canal IMW Complex. Of the four watersheds Stavis Creek is the least developed and will likely be developed more slowly than the other three basins. Most of the lands within the basin are managed for timber production by the owners or by DNR Lands Division. Some rural residential development has occurred along the ridge south of SF Stavis Creek.

Stavis Creek is the second most productive of the Hood Canal IMWs. Production averages 6,000 coho, 1,400 cutthroat, and 70 steelhead smolts (Figure 25). As with Big Beef Creek, coho and cutthroat smolt production in Stavis Creek have been increasing.

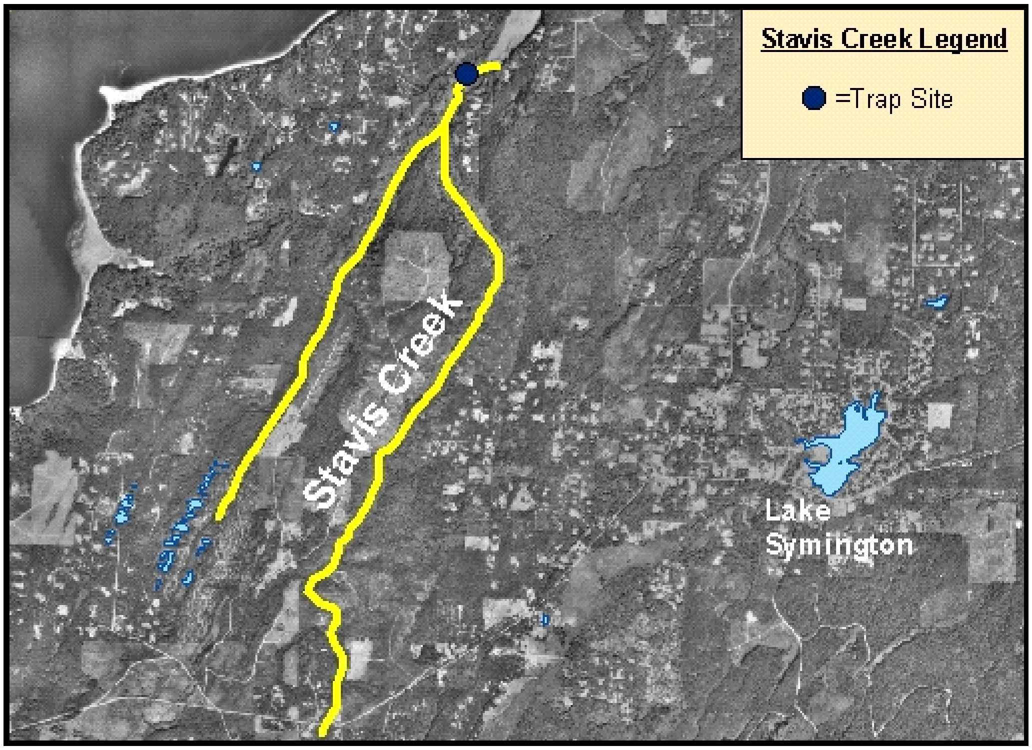

Figure 24. Anadromous fish streams within the Stavis Watershed.

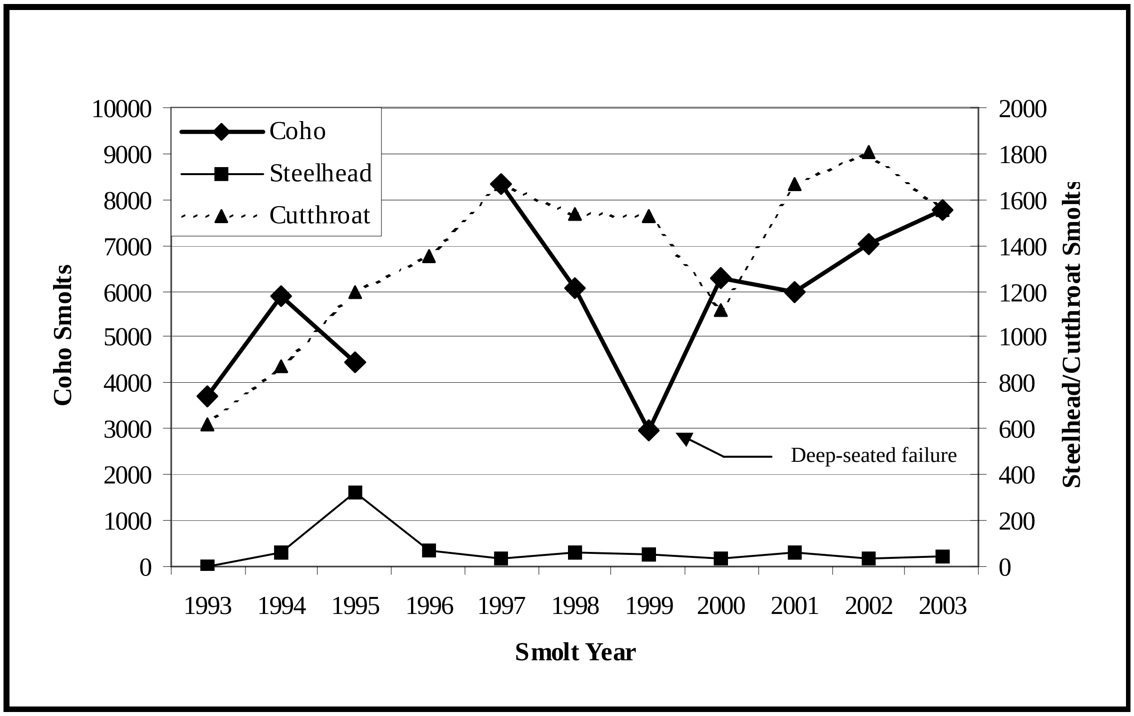

Figure 25. Stavis Creek wild coho, steelhead, and cutthroat production.

Like the other streams in this complex, the amount of streamflow during the summer rearing period affects the number of coho smolts produced (Figure 26). Sediment is one of the factors affecting salmon production in this system. One slope failure located approximately 600-m upstream of the confluence of SF Stavis Creek is especially large. The slide, which occurred during the winter of 1999, was located on a steep slope that had been logged about 10-15 years earlier (Neuhauser pers. comm.). The erosion scar from this slide was estimated at 550 m^2 (WDFW unpublished data). A tremendous amount of fine and coarse sediment was released in this slide impacting spawning habitat down to the mouth of the stream and reducing rearing capacity. Coho smolt production during the spring of 1999 was much reduced, presumably due to impacts from the slide on fish that were over-wintering in the lower watershed below the sediment source (Figure 25). Although the greatest impacts to habitat occurred in the first two years following the slide, sediments continue to be transported downstream and may still be affecting smolt production.

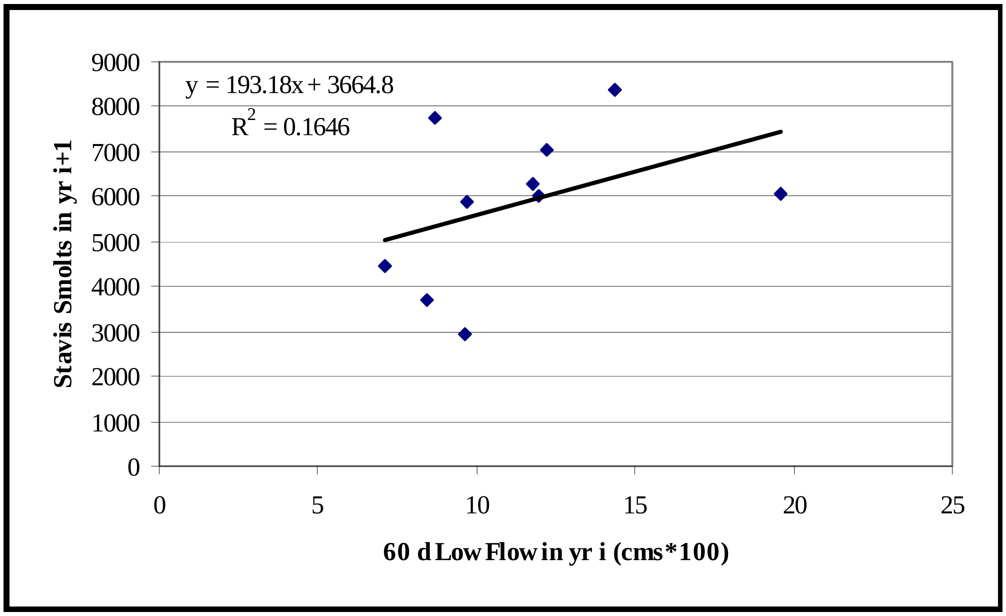

Figure 26. Stavis Creek coho smolt production as a function of the lowest 60-day mean flow from Big Beef Creek.

Implementation of monitoring and restoration

The production constraints are similar among the basins. All streams are rich in coarse sediments and many sections lack large wood, whether from lack of input, removal, or burial, to control the downstream routing of sediment and increase habitat complexity. Less well understood are the causes for the low summer flows that appear to limit production in the four streams. This complex-wide problem needs to be evaluated in the near-term in order to make headway in the restoration of these basins.

This year (July 04-June 05) work in the Hood Canal IMW Complex will focus on:

1. installing the basic monitoring infrastructure (implement monitoring in Table 2-Variables measured);
2. estimating summer abundance of coho, steelhead and cutthroat in reaches accessible to anadromous fishes;
3. collecting additional data to inform specific factors hypothesized to constrain smolt production (Table 15); and
4. working with the local entities to identify, design, and implement restoration projects designed to address one or more identified production constraints.

All monitoring listed in Table 2 is being implemented as planned.

Low summer flow

Two surveys will be done to inform the concerns with low summer flows and summer rearing habitat quantity and continuity. The first will be a survey to identify the major ground water inputs to each stream. The field data will be collated with available aquifer maps to identify where development may impact baseflows. The second effort will be repeated surveys across a range of low flows to estimate available habitat at ten or more stream cross sections throughout the anadromous zone. These data will be used to estimate the relationship between low flow and summer rearing habitat quantity to inform the hypothesis that differences in summer low flows (i.e. habitat) affect smolt production.

Fall spawning flows

Similarly, the relationship of fall spawning flows will be investigated by correlating the spawner and redd counts conducted on the entire anadromous zone in November and December with the corresponding weekly maximum flows.

Predation

No action currently is planned to address bass predation in Lake Symington or to monitor its impact on smolt production.

Sediment input and LWD placement

Objectives for reducing sediment impacts and improving habitat through LWD placement in each basin are listed in Table 16. Identification of specific projects, including the location, design, implementation, and project effectiveness monitoring will be done in close collaboration with the lead entities and the local salmon enhancement groups. To date, one project for LWD placement in Little Anderson Cr between RK 0.7 and 2.0 has been developed by the Hood Canal Salmon Enhancement Group, in collaboration with the IMW oversight committee, and submitted to the USFWS Private Stewardship Grant Program for consideration. A before-after/treatment-reference project effectiveness plan has been written and will be implemented when funding is secured and the project installation plans are final.

Table 15. Primary production constraints are listed by IMW basin along with proposed actions for the next year, July 2004-June 2005.

Constraint	L Anderson	Big Beef	Seabeck	Stavis	Action for 2004
Low summer flow	X	X	X	X	Ground water survey, quantify rearing habitat vs. low flow
Fall spawner flows		X		X	Evaluate fall flow vs. spawner distribution
Predation by exotics		X			None planned.
High water temp		X			Basin wide temp monitoring, delineate stream reach affected by L Symington
Sediment input	X	X	X	X	Identify and design restoration projects
Lack of LWD	X	X	X	X	Identify and design restoration projects

Table 16. Restoration objectives for each treatment basin are listed below. Restoration objectives will be pursued through lead entities or other local salmon restoration group.

	Little Anderson	Big Beef	Seabeck
Sediment	Slow routing of storm runoff and associated erosion into channel	Slow sediment input into lower canyon	Capture coarse sediment in Trib 5 and upstream of Seabeck-Holly Rd.
LWD	Stabilize bed sediments and increase habitat rearing and spawning habitat between RK 0.7 and 2.0 Develop off channel habitat below RK 0.7	Stabilize bed sediments and increase habitat rearing and spawning habitat below Lake Symington	Increase habitat complexity in Trib 5 and Seabeck Cr Narrow channel in lower Seabeck Cr to reduce accumulated coarse sediment

Lower Columbia Complex

Complex Description

The Lower Columbia Complex is comprised of Mill, Abernathy, and Germany Creeks, located within the Elochoman subbasin (WRIA 25), in Cowlitz and Wahkiakum Counties, Washington. Smolt traps in each creek are located within a kilometer of the stream mouths (Figure 27). Watershed areas above the smolt trap are similar ranging from 5,800 to 7,600 hectares. Abernathy and Germany Creeks drain steep basins with headwater elevations of up to 806-m. Mill Creek is a lower elevation basin with headwater elevations of 555-m. The entire complex is largely forested (Table 17) with Washington Department of Natural Resources (DNR) and industrial forest landowners in the upper watersheds and small landowner scattered throughout the lower basins. Most forest land in Germany Creek is privately owned, while Washington Department of Natural Resources (DNR) manages a large share of the Mill Creek and Abernathy Creek watersheds. Residential development is light, although projected to increase substantially within WRIA 25 by 2020, concentrated along public roads in the lower portion of the three basins. Significant agricultural development is present in the lower end of Abernathy Creek and Germany Creek.

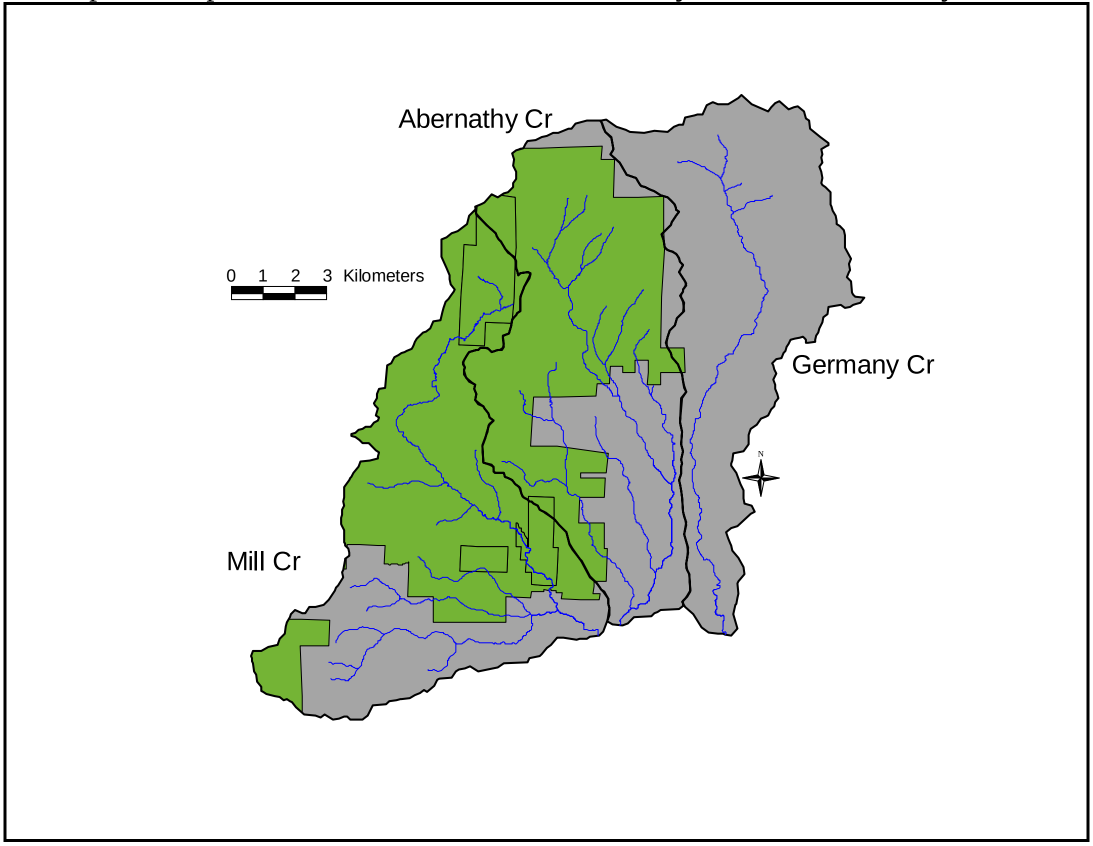

Figure 27. Lower Columbia IMW Complex. Land managed by the Washington Department of Natural Resources is shaded green.

Table 17. Land cover, land management, and ownership percentages for each trap basin are shown below. Land cover is based on satellite imagery from the early 1990s. HCP area is based on 2001 maps provided by U.S. Fish and Wildlife Service. The land under Forest and Fish rules (FFR) is based on a map compiled for DNR and does not include small forest landowners. Public ownership was based on the Major Public Lands map, remaining land was assumed to be private.

Lower Columbia Complex							
Smolt trap	Basin area (acres)	Land cover (%)		Land mgt (%)		Ownership (%)	
		Forested	Developed	FFR	HCP	Public	Private
Mill Cr	18648	94	0	12	66	68	32
Abernathy Cr	18309	92	0	19	62	62	38
Germany Cr	14471	85	0	83	0	0	100

Chum and coho escapements are currently not monitored in these basins. Chinook and steelhead escapements are monitored using the index reach method. Smolt monitoring has been conducted in the Lower Columbia Complex since 2001(Table 18). Average coho smolt production per square kilometer watershed area in the three Lower Columbia Complex streams ranged from 89 in Abernathy Creek to 130 in Germany Creek (Table 19). These levels are substantially lower than those found in Stavis Creek (489 coho smolts/km^2) over the same two years. The low level of coho production in the Lower Columbia Complex may relate to their higher stream gradients, which favor steelhead production, poor habitat condition, and possibly to low coho escapements, which are currently not measured. Wild steelhead smolt production per square kilometer of watershed averaged 20 in Mill Creek, 108 in Abernathy Creek, and 130 in Germany Creek. These levels are much higher than are observed in Stavis Creek over the same two years (4 steelhead smolts/km^2), a much smaller and lower gradient stream.

Table 18. Period of record and data collected at each smolt trap.

Lower Columbia Complex				
Smolt trap	*Watershed analysis?*	*Juveniles*		*Adults*
		Since	*Species*	*Species*
Mill Cr	No	2001	chinook, coho, cutthroat, steelhead	chinook, steelhead
Germany Cr	No	2001	chinook, coho, cutthroat, steelhead	chinook, steelhead
Abernathy Cr	No	2001	chinook, coho, cutthroat, steelhead	chinook, steelhead

Table 19. Average wild coho and steelhead smolt production and productivity for the Big Beef/Seabeck (BBS) complex (1992-2002) and Germany/Mill/Abernathy (GMA) complex (2001-2002).

	Average Smolt Production		Watershed	Average Smolts/km2	
Stream	**Coho**	**Steelhead**	**Area (km^2)**	**Coho**	**Steelhead**
GMA Complex					
Mill Creek	7,912	1,480	75.4	105	20
Abernathy Creek	6,596	7,995	74.3	89	108
Germany Creek	7,579	7,550	58.3	130	130
BBS Complex					
Big Beef Creek	23,443	1,528	36.0	651	42
Little Anderson Creek	263	43	12.0	22	4
Seabeck Creek	1,313	27	13.3	99	2
Stavis Creek	5,239	74	13.1	400	6
Note: Coho and steelhead production estimates for the BBS complex, shown here, represent average smolt trap catches. The actual average production is slightly higher due to unaccounted for migration occurring prior to and following trap operation. Estimates for GMA complex streams represent the average total migrations of coho and steelhead smolts.					

Because of the short monitoring record, few hypotheses regarding factors constraining production can be drawn directly from smolt production data. However, the following data sets have been assembled and reviewed for the Lower Columbia IMW Complex and a list of factors constraining smolt production compiled (Table 20).

- 3 years of smolt production estimates for Mill, Abernathy, and Germany Creeks,
- Lower Columbia Salmon and Steelhead Recovery and Subbasin Plan – May 28, 2004 Draft,
- Salmon and Steelhead Habitat Limiting Factors: Water Resource Inventory Area 25 (Washington State Conservation Commission),
- Habitat data collected by the Cowlitz Conservation District in 2000
- Ecosystem Diagnosis and Treatment (EDT): Level II Environmental Attributes: Habitat Surveys (WDFW),
- Mill/Abernathy/Germany Sub-basin Stock Summary and Habitat Priorities (LCFRB 2004), and
- Aluminum Toxicity Assessment of Mill Creek and Cameron Creek, Wahkiakum and Clark Counties (Memo: Mark Hunter [WDFW] and Art Johnson [DOE] to Brian Cowan [WDFW], 7/5/96).

Much of this information, as well as the Lower Columbia EDT analysis, have been synthesized in the Draft Lower Columbia Salmon and Steelhead Recovery and Subbasin Plan (LCFRB 2004).

Table 20. Constraints to smolt production

Factors limiting smolt production
low habitat diversity
poor channel stability
poor riparian function
reduced floodplain function
altered streamflow
high stream temperature
excess sediment input

Many of these production constraints are correlated and can be attributed to clearing of riparian vegetation for agriculture or timber harvest, road construction in the floodplains, sediment input from forest roads and mass wasting, and direct manipulation of the stream channel.

Another possible constraint to production in portions of Mill Creek and Abernathy Creek is aluminum toxicity related to naturally-occurring aluminum in area soils. Anecdotal evidence of low fish density and low productivity in several tributaries coupled with relatively high levels of total and or dissolved aluminum measured in 1996 raised questions about whether in stream aluminum concentration was related to the Germany soil series (high in aluminum), the spatial extent of Germany soils, and the degree to which aluminum could be impacting aquatic productivity (Hunter and Johnson 1996; White and Johnson 1998).

Implementation of monitoring and restoration

Production constraints are similar among the basins. However, because the existing habitat data are limited, the FY04 (July 04-June 05) efforts will focus on (Table 21):

- installing the basic monitoring infrastructure (implement monitoring in Table 2-Variables measured);
- collecting additional data regarding the sources of sediment and the degree of hydrologic connection between the road network and the streams;
- collecting water quality data to evaluate the likelihood of aluminum impacts to aquatic biota; and
- conducting basinwide habitat assessment on anadromous stream reaches

Water Quality

The potential impact of Al on fish production will be assessed. Initially, existing data on fish abundance and distribution relative to presence of the Al-rich, Germany soil series will be examined for evidence of a correlation. Several tributaries exhibiting a range in the proportion of their watersheds containing Germany series soils will be selected for water quality sampling to assess the effect of these soils on in stream aluminum concentrations. The water quality sampling will be coordinated with the juvenile fish abundance sampling to examine the correlation between aluminum concentration and juvenile fish abundance.

Sediment

There is currently little information about sediment generation and transport in the watersheds in the Lower Columbia complex. Habitat data collected to date does suggest that excess sediment generated by forestry activities may be restricting salmon and steelhead production. However, ascertaining the extent of this problem will require an assessment of the current processes governing sediment production and delivery to streams and the routing of this material through the channel network. During 2005 an assessment will be conducted using Washington Watershed Analysis methods for mass wasting and surface erosion assessments. The information generated by this assessment will provide an indication of the relative impact of sediment on fish production and also identify specific locations and activities in the three watersheds responsible for increasing delivery of sediment to streams.

This initial information will provide the foundation for the development of a restoration strategy to address sediment problems. Sediment budgets will be developed for the watersheds. Restoration measures will be applied in one of the three watersheds and changes in the budget of the treated watershed will be compared with those in the untreated, reference watersheds. If treatments do result in a reductions in sediment levels, fish responses to these changes will be assessed by examining locations and life history stages most apt to benefit from the reduction. The sites where these types of assessments would be most appropriate will be identified during the habitat surveys (see below).

The effectiveness of projects designed to reduce sediment production of delivery also may be addressed at the reach-scale. The purpose of these finer-scale experiments will be to assess the relative efficacy of specific restoration measures. If appropriate, site-level biological responses also may be assessed at these project sites.

Stream and riparian habitat

A Hankin and Reeves habitat assessment will be conducted on approximately 50 km of streams within the complex that are known to support coho salmon in 2004. An additional 10 km that are suspected to support steelhead will be assessed in 2005, providing a complete evaluation of all streams supporting anadromous salmonids in the complex. These data will be used to develop more detailed hypotheses, establish the reference basin, and complete a restoration plan for each treatment basin.

Table 21. Production constraints by IMW basin along with proposed actions for the next year, July 2004-June 2005.

Constraint	Mill	Abernathy	Germany	Action for 2004
Altered flows	X	X	X	Install flow gauges Assess degree of hydrologic continuity between roads and stream channel
Water Quality	X	X	X	Basin wide temp monitoring
Aluminum toxicity	X	X		Conduct targeted WQ monitoring
Sediment input	X	X	X	Conduct WA modules for roads and mass wasting Do sediment budget
Channel stability	X	X	X	Complete complex-wide Hankin and Reeves habitat surveys
Habitat	X	X	X	

Chinook Salmon

Wenatchee River

The Upper Columbia Regional Technical Team and Upper Columbia Salmon Recovery Board have designed a monitoring effort for the Upper Columbia Basin (http://www.cbfwa.org/files/RME/020104UCBmonitoringStrategy.doc) (Hillman 2004). The plan described here addresses the following basic questions:

1. What are the current habitat conditions and abundance, distribution, life-stage survival, and age-composition of fish in the Upper Columbia Basin (status monitoring)?
2. How do these factors change over time (trend monitoring)?
3. What effects do tributary habitat actions have on fish populations and habitat conditions (effectiveness monitoring)?

The plan is designed to address these questions and at the same time eliminate duplication of work, reduce costs, and increase monitoring efficiency by coordinating current monitoring efforts conducted by the U.S. Forest Service, U.S. Fish & Wildlife Service, Washington Departments of Fish and Wildlife, and Ecology, Chelan County, and Chelan County Public Utility District. The coordination is overseen by NOAA Fisheries. The Wenatchee River is represented on the IMW Scientific Oversight Committee to ensure close cooperation and information flow among the various IMW efforts. However, no SRFB funding has been requested for the Wenatchee River.

Skagit River

Chinook salmon are well known for utilizing tidal deltas, “pocket estuaries” (nearshore lagoons and marshes), and other estuarine habitats for rearing during outmigration (Reimers 1973, Healey 1980, Beamer et al 2003). Several studies have linked population responses to availability of estuary habitat, either by examining return rates of groups of fish given access to different habitat zones (Levings et al. 1989) or by comparing survival rates of fish from populations with varying levels of estuary habitat degradation (Magnusson and Hilborn 2003). These studies support the hypothesis that estuarine habitat is vital for juvenile chinook salmon. However, these necessarily coarse-scale studies have ignored how large-scale estuarine habitat restoration within a watershed contributes to population characteristics. These issues may be critical to understand how to best restore chinook salmon populations, as many estuaries within Puget Sound and elsewhere have been lost to agriculture and urbanization. For example, the Duwamish River has lost more than 99% of its tidal delta habitat (Simenstad et al 1982), while the Skagit River, which contains the largest tidal delta in Puget Sound, has lost 80-90% of its habitat area (Collins et al. 2003).

In 1994 the Skagit River tribes initiated field studies to understand wild Skagit Chinook fish habitat relationships for population recovery purposes. The studies were developed in the context of a lifecycle model framework that includes discrete life stages and habitats for multiple juvenile life history types of ocean-type Chinook salmon. Field studies include: (1) identification of juvenile life history types, (2) inventories of current and historic habitat conditions, and (3) fish use patterns for freshwater, estuarine delta, and Skagit Bay near shore life stages. Results after a decade of study show: (1) a strong negative relationship of peak flow during incubation with egg-fry survival, (2) a large historical loss of delta estuarine habitat and a high percentage of wild juvenile Chinook positioned to utilize this habitat for extended rearing, (3) evidence for density dependence in the delta and possibly freshwater habitat areas, (4) density-dependent movement by individual migrants, and (5) strong seasonal preferences in nearshore habitat utilization. The results of the field studies lead independently to a solid biological rationale for for specific recovery actions that would benefit specific juvenile life history types. However, it is critical to understand how chinook salmon populations respond to recovery actions, to be extrapolate these results to other estuaries within Puget Sound and elsewhere that have been lost to agriculture and urbanization.

The goal of this project is to understand changes in population characteristics (primarily abundance, productivity, and life history diversity) of wild chinook salmon in response to reconnection and restoration of estuarine habitat. Researchers have developed a plan to do this via long-term interagency monitoring in the Skagit River watershed involving sampling of outmigrants at Mt Vernon (WA Department of Fish and Wildlife, WDFW), fyke trapping of fish rearing in the tidal delta (Skagit River System Cooperative, SRSC), beach seining of nearshore habitats in Skagit Bay (SRSC), and townetting of offshore areas in Skagit Bay (Northwest Fisheries Science Center, NWFSC). This program provides us a system-wide analysis of patterns of abundance and life history diversity across the migration season. These efforts, in combination with site-specific efforts to examine effectiveness of several large-scale estuary restoration projects, will allow us to evaluate the role of estuary restoration for the recovering chinook salmon population in the Skagit River.

This project capitalizes on four estuary restoration efforts either already completed or to be completed within the next four years along the South Fork of the Skagit River: Deepwater Slough (completed in 2000), Wiley Slough (in progress), Milltown Island (proposed), and Fisher Slough (proposed). These restoration projects involve dike removal and restoration of habitat forming processes such as riverine and tidal inundation. In total these projects will result in restoration and reconnection of 637 acres of wetlands, and therefore will greatly improve habitat availability for juvenile chinook salmon.

Long-term monitoring offers two general approaches for examining how the chinook salmon population respond to restoration of estuary habitat. First, we can examine system-wide population characteristics before and after restoration to look for the “signal” of restoration. For the last 10 years, SRSC has been monitoring the abundance of four life history types of chinook salmon: 1) yearlings, which rear in freshwater for one year before migrating out of the Skagit system without extensively using estuarine habitat, 2) parr migrants, which rear up to three months in freshwater before also rapidly migrating through the estuary, 3) delta fry, which rear for one to three months in freshwater before migrating downstream and rearing in the tidal delta for one to three months, and 4) fry migrants, which rear for a very short period in freshwater before migrating downstream, bypassing the tidal delta, and rearing for and extended period of time in the Skagit Bay nearshore. These life history types can be distinguished based on differences in body size as well as differences in the times that they appear in the smolt traps at Mt Vernon, fyke traps in the Skagit delta, and beach seines in Skagit Bay. Three concomitant patterns in these data are that the density and body size of delta fry and the proportion of fry migrants in beach seine catches all increase as a function of total outmigrant population size. These patterns strongly implicate rearing habitat limitation in the tidal delta. If this is the case, we would expect to see system-wide differences in density and size of delta fry and abundance of fry migrants when we compare data pre- and post-restoration of delta habitat. Continued fyke trapping and beach seining adjusted for outmigration population size measured at Mt. Vernon, can provide sufficient data to address this for the Deepwater Slough restoration project and in the future for the other projects.

A second way to examine population responses to restoration is by using before-after-control designs at smaller scales. The most basic analysis examines site-specific effectiveness of restoration efforts in the tidal delta. The Skagit River System Cooperative is employing this technique via study and reference reaches to examine whether restoration at Deepwater Slough has successfully increased habitat utilization to match reference levels.

In addition to site-specific effectiveness monitoring approaches, the Skagit Watershed offers us a unique opportunity to examine population responses to estuary restoration if we take advantage of the fact that restoration has been targeted primarily on the South Fork of the Skagit. We therefore can compare portions of the outmigrant population that experience the effects of restoration (outmigrants in the South Fork) to those that do not (outmigrants on the North Fork), before and after restoration projects. Continued monitoring of beach seine and tidal delta sites contiguous to the North and South Fork will allow us to examine how size and life history diversity has changed in response to the Deepwater Slough restoration. In the future, we plan to expand on these comparisons to examine effects of other restoration on the South Fork upon residency and survival by marking outmigrants on the North and South Forks and recapturing them by beach seining and townetting. We also plan to take advantage of an acoustic tagging buoy system planned for the entire west coast from Oregon to Alaska. We plan to acquire and position acoustic buoys in Deception Pass and near Crescent Harbor, the two major passages out of Skagit Bay. By acoustically tagging marked fish of appropriate size captured in beach seine catches, we will expand our analysis of survival and address the effects of tidal delta restoration on movement and return rates of chinook salmon and other anadromous salmonids.

The IMW technical oversight group will work with the SRSC, WDFW, and NWFSC to identify and fund tasks to evaluate the effectiveness of estuary restoration. These tasks may include:

Fyke trapping in the tidal delta (SRSC). 10 sites will be monitored biweekly from February through July. This monitoring includes sites on the North and South Forks of the Skagit River, and effectiveness monitoring of Deepwater Slough. Additional sites may be added to accommodate effectiveness monitoring of Wylie Slough.

Beach seining of nearshore sites in Skagit Bay (SRSC). 28 sites will be monitored biweekly from February through September. This monitoring includes sites contiguous to the North and South Forks of the Skagit as well as pocket estuaries.

Townetting of offshore sites in Skagit Bay (NWFSC). 12 sites will be monitored monthly from April to October. This monitoring includes sites contiguous to the North and South Forks of the Skagit and pocket estuaries, as well as sites demarking exit points of Skagit Bay (Crescent Harbor, Deception Pass).

Mark-recapture studies, diet analysis, analyses of life history diversity (NWFSC). NWFSC will extend monitoring efforts by

- conducting mark-recapture studies on the North and South Forks of the Skagit (up to 8 sites)
- conducting an acoustic tagging study of marked fish in Skagit Bay
- analyzing existing collections for differences in diet and life history diversity among sites and life stages.

The SRFB funding may be used to supplement other funding sources or initiate new monitoring as needed.

EXTENSION OF RESULTS TO OTHER WATERSHEDS

Purpose

Because only a few watersheds can be included in the IMW project, extension of the results to other watersheds cannot be accomplished by the traditional method of increasing the sample size (number of watersheds monitored) until a sufficient level of statistical certainty is achieved. We will determine the applicability of our results by classifying watersheds across Washington State based on similarity of physical and biological characteristics in relation to the ten watersheds included in the IMW project. Watersheds which have biophysical characteristics and patterns of human activities comparable to IMW sites will be locations where IMW results can be extended with the greatest degree of certainty.

Method

The initial goal of the (IMW) extrapolation exercise is to classify and group watersheds with similar physical, biological and anthropogenic impact characteristics in relation to the watersheds where intensive watershed monitoring will be conducted (see Fig. 28 for mock example of exercise). Ultimately, the classification process will support the extrapolation of expected results from restoration projects between monitored and non-monitored watersheds, inform the design and distribution of future restoration and monitoring projects, and support the interpolation or imputation of data across regions of the state not monitored as intensively as the IMWs. To generate landscape classification schemes for this purpose requires choosing variables that capture most of the information pertinent to salmonid productivity. The choice of these variables is therefore critical to the success of this exercise. Variables are chosen based on the current understanding of fish-habitat relationships available in the literature. The two main assumptions underlying this exercise are that the variables used are: 1) some of the most important determinants of the overall characteristic of a watershed, and 2) important determinants of salmonid population processes.

The basic list of variables currently thought to correlate to fish productivity includes climate, geology, watershed topology, vegetation, channel confinement and gradient, land-use/cover, ownership, wetlands. In addition, recent work shows that channel size (e.g., drainage area or some regionally calibrated estimate of discharge) and elevation are also important. A variety of studies have shown empirical correlations between fish numbers and these variables. It is feasible to simply seek correlations between the distribution (histograms, cumulative distributions) of these attributes and fish species and population sizes, which would allow extrapolation to other basins that lack monitoring data. However, it may also be useful to look at how these attributes affect fish directly, which may provide a more powerful means of extrapolation.

Ultimately each attribute included in the extrapolation process somehow affects aquatic habitat and these effects occur point by point through the channel network. Thus, it is the combined suite of variables at each point that is important. For example, the relationship of channel gradient and valley width for a reach is lost when the distribution for each variable is viewed independently. A measure of basin productivity requires a method of assessing the effects and interaction of all variables point by point and then aggregating that information over the basin. A number of recent examples of constructing similar geomorphically-based, watershed-intrinsic potential metrics have been very useful for the management and recovery planning of listed anadromous salmonids.

However, existing approaches to classifying landscapes for the purpose of managing and recovering listed anadromous salmonid populations have not included parallel assessments of immutable characteristics of watersheds and human land-use impacts on the watersheds. Therefore, to extend our current understanding of and approaches towards landscape classification specific to aquatic resources, similar methods must be applied to both the geomorphic and anthropogenic determinants of watershed intrinsic potential. Human activity over the past 100 years in the Pacific Northwest has dramatically altered the region’s land- and waterscapes. As such, human activity has impacted the productive potential of most of the region's aquatic systems. In fact, some of the immutable factors used above to describe the inherent potential of aquatic systems have been changed by human activities (e.g., channel confinement, local climate). However, the primary mode by which human activities impact aquatic ecosystems is indirectly through land use practices (e.g., agriculture, urbanization). Therefore, any exercise to characterize broad scale patterns of aquatic productivity would be naïve to ignore the impacts of these activities. Thus, the effect of human activity on the landscape will be assessed through a parallel effort to develop a regional classification of watershed condition as a function solely of human activity. The potential list of human land use practices and activities that have the potential to alter relevant physical and biological processes will include: agricultural activities, forest practices, livestock activities, transportation, channel alteration, mining, urbanization.

Specific tasks and steps

1) Describe immutable and human impacts characteristics of watersheds

To classify the watersheds of Washington State based on their potential to support anadromous salmonids both as a function of underlying geomorphic and physiographic characteristics as well as anthropogenic impacts due to land-use practices and activities requires developing a multidimensional (>10) numerical score for each watershed (6th field HUC) based on reducing multiple spatial data layers. For this effort, the input data will be of two types, basic geomorphic descriptions of the landscape and characterizations of human impact. The precise components to be evaluated will be determined during the scoping phase of the work. Generating the watershed scale descriptors requires the compilation of existing spatial data layers to generate consistent and complete coverages of biophysical condition of and human impacts on aquatic habitat across Washington State. Considerable effort will then be required to standardize and extract watershed descriptions from these layers. To do so, we will (i) use existing or novel numerical algorithms to quantify the geomorphic and physiographic characteristics of watersheds (6th field HUCs) in Washington State based on the list of factors determined to be key determinants of physical and biological processes; and (ii) use existing or novel numerical algorithms to quantify the impact and extent of human land-use practices and activities in watersheds (6th field HUCs) in Washington State based on the list of factors determined to be key modifiers of critical physical and biological processes.

2) Classification of watersheds based on descriptions

Given the watershed scale description of Washington State based on immutable characteristics and human impacts, each 6th field HUC will be scored by reducing the data to a pair of condition vectors for each watershed with respect to immutable biophysical setting and human impacts. This process takes complex continuous data, including multiple data layers that contain significant spatial correlation, and generates a single score for each 6th field HUC. For example, multiple soil or bedrock types could be present within each watershed, thus to score soils or geology, a dominant or most relevant type will be identified and given a numerical score. Alternatively, elevation, precipitation and air temperature within each watershed are continuous variables and are highly correlated, but each contains sufficiently unique information that one could not act as a proxy for all. In this case, watersheds would be classified based on bins of mean elevation (e.g., <100m, 100 – 300m), and classes of temperature and precipitation (e.g., cold-wet, hot-dry)

3) Ordination of classified watersheds

This step revolves around the rigorous quantitative process by which classified watersheds are grouped into clusters of “like” condition independently for immutable characteristics and for human impact scores. The clustering approach most appropriate for these data is a dichotomous ordination and classification procedure that relies on differential characteristics prevalent on one side of a dichotomy. Similar approaches are applied in community ecology analysis (community structure) and phylogenetics. Statistical support for the clusters and branching structure is evaluated by discriminant analysis, cross validation and bootstrapping. There is no preconceived notion of the scale of these clusters, but similar processes have generated groupings of 6th field HUCs that approximate the 4th to 5th field scale, but that are linked by shared condition, not just the hierarchy of stream networks. Separate ordinations processes will be performed for the biophysical classification data and the human impacts data. However, further analysis and assessment may warrant combining some subset of these two classification schemes to construct a single hybrid scheme that represents both the inherent potential of the landscape and the current condition due to human activities. This latter approach would be suggested by testing the classification schemes against field collected data (see below) both separately and combined.

4) Testing and application of resulting predictive maps

The clustering process generates hypotheses regarding the similarity of watersheds with respect to their physical and biological processes. If correct, then biological and physical monitoring data not used to parameterize the classification and ordination steps can be used to test the maps for consistency and accuracy. Several large-scale monitoring programs have generated data that is appropriate for these tests. These data are in hand, and will be used to evaluate and refine the initial mapping process. Once sufficient confidence in the initial ordination has been achieved, the maps will be applied in several tests of the overall approach. First, the current IMW watersheds will be assessed for their being representative samples of broad regions of western Washington State. Second, within each cluster of IMW watersheds, individual streams are being considered as replicates and potential reference/controls. The classification/ordination process will allow an assessment of the validity of these assumptions. Third, the intersection of the two classification/ordination maps will be examined to address the issues of how dramatically human actions have altered the landscape, and have these impacts occurred in a manner that is correlated with or independent of watershed immutable characteristics. The last issue is critical to the design and implementation of future monitoring and restoration actions as it supports a landscape scale evaluation and prioritization of efforts across the State. For example, if human impacts are strongly correlated to watershed characteristics, which they are expected to be since some of the watershed descriptors will be strong determinants of land use practices (e.g., gradient and agriculture), then particular watershed classification clusters must be further subdivided into degree of human impact in order to properly distribute treatments, controls and extrapolation expectations over broad areas.

5) Review, revision and expansion of approach

The potential broad-scale utility of this work demands a rigorous peer review of its results and methodology. NOAA-Fisheries NWFSC is leading this component of the IMW project, and will make use of its existing peer review process, but will also include the appropriate technical groups specific to Washington State's potential interest in the extrapolation exercise (ISP), and PCSRF's reporting and evaluation needs (SRFB identified technical review group). As a result of the technical review process, necessary modification and improvements will be implemented. In addition, NOAA-Fisheries is interested in applying a similar approach on a region-wide basis. Therefore, when the methodologies have been sufficiently refined, the project will be extended to cover at least the three state area of Oregon, Washington and Idaho.

Time line

Task 1 Compilation of base data layers to be complete by Oct. 1, 2004, with more derived layers preliminarily available by Nov. 1, 2004.

Task 2 Classification of base layers complete by Nov. 1, 2004, with more derived layers preliminarily classified by Dec. 1, 2004.

Task 3 Preliminary ordination runs done by Jan. 15, 2005. Refinements and improvements will be continuously updated, with major reporting of progress on a quarterly basis through calendar year 2005.

Task 4 Test of preliminary ordination runs to be completed by Feb. 1, 2005. Feedback on design of ordination and classification process will be continuous after initial implementation and testing. Quarterly progress reporting will be done through calendar year 2005.

Task 5 Preliminary ordination and testing results will be available for peer review March 15, 2005. Revised and updated project will be submitted for peer review by Dec. 31, 2005. Expansion of project to additional areas will be implemented following peer review process.

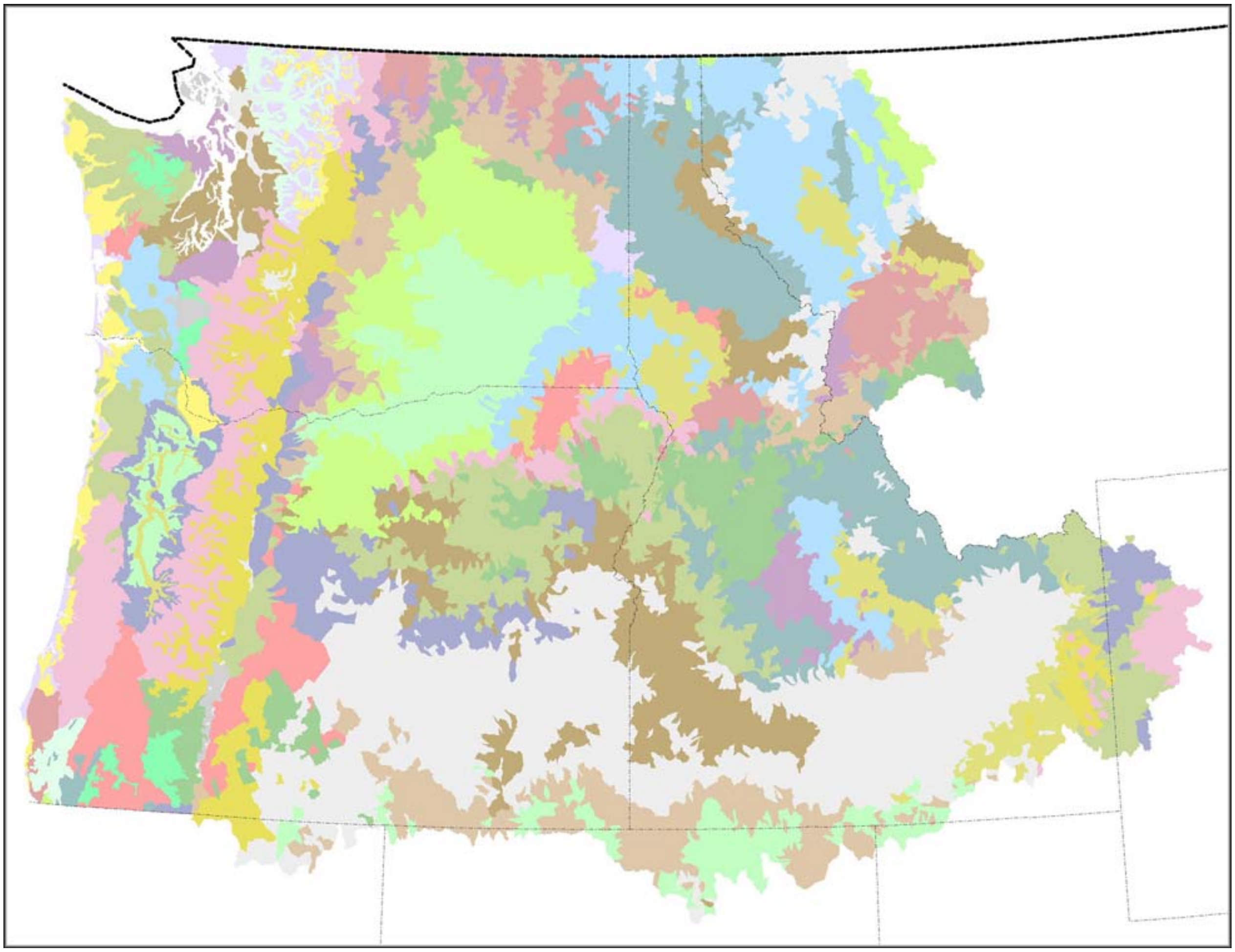

Figure 28. Mock ordination and classification output. Hypothetical clustering of watershed across Washington, Oregon, and Idaho based on biophysical or human impact classification process at 6th field HUC level. Colored regions on map represent clusters of watershed that are more similar to each other than adjacent watersheds. Note that similarity is not a strict function of distance – the same color appears in discontinuous patches. These patterns represent novel hypothesized similarity between regions that may be used in data analysis and monitoring and restoration program design and implementation.

OTHER POTENTIAL IMW SITES

There is interest in identifying other opportunities to establish IMW's to expand the number of species covered and the geographic extent (landscape variability). This chapter describes and implements a process for identifying and ranking candidate IMWs in each of the statewide Salmon Recovery Regions.

Identifying Candidate IMWs

In order to measure population-level response to restoration activities, consideration was given to all watersheds that met the following criteria:

1. Watersheds containing populations of naturally-produced anadromous salmonids, and
2. Watersheds draining directly to saltwater, or
3. Watersheds draining directly into Lake Washington/Sammamish, or
4. Watersheds draining directly into the Columbia/Snake Rivers.

A list of watersheds meeting these criteria was developed using Salmonscape (http://wdfw.wa.gov/mapping/salmonscape/) to determine species utilization. Very small watersheds were grouped by Water Resource Inventory Area (WRIA)(Williams et al. 1975, Phinney and Bucknell 1975) or common point of saltwater entry (e.g. Dyes Inlet).

This list was first partitioned into Statewide Salmon Recovery Regions and then into large, medium, and small watersheds based on basin area. Breakpoints for large, medium, and small watersheds were greater than 500 km^2, 125 to 500 km^2, and less than 125 km^2, respectively. We felt stratification by watershed size was important since it influenced both species utilization and the approach used to assess restoration results. For example, small watersheds in western Washington and small/medium watersheds in eastern Washington generally contained either no chinook or just remnant populations. Furthermore, the reference-treatment watersheds approach advocated for the IMW complexes is generally not feasible for medium and large sized watersheds. In addition, we theorize that given the interannual variability in juvenile production, detection of a significant change in a population level response to salmon restoration activities diminishes as watershed size increases simply due to the proportion of the total basin that is affected by restoration activities. In these larger watersheds, much of the monitoring would need to occur at the sub-basin scale. Sub-basin scale monitoring can be problematic for assessing smolt production for stream type salmonids since movement between sub-basins prior to smolt emigration can confound results.

Ranking Candidate IMWs

Watersheds were ranked based on attributes considered important in successful IMWs using a point system. The attributes were scored as follows:

Species Score: 1 point was given for each ESA-listed salmonid species present in the watershed

Aspect Score:

1. 1 point was given if smolt monitoring was currently occurring in the watershed;
2. 1 point was given if smolt monitoring had historically occurred in the watershed;
3. 1 point was given for each species where current or historical smolt production estimates were made/are available;
4. Points were give based on the longevity of the smolt monitoring data record with 1 point for 1-5 years, 2 points for 6-10 years, 3 points for 11-15 years, and 4 points for >15 years;
5. 1 point was given where it was thought that suitable sites for smolt monitoring existed low in the watershed;
6. 1 point was given where hatchery fish were either absent or the current production levels and presence of hatchery marks made naturally-produced smolt production monitoring feasible; and
7. For small basins, 1 point was given if another small stream was present in the vicinity for use in a paired monitoring design.

Categories 1 to 4 of the aspect score indicate the quantity of of baseline smolt production monitoring information available. These existing data can be invaluable in developing hypotheses regarding factors affecting smolt production and in developing a restoration plan for the basin. The score is weighted toward basins where production estimates have been successfully calculated and that have a large amount of baseline data.

Aspect score categories 5 and 6 ranked basis according to the potential for estimating naturally-produced smolts. Score 7 applied only to small basins. Watersheds were eliminated from consideration if there were no suitable trapping sites, if wild fish could not be identified, if large numbers of hatchery-produced fish preclude wild juvenile salmon monitoring, or if paired basins are not found (small watersheds only).

The species and aspect scores for the remaining watersheds were summed and the total was used to rank the watersheds for suitability as IMWs by size category in each Statewide Salmon Recovery Region (Tables 22-24). These scores can provide the basis for IMW selection by state and federal government or local salmon recovery entities, as needed. Watersheds eliminated from consideration are listed in Table 25 along with the reason for elimination.

Table 22. Candidate small IMWs ranked by score and listed by Recovery Region.

Size	Watershed	Recovery Region	WRIA	Species Score	Aspect Score	Total Score
S	**Mill/Abernathy/Germany Creeks**	Lower Columbia	25	2	8	10
S	WRIA 27 Independents	Lower Columbia	27	2	3	5
S	WRIA 28 Independents	Lower Columbia	28	1	3	4
S	**L. Anderson /BigBeef/Seabeck/Stavis Creeks**	Puget Sound	15	1	12	13
S	Minter/Burley/Purdy Creeks	Puget Sound	15	1	10	11
S	Snow Creek	Puget Sound	17	1	9	10
S	Port Angeles Independents	Puget Sound	18	2	5	7
S	Mission/Union	Puget Sound	15	2	5	7
S	Tahuya River	Puget Sound	15	2	5	7
S	L. Quilcene River	Puget Sound	17	2	3	5
S	Eldon Independents	Puget Sound	16	2	3	5
S	Hoodsport Independents	Puget Sound	16	2	3	5
S	Devil's Hole Creek	Puget Sound	15	0	5	5
S	Quilceda Creek	Puget Sound	7	2	3	5
S	Anderson/Dewatto/Rendsland Creeks	Puget Sound	15	2	3	5
S	Cranberry Creek	Puget Sound	14	0	5	5
S	Dabob Bay Independents	Puget Sound	17	1	3	4
S	Ololla/Crescent Creeks	Puget Sound	15	1	3	4
S	Mill Creek	Puget Sound	14	0	4	4
S	Jimmycomelately Creek	Puget Sound	17	1	3	4
S	WRIA 1 Independents	Puget Sound	1	1	3	4
S	Salmon Creek	Puget Sound	17	1	3	4
S	Percival Creek	Puget Sound	13	1	3	4
S	Woodland Creek	Puget Sound	13	0	3	3
S	Woodard Creek	Puget Sound	13	0	3	3
S	Grass Lake Creek	Puget Sound	13	0	3	3
S	Perry Creek	Puget Sound	14	0	3	3
S	Schneider Creek	Puget Sound	14	0	3	3
S	Kennedy Creek	Puget Sound	14	0	3	3
S	Skookum Creek	Puget Sound	14	0	3	3
S	Other Carr Inlet/Henderson Bay Tribs	Puget Sound	15	0	3	3
S	WRIA 14 Independents	Puget Sound	14	0	3	3
S	McLane Creek	Puget Sound	13	0	3	3
S	Goldsborough Creek	Puget Sound	14	0		
S	**Twin Rivers/Deep Creek**	Washington Coastal	19	0	9	9
S	Straits Independents	Washington Coastal	19	0	9	9
S	Kalaloch/Whale Creeks	Washington Coastal	21	0	3	3
S	Newskah Creek	Washington Coastal	22	0	3	3
S	Elk/Andrews Creek	Washington Coastal	22	0	3	3
S	Johns River	Washington Coastal	22	0	3	3

Table 23. Candidate medium IMWs ranked by score and listed by Recovery Region.

Size	Watershed	Recovery Region	WRIA	Species Score	Aspect Score	Total Score
M	Little White Salmon River	Lower Columbia	29	2	2	4
M	Salmon Creek	Lower Columbia	28	2	2	4
M	Jim Crow/Skamokawa Cr	Lower Columbia	25	2	2	4
M	Cedar River	Puget Sound	8	2	11	13
M	Deschutes River	Puget Sound	13	1	10	11
M	Hamma Hamma River	Puget Sound	16	2	5	7
M	Duckabush River	Puget Sound	16	2	2	4
M	Dosewallips River	Puget Sound	16	2	2	4
M	Samish River	Puget Sound	3	1	2	3
M	Hoko River	Washington Coastal	19	0	8	8
M	Ozette River	Washington Coastal	20	1	2	3
M	Smith Creek	Washington Coastal	24	0	2	2
M	Lyre River	Washington Coastal	19	0	2	2
M	Clallam River	Washington Coastal	19	0	2	2
M	Sekiu River	Washington Coastal	19	0	2	2

Table 24. Candidate large IMWs ranked by score and listed by Recovery Region..

Size	Watershed	Recovery Region	WRIA	Species Score	Aspect Score	Total Score
L	Wind River	Lower Columbia	29	2	7	9
L	White Salmon River	Lower Columbia	29	2	4	6
L	Yakima River	Middle Columbia	37-39	1	10	11
L	Skagit River	Puget Sound	3/4	2	10	12
L	Green River	Puget Sound	9	2	7	9
L	Stillaguamish River	Puget Sound	5	2	4	6
L	Elwha River	Puget Sound	18	2	3	5
L	Nisqually River	Puget Sound	11	1	2	3
L	Tucannon River	Snake River	35	3	9	12
L	Asotin Creek	Snake River	35	1	5	6
L	Palouse River	Snake River	34	3	2	5
L	**Wenatchee River**	Upper Columbia	45	3	9	12
L	Entiat River	Upper Columbia	46	3	3	6
L	Methow River	Upper Columbia	48	3	3	6
L	Okanogan River	Upper Columbia	49	2	2	4
L	Queets River	Washington Coastal	21	1	10	11
L	Chehalis River	Washington Coastal	22/23	0	9	9
L	Hoh River	Washington Coastal	20	1	2	3
L	North River	Washington Coastal	24	0	2	2

Table 25. Watersheds unsuitable for IMWs sorted by recovery region and size (small, medium and large). Reason for rejection is listed.

Size	Watershed	Recovery Region	WRIA	Unsuitability Element
S	Deep River	Lower Columbia	25	5,7
S	Hardy/Hamilton Creeks	Lower Columbia	28	5,7
S	Rock Creek	Lower Columbia	29	5,7
S	WRIA 29 Independents	Lower Columbia	29	5,7
M	Grays River	Lower Columbia	25	5,6
M	Elochoman River	Lower Columbia	25	6
M	Washougal River	Lower Columbia	28	6
L	Cowlitz River	Lower Columbia	26	5,6
L	Lewis River	Lower Columbia	27	5,6
L	Kalama River	Lower Columbia	27	6
S	Brushy Creek	Middle Columbia	40	5
M	Squaw Creek	Middle Columbia	31	5
M	Wood Gulch	Middle Columbia	31	5
L	Klickitat River	Middle Columbia	30	5,6
L	Walla Walla/Touchet River	Middle Columbia	32	5
L	Crab Creek	N/A	41-43	5
S	McAllister Creek	Puget Sound	11	7
S	Chambers Creek	Puget Sound	12	6,7
S	Port Gamble Tribs	Puget Sound	15	6,7
S	Case Inlet Independents	Puget Sound	15	6
S	Dogfish/Grovers/Scandia Creeks	Puget Sound	15	6
S	Dyes Inlet Independents	Puget Sound	15	6
S	Port Orchard Independents	Puget Sound	15	6
S	Chimacum/Ludlow Creeks	Puget Sound	17	7
S	Maxwelton Creek	Puget Sound	6	7
S	WRIA 7 Independents	Puget Sound	7	7
S	Other Lk Wa Tribs	Puget Sound	8	5
S	Bear Creek	Puget Sound	8	7
S	WRIA 9 Independents	Puget Sound	9	5,7
M	Skokomish River	Puget Sound	16	6
M	Big Quilcene River	Puget Sound	17	6
M	Dungeness River	Puget Sound	18	6
M	Issaquah Creek	Puget Sound	8	6
L	Nooksack River	Puget Sound	1	6
L	Puyallup River	Puget Sound	10	5,6
L	Snohomish River	Puget Sound	7	5
M	Alkali Flat Creek	Snake River	35	5
M	Meadows/Deadman Creek	Snake River	35	5
S	Goodman/Mosquito Creeks	Washington Coastal	20	5
S	Beaver Creek	Washington Coastal	21	5
S	Copalis River	Washington Coastal	21	5
S	Moclips River	Washington Coastal	21	5
S	Nemah River	Washington Coastal	24	5,6
S	Bear River	Washington Coastal	24	5
S	Palix River	Washington Coastal	24	5
S	Cedar River	Washington Coastal	24	7
M	Pysht River	Washington Coastal	19	5
M	Sooes River	Washington Coastal	20	6
M	Raft River	Washington Coastal	21	5
M	Wishkah River	Washington Coastal	22	5,6
M	Hoquium River	Washington Coastal	22	5
M	Naselle River	Washington Coastal	24	5,6
M	Willapa River	Washington Coastal	24	5,6
L	Quillayute River	Washington Coastal	20	6
L	Quinault River	Washington Coastal	21	5,6
L	Humptulips River	Washington Coastal	22	5,6

Unsuitability Codes: 5 – Poor trap site availability, 6 – Hatchery releases impact wild production estimates, 7 – No reference site for small watershed

BUDGET

Estimated costs by task for each IMW Complex are listed in Table 26 below. These costs represent the baseline monitoring of fish, habitat, water quality, and water quantity needed for each complex. Annual cost should remain relatively constant except for refinements in sampling design and methodology. The IMW Scientific Oversight Committee is working with CMER to engage them in this project and will engage other parties interested in contributing to the overall effort while ensuring the scientific integrity of the project is not compromised.

Table 26. Estimated annual budget by IMW Complex.

IMW Complex	**Cost**	
Hood Canal	**By task**	**Total**
Smolt Monitoring and adults at B Beef Cr	150.0	
Spawners	26.9	
Habitat	66.0	
Summer parr population	9.6	
Data management and analysis	46.5	
Flow	63.0	
Climate/WQ	41.1	
Total by basin		**$403**
Lower Columbia		
Smolt Monitoring	150.0	
Spawners	73.8	
Habitat	33.0	
Summer parr population	20.6	
Data management and analysis	36.0	
Flow	28.5	
Climate/WQ	31.0	
Total by basin		**$373**
Straits		
Smolt Monitoring	15.0	
Spawners	11.5	
Project Monitoring	22.5	
Habitat	41.0	
Summer parr population	15.0	
Data management and analysis	30.0	
Flow	28.5	
Climate/WQ	31.0	
Total by basin		**$194**
Skagit Estuary restoration monitoring		**$220**
Estimated Annual IMW Budget		**$1,190**
Request for state FY05 ($100k carryover from FY04 was subtracted)		**$1,090**

This budget does not include funds for the design, installation, or monitoring of restoration projects. We will work with the local salmon recovery entities to identify suitable restoration projects, then work through the entities to design, fund, and implement the projects.

Scientific oversight of the IMWs will be provided by the Washington Department of Ecology, Department of Fish and Wildlife, and other IWM partners through the IMW Scientific Oversight Committee. In kind contributions to IWM oversight and other monitoring efforts are shown in Table 27.

Table 27. In kind contributions toward oversight and monitoring.

IWM collaborator	In kind contribution
WDOE	$51,924
WDFW	$90,962
EPA	$31,582
NWFSC	$17,000
Elwha Klallam	$24,500
Weyerhaeuser	$78,900
Total	**$294,868**

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