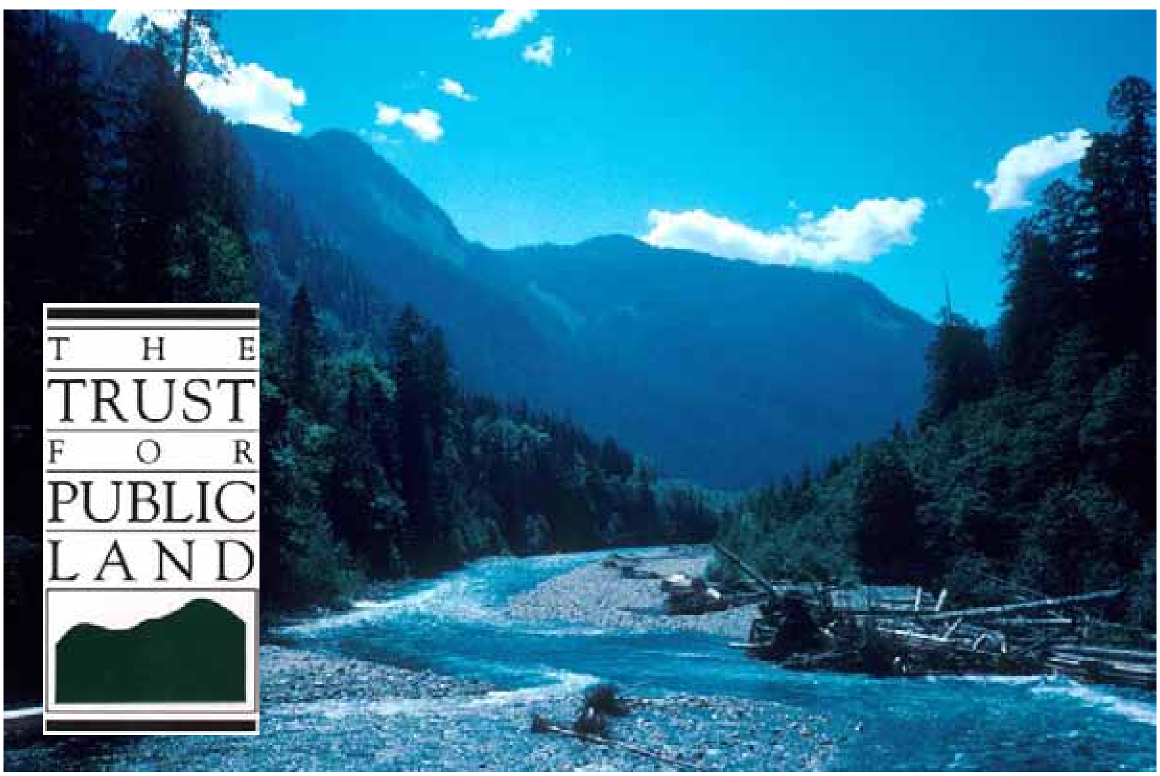
CONSERVATION PRIORITIES:

AN ASSESSMENT OF FRESHWATER HABITAT FOR PUGET SOUND SALMON



PREFACE

This report entitled **Conservation Priorities: An assessment of freshwater habitat for Puget Sound Salmon** was prepared at the request of the Trust for Public Land (TPL) to provide a regional snapshot of Puget Sound's most pristine, intact freshwater salmon habitat. TPL is a leading land conservation organization whose mission includes conserving land for people which often means protecting habitat critical to the health of salmon and other species. We believe the assessment can complement and enhance the work of many organizations that are striving to recover our Puget Sound salmon runs.

The assessment is a synthesis of existing information and expert opinion. The report describes or attempts to draw from what is known, published and described by experts within agencies, tribes and watershed groups having direct knowledge of these ecosystems and populations. The assessment provides a priority listing and map of the most intact freshwater habitats for salmon in the Puget Sound. The prioritized list of habitats, together with the summarized information and compiled sources, can be used to help guide cost-effective conservation decision making in the near term for the benefit of salmon and encompasses the whole Puget Sound basin.

Dr. Chris Frissell, of the Flathead Lake Biological Station at the University of Montana; Peter Morrison, Pacific Biodiversity Institute; Jim Kramer, natural resource consultant; and Marie Mentor, a consultant and former TPL Washington State Director, were retained to produce the assessment.

This effort would not have been possible without the significant support provided by The Brainerd Foundation, the Kongsgaard-Goldman Foundation, King County, the Bullitt Foundation, and in-kind contributions from Pacific Biodiversity Institute and TPL. We also are grateful to the many people in agencies, tribes and watershed groups who provided much of the baseline information and knowledge that support this assessment.

The assessment is built on the ecological principle that protecting existing high quality salmon habitats is essential to the long-term survival of salmon. It is not the only action needed, but without protection or restoration actions to safeguard these areas it may not be possible to save the salmon. Moreover, it will be much more expensive, and perhaps infeasible in many respects, to restore these high-value habitats should they be further damaged.

Long-term protection will require a partnership with the landowners and creative approaches tailored to the local circumstances. In many cases, the priority habitats identified in the assessment only remain intact because of the good stewardship of existing landowners. Their history of stewardship needs to be recognized and supported.

Thank you for your interest in natural resource conservation and saving salmon in Puget Sound. We also wish to thank the many contributors who made this assessment possible.

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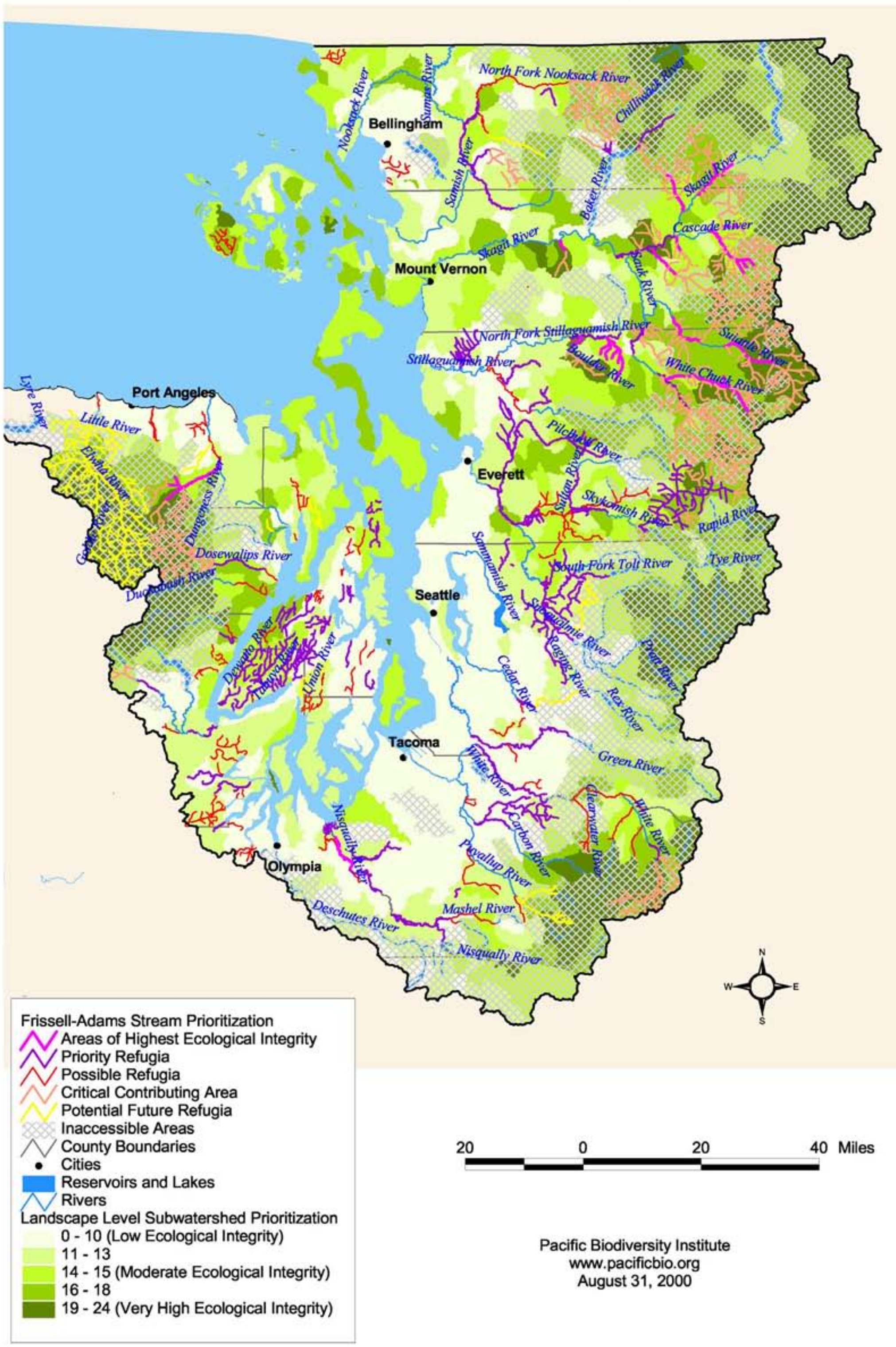
Conservation Priorities:

An Assessment of Freshwater Habitat for Puget Sound Salmon



EXECUTIVE SUMMARY

INTRODUCTION

Historically, Puget Sound's salmon runs were legendary. From the lush forests of the Elwha River ecoregion, to the broad Nisqually River delta, the area is as diverse as it is beautiful. The conditions for producing an abundance of native salmon were ideal and most of our native salmon species flourished here.

In the last several decades, many salmon runs in the Puget Sound basin have declined dramatically resulting in federal agency actions to list and protect some stocks under the authority of the Endangered Species Act. Because causes of decline are numerous, recovery of salmon in Puget Sound will require a comprehensive approach addressing the many factors contributing to their decline. The importance of habitat for survival of salmon is well-documented, but a roadmap to identify priority intact habitat for the whole basin was missing. The Conservation Priorities: An assessment of freshwater habitat for Puget Sound Salmon report and regional map now provide this essential information. It can be used to inform landowners, conservation groups, private foundations and others of significant places for conservation of salmon habitat.

Scientists believe that the recovery of Puget Sound salmon will require protection of these productive freshwater habitats and watersheds as a crucial anchor to maintain the ecological health of salmon populations throughout the region. However, successful recovery will also depend on protection of nearshore areas and restoration of damaged freshwater and marine habitats, these issues are important to address, but are beyond the scope of this assessment.

HABITAT PRIORITIES

The assessment involved gathering and synthesizing a large body of existing information about salmon populations, habitat conditions and landscape influences, such as road density, for each of the region's Watershed Resource Inventory Areas (WRIAs).

There are 14 recognized basins that make up the Puget Sound region. The assessment includes an overview of each basin and relevant information about fish stocks, followed by a description and justification for the classification of stream reaches into one of five priority categories. The results are summarized in a map of the study area (Figure 14 in the main report). At the end of each basin assessment in Chapter 4, a table summarizes the streams and segments that we identified as highest priority for conservation.

To identify key areas within each of the basins, a biological or fish-centered approach was used, and streams or stream segments analyzed for following attributes:

- a large proportion of their historic species assemblage;
- stable or increasing runs of native, wild (not hatchery) fish;
- a disproportionate share of the high quality habitat or productive populations of a native fish run in the basin;
- relatively intact habitat and ecosystem processes.

Those areas that registered as having high value for one or more of these factors were then placed into one of the following categories:

Category 1: Areas of Highest Ecological Integrity. Category 1 designated areas contain the most abundant natural populations and most nearly intact native assemblages of salmon relative to their historic conditions. In most of these areas, natural conditions have been relatively undisturbed by major environmental alterations, such as extensive logging, drainage or dam obstructions. In many cases these areas are not pristine, but ecological recovery from historic disturbances is far advanced.

Category 2: Priority Refugia with Altered Ecological Integrity. Category 2 areas are known to be somewhat altered from historic conditions, but at least some fish populations appear to be self-sustaining and resilient. These areas are not pristine, but frequently constitute the best of what salmon habitat remains within highly developed basins.

Category 3: Possible Refugia. Category 3 areas are where we have some indication, based on fish and habitat information that the stream reach might belong in Category 2. However, because of minimal, outdated, or unverified information, we are not able to fully justify including them with other Class 2 areas. We believe these areas are a high priority for field surveys and further assessment.

Category 4: Critical Contributing Areas. Category 4 areas have relatively high ecological integrity and an important hydrologic influence on Category 1 or 2 segments that lie downstream. For various reasons, these areas do not contain viable salmon populations, but are of recognized importance to maintaining the integrity of downstream priority areas that do contain salmon habitat and populations.

Category 5: Potential Future Refugia. These areas contain excellent habitat but lack native, anadromous fish due to artificial downstream barriers such as dams or hatchery racks. Removal of these barriers could restore access to high-quality habitat for future, newly colonizing salmon populations.

LANDSCAPE INFLUENCES

An analysis of the landscape condition of individual subwatersheds in the Puget Sound basin was conducted as a separate analysis from the fish-centered method described above. This inquiry was expected to provide additional data to either support or question the findings of the fish-centered approach.

The review of landscape influences, led by Peter Morrison of the Pacific Biodiversity Institute, analyzed eight factors to assess overall functioning and landscape influences of the region's watersheds. These factors were:

- road density
- hydrologic alterations (dams)
- natural wetlands
- roadless areas
- bald eagle presence (a bio-indicator of fish distribution and abundance as well as riparian habitat conditions)
- subwatershed slope steepness
- land use-land cover
- hatchery influence

The results of this assessment are based on analysis of multiple digital coverages in a geographic information system described in Chapter 3 of this report. Landscape level influences were mapped and prioritized for the region and are depicted on the map attached (Figure 14 in the main report).

RELATIONSHIP BETWEEN TWO METHODS

The two independent assessment methods provide highly complementary information that can be used to help frame conservation efforts. The landscape-level subwatershed prioritization yielded a relatively coarse-grained, but comprehensive assessment of factors that may influence the health of salmonid populations across the Puget Sound Basin. By contrast the fish-centered approach rests on very detailed information or accounts from specific sites and populations. For various reasons, the results of these two analyses only partially correspond (see Figure 14 in the main report). Lack of strong correspondence is likely a real biological phenomenon typical of regions experiencing extensive perturbation and impacts from multiple sources (e.g., hatcheries, fisheries, and damage to marine environments may affect population status in combination with freshwater habitat conditions). However, it also may result from gaps or biases in the available biological information.

Some areas are recognized as having value under both the landscape- and fish-centered approaches. These are likely to be of unqualified conservation value and, where they remain unprotected, should be high priority for immediate action. Areas identified as having relatively high ecological integrity in the landscape assessment, but not flagged as having high fish values, may suffer from biological data gaps and should be targeted for further analysis and surveys to determine the status of their salmon populations. Areas scoring low in the landscape analysis but high in the fish-centered assessment also merit close scrutiny. Some of these cases may represent "living dead" populations, doomed to future decline as the effects of recent disturbances become fully realized. However, others may represent critical pockets of diversity (i.e., fine-grained refugia) where salmon habitat has remained exceptionally resilient or robust to past human perturbations. In these latter two cases, restoration and protection efforts may be warranted, but to be effective will need to be carefully crafted to fit the local ecological, historical, and social circumstances.

CONCLUSIONS

Regional efforts to protect and restore Puget Sound salmon will fall short unless we protect the last remaining best habitat, first. The Conservation Priorities: An assessment of freshwater habitat for Puget Sound Salmon report provides, for the first time, a road map leading us to the highest value habitat throughout the region. Identification and descriptions of these areas for each basin will allow TPL and others to prioritize conservation actions in the near term. Safeguarding or improving ecological conditions and salmon populations within these areas may not alone be sufficient to create salmon recovery, but it represents an urgent, safe, and likely cost-efficient initial investment of restoration resources.

The assessment identifies many of the important habitats for salmon but does not support writing off other habitat areas. The prioritization of fish habitat is a provisional attempt to identify areas of recognized high value to natural fish production and diversity. Areas may exist that have high biological value as salmon refugia but that remain unrecognized due to limited survey efforts. While there is a high level of confidence that the vast majority of areas identified in this report as salmon refugia (or "priority areas") are productive and important, we strongly emphasize that areas that are not so identified should not necessarily be considered to be unimportant. We expect there will be a need for update and revision of the assessment as new or missed information becomes available, and some areas may have been overlooked in this assessment simply because few data were available for them. The assessment cannot and should not be used to justify sacrificial development or loss of areas outside of presently mapped refugia.

Prioritization of high quality habitat for conservation is an initial step in a strategic approach to salmon recovery. However, no analysis has shown that preservation of these mapped refugia would be sufficient to protect salmon species, evolutionarily significant units (ESU's), or populations from extinction, nor that it would necessarily prove adequate to sustain viable salmon fisheries. The question of the net effect of future habitat damage or loss to salmon can only be addressed through specific analyses of local and regional population dynamics and detailed studies of ecosystem change, which is far beyond the scope of this assessment (or of any extant study of which we are aware). What we can say with some certainty is that per increment of landscape disturbance or habitat loss, the biological consequences of losing habitat identified in this assessment will be high and significant for the region. Outside of these areas, the biological effects are likely to be variable, more subtly and cumulatively expressed, and thus far less predictable.

Conservation efforts will have the greatest near-term benefit for salmon by focusing in basins where large areas of intact habitat still remain, but conservation efforts will be necessary in each basin to maintain the diversity of salmon populations and meet the region's interests. This assessment provides a useful framework for establishing regional and especially within-basin priorities for conservation investments intended to benefit salmon. The assessment is not intended to provide a strictly objective basis for prioritizing *among* Puget Sound basins, but rather for identifying priority areas *within* each basin. There are only a few Category 1 areas left in Puget Sound, and Category 2 areas include the best of what remains in most basins. The range of conditions actually found within Category 2 areas varies dramatically, and it is more difficult to compare the importance of these areas across basins. It is clear that some basins, such as the Skagit, include many large areas of relatively high salmon productivity and Category 2 areas of high quality, whereas other basins, such as the Puyallup, include relatively few areas that can be considered to fit our criteria as a refuge in any sense, and in many cases their quality is relatively low. Ecologically, it is probably true that long-term conservation efforts are likely to be more effective in basins with extensive refugia than in those with small and poor-quality refugia. However, social and cultural priorities, as well as genetic and biogeographical arguments pertaining to local adaptation, ease of recolonization, and spreading of risk against catastrophic local loss, argue for the protection and restoration of ecological function in every basin of Puget Sound. In our view it is not appropriate to cast the results of this assessment as an argument to avoid conservation investments in "poor-quality" basins and focus it exclusively in "high-quality" basins.

The majority of the most productive areas for salmon, Lowland river channels and tributaries, have been severely degraded, and the areas presently afforded most protection are higher elevation systems. These headwater areas hydrologically support the productivity of lowland streams, but historically did not include the most productive and diverse habitat and populations. Perhaps the most surprising result of our "fish-centered" assessment is the relative dearth of refuge areas considered to be relatively pristine in their ecological condition. Of the few such Category 1 areas identified, most occur in already protected areas, such as portions of Olympic National Park or various National Forest Wilderness Areas. What is most striking is that relatively few of the large protected watersheds within national parks or wilderness around Puget Sound offer habitat for salmon. The subwatersheds with the highest landscape integrity ratings were almost entirely found in the higher mountainous parts of the Puget Sound basin where the landscape is still intact and less disturbed by human alterations than more accessible areas.

Ironically, nearly all of these areas are also historically inaccessible to salmonid fish because of natural barriers or are now above major dams. The subwatersheds above the natural barriers do not provide habitat for salmonids, but they do contribute high quality water and woody debris to accessible areas located lower in the stream system. Many of these areas should be considered critical contributing areas.

The perspective provided by the report's regional map (see Figure 14 in the main report), which attempts to synthesize the body of available information on the status of the region's existing salmon habitat and populations, makes it clear that coastal zones have lost their ecological connection to the healthier upland streams. Salmon abundance and diversity are low in these important lowland areas where all salmon travel, where many spawn and rear their young, and where salmon production was once greatest.

Conservation and restoration efforts need to be focused geographically and significantly expanded to ensure the long-term productivity of the high quality habitats in Puget Sound. Our approach assumes that areas with high-quality habitat, relatively intact and naturally functioning ecosystems, and hosting relatively robust salmon populations, constitute a high priority for protection and restoration efforts. This implies that conservation efforts will be most successful where healthy population-habitat-ecosystem relationships remain. This is an important consideration to ensure the success and value of conservation efforts, in addition to priorities based on demographic, genetic, or other commonly used biological metrics that may only indirectly or partially reflect ecosystem conditions and history.

There are several important private and public efforts to conserve refugia areas, but these tend to be small in geographic scale when compared to the need. Also, a number of regulatory programs have been adopted to address part of the need but no assessment has been made of their effectiveness. Salmon conservation can be achieved only by involving large portions of the landscape that currently, or in the past, have been managed primarily for natural resource extraction or intensive development. Agriculture and timber management have been the two most dominant uses of these areas. Although these economic and cultural activities conflict in many ways with salmon habitat conservation (and may be shown to have caused significant declines in salmon production and diversity in most of these areas), the fact that these Category 2 areas represent "the best of what is left" for salmon indicates that some level of ecological function and salmon productivity was retained or regained in the face of human activity. These areas likely have lost some portion of their historic productivity for salmon, but they remain among the most important parts of the landscape for present and future salmon conservation.

Conservation of Category 2 areas will require substantial investment of resources in both protection and active restoration actions. Purchases of development rights or title to preclude disturbance and development of sensitive lands, active restoration of streamflow to depleted reaches, and hydrologic rehabilitation or obliteration of existing roads and railroad grades are among the common needs for these areas if the existing salmon habitat conditions are to be maintained into the future. For many of these refugia, effective conservation will not be as simple as maintaining existing patterns of land and water use and ownership. We believe that as a general rule, restoration needs in these and similar areas should be the priority for investment of salmon restoration resources in the next decade. In these areas, enough salmon production and diversity remains that populations can be expected to respond positively as habitat responds to restoration actions (Frissell 1997). In parts of the landscape that are more depleted of salmon populations (and not mapped here as refugia), restoration of physical habitat conditions may not lead to the desired biological response because fish populations are constrained by small population size, inadequate distribution, lack of life history or behavioral diversity, the masking effects of other untreated mortality sources, or adverse interactions with other species that respond more favorably to habitat changes.

Existing efforts for salmon recovery need to be supported and expanded. This report and series of maps is a first step toward providing the needed information. The habitat we have identified is critical to restoring the biological integrity of Puget Sound's salmon stocks, but restoration and protection in other areas is also needed. Our findings are not intended to undercut ongoing efforts to protect more impacted areas in our communities and throughout this basin. Widespread investment in helping restore our salmon runs in our communities, tribal lands, agricultural lands – across the landscape – is urgently needed to reverse salmon declines over the long-term. All well-conceived efforts should be encouraged.

The Trust for Public Land is poised to work with others to secure this critical habitat for salmon. We believe this assessment is but a first step toward identifying these important lands and placing them into permanent protection. More analysis is needed and over a larger area in Washington State. But we should not hesitate to act now to work to safeguard the ecological value of these high priority areas. The map developed from our analysis, viewed against the history of salmon decline and the projected future of human development, shows all too clearly what the consequences may be if we do not step up to the challenge and conserve the last best habitat for Puget Sound salmon populations.

PREPARED AT THE REQUEST OF THE TRUST FOR PUBLIC LAND

BY

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NOVEMBER, 2000

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ACRONYMS AND ABBREVIATIONS

CWA	CLEAN WATER ACT
FEMAT	Forest Ecosystem Management Assessment Team
MBSNF	Mount Baker-Snoqualmie National Forest
NMFS	National Marine Fisheries Service
NPS	National Park Service
NWIFC	Northwest Indian Fisheries Commission
pers. comm.	personal communication
SASSI	Salmon and steelhead stock inventory
WAU	watershed analysis unit
WDFW	Washington Department of Fish and Wildlife
WRIA	water resources inventory area
WDOE	Washington Department of Ecology

SCIENTIFIC NAMES OF ORGANISMS MENTIONED IN TEXT

FISH	
brook trout	Salvelinus fontinalis
bull trout	Salvelinus confluentus
chinook salmon	Oncorhynchus tschawytscha
chum salmon	Oncorhynchus keta
coastal cutthroat trout	Oncorhynchus clarki clarki
coho salmon	Oncorhynchus kisutch
Dolly Varden	Salvelinus malma
pink salmon	Oncorhynchus gorbuscha
sockeye salmon	Oncorhynchus nerka
steelhead / rainbow trout	Oncorhynchus mykiss

OTHER	
bald eagle	Haliaeetus leucocephalus
beaver	Castor canadensis
black bear	Ursus americanus
California seal lion	Zalophus californianus
elk	Cervus elaphus
freshwater mussel	Margaritifera falcata
mink	Mustela vison
muskrat	Ondatra zibethicus
northwest salamander	Ambystoma gracile
Pacific giant salamander	Dicamptodon ensatus
red-legged frog	Rana aurora
otter	Lutra canadensis

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CHAPTER 1: SCOPE OF THE PROJECT AND REPORT

GENERAL INTRODUCTION

Salmon runs in the Puget Sound basin have declined dramatically over the past several decades, culminating in the extinction of some stocks. Causes of the decline are numerous, and recovery of salmon in Puget Sound will require a comprehensive approach that addresses the many factors contributing to decline. Despite widespread habitat degradation, there are many places within the region where habitat still retains a substantial measure of its historic natural productivity for salmon. Recovery of Puget Sound salmon will require the preservation of these productive habitats as a crucial anchor for existing runs and for efforts to rehabilitate damaged areas. This project, an assessment of high-priority areas for conservation of Puget Sound salmon, aims to support the early actions necessary to preserve the last remaining best places for wild salmon spawning and rearing in Puget Sound. Protection of these areas is essential, but protection alone will not be sufficient to ensure long-term survival or recovery of declining salmon populations.

The assessment was funded by the Brainerd Foundation, King County, and the Kongsgaard-Goldman Foundation and the Bullitt Foundation. The results of the assessment can be used by various groups involved in salmon recovery as a starting point to identify the key habitats that must be protected. One of the first steps in a successful salmon recovery effort is to ensure that functioning habitats retain their capacity to support salmon into the future. The assessment provides a broad overview of the key intact habitats in the Puget Sound area. There may be other habitats important to the recovery of salmon that were not identified in this assessment and that should be added to a comprehensive list. The habitats identified in this assessment are based on the knowledge of many experts in the region and serve as a strong foundation for the start of a long effort to recover salmon in Puget Sound.

The assessment was conducted using two different methods for identifying important habitats and contributing areas. The primary method used to identify the important habitats is a "fish-focused" assessment, concentrating on qualitative synthesis of available data on fish populations and habitat conditions. The second method was "landscape-focused" and quantitatively ranked areas at a subwatershed level using a GIS analysis of several factors that may indicate landscape influences on salmon habitat and survival.

After both assessments were completed, the landscape results were compared to the fish population and habitat assessment to 1) characterize the watershed conditions influencing the priority streams identified in the present "fish-focused" assessment, and 2) identify additional areas of high ecosystem integrity that merit further consideration as priority areas for salmon populations. The two efforts are complementary and are intended to be mutually supporting. The results of both efforts are summarized and cross-referenced in this report.

The report is organized in a manner that can be useful for people interested in understanding the overall assessment of conditions in Puget Sound and for those who are only interested in information on one or more watersheds. Chapter Two describes the methodology and overall findings of the fish population and habitat portion of the assessment. Chapter Three describes the landscape methodology. Chapter 4 provides a basin-by-basin description of each watershed in Puget Sound. Each basin description includes an overview of the basin and its general conditions for fish, as well as a discussion of fish use of the basin, and identifies the areas recommended for protection and their justification. Appendix A provides a partial list of related studies that were not used in this report due to lack of time or availability. Appendix B provides the affiliations of individuals cited in the report as providing personal communication. Appendix D contains the value tables that result from the landscape assessment.

CHAPTER 2: FISH-POPULATION/HABITAT ASSESSMENT AND CLASSIFICATIONS FOR REFUGE AREAS

Christopher A. Frissell, Susan B. Adams and Nathaniel P. Hitt

INTRODUCTION AND OBJECTIVES

The goal of this portion of the study was to develop a preliminary yet comprehensive survey and synthesis of existing information and expert opinion about the locations of areas of relatively high ecological integrity and importance for the production and diversity of natural populations of anadromous salmonids. This effort involved acquiring and reading hundreds of documents, contacting dozens of experts, and tabulating and synthesizing the resulting data into a conceptual framework that categorized stream reaches and subwatersheds according to their functional role for salmon conservation (modified from Frissell 1997 and Frissell 1998). This effort was time-consuming and detailed. It was not, however, intended to be exhaustive or completely systematic. The project was limited by available time and budget, the large scale and ecological complexity of the study region, and the broad variations across the study region in the sources, type, completeness, quality, and accessibility of available information. In consideration of these challenges, the goal was to comprehensively identify the most obviously important areas within each major drainage where habitat protection might most productively be applied for both short-term and long-term salmon conservation.

Our methods and descriptions of the refugia categories used in the "fish-centered" assessment are described below, followed by a brief discussion of general results and implications. A basin-by-basin synopsis of results, beginning with the Nooksack and continuing south and west (clockwise) in the order of WRIA numbers, is provided in Chapter 4. Each basin synopsis includes an overview of the basin and relevant information about the fish stocks, followed by a description and justification for each area that we classified into one of five refugia categories. At the end of each basin synopsis, a table summarizes the streams and segments that we identified as potentially important for preservation. We do not include justifications for areas not identified as refugia because that is beyond the scope of the report. Each basin or geographic region synopsis is accompanied by a summary that assigns the designations of streams and stream segments to the categories described above. The designations are also mapped in the overall map included with the report.

METHODS FOR THE "FISH-CENTERED" ASSESSMENT

The fish-centered assessment results in a prioritization of areas for conservation within each basin of Puget Sound. To identify key areas within each basin, information on streams or stream segments was analyzed to see whether a particular area contained the following characteristics:

1) a large proportion of historic species-assemblage

2) stable or increasing runs of native, wild (not hatchery-origin) fish

3) a disproportionate share of the high-quality habitat or productive populations of a native fish run in the basin

4) relatively intact habitat and ecosystem processes

This approach was qualitative and synoptic because the available information varied widely among basins, and because adequate data for a quantitative assessment was not available in most areas. No rigid or conventional or universally defensible criteria were available to describe each of the above four categories. Information was diverse in origin and uneven in coverage and reliability. Primary sources of information included published and unpublished reports, information from local biologists, and the WDFW spawner database. For each basin, we reviewed all of the recent fisheries reports, fish distribution maps, watershed analyses, and other related reports that we could obtain. We attempted to contact biologists who are familiar with each basin to discuss available information and their professional opinions about the areas with the greatest integrity in each basin. In most basins we spoke with one or several biologists.

For a subset of basins, we examined time series data from the WDFW spawner database, which was provided by Dick O'Connor and has been updated through 1997. We encountered several difficulties in applying the data set to our purposes, and thus made limited use of the data. The greatest difficulty was caused by a lack of information about 1) the target species for each survey, 2) the proportion of hatchery fish in a survey, and 3) the influence of fishing on escapement levels. While such hurdles could be overcome in many cases, the time required to do so for all of the surveyed streams in the study area was prohibitive. Therefore, in most cases we inspected the data and made a qualitative assessment of the trends in spawner counts. If a stream or segment appeared to have stable or increasing trends of one or more stocks that were not heavily influenced by hatchery stocking, we generally classified it in one of our categories of refugia or possible refugia. In no instance did we remove a stream from a refuge category based on the spawner data if other criteria indicated it was suitable for designation. This was because we were unable to reliably disentangle the effects of fishing, changes in stocking or survival of hatchery fish, changes in the timing or distribution of spawners, and other sources of survey variation or error from true population declines.

STREAM SEGMENT AND SUBWATERSHED CATEGORIES

Below is a description of the categories used in Chapter 4 to identify the importance and priority of stream segments in regard to salmon habitat value. This classification was developed by Dr. Chris Frissell and has been used in several other areas of the Northwest.

1 = Areas of Highest Ecological Integrity.

These areas contain fish assemblage composition and abundance comparable to historic conditions. Generally, natural conditions have not been disturbed by *major* environmental alterations, including floodplain or upland land uses such as extensive logging or urbanization. We define *major* alterations as those causing direct changes in land cover, soil disturbance, stream flow routing, and other hydrologic processes affecting more than 10 to 20 percent of the landscape or freshwater habitat area. A dam that blocks migratory fish passage is considered a major alteration. The proliferation of self-sustaining populations of introduced species that adversely affect salmon may also be considered a major alteration. Where past landscape or surface water alterations have occurred within these areas, only very limited changes in human influence or management have occurred in the past decade, and fish populations appear to be relatively resilient to the historical changes. Because of the extensive history of logging, agriculture, grazing, dam-building, and industrial and urban development in Puget Sound, very few areas meet the criteria for inclusion in this category. Many of the watersheds that retain high integrity from the standpoint of landscape alteration are found at higher elevations, above natural or artificial barriers to salmon migration, and thus they are not identified as priority areas in this study unless they directly affect the hydrology of associated refuge areas (*see Critical Contributing Areas*, defined below).

2 = Priority Refugia Where Ecological Integrity has been diminished but remains high.

These areas are ecologically altered from their aboriginal condition, but support the largest remaining numbers of native fishes or most complete species complements within a basin. Often both habitat quality and fish populations are reduced from historic levels, but the fish populations have demonstrated some resilience and appear to be at least marginally self-sustaining under present conditions. These areas are not pristine, but frequently they constitute the best of what salmon habitat remains within highly developed basins. It is important to recognize that because of the pervasive nature of past human impact and potential for lagged or interacting effects, simple land and water protection may not be enough to maintain the integrity of some of these areas, and more complex environmental rehabilitation measures may be necessary. This category comprises the majority of priority conservation areas identified in this report.

3 = Possible Refugia

These are areas where we have some indication, based on fish or habitat information or expert opinion that the stream segment might belong in category 2. However, because of minimal, outdated, or uncorroborated information, we were not able to justify its inclusion in category 2 with a moderate level of certainty. These areas are high in priority for near-term field surveys and further assessment. A large number of areas fall into this category because sufficient field-verified data are lacking for many watersheds in Puget Sound.

4 = Critical Contributing Areas

These are areas of high ecological integrity located upstream of category 1 or 2 stream segments. These areas do not contain salmon populations but are recognized or special for their importance in maintaining the integrity of downstream priority areas that do contain salmon habitat and populations.

5 = Potential Future Refugia

These are areas that contain excellent habitat but that lack native, anadromous fishes due to artificial downstream barriers such as dams or hatchery racks. If the barriers were removed or modified to allow passage, and if salmon successfully recolonize, the areas appear to retain the habitat potential to serve in the future as important refugia for native anadromous fishes. The ability of these areas to sustain native, anadromous salmonid populations is highly speculative, but they warrant special recognition because many of the ingredients of ecosystem integrity remain intact, and because in many basins few other viable options for salmon recovery remain.

No Number = Other

Subwatershed and streams that were not assigned to categories 1-5 fall into three general, undiscriminated classes. One class consists of areas about which we found no information. These areas were not mentioned in reports we reviewed or in personal communications as being important to anadromous fish populations. In some instances, virtually nothing is known about fish populations in the areas. Some remote, glacially influenced streams are likely to fall into this class due to difficulties inherent in assessing their fish populations and limited efforts to do so. The second class includes areas where the available information indicates that conditions do not meet our criteria for categories 1-5, most often due to pervasive habitat degradation.

The third class includes areas located above *natural* barriers to salmon migration, including some streams where trap-and-haul or other passage or hatchery outplanting programs have established salmon populations. In most if not all such cases, it is difficult to assess the degree to which wild, self-sustaining populations have resulted. Ostensibly, the populations would disappear if the technological enabling mechanism should fail, and thus their sustainability is precarious. Moreover, the genetic heritage of such populations, and thus their role in regional recovery of listed ESU's, is questionable. Finally, the impact of such programs on the indigenous, non-anadromous fishes that inhabited the systems naturally could be highly negative, calling into question the virtues of prioritizing such areas for salmon restoration.

In addition to the high level of uncertainty implicit in each of these three classes, we chose not to distinguish between them for another important reason: we chose to focus this project, to the highest degree possible, on the preservation, rather than the restoration, of anadromous fish habitat and populations. **It is important to recognize that our analytic criteria and data are not sufficient to justify any conclusion that the areas outside of our designated refugia or priority areas are unimportant in salmon recovery and survival.** No such implication can be supported. All that our present effort can accomplish is to identify areas that are known or are strongly suspected to be of relatively high ecological integrity or that are otherwise functional in sustaining existing salmon populations and salmonid diversity. We also reiterate that our assessment is not intended to imply in any way that protection of the designated areas alone is biologically sufficient to sustain existing populations or to achieve any particular viable or sustainable level of natural salmonid production.

UPLAND AREAS

We assigned categories to two types of map features: stream segments and subwatersheds. In general, the stream segment is the fundamental unit of our analysis, although in some areas we had information about a small region but not about particular streams (this was the case primarily for areas with numerous independent drainages such as Southwest Puget Sound). The fish data we used pertains only to streams and rivers, but many reports, such as watershed analyses and limiting factors reports, as well as discussions with biologists, related to upland areas adjacent to the streams. In instances where we had information pertaining to upland areas, we assigned the same categories to whole subwatersheds as we assigned to streams. Where we had no knowledge of upland conditions, or where we had reason to believe that upland conditions did not mirror the integrity of the fish community, we did not assign categories to the subwatersheds. In a few limited cases a stream segment with one category attribute is shown in the midst of a subwatershed with a different attribute. This scenario typically arose where subwatersheds either included stream segments above and below a barrier or where parts of different streams were included in one subwatershed. If one considers the stream segment the primary source of information, the interpretation should be clear. To improve map clarity, we displayed the boundaries of only the subwatersheds where we had sufficient information to apply of one of the categories of refugia.

SOURCES OF ALTERATIONS TO ECOLOGICAL INTEGRITY

All of our refuge categories include some stream segments where the integrity of the habitat has been altered. Within each identified refugia area in Chapter 4, we assigned descriptors of the major source(s) of alteration, as described in fisheries or watershed reports or by experts who provided comments via personal communications (see table at the end of each basin summary). Sources of alterations assigned to fish refugia do not necessarily coincide with those in the GIS habitat analysis, because alterations in the "fish-centered" approach often refer primarily to land uses and habitat alterations near rivers and on floodplains rather than incorporating all upland areas of the subwatershed. We summarized sources of alterations in the following categories:

- *Agricultural/rural residential.* This includes farmlands, very low-density housing and "hobby farms". When such land uses occur near rivers in the Puget Sound area they are frequently accompanied by flood and erosion control efforts, including river channelization, diking, and bank hardening. Riparian vegetation is frequently diminished.

- *Dams.* The influence of dams extends both upstream and downstream. Downstream effects include reductions in the supply of large woody debris and sediment, alterations in flow regimes, and extreme alterations in temperature regimes. Effects are the most extreme in bypass reaches, where water is shunted around a segment of the river to a downstream powerhouse. Dams cause obvious negative impacts on upstream migration, but they also can serve as hindrances to downstream migration.

- *Forestry.* The impacts of logging on anadromous fishes are numerous and widespread in the Puget Sound region. In some basins, the full effects of previous logging on fish habitat are likely yet to come.

- *Hatcheries and fish culture.* The ecological displacement, behavioral interference, and potential or realized genetic disruption that can be caused by the stocking of hatchery fish over wild populations is recognized here as an important threat to conservation of fish populations and natural diversity.

- *Industrial or urbanized.* Increases in peak flows; decreases in low flows; channelization; chemical, nutrient and thermal pollution; and elimination of riparian vegetation are typical in urbanized areas.

- *Exotic invasive species.* Invasive species identified as detrimental to anadromous salmonids were primarily exotic; aquatic plants that substantially alter water flow and habitat.

- *Planned development.* In some areas identified as refugia, extensive residential development such as platted subdivisions is imminent and is likely to contribute substantially to fish habitat degradation.

- *Not altered.* This applied only to wilderness and some National Park areas.

- *Other*. This included primarily impacts due to diking or roads, where not accompanied by other sources of alteration, and mining.

TECHNICAL REVIEW AND POST-REVIEW REVISIONS

In November and December of 1999, a draft of this report was circulated for review to agency, tribal, and other scientists and technical experts with knowledge of the ecosystems and salmon in the study area. In addition, daylong workshops were held in Port Townsend and Seattle to provide technical and policy experts with the opportunity for dialogue and direct discussion with the project scientists and directors. During these sessions substantial comment about specific areas was received and recorded on maps and in notebooks. In addition, we received numerous comments on the draft report and maps by mail, e-mail, and telephone.

During technical review of the draft report, we received numerous suggestions for areas to include under the various refugia categories. Because changes made after the review would not undergo further peer review, we were more conservative about recommending refuge areas based on personal communications received during, rather than prior to, the review period. We added additional refugia areas based on comments received in review primarily if: 1) the comments included substantive justifications, 2) we were able to corroborate the comments with previously reported information, or 3) several reviewers made similar comments about an area. We did not include some suggested areas in our maps and tables for several reasons: 1) no justification was given and we found little or no reported information about the area in question, 2) the comments were justified but the area did not meet our definition for a particular refugia category (this was commonly the case with critical contributing areas), or 3) we found conflicting information. We do recognize the likelihood that certain areas where we did not heed reviewer comments may well be very important for salmon recovery, and would probably meet others' definitions of refuge areas even if they do not meet those used in this assessment. Therefore we attempt to document such "unheeded recommendations" in the text summary for each basin.

RESULTS AND IMPLICATIONS

Perhaps the most surprising result of our "fish-centered" assessment is the relative dearth of refuge areas considered to be relatively pristine in their ecological condition. Of the few such Category 1 areas identified, most occur in already protected areas, such as portions of Olympic National Park or various National Forest Wilderness Areas. What is most striking is that relatively few of the large protected watersheds within national parks or wilderness around Puget Sound offer habitat for salmon. Most such areas are either located above historic barriers to salmon migration or they have been blocked to salmon access by the construction of mainstem dams downstream. The importance of these watersheds in sustaining water quality to downstream salmon populations must be recognized, as we have attempted to do by delineating many of them as Critical Contributing Areas in our assessment. Nevertheless, it is important to realize that only very limited steps toward salmon conservation have been achieved by past efforts at public land protection in the Puget Sound region. There are several very important private and public efforts that have been implemented to conserve refugia areas, but these tend to be small in geographic scale when compared to the need. Also, a number of regulatory programs have adopted to address part of the need but no assessment has been made of their effectiveness. The results of the regions past and current efforts in conservation has two very important implications for salmon recovery in Puget Sound. First, salmon conservation can be achieved only by involving large portions of the landscape that currently or in the past have been managed primarily for natural resource extraction or intensive economic development. Agriculture and timber management have been the two most dominant uses of these areas. Although these economic and cultural activities conflict in many ways with salmon habitat conservation (and probably have caused significant declines in salmon production and diversity in most of these areas), the fact that these Category 2 areas represent "the best of what is left" for salmon indicates that some level of ecological function and salmon productivity was retained or regained in the face of prior human development. These areas likely have lost some portion of their historic productivity for salmon, but they remain among the most important parts of the landscape for present and future salmon conservation. This category includes a grab-bag of types of areas and conditions, including some that may be naturally resilient to land use disturbances, others that may be highly sensitive but simply were subject to less intensive or anomalous land and water management impacts compared to surrounding areas, and still others where the present relatively good habitat conditions may be fated to inexorable deterioration because of the lagged effects of recent landscape change.

It is clear **that conservation of these previously and partly impacted Category 2 areas will require substantial investment of resources in both protection and active restoration actions (see Frissell 1997, Frissell and Bayles 1996, Frissell et al., 1993).** Purchases of development rights or title to preclude disturbance and development of sensitive lands, active restoration of streamflow to depleted reaches, and hydrologic rehabilitation or obliteration of existing roads and railroad grades are among the common needs for these areas if the existing salmon habitat conditions are to be maintained into the future. For many of these refugia, effective conservation will not be as simple as maintaining existing patterns of land and water use and ownership. There is a large backlog of acquisition, maintenance, and active restoration that will be necessary if current conditions in these refugia are to be sustained and improved to the benefit of salmon recovery. We believe that as a general rule, restoration needs in these and similar areas should be the priority for investment of salmon restoration resources in the next decade. In these areas, enough salmon production and diversity remains that populations can be expected to respond positively as habitat responds to restoration actions (Frissell 1997, Frissell et al. 1993, Doppelt et al. 1993). In parts of the landscape that are more depleted of salmon populations (and not mapped here as refugia), restoration of physical habitat conditions may not lead to the desired biological response because fish populations are constrained by small population size, inadequate distribution, lack of life history or behavioral diversity, the masking effects of other untreated mortality sources, or adverse interactions with other species that respond more favorably to habitat changes.

Our fish-centered assessment is but a provisional attempt to identify areas of recognized high value to natural fish production and diversity. Areas may exist that have high biological value as salmon refugia but that remain unrecognized due to limited survey efforts. Some of these areas may be identified in the "landscape-centered" analysis described in the next section of this report. **While we have a high level of confidence that the vast majority of our areas identified as salmon refugia are productive and important, we strongly emphasize that areas that are not identified should not be considered to be unimportant!** In other words, many important areas have no doubt been missed because of inadequate information or other sources of error. We expect there will be a need for update and revision of our assessment. Where additional areas or other adjustments can be justified through new information or correction of errors, revisions and exceptions should be made.

All basins can benefit from improved and expanded biological surveys to better identify centers or refugia of salmon productivity and diversity. Areas we flagged for various reasons as "potential refugia" should be considered high priority for field surveys that could validate their biological values. Most importantly, **our assessment cannot and should not be used to justify sacrificial development or loss of areas outside of presently mapped refugia. Any attempt to justify further habitat degradation in Puget Sound watersheds is fraught with risk.**

No analysis has shown that preservation of these mapped refugia would be sufficient to protect salmon species, evolutionarily significant units (ESU's), or populations from extinction, nor that it would prove to sustain viable salmon fisheries. The question of the net effect of future habitat damage or loss to salmon can only be addressed through a specific analysis of local and regional population dynamics and detailed studies of ecosystem change, which is far beyond the scope of the present study (or of any extant study of which we are aware). What we can say with some certainty is that per increment of landscape disturbance or habitat loss, the biological consequences are likely to be high and thus of regional consequence in the areas we have mapped as salmon refugia. Outside of these areas, the biological effects are likely to be variable, more subtly and cumulatively expressed, and thus far less predictable.

This assessment provides a useful but provisional framework for establishing regional and especially within-basin priorities for conservation investments intended to benefit salmon. The assessment is not intended to provide a strictly objective basis for prioritizing *among* basins across Puget Sound, but rather for identifying priority areas *within* each basin. Because Category 2 areas include the best of remaining areas in each basin, the range of conditions actually found within Category 2 areas varies dramatically. It is clear that some basins, such as the Skagit, include many large areas of relatively high salmon productivity and category 2 areas of high quality, whereas other basins, such as the Puyallup, include relatively few areas that can be considered to fit our criteria as a refuge in any sense, and in many cases their quality is relatively low. Ecologically it is probably true that long-term conservation efforts are likely to be more effective in basins with extensive refugia than in those with small and poor-quality refugia. However, social and cultural priorities, as well as genetic and biogeographical arguments pertaining to local adaptation, ease of recolonization, and spreading of risk against catastrophic local loss, argue against a regional strategy that "writes off" some entire basins. We wish to emphasize that in our view it is not appropriate to cast the results of this assessment as an argument to avoid conservation investments in "poor-quality" basins and focus it exclusively in "high-quality" basins.

CHAPTER 3: LANDSCAPE-LEVEL ASSESSMENT OF SUBWATERSHEDS

Peter H. Morrison and Lindsey H. Swope

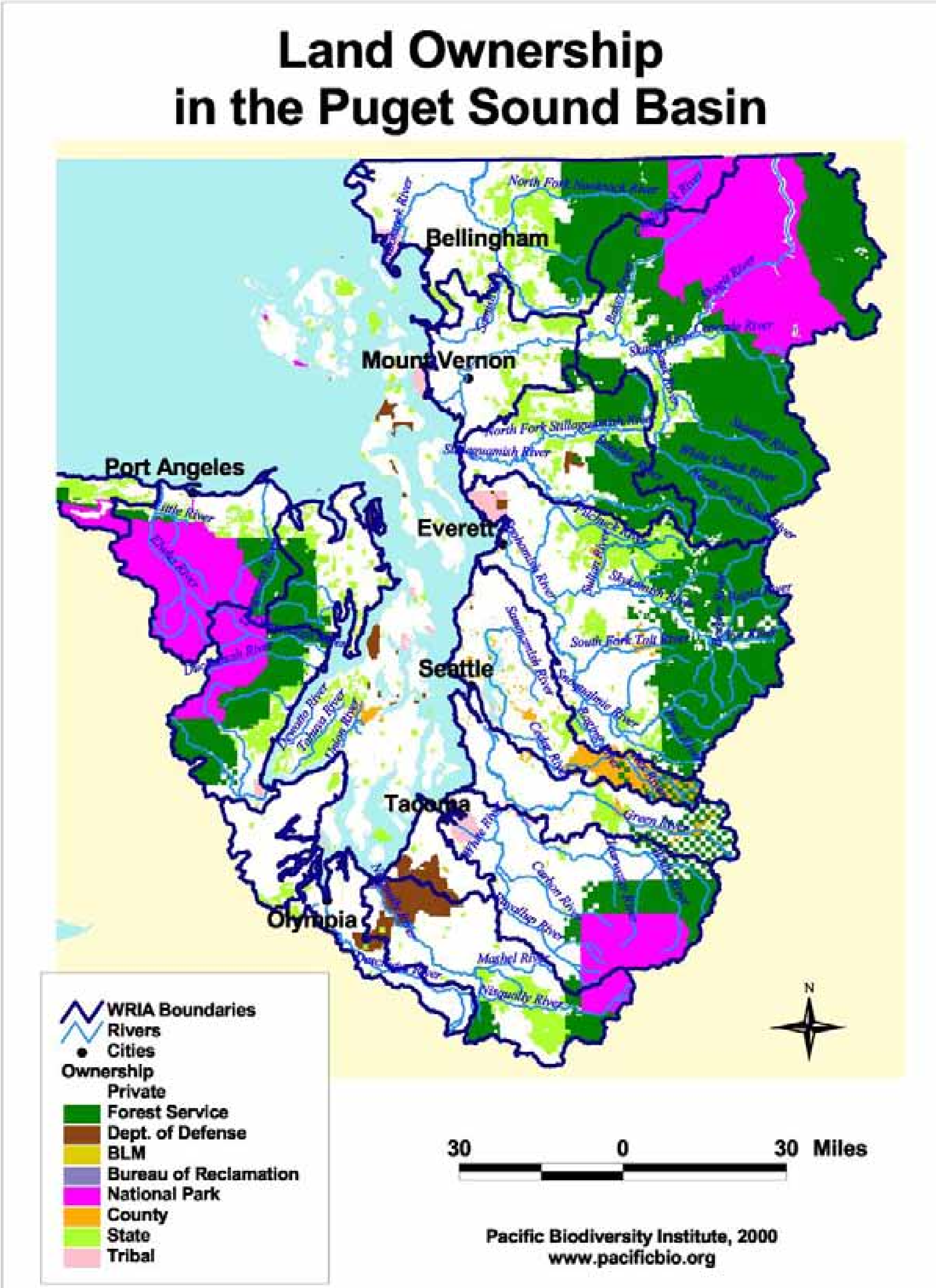
INTRODUCTION

This chapter of the report describes the methodology for the landscape GIS assessment. The landscape assessment used landscape characteristics that reflect ecological integrity and salmon habitat quality to complement the fish population and habitat analysis described in Chapter 2. The landscape analysis covers all land ownerships in the Puget Sound Basin (Figure 1). Each Water Resource Inventory Area (WRIA) in the Puget Sound Basin was subdivided into subwatersheds averaging about 3,000 hectares (8,220 acres) in size (Figure 2). Each subwatershed was analyzed according to eight factors that serve as indicators of overall landscape condition from the standpoint of health, diversity, and productivity of salmon populations. These factors are:

- *road density*
- *hydrologic alteration*
- *area occupied by natural wetland*
- *relative amount of undisturbed and roadless terrestrial and aquatic habitat*
- *bald eagle presence (a bio-indicator of fish abundance)*
- *subwatershed slope steepness*
- *land use/land cover*
- *hatchery influence*

These factors were categorized as either Plus factors, those that contributed to ecological integrity, or Minus factors, those that diminished the ecological functioning of a subwatershed. A complete listing of all landscape factors for each subwatershed can be found in Appendix D. Appendix D is organized by WRIA and includes a table of subwatershed landscape factors and a map of each WRIA with all the subwatersheds delineated and numbered.

Accessibility and biogeographic distribution factors were considered separately. We mapped artificially established populations (truck and haul facilities), naturally inaccessible areas, and areas above reservoirs and major dams. These factors influence the use of subwatersheds by fish. Areas of high ecological integrity that are inaccessible to fish may provide important off-site functions that are important to sustaining salmon, but that may be of less immediate concern than areas that are directly accessible to indigenous populations of anadromous fish. We assume that artificially established salmon populations in habitat located above natural barrier falls are of questionable heritage, sustainability, and adaptive significance from the standpoint of salmon conservation. We recognize there is debate about this assumption and that some managers may choose to treat these areas differently than we did. Landscape ratings for all areas of Puget Sound are provided in this report.



Land Ownership
in the Puget Sound Basin
Bellingham
Mount Vernon
Port Angeles
Everett
Seattle
Tacoma
Olympia
WRIA Boundaries
Rivers
Cities
Ownership
Private
Forest Service
Dept. of Defense
BLM
Bureau of Reclamation
National Park
County
State
Tribal
30 0 30 Miles
Pacific Biodiversity Institute, 2000
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Figure 1

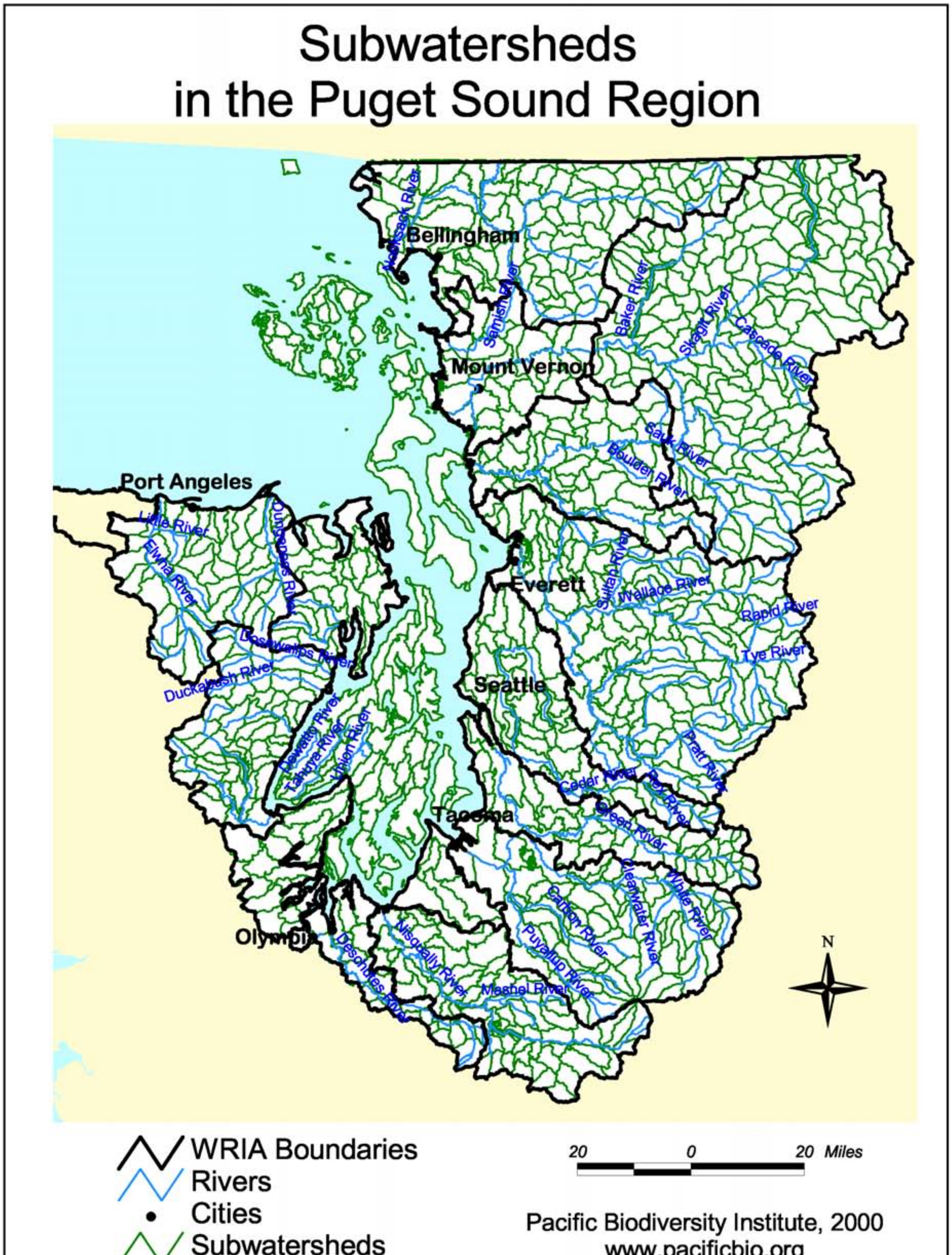
Subwatersheds
in the Puget Sound Region
Bellingham
Mount Vernon
Port Angeles
Everett
Seattle
Tacoma
Baker River
Skagit River
Cascade River
Sauk River
Boulder River
Little River
Elwha River
Sultan River
Wallace River
Rapid River
Tye River
Duckabush River
Pratt River
Cedar River
Green River
White River
Carbon River
Puyallup River
Mashel River
Nisqually River
Clearwater River
WRIA Boundaries
Rivers
Cities
Subwatersheds
20
0
20 Miles
N
Pacific Biodiversity Institute, 2000
www.pacificbio.org

Figure 2

In our initial analysis, we also analyzed three factors that relate to fish distribution. This portion of the study was based on analysis of the STREAMNET database maintained by the Washington Department of Fish and Wildlife. We created maps that illustrate:

- *the number of native salmonid fish species present*
- *the number of ESA-listed salmonid fish species present*
- *the number of non-native fish species present*

Comments from reviewers lead us to conclude that the STREAMNET data was not adequately reliable and could be misleading in some cases for our purposes, so these factors were dropped from our final analysis. This information is included in Appendix D.

Our approach was based on a quantitative analysis and ranking of the above factors across individual subwatersheds. We used geographic information system (GIS) software provided by Environmental Systems Research Institute (ESRI) to conduct this analysis. We based our study on digital spatial databases (GIS layers) that uniformly covered the entire Puget Sound basin. In this study, the selected GIS coverages were used to assess the condition of each subwatershed. This study resulted in a ranking of ecological integrity (as indexed from the salmon's point of view) of all subwatersheds in the basin.

We also conducted a preliminary evaluation of the influence of various water pollution factors in each subwatershed. This information is attached in Appendix F as a series of maps that indicate which subwatersheds contain various water pollution factors, but because of questions about its accuracy and comprehensiveness this information was not used in our analysis.

METHODS AND DATA LAYERS

The following layers were developed and used in the landscape-level subwatershed prioritization GIS analysis of salmonid habitat in the Puget Sound basin. Several base layers were used in the study. These layers included a digital elevation model (DEM), a shaded relief image, a land ownership layer, Landsat satellite imagery, and several cartographic layers.

SUBWATERSHED DELINEATION

Because there was no preexisting delineation of subwatersheds across the Puget Sound basin at the appropriate resolution (equivalent to US Geological Survey Hydrologic Unit Code 6 [huc 6 subwatershed]) we developed a new subwatershed GIS layer for the entire US portion of the Puget Sound basin. A GIS based hydrologic modeling approach using 30-meter digital elevation model (DEM) data originating from the US Geological Survey was used to create a first-draft of subwatersheds based on topography. The DEM was a composite of 10-meter data (for most of the Puget Sound basin) and some 30-meter data. The original 7.5-minute USGS quad level DEM data was merged and resample by Harvey Greenberg at the University of Washington's Department of Geological Sciences.

The DEM was first processed into flow direction and flow accumulation grids. The flow accumulation grid was converted to a stream grid using a threshold value of 5,000. The resulting stream grid was used in conjunction with the flow direction and flow accumulation grid in calculating an initial layer of small subwatershed "building blocks." These grid-generated subwatersheds were then compared with the best available stream data, with the existing Watershed Analysis Unit (WAU) layer from Washington Department of Natural Resources (DNR) and with shaded relief imagery to determine how to group and split the small subwatershed "building blocks" into meaningful subwatershed units (Figure 3).

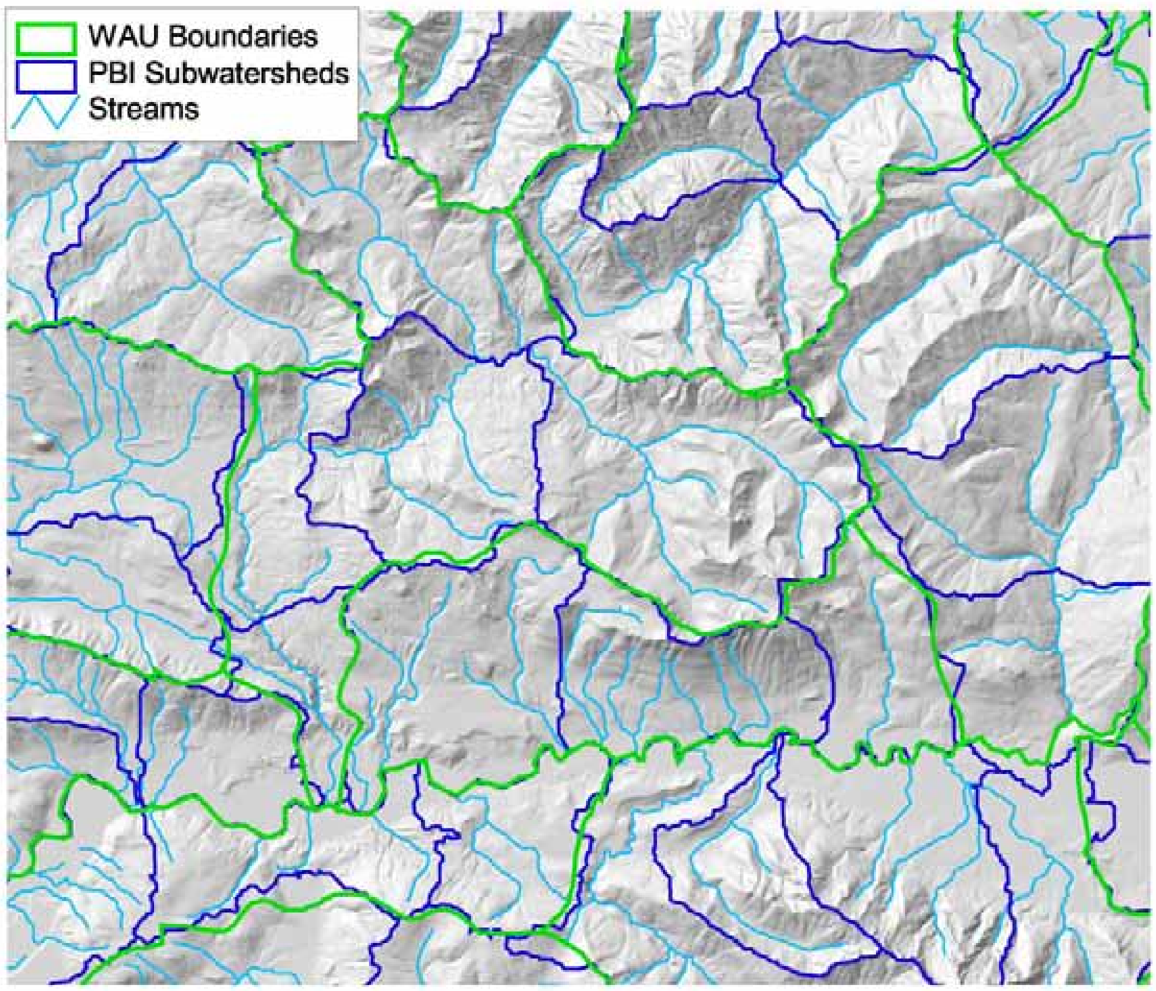

Figure 3

The goal was to create a finer-scale and more precise delineation of subwatershed unit boundaries than was available in the WAU layer. USGS Digital Raster Graphic images (7.5- minute topographic maps) were also used in places were it was difficult to ascertain the topographical relief. Stream coverage from the Washington Department of Fish and Wildlife was used, along with more detailed stream covers from King and Snohomish Counties. The resulting cover was then intersected with a coastline cover and the process was repeated along the coast, so that river mouths could be integrated into the subwatersheds. Subwatersheds nest fully into existing WRIAs and, where feasible, nest to existing WAUs. However, extensive errors in WAU boundary locations and large variances in WAU size precluded a close match to WAU boundaries.

LANDSCAPE CONDITION FACTORS

TOTAL AREA IN NATURAL WETLANDS

This factor assumes that naturally functioning wetlands contribute to salmon productivity and population health through their beneficial effects on water quality and quantity, as well as the fact that many wetlands serve directly as habitat for salmon. Natural wetlands that have not been drained or unduly modified were selected from the National Wetland Inventory GIS data and intersected with the subwatershed layer, attributing each wetland polygon with the number of the subwatershed in which it is situated. The total surface area of inventoried natural wetlands in each subwatershed was then calculated. The total values for all subwatersheds in the Puget Sound Basin were then grouped into five equal area divisions plus a zero class, and coded as such (Figure 4). The total natural wetland value was then used as a Plus Factor in the subsequent landscape-level subwatershed prioritization.

HYDROLOGIC ALTERATION INDEX

The area of recently hydrologically altered wetlands (wetlands that have been diked, drained, or otherwise substantially hydrologically modified) in each subwatershed was calculated from the National Wetlands Inventory data. This factor assumes that human alteration of wetlands generally compromises their benefits to salmon by decoupling their hydrologic functions and reducing the quality or quantity of salmon habitat. Codes containing “K” and “X” were selected as being hydrologically modified. We acknowledge that significant wetland modification occurred in the more distant past and that such historic wetland modification is not well revealed in the National Wetland Inventory data used in this study. Nevertheless, the more recent alterations may pose the most risk of causing further declines in extant salmon populations, so the recent record is germane to our analysis. A Hydrologic Alteration Index for each subwatershed was calculated using the following formula: (altered wetland area/total wetland area) x (total wetland area/total subwatershed area).

The resulting values were then grouped into five equal area divisions and coded from one to five (Figure 5). The resulting hydrologic alteration value was then used as a Minus Factor in the subsequent landscape-level subwatershed prioritization.

ROAD DENSITY

This layer assumes that roads pose a wide range of threats to salmon and their habitat (Trombulak and Frissell 2000), and that road density is a reasonable direct or indirect measure of these combined influences (e.g., see Baxter et al. 1999). A road layer was created by combining Forest Service roads for National Forest lands and US Census Department TIGER roads for private lands. This layer was then intersected with the subwatershed layer so that each road segment was attributed to the number of the subwatershed in which it is situated. The total road length in each subwatershed was then calculated. The total length was then divided by the total subwatershed area to arrive at the road density for each subwatershed, expressed in kilometers per square kilometers. Later, we updated our initial road density GIS layer with a new road density layer calculated in an identical fashion as the one above from new road data provided by the Washington Department of

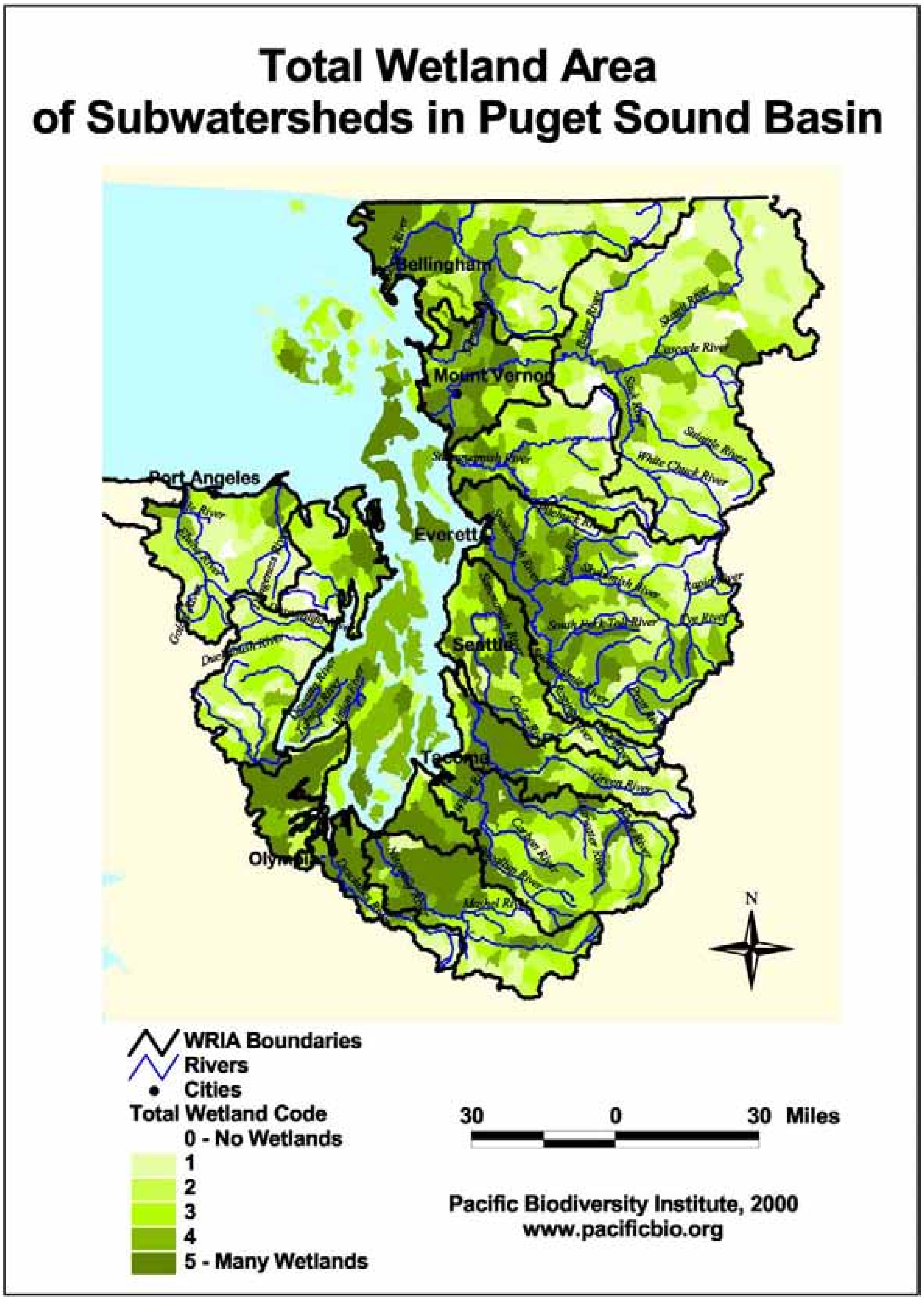
Total Wetland Area
of Subwatersheds in Puget Sound Basin
Bellingham
Mount Vernon
Port Angeles
Everett
Seattle
Tacoma
Cascade River
White Chuck River
Green River
N
WRIA Boundaries
Rivers
Cities
Total Wetland Code
0 - No Wetlands
1
2
3
4
5 - Many Wetlands
30 0 30 Miles
Pacific Biodiversity Institute, 2000
www.pacificbio.org

Figure 4

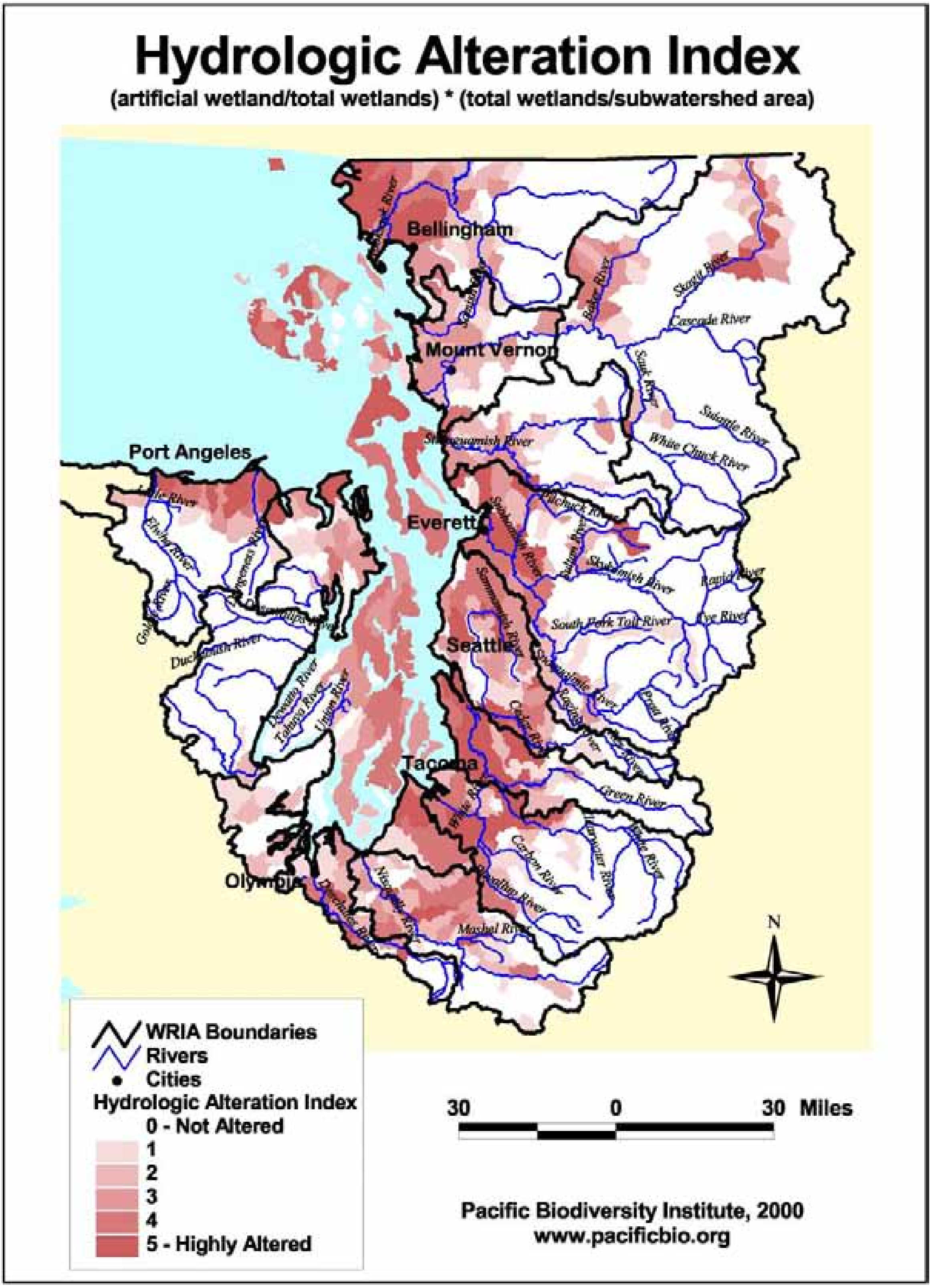
Hydrologic Alteration Index
(artificial wetland/total wetlands) * (total wetlands/subwatershed area)
Bellingham
Mount Vernon
Port Angeles
Everett
Seattle
Tacoma
Olympia
Cascade River
Sauk River
Suiattle River
White Chuck River
Green River
Carbon River
Mashel River
N
WRIA Boundaries
Rivers
Cities
Hydrologic Alteration Index
0 - Not Altered
1
2
3
4
5 - Highly Altered
30
0
30 Miles
Pacific Biodiversity Institute, 2000
www.pacificbio.org

Figure 5

Natural Resources (DNR). Subwatersheds with a higher road density in the DNR-based layer were updated with this value. The calculated road density for all subwatersheds in the Puget Sound Basin was then grouped into five equal area classes and coded from one to five (Figure 6). Subwatersheds with no roads were coded as zero. This final road density value was then used as a Minus Factor in the subsequent landscape-level subwatershed prioritization.

UNDEVELOPED HABITAT AREAS

This GIS layer was created by PBI by combining US Census Department TIGER road data with the road data from the Forest Service and from the State Department of Natural Resources. We also used clearcut data from the US Forest Service and road and clearcut updates developed by PBI and derived from interpretation of aerial photography and satellite imagery. Roadless and undeveloped habitat areas were defined to be areas beyond a road effect zone of 100 meters from a road centerline (Forman 2000, Forman and Deblinger 2000, Haskell 2000) and greater than 400 hectares in size (Henjum and other 1994). Undeveloped habitat areas were mapped on all ownerships. The layer was checked for accuracy and updated using digital orthophotography and Landsat satellite imagery. A chronosequence of Landsat satellite imagery from 1972 through 1998 was used in the updating process. The methodology used to develop this layer is described more fully in *Unprotected Wildlands in Washington State* (Morrison and others 1998).

This layer was then intersected with the subwatershed layer and the percentage of each subwatershed in roadless and undeveloped condition was calculated. The result was then grouped into five equal-area categories, plus a zero category (Figure 7). This resulted in each subwatershed receiving a code ranging from 0 to 5 representing its undeveloped habitat condition. This variable was use as a Plus Factor in the subsequent landscape-level subwatershed prioritization.

SUBWATERSHED SLOPE STEEPNESS

We assumed that the proportion of a watershed with relatively steep slopes (higher than 60 percent) represented its proneness to accelerated landslides and other slope erosion in the face of human disturbance. Another way to view this assumption is that watersheds with fewer erosion-prone areas may be more resistant or resilient to a given level of disruption of natural land cover. A slope-steepness GIS layer was calculated from 30-meter digital elevation data. This digital elevation model (DEM) data, which originated from the US Geological Survey, was a composite of 10-meter data (for most of the Puget Sound Basin) and some 30-meter data. The original 7.5 minute USGS quad level DEM data was merged and resampled by Harvey Greenberg at the University of Washington's Department of Geological Sciences. We calculated the percent of each subwatershed with a slope of more than 60 percent and attributed the subwatersheds with this value. The result was then grouped into five equal-area categories (Figure 8). The resulting slope steepness value was then used as a Minus Factor in the subsequent landscape-level subwatershed prioritization.

BALD EAGLE PRESENCE

Data on Bald Eagle observations was used as a bio-indicator of fish abundance. The data were extracted from the Natural Heritage database of the Washington Department of Wildlife. Reported element occurrences of bald eagles in that database generally represent perch trees or nesting sites, which are associated with healthy riparian habitat. Our assumption is that eagle distribution is an integrated indicator of ecological integrity with a strong link to salmon populations as a principal food resource. We assume that eagles aggregate where salmon availability is high and where returns

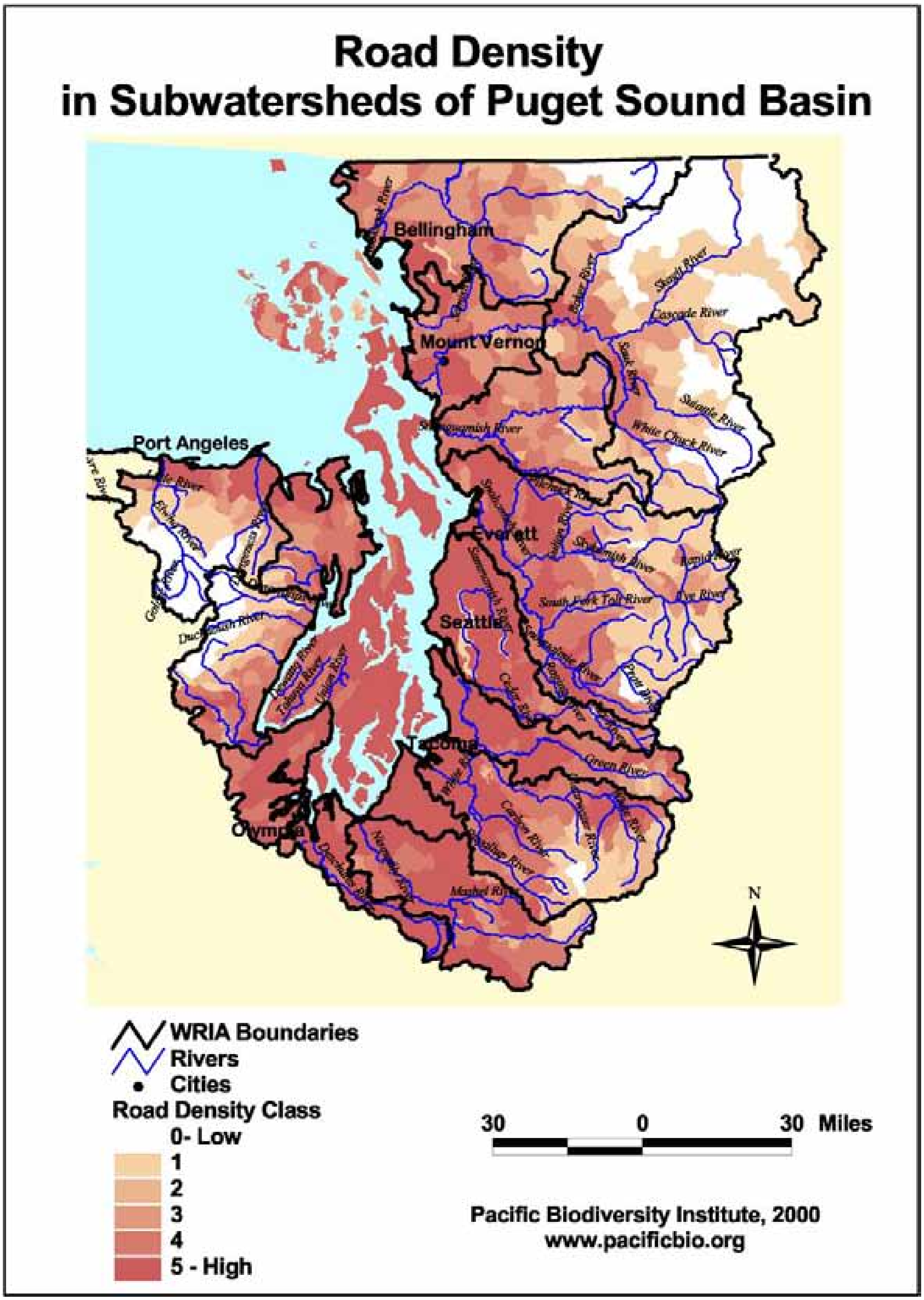
Road Density
in Subwatersheds of Puget Sound Basin
Bellingham
Mount Vernon
Port Angeles
Everett
Seattle
Tacoma
Olympia
N
WRIA Boundaries
Rivers
Cities
Road Density Class
0- Low
1
2
3
4
5 - High
30
0
30 Miles
Pacific Biodiversity Institute, 2000
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Figure 6

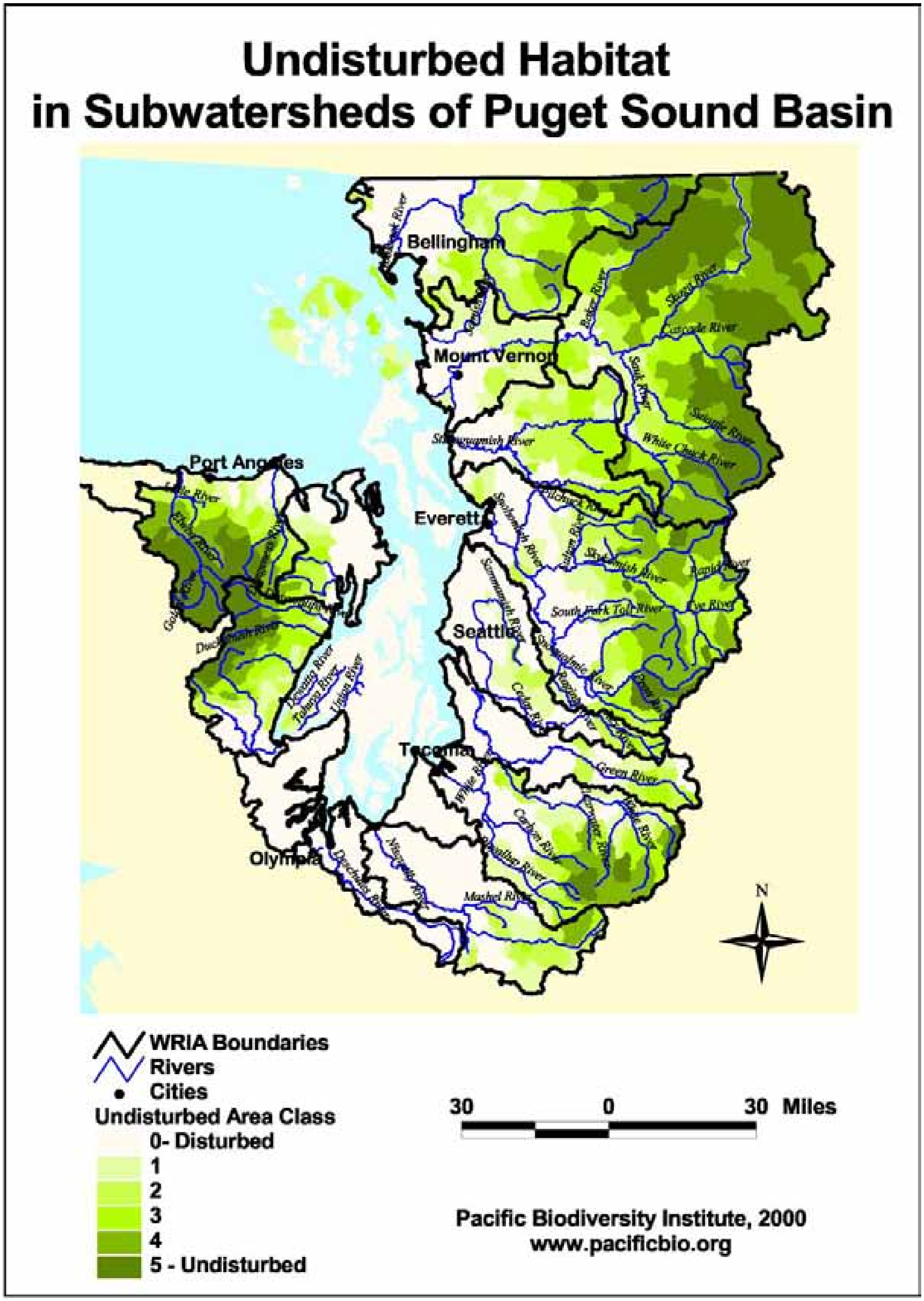
Undisturbed Habitat
in Subwatersheds of Puget Sound Basin
Bellingham
Mount Vernon
Port Angeles
Everett
Seattle
Tacoma
Olympia
Cascade River
White Chuck River
Green River
Carbon River
Mashel River
N
WRIA Boundaries
Rivers
Cities
Undisturbed Area Class
0- Disturbed
1
2
3
4
5 - Undisturbed
30
0
30 Miles
Pacific Biodiversity Institute, 2000
www.pacificbio.org

Figure 7

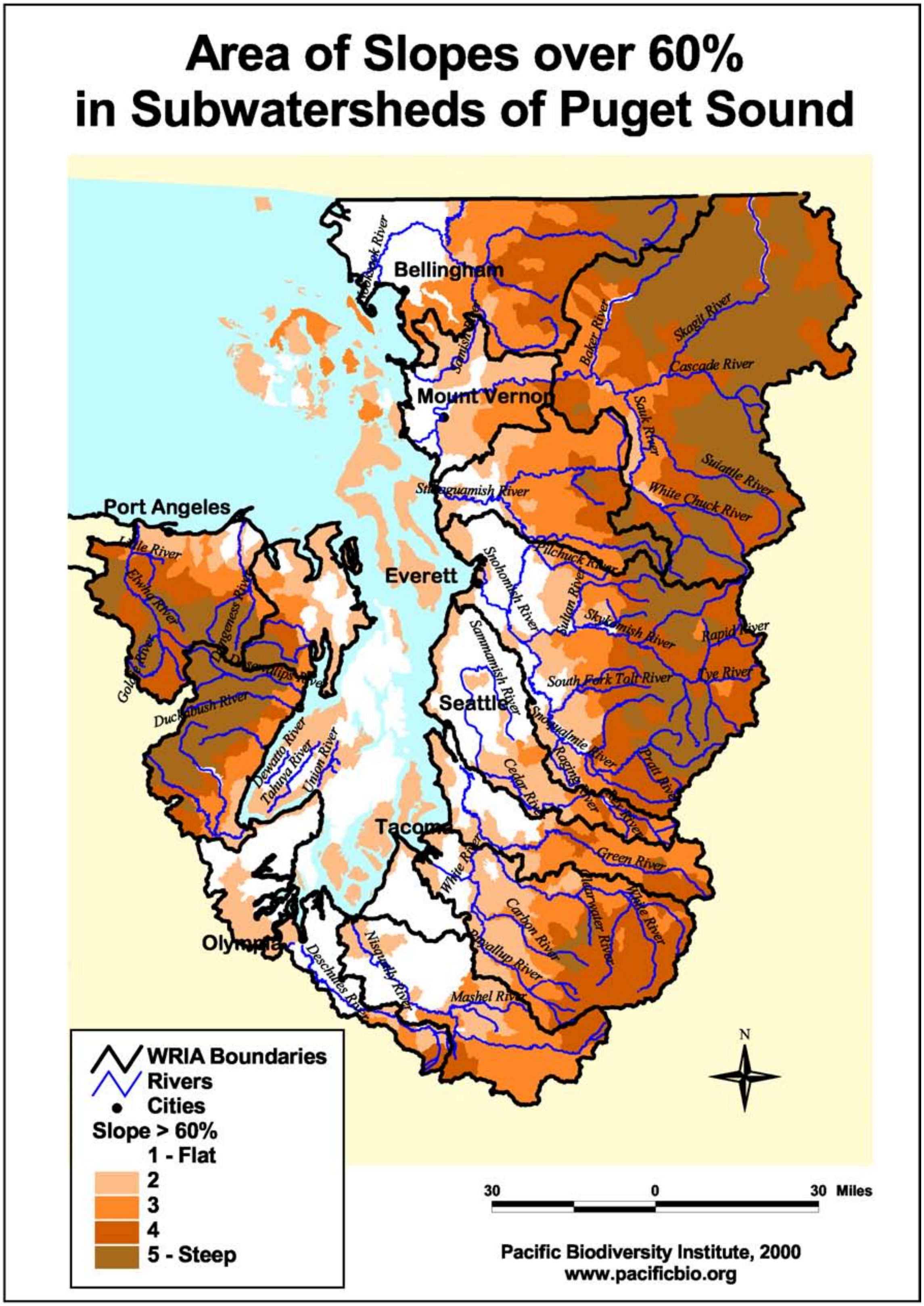
Area of Slopes over 60%
in Subwatersheds of Puget Sound
Bellingham
Mount Vernon
Port Angeles
Everett
Seattle
Tacoma
Olympia
Skagit River
Cascade River
Baker River
Sauk River
Suiattle River
White Chuck River
Stillaguamish River
Pilchuck River
Snohomish River
Sultan River
Skykomish River
Rapid River
Tye River
South Fork Tolt River
Sammamish River
Snoqualmie River
Raging River
Pratt River
Cedar River
Green River
White River
Carbon River
Puyallup River
Mashel River
Nisqually River
Deschutes River
Elwha River
Duckabush River
Dewatto River
Tahuya River
Union River
WRIA Boundaries
Rivers
Cities
Slope > 60%
1 - Flat
2
3
4
5 - Steep
N
30
0
30 Miles
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Figure 8

are extended over longer periods of time, indicating both productive and diverse salmon populations.

The number of element occurrences of bald eagles was totaled for each subwatershed. The result was then grouped into five equal-area categories, plus a zero category (Figure 9). The resulting value was then used as a Plus Factor in the subsequent landscape-level subwatershed prioritization.

PAST LAND USE AND LAND COVER INFLUENCES

We used Land Use/Land Cover data developed by the US Geological Survey from aerial photography acquired by NASA and the USGS during the 1970s and 1980s. Manually interpreted land use and land cover polygons were compiled at a 1:250,000 scale to assess past land use and land cover in each subwatershed. This data identifies 37 land use and land cover types. We grouped these types into four habitat groups, which reflect the probable influence of each class on salmonid fish in the subwatershed. (Table 1). Land use/land cover classes that reflect landscape conditions that are often beneficial to salmon are ranked higher than those classes that have less value or are associated with a high incidence of threats to salmon (Figure 10). The resulting value was used as a Plus Factor in the landscape-level analysis.

TABLE. 1: LAND USE / LAND COVER CODE GROUPINGS

LAND USE / LAND COVER TYPE	LULC CODES	HABITAT GROUP
Residential	11	1
Commercial, Industrial	12, 13, 15	1
Transportation, Communications	14	1
Mixed and other Urban	16, 17	1
Agricultural Land	21,22,23,24	2
Rangeland	31,32,33	3
Forest Land	41,42, 43	4
Streams, Lakes, Bays and Estuaries	51,52	4
Reservoirs	53	2
Wetlands	61,62	4
Salt flats, beaches, other natural bare areas	71,72,73,74	3
Strip-mines, quarries, gravel pits, etc.	75,76,77	1
Tundra	81,82,83,84,85	3
Snowfields and glaciers	91,92	2

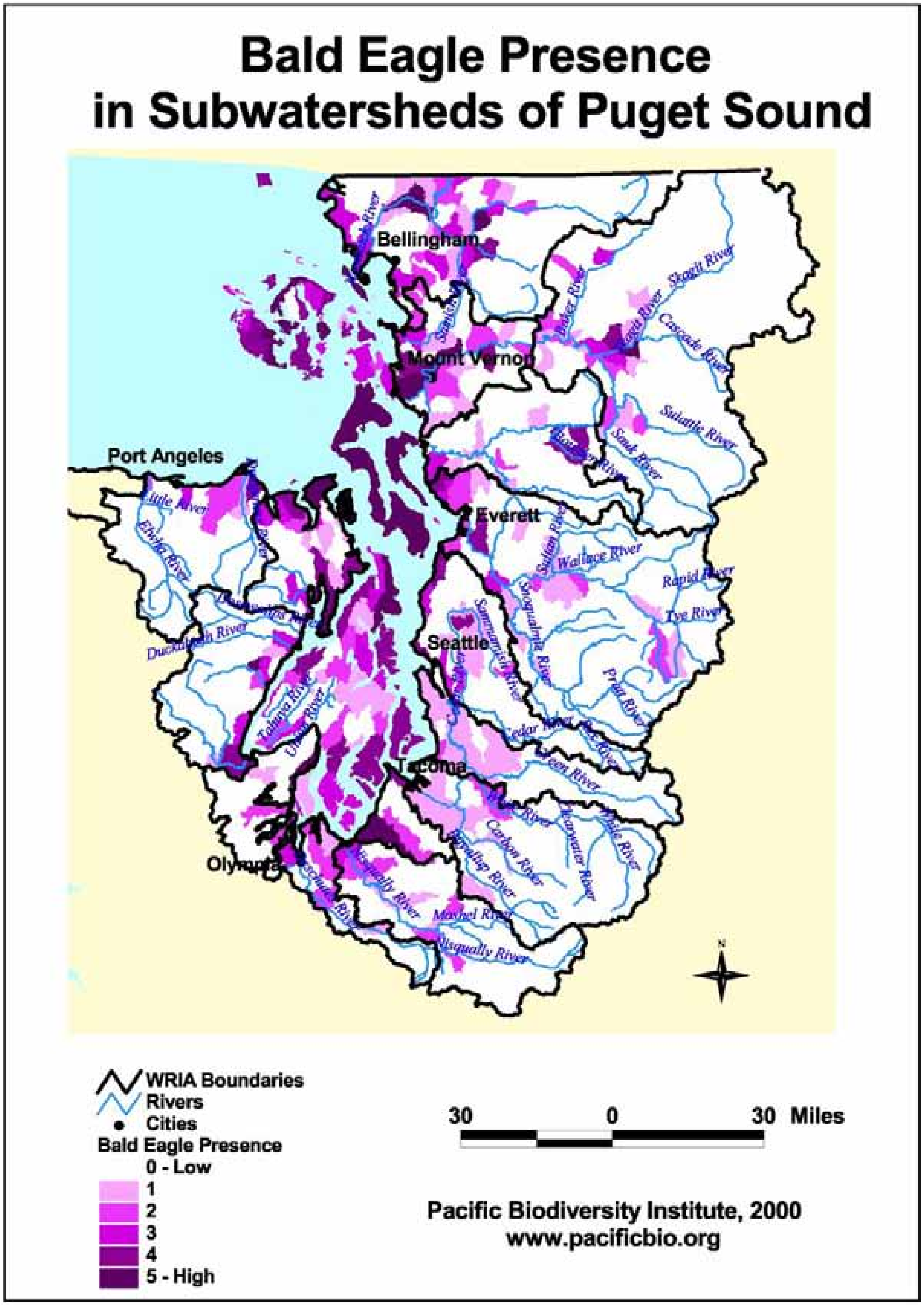
Bald Eagle Presence
in Subwatersheds of Puget Sound
Bellingham
Mount Vernon
Port Angeles
Everett
Seattle
Tacoma
Skagit River
Cascade River
Suiattle River
Sauk River
Baker River
Wallace River
Rapid River
Tye River
Snoqualmie River
Sammamish River
Pratt River
Cedar River
Green River
Carbon River
Puyallup River
Nisqually River
Mashel River
Elwha River
Little River
Dungeness River
Duckabush River
Tahuya River
Union River
Skookumchuck River
N
WRIA Boundaries
Rivers
Cities
Bald Eagle Presence
0 - Low
1
2
3
4
5 - High
30
0
30 Miles
Pacific Biodiversity Institute, 2000
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Figure 9

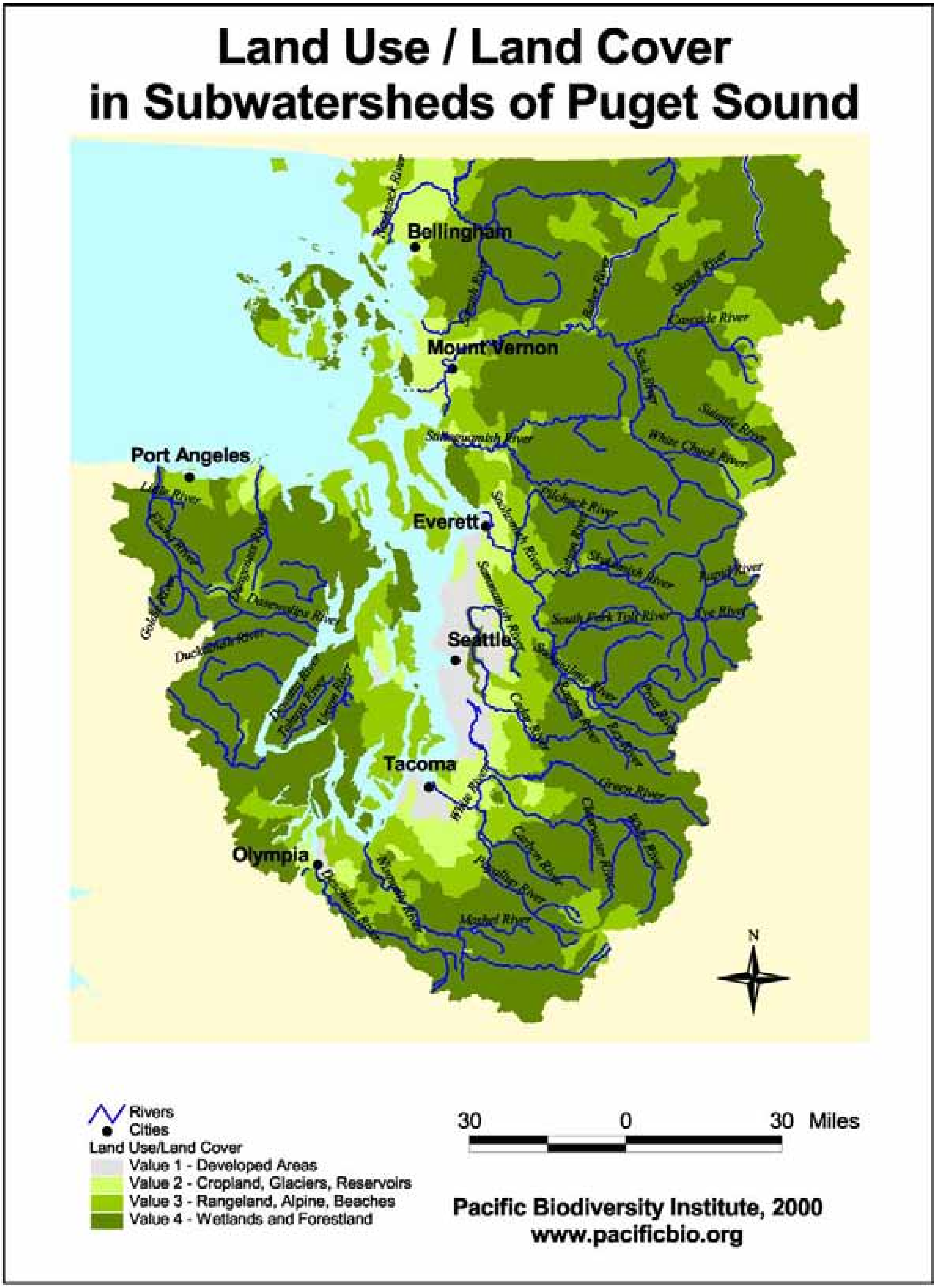
Land Use / Land Cover
in Subwatersheds of Puget Sound
Bellingham
Mount Vernon
Port Angeles
Everett
Seattle
Tacoma
Olympia
Rivers
Cities
Land Use/Land Cover
Value 1 - Developed Areas
Value 2 - Cropland, Glaciers, Reservoirs
Value 3 - Rangeland, Alpine, Beaches
Value 4 - Wetlands and Forestland
30 0 30 Miles
N
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Figure 10

HATCHERY, NET PEN, AND REARING POND INFLUENCE

A ten-mile zone was created around any hatchery. This is assumed to reflect a general zone of influence within which outplanting and escape of juvenile fish and straying of returning adult fish of hatchery origin are most likely to be concentrated and adversely affect natural salmon populations through competition, predation, disease, predator attraction, or genetic introgression. Where zones from neighboring facilities overlapped, the resulting polygons, referred to as hatchery areas, were coded with the total number of zones to record influence from multiple facilities. This layer was then intersected with the subwatershed layer and the proportion of each subwatershed within each hatchery zone was calculated and multiplied by the number of hatcheries. For example, if one-half of a subwatershed fell within the ten-mile zone of two hatcheries, this proportion was doubled; if it fell within ten miles of three hatcheries the proportion was tripled, etc. These numbers were then totaled for each subwatershed and the resulting figure multiplied by two to give it weighting over the net pens and rearing ponds (Figure 11). The same process was followed for net pens and rearing ponds except that the resulting total was not multiplied by two. Hatchery, Net Pen and Rearing Pond data all came from the Washington Department of Fish and Wildlife's STREAMNET database.

The resulting values for hatchery influence and netpen/rearing pond influence were totaled. This value was then grouped into five equal-area categories, plus a zero category. This final value was then used as a Minus Factor in the subsequent landscape-level subwatershed prioritization.

ARTIFICIALLY ESTABLISHED POPULATIONS, INACCESSIBLE SUBWATERSHEDS AND AREAS ABOVE MAJOR DAMS

WDFW STREAMNET data, field-based information, and expert advice from the report's authors and reviewers were used to map subwatersheds influenced by artificially established or maintained salmonid populations (truck and haul facilities), inaccessible subwatersheds, and areas above major dams (Figure 12). This information was not incorporated as part of the ranking process, but was added as an overlay or "screen" in the final prioritization map. The final map represents landscape scores calculated and categorized for all subwatersheds in the region. This global ranking helped place the ecological integrity of salmon-accessible lands in the context of the overall landscape. Historically or currently inaccessible and artificially populated watersheds are distinguished from natural salmon watersheds by a shade pattern.

EVALUATION OF OVERALL SUBWATERSHED CONDITION

To assess the overall subwatershed condition, we subtracted the sum of all of the Minus Factors (described above) from the sum of all of the Plus Factors. This sum was then normalized to fall within a 0 to 30 range of values.

RESULTS AND CONCLUSIONS

To assess the overall subwatershed condition, we subtracted the sum of all the Minus Factors (described above) from the sum of all the Plus Factors. The resulting values ranged from a low of -14 to a high of 10. In more than 51 percent of the subwatersheds the sum of the Plus Factors exceeded the sum of the Minus Factors, resulting in a positive value. We then transformed these values into a range of final values that range from a low of 0 to a high of 24 by adding 14 to sum of

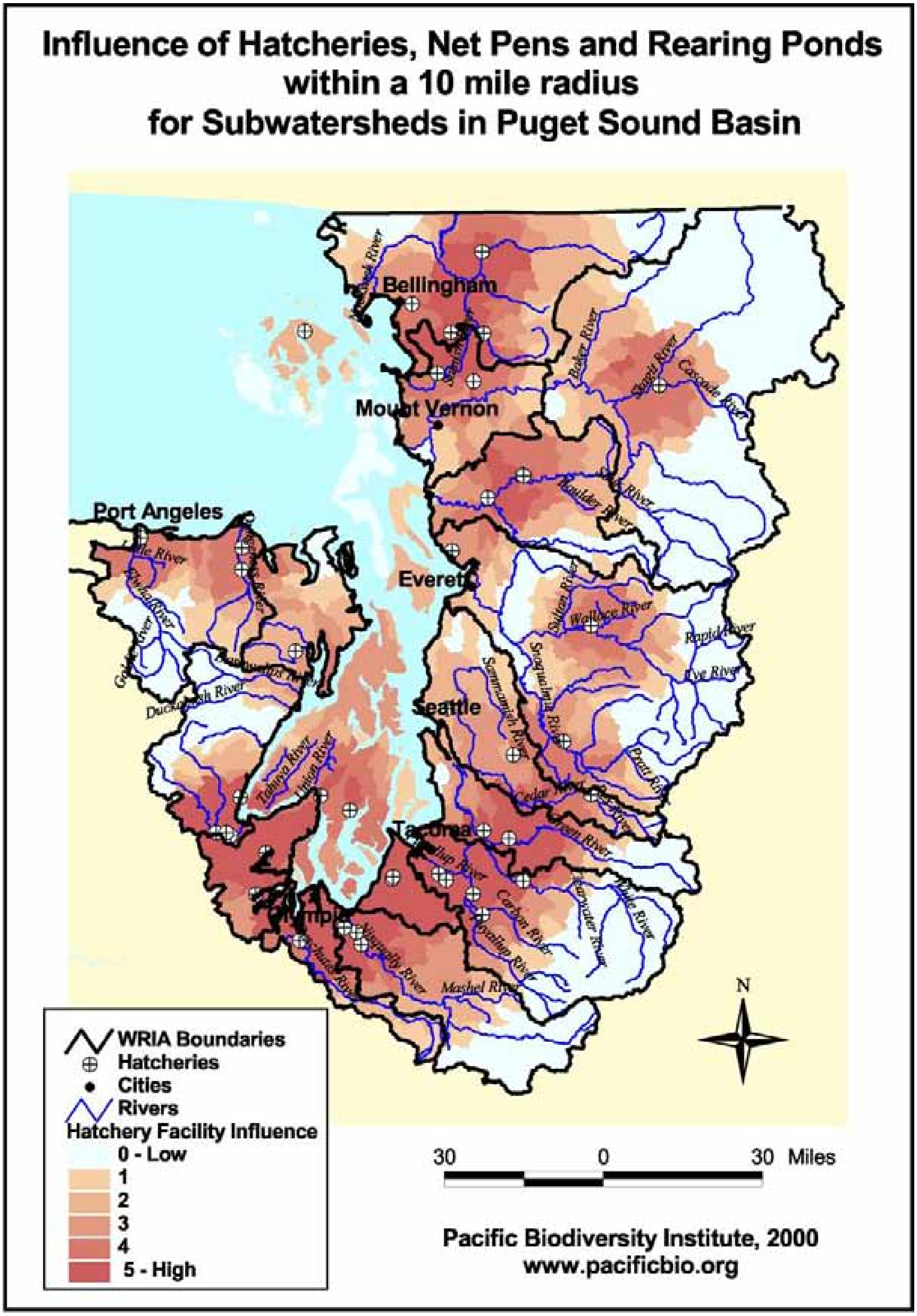
Influence of Hatcheries, Net Pens and Rearing Ponds
within a 10 mile radius
for Subwatersheds in Puget Sound Basin
Bellingham
Mount Vernon
Port Angeles
Everett
Seattle
Tacoma
WRIA Boundaries
Hatcheries
Cities
Rivers
Hatchery Facility Influence
0 - Low
1
2
3
4
5 - High
N
30
0
30 Miles
Pacific Biodiversity Institute, 2000
www.pacificbio.org

Figure 11

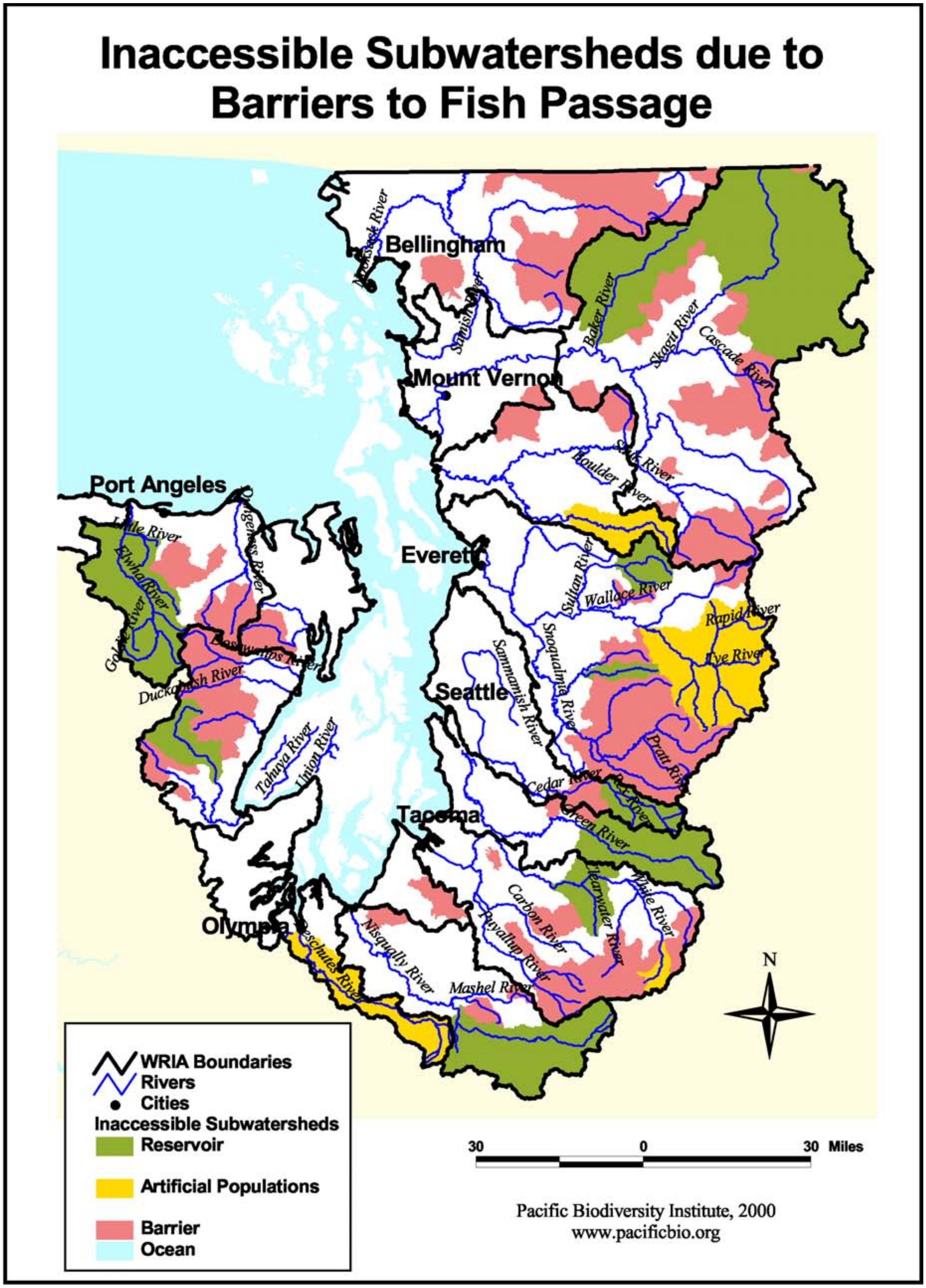
Inaccessible Subwatersheds due to Barriers to Fish Passage
Bellingham
Mount Vernon
Port Angeles
Everett
Seattle
Tacoma
Olympia
Nooksack River
Samish River
Baker River
Skagit River
Cascade River
Boulder River
Sauk River
Little River
Elwha River
Dungeness River
Goldie River
Sultan River
Wallace River
Rapid River
Tye River
Snoqualmie River
Sammamish River
Duckabush River
Tahuya River
Union River
Pratt River
Cedar River
Green River
Clearwater River
White River
Carbon River
Puyallup River
Nisqually River
Mashel River
Deschutes River
N
WRIA Boundaries
Rivers
Cities
Inaccessible Subwatersheds
Reservoir
Artificial Populations
Barrier
Ocean
30
0
30 Miles
Pacific Biodiversity Institute, 2000
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Figure 12

the Plus Factors and the Minus Factors. We identified 143 subwatersheds with very high relative landscape integrity ratings. Sum scores in these subwatersheds range from 19 to 24. We also identified an additional 153 subwatersheds with high ecological integrity ratings, where landscape-level subwatershed prioritization values ranged between 17 to 18. An overview of our landscape-level subwatershed prioritization for the Puget Sound basin also revealed many subwatersheds with moderate prioritization values, where restoration efforts have a relatively high likelihood of restoring ecological integrity (Figure 13).

The subwatersheds with the highest landscape integrity ratings were almost entirely found in the higher mountainous parts of the Puget Sound basin where the landscape is still intact and less disturbed by human alterations than more accessible areas. Ironically, nearly all of these areas are also historically inaccessible to salmonid fish because of natural barriers or are now above major dams. The subwatersheds above the natural barriers do not provide *in situ* habitat for salmonids, but they do contribute high quality water and woody debris to accessible areas located lower in the stream system. Many of these areas should be considered critical contributing areas.

A complete listing of all subwatersheds grouped by WRIA, along with their relative landscape condition values, fish distribution and hatchery influence values and overall landscape-level prioritization values, is presented in Appendix D.

We compared our landscape-level subwatershed prioritization results with the fish-centered stream level prioritization results (this report, previous section). Substantial agreement exists between these two approaches, which used independent methodologies (Figure 14). Many subwatersheds that we ranked in the top two tiers of the landscape assessment (landscape integrity rating greater than 2) contained streams identified in the fish-centered assessment as Category 1, 2, or 3 streams. We identified other subwatersheds that appear to have relatively high ecological integrity but were not identified in the fish-centered analysis. Likewise, the fish-centered analysis identified several Category 2 or 3 streams that did not receive a high value in our analysis.

Our landscape-level subwatershed prioritization yielded a gross scale, comprehensive assessment of factors that influence the health of salmonid populations across the Puget Sound Basin. This assessment complements the fish-centered assessment. Areas that we have identified as having relatively high ecological integrity from a landscape perspective should be targeted for further analysis using the fish-centered approach. These areas may not have received high values in the fish-centered approach due to data gaps or variations in data quality between stream reaches. It is also quite possible that stream habitat conditions that are too fine to be picked up at a landscape scale greatly influence the habitat conditions in these areas and that the fish-centered approach is more accurate in some situations.

Subwatersheds that receive high values in both the fish-centered approach and the landscape-level subwatershed prioritization are certainly the subwatersheds that should receive the highest conservation attention. Two independent methodologies have identified these as the highest priority subwatersheds. There is abundant evidence that the areas that rank the highest in both studies represent the best remaining salmon habitat in the Puget Sound basin.

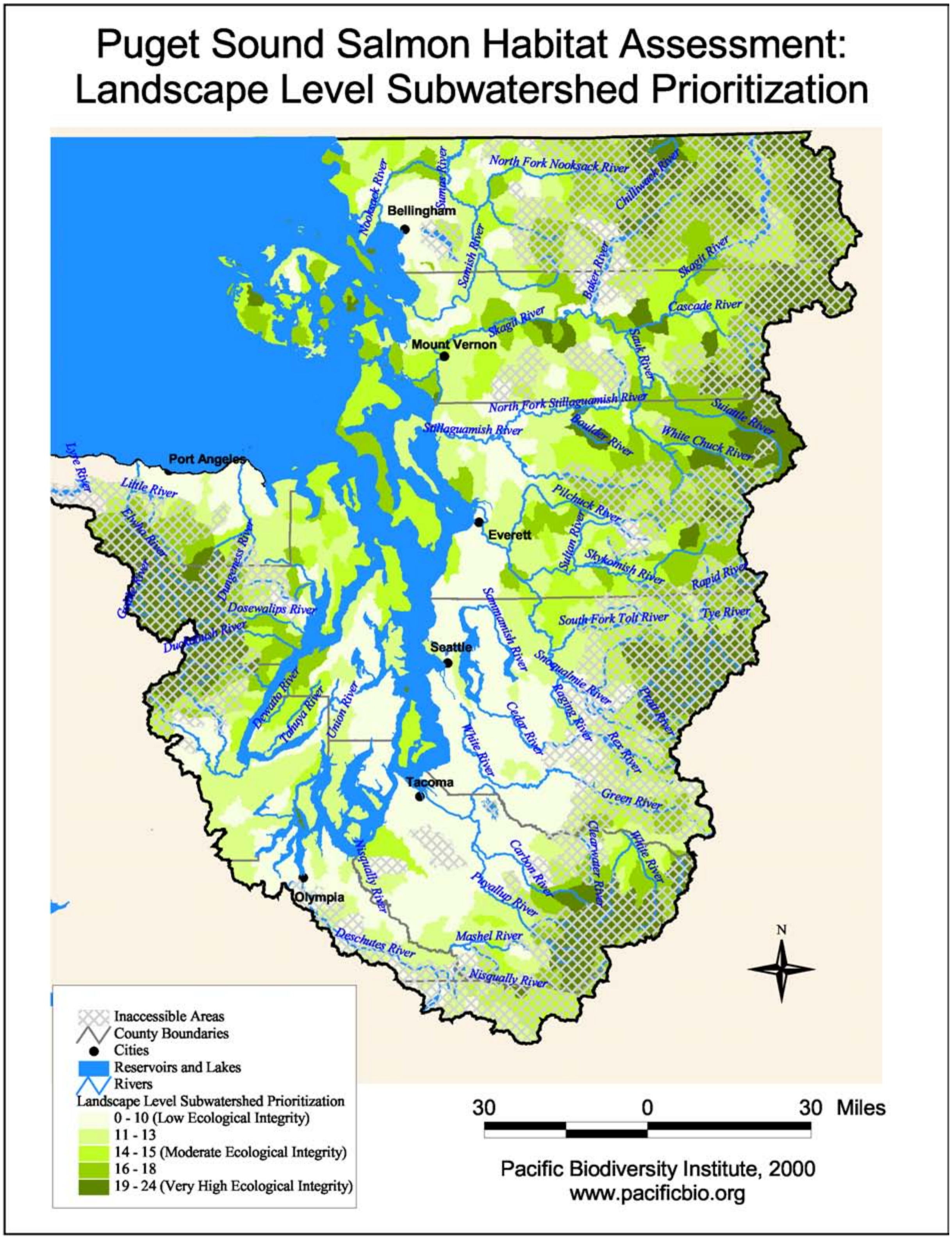
Puget Sound Salmon Habitat Assessment:
Landscape Level Subwatershed Prioritization
North Fork Nooksack River
Chilliwack River
Nooksack River
Sumas River
Bellingham
Samish River
Baker River
Skagit River
Cascade River
Mount Vernon
Sauk River
North Fork Stillaguamish River
Suiattle River
Stillaguamish River
Boulder River
White Chuck River
Port Angeles
Lyre River
Little River
Elwha River
Pilchuck River
Everett
Sultan River
Dungeness River
Skykomish River
Rapid River
Dosewalips River
Sammamish River
South Fork Tolt River
Tye River
Duckabush River
Seattle
Snoqualmie River
Dewatto River
Tahuya River
Union River
Cedar River
Raging River
Pratt River
White River
Rex River
Tacoma
Green River
Clearwater River
Carbon River
Nisqually River
Olympia
Puyallup River
Deschutes River
Mashel River
N
Inaccessible Areas
County Boundaries
Cities
Reservoirs and Lakes
Rivers
Landscape Level Subwatershed Prioritization
0 - 10 (Low Ecological Integrity)
11 - 13
14 - 15 (Moderate Ecological Integrity)
16 - 18
19 - 24 (Very High Ecological Integrity)
30 0 30 Miles
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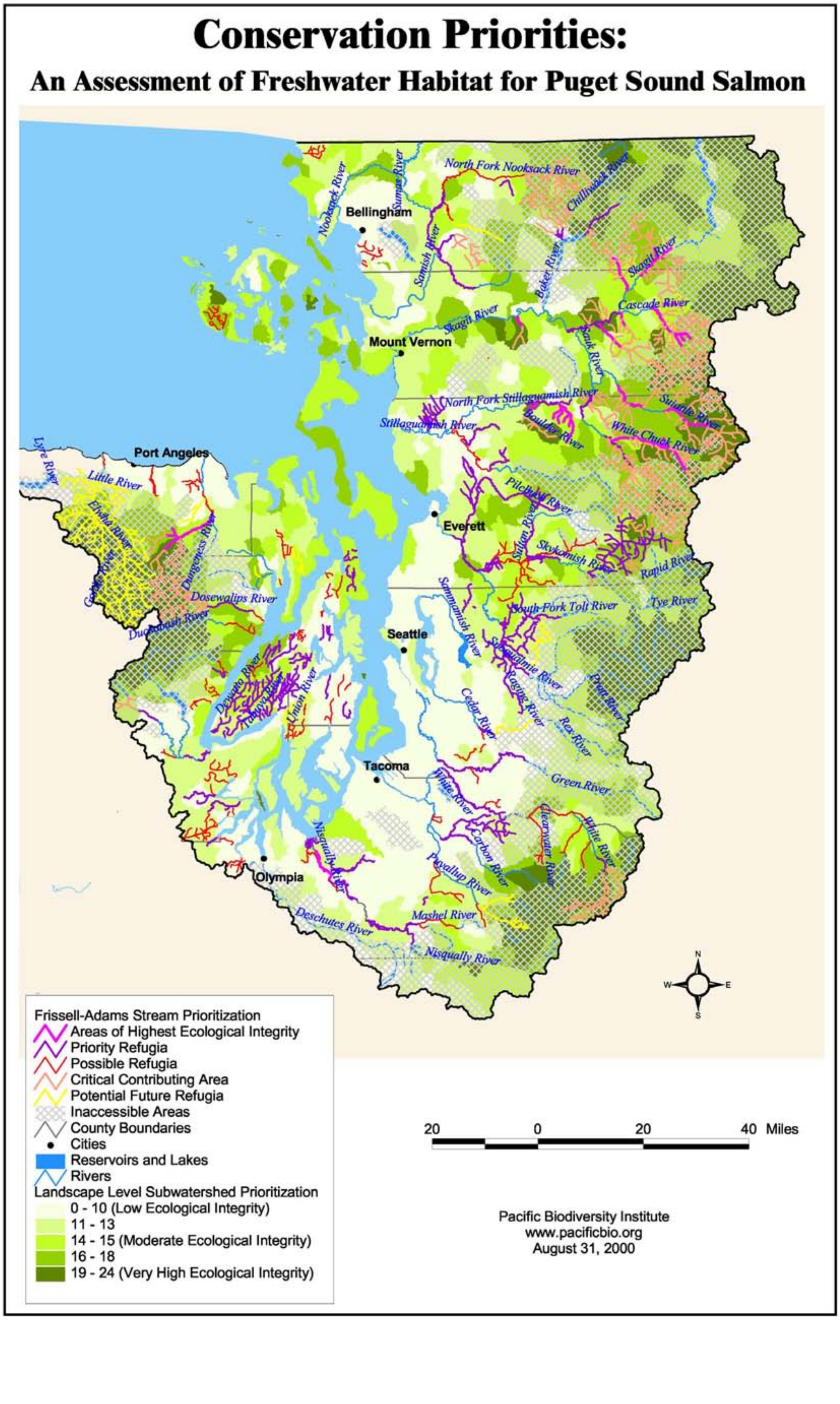
Figure 13



Conservation Priorities:
An Assessment of Freshwater Habitat for Puget Sound Salmon
Bellingham
Mount Vernon
Port Angeles
Everett
Seattle
Tacoma
Olympia
North Fork Nooksack River
Nooksack River
Sumas River
Chilliwack River
Samish River
Baker River
Skagit River
Cascade River
Sauk River
North Fork Stillaguamish River
Stillaguamish River
Suiattle River
Boulder River
White Chuck River
Lyre River
Little River
Elwha River
Dungeness River
Pilchuck River
Sultan River
Skykomish River
Rapid River
Tye River
South Fork Tolt River
Dosewalips River
Duckabush River
Sammamish River
Snoqualmie River
Union River
Cedar River
Raging River
Rex River
Green River
White River
Clearwater River
Carbon River
Puyallup River
Nisqually River
Mashel River
Deschutes River
N
E
S
W
Frissell-Adams Stream Prioritization
Areas of Highest Ecological Integrity
Priority Refugia
Possible Refugia
Critical Contributing Area
Potential Future Refugia
Inaccessible Areas
County Boundaries
Cities
Reservoirs and Lakes
Rivers
Landscape Level Subwatershed Prioritization
0 - 10 (Low Ecological Integrity)
11 - 13
14 - 15 (Moderate Ecological Integrity)
16 - 18
19 - 24 (Very High Ecological Integrity)
20 0 20 40 Miles
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August 31, 2000

NOOKSACK RIVER BASIN AND INDEPENDENT DRAINAGES

OVERVIEW

This region consists of Water Resource Inventory Area 1, including over 1,300 linear miles of streams and rivers (Williams et al. 1975). Hydrology of the Middle Fork and North Fork of the Nooksack River system is dominated by glacial melt from Mount Baker (10,778 feet in elevation) and Mount Shuksan (9,127 feet in elevation). As a result, sediment loading can be high in these areas, relative to the South Fork of the Nooksack River, which is not influenced by glacial runoff (MBSNF 1995b). Despite these differences, all forks of the Nooksack River are considered to be important for salmon (D. Griggs, pers. comm.) and contain several salmon refugia.

Although most portions of the Nooksack basin have been affected by some degree of logging and/or agricultural practices, habitat quality is markedly greater in the forks of the Nooksack River than in the mainstem. From the mouth of the river to approximately RM 35, agricultural and rural/urban development have left a legacy of dikes, diversions, and bank armoring (W. Sherrer, pers. comm.; G. Scott pers. comm.). As a result, fish habitat in the mainstem declined dramatically from historic levels (D. Griggs, pers. comm.). In addition, agricultural water use has exacerbated the low-flow limiting factors of most independent stream systems within this region (G. Scott, pers. comm.). In contrast, much of the North Fork and South Fork within the boundaries of the Mt. Baker-Snoqualmie National Forest are protected as FEMAT key watersheds (FEMAT 1993).

FISH

The Nooksack River basin supports all five species of Pacific salmon (WDF et al. 1993) as well as bull trout/Dolly Varden, steelhead, and coastal cutthroat trout (Busby and six others 1996; WDFW 1998; Johnson and seven others 1999). With the exception of hatchery-homogenized coho salmon, distinct salmon stocks are generally recognized between the North, South, and Middle Forks and the lower mainstem of the Nooksack River (WDF et al. 1993). Based on genetic and life history information, distinct stocks of bull trout/Dolly Varden have been identified in the lower Nooksack River, Canyon Creek (North Fork), and the upper Middle Fork (WDFW 1998).

The status of native, wild salmonid populations in the North Fork of the Nooksack River varies between species. Although chinook populations in the North Fork are decreasing at a slower rate than stocks in the lower mainstem of the Nooksack River (Myers and ten others 1998), the status of the North Fork stock was considered to be "critical" by SASSI (WDF et al. 1993). In 1991, the North Fork spring chinook stock was proposed for the USFS Region 6 sensitive species list (MBSNF 1995b).

The authors of the SASSI report disagreed on the status of the North Fork pink stock but agreed that chum salmon in the North Fork were "healthy." Huntington et al. (1996) concurred with this determination for chum salmon and listed the North Fork stock as healthy, native, and with abundances of at least two-thirds of those expected in the absence of anthropogenic impacts. Additionally, RM 60 in the North Fork was reported to contain the only sockeye salmon spawning habitat in the Nooksack basin (Williams et al. 1975), although this population is not recognized in more recent reports (WDFW and WWTIT 1994a; Shaklee et al. 1996; Gustafson et al. 1997).

As recognized by the WDF (1993), the South Fork of the Nooksack River supports regionally distinct stocks of chinook, chum, and pink salmon, as well as winter and summer steelhead trout. The health of these stocks is generally unknown (WDF et al. 1993). However, the South Fork chinook stock is known to be "depressed" (WDF et al. 1993) and has shown consistently decreasing population numbers since the 1950s (Myers and ten others 1998). This stock was proposed for addition to the USFS regional sensitive species list in 1993 (MBSNF 1995b).

Less information is available about salmonid use in the Middle Fork (MBSNF 1995b). Although one unique stock (winter steelhead) is recognized for this fork of the Nooksack River, the status of this stock is unknown (WDF et al. 1993). However, it is clear that allowing fish passage over the City of Bellingham's diversion dam would significantly improve fish habitat in this fork of the Nooksack River (G. Dunphy pers. comm.; G. Scott pers. comm.).

Independent streams in this region are utilized primarily by coho and chum salmon. All of these streams have been impacted by agricultural use, commercial development, and/or hatchery influences to some extent (Williams et al. 1975). However, some opportunities for conservation of wild salmon remain in the northernmost independent streams (G. Scott pers. comm.).

AREAS RECOMMENDED FOR WITHIN-BASIN REFUGIA DESIGNATION AND JUSTIFICATIONS: REFUGIA - ALTERED (CATEGORY 2)

Hutchinson Creek (South Fork).

Located in the headwaters originating from west slope of Bowman Mountain, this tributary meets the South Fork of the Nooksack River at RM 10. Ownership is Washington State Department of Natural Resources (DNR) land in the headwaters and higher elevations, private land in lower elevations, and Whatcom Land Trust holdings in the South Fork Nooksack mainstem, adjacent to mouth of Hutchinson Ck and a 100-acre parcel at RM 4.5 within Hutchinson Creek (G. Scott, pers. comm.). This tributary was historically productive habitat for salmon (Williams 1975), and is currently productive habitat for pink, coho, and chum salmon, and steelhead (G. Dunphy, pers. comm.). It appears that populations of coho, pink, and chum salmon are not crashing (WDFW spawner database). The tributary is of high relative habitat quality (D. Griggs, pers. comm..; G. Scott, pers. comm.).

Skookum Creek (South Fork)

The headwaters originate from the west slope of Twin Sisters Mountain (Mt. Baker-Snoqualmie National Forest), and the stream meets the South Fork of the Nooksack at RM 14.3. Ownership is Mt. Baker-Snoqualmie National Forest in highest elevations, Washington State DNR land in mid-elevations, and private land near confluence with South Fork. Stocking of South Fork chinook by the Skookum Hatchery (Lummi Nation) was discontinued in 1993 due to declining returns (Marshall et al. 1995). Skookum Creek provides important spawning habitat for salmonids (G. Dunphy pers. comm.; G. Scott, pers. comm.). The Arlecho Creek watershed (see below) contains important old-growth forest and provides high-quality water to Skookum Creek and the South Fork of the Nooksack River. Hatchery influences (excluding chinook) from Skookum hatchery may limit the value of this stream as a conservation reserve.

Canyon Creek (Middle Fork)

Canyon Creek flows west into the Middle Fork of the Nooksack River at RM 1, near the community of Kulshan. Canyon Lake occurs at RM 3.5-4. Ownerships Washington State DNR, County Parks, Western Washington University (protected land with a conservation easement through the Whatcom Lake Trust for areas above Canyon Lake), and private land. There was strong historical use by chinook, pink, chum, and coho salmon (Williams 1975). The area is currently occupied by populations of chinook, pink, and chum salmon that are apparently not declining (WDFW spawner database). Forestry-related impacts occur, but do not dominate landscape condition. A conservation easement in the headwaters offers habitat security (G. Scott pers. comm.).

Three forks confluence (RM 37-42, 0-1)

The North Fork, South Fork and Middle Fork of the Nooksack River converge within a 5-mile region east of the community of Deming. Ownership is entirely private land. The river is highly sinuous in this region and supports multiple, complex off-channel and wetland habitats (G. Scott, pers. comm.). Salmonid use of this river section is known to be extensive (D. Griggs, pers. comm.; G. Dunphy, pers. comm.). As a relatively large-volume section, this section offers important chinook spawning opportunities (G. Dunphy pers. comm.). Bald eagle and elk utilize this region extensively; eagles may depend on salmon from this area (G. Scott, pers. comm.). WDFW spawner count surveys suggest generally stable or increasing populations in this region (WDFW Spawner database).

Thompson Creek (North Fork)

Thompson Creek flows northward from Mount Baker for 5 miles and meets Glacier Creek, a tributary to the North Fork of the Nooksack River, just east of the community of Glacier. The majority of this watershed is administered by the Mt. Baker-Snoqualmie National Forest. The uppermost headwaters are protected within the Mount Baker Wilderness Area. One relatively small section of private land occurs as a narrow swath bordering the stream from RM 1-2. Historically, this area was very important for pink salmon spawning (Williams 1975) Pink salmon use of this region remains prolific (WDFW Spawner database). Salmonid habitat generally intact in this region, although logging has impacted habitat quality (G. Dunphy pers. comm.).

South Fork (RM Acme to RM31) mainstem

This mainstem section extends from natural anadromous barrier at RM 31 downstream to the town of Acme (N. Currents pers. comm.). Ownership of the South Fork is divided between private landowners and the State of Washington DNR. This mainstem was historically important for chinook, pink, chum, and coho salmon and steelhead (Williams 1975). These mainstem sections provide important opportunities for chinook spawning (D. Griggs pers. comm.; Bishop and Morgan 1996) and refugia for YOY coho migrations (T. Beechie pers. comm.). Each of these sections currently supports the historical complement of species and does not show evidence of drastic population declines (WDFW Spawner database). The Whatcom Land Trust has targeted the South

Fork of the Nooksack River between the communities of Acme and Saxon (RM 9-13) for salmon conservation and currently administers 4.5 miles of the right bank in this region (G. Scott, pers. comm.)

POSSIBLE REFUGIA (CATEGORY 3)

Chuckanut Creek (independent)

This independent stream is located south of Bellingham and flows for a distance of 6 miles from Lookout Mountain to Chuckanut Bay. This stream system supports relatively robust chum salmon stock (WDFW Spawner database) and may support extensive coho salmon use (Williams 1975). The stream system faces direct impacts from roads (i.e. U.S. Interstate 5), land use practices (including agriculture and golf courses), as well as increasing pressures for development in low-gradient areas as Bellingham expands.

Dakota Creek (independent)

Dakota Creek is the northernmost independent stream in this basin, meeting Drayton Harbor just south of the community of Blaine. This stream consists primarily of low-gradient pool-riffle habitat. Historically, this stream supported a unique run of spring coho (Williams 1975). Currently, this stream system supports a productive, wild coho stock (WDFW Spawner database) and may support chum salmon production in the upper reaches of each tributary (G. Scott pers. comm.). This watershed faces increasing pressures for industrial and agricultural development.

Middle Fork (RM 1-7) and North Fork (RM 42-65) mainstems, and South Fork mainstem from confluence to Acme

These mainstems sections extend from anadromous barriers downstream to their connections with the Nooksack River. Barriers on the North Fork are natural; the Middle Fork barrier (RM 7) is caused by a diversion dam to provide a municipal water source for the city of Bellingham. Ownership of the Middle Fork and lower South Fork are divided between private landowners and the State of Washington. The North Fork also shows this pattern, but includes national forest land (Mt. Baker-Snoqualmie National Forest) within approximately 7 miles of the falls at RM 65. Each of these mainstems was historically important for chinook, pink, chum, and coho salmon and steelhead (Williams 1975). These mainstem sections provide important opportunities for chinook spawning (D. Griggs pers. comm.; Bishop and Morgan 1996) and refugia for young-of-the-year coho migrations (T. Beechie pers. comm.). Each of these sections currently supports the historical complement of species and does not show evidence of drastic population declines (WDFW Spawner database). The City of Bellingham is currently considering a proposal to allow fish passage around its diversion dam on the Middle Fork. Opening the Middle Fork to its original level of access for salmonids would significantly increase habitat availability in the region (G. Dunphy pers. comm.; G. Scott pers. comm., N. Currents pers. comm.).

Kendall Creek, Maple Creek (RM 0-1), Boulder Creek (North Fork)

These streams flow generally southward into the North Fork of the Nooksack River between RM 50-53. The majority of these watersheds are under private ownership, although portions of state-owned land occur in each. Crown Pacific Timber Company is the largest private landowner in these areas, with concentrated holdings in the upper Boulder Creek watershed. Kendall Creek shows generally stable runs of pink salmon (WDFW Spawner database). Below Maple Falls at RM 1, Maple Creek supports important chinook habitat (G. Scott pers. comm.) and use (WDFW Spawner database). Although it has been extensively logged, Boulder Creek contains potentially important salmonid habitat (G. Scott pers. comm.) and has served as a refuge for pink salmon during mainstem flood/aggradation events (G. Dunphy pers. comm.). Kendall Creek has been severely impacted by agricultural development, limestone mining, and golf course development; Boulder Creek has been significantly degraded by logging on private and state lands. The impacts of the Nooksack Hatchery (near the headwaters of Kendall Creek) are uncertain.

Cornell Creek, Gallop Creek, Deadhorse Creek (North Fork)

These streams flow north to the North Fork of the Nooksack River from headwaters along the northern foothills of Mount Baker. Cornell and Gallop Creeks enter the North Fork near the community of Glacier (RM 57); Deadhorse Creek enters further upriver at RM 63. Cornell and Gallop watersheds are almost entirely privately owned. The Deadhorse Creek watershed is administered by the Mt. Baker-Snoqualmie National Forest, with upper half of the watershed protected within the Mount Baker Wilderness Area. Each of these streams historically provided important pink salmon spawning habitat (Williams 1975) and maintains robust populations currently (WDFW Spawner database).

CRITICAL CONTRIBUTING AREAS (CATEGORY 4)

Arlecho Creek (Tributary to Skookum Creek, South Fork)

Arlecho Creek flows northward from Bald Mountain and meets Skookum Creek (see above) near RM 4. It is inaccessible to salmon under most conditions (Williams 1975). A considerable tract of old-growth forest remains in this watershed. The Lummi Nation is currently attempting to purchase this land to provide a secure, high-quality water source for the Skookum Hatchery downstream (G. Dunphy pers. comm.).

North Fork mainstem (RM 65-headwaters)

This region includes all watersheds from Nooksack Falls (a barrier to anadromous salmonids) at RM 65 to the headwaters of the North Fork. The Mt. Baker-Snoqualmie National Forest administers the majority of this region, and the upper headwaters protected within the North Cascades National Park. Some privately owned lands occur along the mainstem. Although access to anadromous salmonids is completely blocked, this region produces high-quality water (USFS 1995, Watershed Analysis: North Fork Nooksack River). Due to ecological and political limitations, historical levels of timber harvest will not be repeated in this section of the Mt. Baker-Snoqualmie National Forest (USFS 1995, Watershed Analysis: North Fork Nooksack River).

POTENTIAL REFUGIA ABOVE ARTIFICIAL BARRIERS (CATEGORY 5)

Middle Fork Nooksack River mainstem above City of Bellingham Diversion Dam

The City of Bellingham is currently considering restoration of anadromous fish passage around this structure, potentially allowing present populations of chinook salmon, summer steelhead, and possibly pink salmon to colonize high-quality habitat areas upstream (J. Doyle, pers. comm.; N. Currents, pers. comm.). Despite impacts from past logging, the area is presently protected as a Late-Successional Old-Growth Reserve on national forest land, and state DNR lands in this area gain protection as critical spotted owl habitat in the DNR's habitat conservation plan (N. Currents pers. comm.).

TABLE 2. NOOKSACK RIVER BASIN AND NEARBY INDEPENDENT STREAMS AND STREAM SEGMENTS CLASSIFIED IN ONE OF THE REFUGIA CATEGORIES.

STREAM OR SEGMENT NAME	CATEGORY[A]	ALTERATION CLASS[B]	SOURCE TYPES[C]
Independent DRAINAGES			
Dakota Creek	3	AI	PS
Chuckanut Creek	3	AHI	PS
SOUTH FORK Nooksack River			
South Fork mainstem (RM 0-25)	3	AFHI	PRS
Hutchinson Creek	2	F	PRS
Skookum Creek	2,4	FH	PR
Arlecho Creek	4	F	P
NORTH FORK NOOKSACK RIVER			
Middle Fork mainstem (RM 0-7)	3	DFI	PRS
Canyon Creek	2	F	PRS
Middle Fork mainstem above City of Bellingham Diversion Dam	5	DF	P
Three forks confluence (RM 37-42, 0-1)	2	F	PRS
North Fork mainstem (RM 42-65)	3	F	PRS
North Fork mainstem (RM 65-headwaters)	4	F	PR
South Fork Mainstem, Acme to RM 31	2	F	P
Kendall Creek	3	F	S
Maple Creek (below bridge)	3	FI	PS
Boulder Creek	3	F	PRS
Cornell Creek	3	F	S
Gallup Creek	3	F	S
Thompson Creek	2	F	PRS
Deadhorse Creek	3	F	PS

[A]Stream categories: 1 = areas with high ecological integrity; 2 = anadromous salmonid refugia but with impaired integrity; 3 = possible refugia but more data are needed; 4 = critical contributing area; 5 = areas with exceptional habitat that is currently inaccessible to anadromous fishes due to an artificial barrier such as a dam or hatchery rack

[B]Categories of alterations: A = Agricultural/rural residential (often including diking); D = Dam influenced, either by passage issues downstream or flow issues from upstream (including diversions); F = Forestry; H = hatchery; I = Industrial or urbanized; E = Exotic invasive species; N = Not managed; O = Other; P = Planned development (e.g. platted subdivision); U = unknown

[C]Types of information sources that provide support for the category designations include: P = personal communications; R = reports or articles; S = WDFW spawner database; D = other data sets; O = other

SKAGIT RIVER BASIN AND INDEPENDENT DRAINAGES

OVERVIEW

As the largest and most productive basin within the Puget Sound area (Williams et al. 1975), the Skagit River system offers some of the best opportunities for preservation of wild salmonid populations. From its headwaters in Canada to its mouth in Samish Bay, the Skagit River stretches for more than 160 miles; 96 miles of the mainstem (upstream to the Gorge Dam) and thousands of miles of tributaries are utilized by salmon for spawning, rearing, and/or migration habitats in this basin (WDF et al. 1993). Major tributaries to the Skagit River include the Sauk, Suiattle, White Chuck, Baker, and Cascade rivers as well as Nookchamps, Day, Finney, Jackman, Illabot, Diobsud, Bacon, and Newhalem creeks. In addition, the Samish River is a large independent river that supports relatively large salmon runs.

Elevations within this region range from sea level to Mount Baker (3,275 meters) and Glacier Peak (3,213 meters). Although glaciers influence several rivers in this region, the Suiattle River (a tributary to the Sauk River) is most visibly affected by glacial melt and glacial flour (B. Carey, pers. comm.). Additionally, flow volume also depends on rainfall, which has ranged from about 90 centimeters per year in low elevation floodplains to more than 460 centimeters per year in the highest elevations (Beamer and Morgan 1996).

In the higher elevations to the north and south of the Skagit River, the principal landowners are the US Forest Service (MBSNF, including the Ross Lake National Recreation Area, Glacier Peak Wilderness Area, and the Noisy Diobsud Wilderness Area) and the National Park Service (North Cascades National Park). In the lower elevations, approximately 19 percent of the basin is owned privately or by the State of Washington (Beamer and Morgan 1996). Accordingly, the dominant land use practices of the basin, forestry and agriculture, are limited not only by the topography but also by the ownership of the land.

Major limiting factors for salmon production in the Skagit include spawning habitat degradation from logging practices (MBSNF 1996c), hydroelectric dams (Hayman, 1996 cited in Puget Sound Salmon Stock Review Group 1997), low flows (WDF et al. 1993), and estuary habitat losses (Puget Sound Salmon Stock Review Group 1997). In the lower elevation areas, many important side-channel rearing habitats have been lost or degraded due to irrigation diversions, floodplain development, and bank armoring in the lower elevation river segments and tidal marsh areas of the basin (T. Beechie pers. comm.). Beechie et al. (1994) estimated a 54 percent loss of side-channel habitats in the lower Skagit River basin. Moreover, from the mouth of the Skagit River to the city of Burlington (RM 18), the riverbanks have been almost entirely diked and armored (B. Carey and T. Beechie, pers. comm.), thus eliminating natural patterns of river movement and habitat complexity in this segment.

FISH

The Skagit River system is the only basin in the Puget Sound region that supports natural production of all five species of Pacific salmon and anadromous trout (MBSNF 1996c). Moreover, the Skagit basin produces larger populations of each species than any other river basin in the Puget

Sound region (Williams et al. 1975). With the exception of "depressed" stocks of coho in the Skagit River and summer chinook in the Suiattle River, most salmon stocks were categorized as "healthy" by the SASSI report (WDF et al. 1993). Moreover, all salmon stocks were considered wild in origin and only the Skagit River coho stock is partially maintained by hatchery out-plants (WDF et al. 1993). Specifically, Huntington et al. (1996) recognized the Skagit River pink stock as a healthy and wild stock with near historical levels of abundance.

Sockeye salmon constitute a notable exception to this trend of native, wild, and healthy stocks in the Skagit River system. With the construction of the Lower Baker Dam in 1927 and the Upper Baker Dam in 1959, natural runs of sockeye were decimated. Kemmerich (1945, cited in Gustafson et al. 1997) reported that during the first year of the Lower Baker Dam, only 40 of the estimated 8,000 to 10,000 sockeye that were moved above the dam reached their lake spawning habitat. Currently, a trap and haul facility just above the mouth of the Baker River moves sockeye above the dam on an annual basis (Doyle 1999a).

Because most of the Baker River watershed is contained within the North Cascades National Park and the Noisy-Diobsud Wilderness Area, much of this land is in a pristine condition and serves as refugia for resident, native char (Doyle 1999a). The SASSI report's appendix on bull trout/Dolly Varden (WDFW 1998) recognized the Baker River char as one stock with wild production but an "unknown" status.

The Sauk River watershed (and associated tributaries) supports several robust stocks of salmon and trout. Huntington et al. (1996) characterized the Sauk River stocks of chum salmon and winter steelhead as native and wild stocks with current abundances at two-thirds the level expected in the absence of anthropogenic impacts. In particular, the Sauk River mainstem from the Sauk Prairie area near Darrington downstream to the mouth of the Suiattle River provides excellent multiple channel habitat (T. Beechie pers. comm.). Reflecting their relatively natural state, the Sauk and Suiattle rivers are designated as Wild and Scenic rivers as well as FEMAT key watersheds within national forest jurisdiction (FEMAT 1993).

AREAS RECOMMENDED FOR WITHIN-BASIN REFUGIA DESIGNATION

The rationale for the selection of refugia was to defer to the recommendations of Eric Beamer and Tim Beechie regarding integration of the results of the Skagit Watershed Council's strategy document, River Basin Analysis of the Skagit and Samish Basins: Tools for Salmon Habitat Restoration and Protection (Beamer et al. 1999). This approach is a comprehensive, habitat-based assessment using various overlaid GIS themes. The Skagit River system and its tributaries were mapped according to their relative scores for several integrated ecological indicators. We simply interpreted these scores relative to our criteria for salmon refuge classification. We found our criteria to be quite compatible with Beamer et al's methodology. However we suggest there may be additional useful information (e.g. helpful to validate habitat-based models) in existing biological information on fish population abundance and status. Because of the large volume of such data available for the Skagit, we were unable to complete such analyses ourselves, and thus largely deferred to the results for the Beamer et al. studies.

In this section we do not provide detailed descriptions of the selected priority areas. Information is available from various sources at the Skagit Watershed Council. Areas are briefly described below.

Critical contributing areas are extensive and are not itemized, but are described geographically for each refuge area.

REFUGIA - ECOLOGICAL INTEGRITY INTACT (CATEGORY 1)

Pressentine Creek (lower reach). Critical contributing (CCA) area comprises the whole Pressentine Creek basin.

Bacon Creek. CCA is Bacon Creek basin.

Goodell Creek. CCA is Goodell Creek basin.

Cascade River, Middle Fork to Marble Creek. CCA is contributing drainage area above Marble Cr.

Jordan Creek. CCA is Jordan Creek basin.

Illabot Creek. CCA is Illabot Creek basin.

White Chuck River, Pumice Creek to mouth. CCA is contributing drainage area, i.e. White Chuck River Basin.

Middle Suiattle River, Buck Creek to Tenas Creek. CCA is entire Suiattle River drainage above Tenas Cr.

Upper Suiattle River, Dolly Creek to 1.5 miles below Downey Creek. CCA is entire Suiattle River drainage above and including Downey Creek.

REFUGIA - ALTERED (CATEGORY 2)

Park Creek (Baker Lake). Critical contributing area is the whole Park Creek basin. Impaired by partial blockage and inundation by Baker Lake.

Swift Creek and Moronitz Creek (Baker Lake). CCA is Menonitz Creek, Rainbow Creek, and Swift Creek and Shuksan Creek basins. Impaired by partial blockage and inundation by Baker Lake.

Upper Baker River to Mineral Creek. CCA is Baker River above Baker Lake. Impaired by partial blockage and inundation by Baker Lake.

Mainstem Skagit River, Goodell Creek to Damnation Creek. CCA includes tributaries directly adjoining this segment.

Mainstem Skagit River, Jordan Creek to Sauk River confluence. CCA includes tributaries directly adjoining this segment.

Sauk River at Sauk Prairie, Darrington to Suiattle River confluence. CCA includes tributaries directly adjoining this segment and headwaters of the Sauk River.

Upper Sauk River, North Fork Sauk to White Chuck River. CCA includes tributaries directly adjoining this segment and contributing headwaters of the White Chuck River.

POTENTIAL REFUGIA ABOVE ARTIFICIAL BARRIERS (CATEGORY 5)

None were identified. Partial passage is provided to native stocks at Baker Lake. Beamer and Beechie (memo, January 6, 2000) state that the existing dam blockage on the mainstem Skagit is at or upstream of the historical barrier to anadromous fish migration. However, it appears that such an important conclusion should be substantiated with more or better-documented evidence than presently appears to be available.

TABLE 3. SKAGIT RIVER BASIN STREAMS AND STREAM SEGMENTS CLASSIFIED IN ONE OF THE REFUGIA CATEGORIES.

STREAM OR SEGMENT NAME	CATEGORY[A]	ALTERATION CLASS[B]	SOURCE TYPES[C]
BAKER RIVER			
Park Creek (Baker Lake)	2	D,N	R
Swift Creek and Moronitz Creek (Baker Lake)	2	D,N	R
Upper Baker River to Mineral Creek	2	D,N	R
UPPER MAINSTEM SKAGIT RIVER			
Bacon Creek	1	F,H	R
Goodell Creek	1	F,H	R
Cascade River, Middle Fork to Marble Creek	1	F,H	R
Jordan Creek	1	F	R
Illabot Creek	1	F	R
Mainstem Skagit River, Goodell Cr to Damnation Cr	2	F,H,D	R
Mainstem Skagit River, Jordan Cr to Sauk R	2	F,H,D	R
SAUK RIVER			
Sauk River at Sauk Prairie, Darrington to Suiattle R.	2	F,H	R
Upper Sauk River, North Fork Sauk to White Chuck R.	2	F,H	R
White Chuck River, Pumice Creek to Mouth	2	F,H	R
Middle Suiattle River, Buck Cr to Tenas Cr	1	F, H?	R
Upper Suiattle River, Dolly Cr to 1.5 miles below Downey Cr.	1	F, H?	R
NOTE: Each of above refugia is associated with a Critical Contributing Area as described in text above.			

[A]Stream categories: 1 = areas with high ecological integrity; 2 = anadromous salmonid refugia but with impaired integrity; 3 = possible refugia but more data are needed; 4 = critical contributing area; 5 = areas with exceptional habitat that is currently inaccessible to anadromous fishes due to an artificial barrier such as a dam or hatchery rack

[B]Categories of alterations: A = Agricultural/rural residential (often including diking); D = Dam influenced, either by passage issues downstream or flow issues from upstream (including diversions); F = Forestry; H = hatchery; I = Industrial or urbanized; E = Exotic invasive species; N = Not managed; O = Other; P = Planned development (e.g. platted subdivision); U = unknown

[C]Types of information sources that provide support for the category designations include: P = personal communications; R = reports or articles; S = WDFW spawner database; D = other data sets; O = other

WHIDBEY-CAMANO AND SAN JUAN ISLANDS

OVERVIEW

This region includes more than 470 islands within Water Resources Inventory Areas 2 and 6 (Williams et al. 1975). According to historical records, coho and chum salmon have been observed in the freshwater streams of larger islands, including Whidbey, Camano, San Juan, and Orcas islands (Williams et al. 1975). However, spawner count surveys are not currently implemented in these islands by the Washington Department of Fish and Wildlife (J. O'Connor pers. comm.). Additionally, because many of these streams are intermittent and limited by low flows (Williams et al. 1975), in the past the WDFW has not pursued fisheries management or restoration activities in these islands (K. Bauersfeld, pers. comm.).

AREAS RECOMMENDED FOR WITHIN-BASIN REFUGIA DESIGNATION AND JUSTIFICATIONS

POSSIBLE REFUGIA (CATEGORY 3)

Unnamed Stream (WDFW Stream Catalogue #020027), San Juan Island

This low-gradient stream flows southeast for 7 miles, meeting the Puget Sound near False Bay on the south side of San Juan Island. This stream is influenced by a small lake near Cady Mountain, which may mitigate chronic low flow problems found within this region. Coho and chum use has been observed within this stream network (Williams 1975). However, the productivity or stability of this stream is unknown. As with all streams within the region, this stream network is subject to low flow stress. Site inspection and surveying efforts would be essential before any major conservation effort was undertaken in this watershed.

TABLE 4. STREAMS AND STREAM SEGMENTS IN THE ISLAND WRIA CLASSIFIED IN ONE OF THE REFUGIA CATEGORIES.

STREAM OR SEGMENT NAME	CATEGORY[A]	ALTERATION CLASS[B]	SOURCE TYPES[C]
Unnamed Stream (020027), San Juan Island	3	A	R

[A]Stream categories: 1 = areas with high ecological integrity; 2 = anadromous salmonid refugia but with impaired integrity; 3 = possible refugia but more data are needed; 4 = critical contributing area; 5 = areas with exceptional habitat that is currently inaccessible to anadromous fishes due to an artificial barrier such as a dam or hatchery rack

[B]Categories of alterations: A = Agricultural/rural residential (often including diking); D = Dam influenced, either by passage issues downstream or flow issues from upstream (including diversions); F = Forestry; H = hatchery; I = Industrial or urbanized; E = Exotic invasive species; N = Not managed; O = Other; P = Planned development (e.g. platted subdivision); U = unknown

[C]Types of information sources that provide support for the category designations include: P = personal communications; R = reports or articles; S = WDFW spawner database; D = other data sets; O = other

STILLAGUAMISH RIVER BASIN - WRIA 5

OVERVIEW

The Stillaguamish River has a watershed area of 1,774 km^2, the fifth largest in Puget Sound. Nevertheless, between 1956 and 1965, the Stillaguamish contributed an estimated 20 percent of the total anadromous fish production from the seven largest basins in the region (MBSNF 1996d). Only the Skagit produced a larger percentage of the total anadromous fish.

The North and South fork drainages of the Stillaguamish include the majority of area and stream kilometers in the basin. The mainstem is about 29 km long, whereas the North and South Forks are about 78 and 84 km long, respectively. However, waterfalls prevented fish from accessing much of that habitat historically. Granite Falls limited anadromous fish to the lower 26.5 km of the South Fork, and a waterfall on the North Fork blocks access to the uppermost 18 km of river. In 1954, a fish ladder was built to provide anadromous fish access over Granite Falls and into the upper South Fork (Williams et al. 1975). A small trap-and-haul operation is also used to transport some fish beyond the falls and Robe Canyon (WDFW and WWTIT 1994a). Because of the lack of historical access, we considered areas in the upper South Fork candidates for "critical contributing areas" but not for anadromous fish refugia (see report Introduction).

The absence of large dams in the basin is unique among the larger basins in Puget Sound. Within the anadromous zone, land use adjacent to streams is 60 percent forestry, 22 percent rural residential, 15 percent agriculture and 2 percent urban (Pess et al. 1999). The North Fork, South Fork and Deer Creek are designated FEMAT key watersheds within National Forest boundaries (FEMAT 1993).

IMPAIRMENT OF ECOLOGICAL INTEGRITY

Within the Stillaguamish watershed, the vast majority of the habitat has been impacted, at some level, by human activities (WCC 1999). Anadromous fish habitat in the upper watershed is degraded largely as a result of logging and road building activities on inherently erodible rock and alluvial deposits (Perkins and Collins 1997; WCC 1999). By the early 1940s, riparian forests along nearly the entire anadromous channel network had been logged (Collins 1997). Approximately 11 percent of the riparian forests are presently "intact", with a best-case-scenario estimate of 41 percent of the historic riparian forest area that could be fully functional to provide large woody debris 100 years from now (Pollock 1998). The vast majority of intact riparian forests in the basin are on federally managed land: 39 percent of the riparian forests on federal land are intact compared to fewer than 1 percent on non-federal lands (Pollock 1998). Massive, deep-seated landslides have occurred in both the North Fork (in the mainstem near Hazel (RM 20.4) and in Deer Creek near DeForest Creek) and the South Fork (in the Gold Basin area). The DeForest Creek slide alone doubled sediment loads in the entire Stillaguamish River basin. Turbidity levels are elevated in all seasons as a result of large, deep-seated landslides (Collins 1997). The Deer Creek slide is becoming less active (pers. comm. G. Pess). Numerous smaller slides (1,080 slides in 50 years, Perkins and Collins 1997) cumulatively contribute large amounts of sediment directly to the creeks and rivers in the upper watershed (Williams et al. 1975; WDFW and WWTIT 1994a; Pess et al. 1999). Annual peak flows in the North Fork, but not the South Fork, of the Stillaguamish have increased significantly over the period of record beginning in 1929 (Collins 1997). Ten of the 11 largest peak flows on record in the North Fork occurred between 1980 and 1995 (Collins 1997).

Lower in the watershed, other land uses, including agriculture, suburban development, and gravel mining, have degraded habitat via changing channel morphology and floodplain connectivity (e.g. diking), removal of riparian vegetation, reduction of stream flows, and nutrient and toxin loadings to streams. Also within the anadromous zone, more than 80 percent of beaver pond habitat has been lost, and 78 percent of historic wetlands have been lost or degraded, leaving 2,537 ha of wetlands in the basin (Pollock and Pess 1998; WCC 1999). Side channel and tributary sloughs have been reduced by about 59 percent and 81 percent, respectively (Pess et al. 1999). More than 85 percent of the salt marsh in the river delta has been reclaimed for agriculture (Collins 1997). Collins (1997) and Pollock and Pess (1998b) provide extensive discussions of habitat losses in the basin. As in most Puget Sound basins, the estuary has been drastically altered. Approximately 90 percent of the lower estuary and associated wetlands have been extensively diked and converted to agricultural lands (WDFW and WWTIT 1994a). Non-native cordgrasses (*Spartina* spp.) are invading the estuary and can cause dramatic and relatively rapid estuarine habitat changes (WCC 1999). However, nearshore habitats are in relatively good condition when compared to urbanized nearshore areas (WCC 1999), and programs to control the cordgrass invasions are underway.

FISH

The Stillaguamish River basin contains summer and fall chinook, fall chum, coho, and odd-year pink salmon, summer and winter steelhead, anadromous cutthroat trout, anadromous char, and small numbers of riverine sockeye salmon (WDF et al. 1993; MBSNF 1996d; WDFW 1998). Native chum and pink salmon were tentatively categorized into separate North Fork and South Fork stocks (WDF et al. 1993), all of which were classified as "healthy" by Huntington et al (1996). However, body sizes of adult pink salmon have been declining, which could reduce population growth rates (MBSNF 1996d). WDF defined one stock for all winter steelhead in the basin, but Huntington et al (1996) considered two winter steelhead stocks, Stillaguamish River winter steelhead and Pilchuck River steelhead, "healthy.". Natural winter steelhead escapement averages about 1,200 fish (Busby and six others 1996).

Other native stocks in the basin have not fared as well. Native Stillaguamish spring chinook are thought to be extinct (Nehlsen et al. 1991). Native Stillaguamish summer chinook, which spawn primarily in September in the North Fork Stillaguamish River, were considered "depressed" in SASSI (WDFW and WWTIT 1994). Native Stillaguamish fall chinook spawn primarily in the mainstem and South Fork Stillaguamish River in October and are also considered depressed (WDFW and WWTIT 1994). Deer Creek contains native stocks of coho salmon and summer steelhead whose status ratings according to the SASSI report were unknown and critical, respectively (WDF et al. 1993). The Deer Creek coho are one of only three coho stocks in Puget Sound listed as "native" in origin in the SASSI report. Although little data were available, limited sampling suggested that the Deer Creek coho stock may be "extremely depressed or nonexistent" (WDFW and WWTIT 1994a). The population size of Deer Creek summer steelhead may always have been small, and the drainage has been closed to harvest of wild, summer steelhead since the 1930s (WDFW and WWTIT 1994a). In the early 1990s the summer steelhead were considered to be at a "high risk of extinction" (Nehlsen et al. 1991). However, WDFW has data demonstrating a recent increasing trend for summer steelhead (pers. comm. J. Doyle). Deer Creek is also the only large drainage in the basin where native char are thought to be declining (WDFW 1998).

Small numbers of even-year pink salmon spawn in the basin (WCC 1999), but the origin of these fish is unknown. As in most large Puget Sound streams, a small riverine population of sockeye salmon consistently spawn and produce smolts in the Stillaguamish basin, but little is known about them (WCC 1999). They are not closely genetically related to the nearest lake spawning sockeye salmon populations (pers. comm. with D. Hendrick cited in WCC 1999).

HATCHERY INFLUENCES

The only stock described in the SASSI report as non-native was South Fork Stillaguamish summer steelhead (WDF et al. 1993). Skamania hatchery summer steelhead are planted over native summer steelhead stocks (Crawford 1979 cited in Busby and six others 1996). Canyon Creek summer steelhead are of mixed hatchery and native origin (WDF et al. 1993). Phelps et al. (1994, cited in Busby et al. 1996) concluded, based on genetic data, that Deer Creek, North Fork Stillaguamish, and Wind River steelhead had limited hatchery introgression, but Busby et al. (1996) suggest the conclusion be regarded as tentative (pp. 37-38).

The origin of Stillaguamish fall chinook is unknown (WDF et al. 1993). Although Stillaguamish summer chinook are considered a native stock, production of North Fork Stillaguamish summer chinook stock is supplemented with native hatchery stock (WDF et al. 1993; Marshall et al. 1995). Broodstock are taken from the spawning grounds (WDFW and WWTIT 1994a), and fingerling chinook are released from Whitehorse ponds at RM 27.8 in the North Fork (Marshall et al. 1995).

Stillaguamish coho are also of mixed origin (WDF et al. 1993). However, hatchery stocking of coho salmon is much less intensive in the northern Puget Sound area than in the southern Puget Sound area (see "hatchery influences" section in the Snohomish basin overview) (Weitkamp 1995). Although hatchery cutthroat trout were stocked prior to 1985, they probably had little influence on wild populations (Johnson et al. 1999). The SASSI report indicates that WDFW continued to release hatchery "trout" in the North Fork (WDFW and WWTIT 1994a).

AREAS RECOMMENDED FOR WITHIN-BASIN REFUGIA DESIGNATION AND JUSTIFICATIONS:

REFUGIA - ECOLOGICAL INTEGRITY INTACT (CATEGORY 1)

NORTH FORK STILLAGUAMISH:

Squire Creek

Squire Creek provides important spawning habitat for nearly all of the anadromous species in the North Fork. Since 1984, Squire and Fortson creeks have produced more than 50 percent of the coho escapement in the basin (WCC 1999). It is an important spawning tributary for chum and pink salmon, and winter steelhead trout (WCC 1999; WDFW 1999). Chinook spawn in the mainstem of Squire Creek, whereas pink, chum, and coho salmon spawn more in the tributaries (Williams et al. 1975). Even small numbers of sockeye salmon consistently spawn in the stream (WCC 1999). Bull trout also occur in the creek (WCC 1999).

As of the mid-1970s, little development had occurred in the drainage (Williams et al. 1975). In the lower 2 miles of Squire Creek and the lower ends of the tributaries, Ashton and Furland creeks, farms were scattered and some bank protection projects were in place or proposed (Williams et al. 1975). Forestry is the dominant land use in the sub-basin (Pess et al. 1999). The upper half of the drainage is in a very steep-walled valley. Upstream of Buckeye Creek, the stream is bordered on the west by the Boulder River Wilderness. The wilderness also incorporates much of the east side of the upper drainage, but does not border the stream. The headwaters of all four major tributaries are in the wilderness as well. The creek was among streams with the most intact riparian forest within the anadromous zone of the Stillaguamish River basin (Pollock and Pess 1998a) and ranked in the upper third of sub-basins for the estimated area of beaver ponds in 1991 (Pollock and Pess 1998). Of 517 landslides documented in the North Fork Stillaguamish drainage, 19 occurred in the Squire Creek sub-basin (Perkins and Collins 1997).

Boulder River

Boulder River is accessible to anadromous fish for the lower 2.9 miles, below a barrier falls. Below the falls is an important spawning area for pink salmon and winter steelhead trout and is also used by spawning coho, chum, summer/fall chinook, and sockeye salmon and char (Williams et al. 1975; WDFW and WWTIT 1994a; WCC 1999). Some spring chinook may also use the system (Williams et al. 1975). Summer steelhead rear in the river and anadromous cutthroat are presumed to rear there (WCC 1999). Bull trout occur in the drainage, but it is not clear from the report whether they spawn below the falls (WCC 1999).

As of the mid 1970s, development was virtually non-existent in the drainage, but some bank protection and channelization existed in the lower 0.5 miles of stream (Williams et al. 1975). The dominant land use is forestry (Pess et al. 1999). The drainage was assigned a Tier II ranking in the WCC's list of "best functioning habitats in need of protection" (WCC 1999). The Boulder Ridge sub-basin ranked tenth out of 27 sub-basins for the estimated area of beaver ponds as of 1991 (Pollock and Pess 1998) and received a middle ranking for current fish production (WCC 1999). The creek was included in a list of relatively large drainages with highest proportions of intact or recovering riparian forests in the basin (Pollock 1998). The Boulder Ridge sub-basin contained 31 of 517 landslides documented in the North Fork Stillaguamish River drainage (Perkins and Collins 1997).

REFUGIA - ALTERED (CATEGORY 2)

STILLAGUAMISH:

Pilchuck Creek below falls

The lower 6 or 7 miles of Pilchuck Creek is one of the basin's major spawning areas for most of the anadromous salmonids in the basin (Williams et al. 1975). Chinook, coho, pink and sockeye salmon spawn in lower Pilchuck Creek, and spawning of chum salmon and anadromous cutthroat trout is presumed (WCC 1999). In addition, char are presumed to use the lower creek for rearing (WCC 1999). Pilchuck Creek is one of three areas where South Fork Stillaguamish pink salmon spawning is concentrated (WDFW and WWTIT 1994a). Native South Fork pink salmon spawn in the lower six miles, and Stillaguamish winter steelhead spawn up to the barrier falls (WDFW and WWTIT 1994a).

Pilchuck Creek was rated in the first tier of streams with the best functioning habitat in the basin that was in need of protection (WCC 1999). Upper Pilchuck Creek was included in a list of relatively large sub-basins that contained the best riparian conditions in the Stillaguamish basin (Pollock 1998). Agriculture is the dominant land use in the Pilchuck Creek sub-basin (Pess et al. 1999). Extensive logging had occurred in the watershed and suburban development was increasing as of the mid-1970s (Williams et al. 1975).

Low summer flows frequently impede passage and cause stranding of some species in the drainage (Williams et al. 1975; WCC 1999). Pilchuck Creek experienced a slight upward trend in peak flows over the period of record (1953 to 1989), with most of the highest flows occurring in the 1970s and late 1950s (Collins 1997). Stream channelization and bank protection are a serious problem in lower Pilchuck Creek (Williams et al. 1975).

NORTH FORK:

Mainstem - town of Hazel (RM 22) to RM 35.5

The upper 7 miles of this segment includes the mainstem North Fork's major spawning concentrations of many anadromous salmonids (Williams et al. 1975). Chinook, chum, and pink salmon and winter steelhead trout are known to spawn in the segment, and sockeye salmon are presumed to spawn there (WCC 1999). Coho rear in this mainstem segment and spawn in nearly all of its tributaries (WCC 1999). Biologists presume that summer steelhead trout, anadromous cutthroat trout, and char use the segment for rearing (WCC 1999). It currently contains some of the best summer/fall chinook salmon spawning habitat in the basin (WCC 1999) and the heaviest mainstem spawning of pink and chum salmon in the North Fork sub-basin (WDFW and WWTIT 1994a). Most winter steelhead spawning in the basin occurs in the mainstems of the North and South forks (WCC 1999). The majority of pink salmon spawning occurred in the North Fork until 1987 when, due to drought conditions, more fish spawned in the South Fork. As of the mid-1990s, the South Fork still had more spawners, but the North Fork run was rebuilding (Hard et al. 1996). Stillaguamish summer chinook spawn from RM 0.0 to 34.4 in the North Fork, with most spawning occurring between RM 14.3 and 30.0 (WDFW and WWTIT 1994a; WCC 1999). A. Haas (pers. comm.) noted that spawning was even further concentrated above RM 21.

Fortson Creek and Fortson Ponds are on the floodplain south of the river between French and Moose creeks and are included in this refugia area. More than 90 percent of Fortson Creek consists of wetlands, beaver ponds, and lakes. Although very small, the creek contributes a substantial portion of the coho salmon production in the basin and is also thought to provide a refuge to coho salmon migrating from upstream (WCC 1999).

Although important spawning areas occur downstream of Hazel, the habitat has been degraded by a large landslide near Hazel and thus was not included in our refugia category.

SOUTH FORK:

Jim Creek - mouth to above Cub Creek (RM 13.0)

The lower 4 miles of Jim Creek is a primary spawning area for chinook, coho, pink, and chum salmon and winter steelhead trout (Williams et al. 1975; WDFW and WWTIT 1994a; WCC 1999). Jim Creek is one of three areas where South Fork Stillaguamish pink salmon spawning is concentrated (WDFW and WWTIT 1994a). Scattered pink salmon spawning occurs from Bear Creek up to about RM 9.0. Some sockeye salmon also spawn in the creek and anadromous cutthroat trout are presumed to spawn there (WCC 1999). A partial migration barrier downstream of Bear Creek (RM 4.3) hinders passage of some fish species, particularly during low flows. A complete barrier exists at RM 13.0.

The dominant land use in the Jim Creek sub basin is residential housing (Pess et al. 1999). Jim Creek was placed in the middle tier of streams with the best functioning habitat in the basin and in need of protection (WCC 1999). The sub-basin ranked fifth in number of beaver ponds (24), but much lower for total area of ponds in the Stillaguamish basin (Pollock and Pess 1998). It received a medium ranking for fish production (WCC 1999) and was also listed among watersheds with more than 70 percent of their riparian zone in degraded condition (Pollock 1998). The upper watershed has been extensively cleared, contributing to increases in peak flows, bed scouring, and sedimentation (Williams et al. 1975, Collins 1997). Jim Creek had a slight upward trend in peak flows over the period from 1938 to 1968 (Collins 1997). Of 306 landslides documented in the South Fork Stillaguamish River drainage, 63 occurred in the Jim Creek sub-basin (Perkins and Collins 1997).

Canyon Creek - up to, and including, Tiger Creek

Canyon Creek is used by chinook, coho, winter steelhead, anadromous cutthroat, and native char. Tiger Creek, a tributary of Canyon Creek, has more than 90 percent of its area in wetlands, beaver ponds, and lakes, and contributes a substantial proportion of the coho salmon production in the basin (WCC 1999). Anadromous cutthroat trout also use Tiger Creek (MBSNF 1996d). Canyon Creek has a falls at about RM 2.8 that was historically ascended only by chinook and coho salmon during certain flow conditions (not very high or low flows) (Williams et al. 1975). A natural barrier on the South Fork of Canyon Creek blocks passage of all anadromous fishes.

Canyon Creek was ranked in the middle tier of streams with the best functioning habitat in the basin in need of protection (WCC 1999). Although it received a low ranking for fish production, the habitat in Tiger Creek and in lower Canyon Creek is apparently still important to multiple species. Forestry is the dominant land use in the sub-basin (Pess et al. 1999). Canyon Creek was ranked among sub-basins with the most intact riparian forest (more than100 km) where anadromous fish occur (WCC 1999). In 1975, however, Williams et al. stated "a potentially serious condition exists with the logging and road building activities in the upper watershed." Habitat in the upper watershed is now severely degraded (WDFW and WWTIT 1994a), and riparian forests in the upper South Fork Canyon Creek were logged extensively (MBSNF 1996d). Of the 306 landslides documented in the South Fork Stillaguamish River drainage, 112 occurred in the Canyon Creek sub-basin (Perkins and Colllins 1997). Two large slides exist in Canyon Creek just upstream of Tiger Creek (Williams et al. 1975). "Canyon Creek is the only major sub-basin for which our data show increased rates of landsliding in the early 1990s photos," according to Perkins and Collins, 1997. Large woody debris is lacking through much of the South Fork Stillaguamish River and Canyon Creek, although the potential for wood recruitment is better in the latter than in the former (DEA 1999a). Due to 5 years of Northwest Forest Plan protection and restoration efforts, the process of recovery has begun in the upper basin (pers. comm. J. Doyle).

POSSIBLE REFUGIA (CATEGORY 3)

Mainstem North Fork Stillaguamish - mouth to RM 7

As of the mid 1970s, this segment contained excellent pools for rearing and adult holding (Williams et al. 1975). However, the Hazel Slide, a major landslide composed largely of sand and mud, entered the North Fork just downstream of Rollins Creek in 1967 (Williams et al. 1975). The large slide, in concert with numerous smaller slides and increases in peak flows, has contributed to pool filling, channel aggradation, and channel widening in the North Fork (Williams et al. 1975; Perkins and Collins 1997). Therefore, the value of this lower river segment for rearing and holding may have been seriously reduced, and even if adjacent lands are protected, impacts may continue to accrue from upstream sediment sources. According to G. Pess (pers. comm.), however, the effect of the Hazel slide is not large in all years, and chinook, chum, and pink salmon and steelhead trout still spawn immediately below the slide.

Mainstem South Fork - confluence with North Fork to Granite Falls

The segment of the South Fork that is historically accessible to anadromous fishes still receives substantial numbers of spawners. Most winter steelhead, pink, and chum salmon spawning in the basin occurs in the mainstems of the North and South forks. Chinook salmon and anadromous cutthroat trout also spawn in the South Fork below the falls. However, we found little information on the actual productivity of the South Fork for fish. Mainstem spawning of pink salmon occurs from Canyon Creek (RM 34) down into the mainstem near Silvana (RM 6)(WDFW and WWTIT 1994a). Spawning is concentrated in the South Fork between RM 19 and 30, as well as in Jim and Pilchuck creeks (WDFW and WWTIT 1994a). The majority of pink salmon spawning occurred in the North Fork until 1987 when, due to drought conditions, more fish spawned in South Fork. As of the mid-1990s, the South Fork still had more spawners, but the North Fork run was rebuilding (Hard et al. 1996). Stillaguamish fall chinook spawn throughout the mainstem Stillaguamish and the South Fork to RM 34.6 (Marshall et al. 1995).

The river lacks large woody debris (DEA 1999a) and suffers from increased sedimentation. A massive landslide occurred above the falls near Hemple Creek and contributed large amounts of fine sediment to the river (Williams et al. 1975). However, riparian forests in the lower South Fork sub-basin are recovering and were ranked among sub-basins with the best riparian conditions (WCC 1999).

POSSIBLE REFUGIA RECOMMENDED DURING THE REVIEW PERIOD BUT WITHOUT SUPPORTING JUSTIFICATION OR DOCUMENTATION (NOT MAPPED)

Deer Creek

Deer Creek is a large tributary of the North Fork Stillaguamish River. During the technical review, J. Doyle recommended adding this creek as an "altered refugia, Category 2."

CRITICAL CONTRIBUTING AREAS (CATEGORY 4)

Boulder River above falls (RM 2.9)

Most of the mainstem and tributaries above the barrier falls is in the Boulder River Wilderness. The nearly pristine habitat conditions contribute to the integrity of the important spawning segment below the falls.

CRITICAL CONTRIBUTING AREAS RECOMMENDED DURING THE REVIEW PERIOD (NOT MAPPED)

While we acknowledge that habitat in all of the areas is very important to the continued existence of downstream fish populations, the information we have does not suggest that the areas meet the "nearly pristine habitat" portion of our definition for critical contributing areas. In some cases, we may lack the appropriate, relevant documentation for the areas.

- *South Fork Stillaguamish above Granite Falls - K. Nelson and J. Doyle.*
- *Pilchuck Creek above falls - K. Nelson*
- *Canyon Creek above Tiger Creek - J. Doyle*
- *North Fork Stillaguamish River above RM 37 - J. Doyle*

K. Nelson (memo Nov. 30, 1999) also noted that the upper North Fork Stillaguamish has "significant influence on the channel downstream" and deserved mention, but also added that "the landscape has been highly altered through extensive logging and road building."

TABLE 5 . STILLAGUAMISH RIVER BASIN STREAMS AND STREAM SEGMENTS IN ONE OF THE REFUGIA CATEGORIES.

STREAM OR SEGMENT NAME	CATEGORY[A]	ALTERATION CLASS[B]	SOURCE TYPES[C]
MAIN STILLAGUAMISH			
Pilchuck Creek below falls	2	ADF	R
NORTH FORK			
Mainstem - Hazel to RM 35.5	2	AF	R
Mainstem - mouth to RM 7	3	AF	R
Boulder River - below falls	1	AF	R
Boulder River - above falls	4	F	R
Squire Creek	1	AF	R
SOUTH FORK			
Mainstem - mouth to Granite Falls	3	AF	R
Jim Creek - mouth to falls	2	F	R
Canyon Creek - up to and including Tiger Creek	2	F	R

[A]Stream categories: 1 = areas with high ecological integrity; 2 = anadromous salmonid refugia but with impaired integrity; 3 = possible refugia but more data are needed; 4 = critical contributing area; 5 = areas with exceptional habitat that is currently inaccessible to anadromous fishes due to an artificial barrier such as a dam or hatchery rack

[B]Categories of alterations: A = Agricultural/rural residential (often including diking); D = Dam influenced, either by passage issues downstream or flow issues from upstream (including diversions); F = Forestry; H = hatchery; I = Industrial or urbanized; E = Exotic invasive species; N = Not managed; O = Other; P = Planned development (e.g. platted subdivision); U = unknown

[C]Types of information sources that provide support for the category designations include: P = personal communications; R = reports or articles; S = WDFW spawner database; D = other data sets; O = other

SNOHOMISH RIVER BASIN - WRIA 7

OVERVIEW

The Snohomish River basin has a watershed area of 1,856 square miles, making it the second largest basin in the analysis area (SBSRTC 1999). The drainage consists of three main rivers: the Snohomish River and its forks, the Skykomish and the Snoqualmie Rivers. Both forks have waterfalls that prevent anadromous fishes from using large portions of the drainages. A trap and haul program on the South Fork began providing anadromous fish access above Sunset Falls in 1952. No access is provided around Snoqualmie Falls, although hatchery fish have been planted above the falls (Williams et al. 1975).

Portions of the Snoqualmie and Skykomish drainages are in the Alpine Lakes Wilderness. The headwaters of the North Fork Skykomish are in the Henry M. Jackson Wilderness. Much of the remainder of the Skykomish sub-basin has been logged, and some mining has occurred, creating water quality problems in several locations. About 30 percent of the forested MBSNF area in the forks of the Skykomish (lower North and South Forks and upper mainstem) are "late seral" stage (DEA 1999b). In the North Fork, most subwatersheds contain greater than 40 percent mature riparian vegetation (Lower Trout Creek: 58 percent, Middle North Fork: 43 percent, and upper North Fork: 80 percent mature riparian forests). The lower South Fork Skykomish River contains about 36 percent mature riparian forests (DEA 1999b). The north and south forks of the Skykomish River are designated as FEMAT key watersheds (FEMAT 1993).

IMPAIRMENT OF ECOLOGICAL INTEGRITY

Both peak and low flows, exacerbated by logging and development, contribute to habitat degradation throughout the drainage. A dam on the Sultan River creates flow regimes that are detrimental to fish (Williams et al. 1975). A dam just upstream of Snoqualmie Falls diverts water to a powerhouse less than a mile downstream, but we found no discussion of any detrimental effects of the hydropower operation on fish. Water quality problems, including temperature and dissolved oxygen (pers. comm. A. Haas) exist in the lower Snohomish River and in the estuary. Temperatures can reach lethal levels in some of the higher tributaries, as well as in the lower Snohomish River (Williams et al. 1975).

Within the forks of the Skykomish, timber harvest, associated road construction, and development associated with the BNRR (South Fork) are the largest anthropogenic disturbances contributing to habitat degradation (WDFW 1998; DEA 1999b). Several segments of the mainstem Skykomish River do not meet standards for temperature and fecal coliform. Temperature, large woody debris, and pool frequency and quality are "functioning at unacceptable risk" by Forest Service standards near the confluence of the Skykomish Forks (DEA 1999b). Unstable soils, logging and roading, and rain-on-snow events have caused channel alterations, including channel widening and riverbed aggradation, in the North Fork (MBSNF 1997; DEA 1999b). Roads in the floodplain of the North Fork have constricted the channel, leading to a loss of off-channel habitat (WDFW 1998).

The independent drainages in WRIA 7 are generally small and support limited runs of coho and chum salmon (Williams et al. 1975). Quilceda Creek is the largest independent drainage in the WRIA and still supports some anadromous fishes, principally coho, chum, and cutthroat (Nelson 1996). However, development, channelization, diking, and the removal of riparian cover have degraded habitat in the creek.

FISH

Spring and summer/fall chinook, pink, chum, and coho salmon, steelhead and anadromous cutthroat trout, and anadromous char, as well as resident salmonids, exist, or historically existed, in the basin (Williams et al. 1975; WDFW 1998). Stocks identified as "healthy" by Huntington et al. (1996) included Skykomish River chum salmon, Snohomish River odd-year pink salmon, Pilchuck River winter steelhead, and Snohomish/Skykomish winter steelhead (the latter was considered level 1, which meant it was at least two-thirds as abundant as it was historically). The Skagit (7,200 fish) and Snohomish (6,800 fish) basins have the largest natural escapements of winter steelhead in the Puget Sound area and the only populations with increasing trends (Busby and six others 1996). Consensus among fisheries biologists working in the basin is that the Snoqualmie sub-basin is "one of the most critical native coho production areas in the state and needs protection" (Nelson 1996).

The Snohomish River basin supports Washington's only large population of even-year pink salmon (a few even year pinks are observed each year in the Stillaguamish River) (WDF et al. 1993). The even-year fish are genetically very distinct from all other Puget Sound pink salmon and belong to a different "major ancestral lineage" (Shaklee et al. 1995). Two genetic analyses strongly suggest that the even-year population did not arise from hatchery plants from Alaska or British Columbia (Hard et al. 1996). The NMFS assigned Snohomish even-year pinks to a distinct ESU (Hard et al. 1996). The even-year run increased from 1980 to 1994 and had an estimated escapement of 1,600 fish in 1994 (Hard et al. 1996). Both even- and odd-year pinks spawn in the mainstem between RKm 21-34, especially above RKm 29 (Hard et al. 1996). Both spawn in the Skykomish, but more odd-year fish tend to do so. The distribution of pink spawners is expanding since the "base years" so recent escapement estimates may be biased downwards (Hard et al. 1996).

Four chinook salmon stocks are presently recognized in the Snohomish River basin: Snohomish River summer, Snohomish River fall, Bridal Veil Creek fall, and Wallace River summer/fall (SBSRTC 1999). Wallace River summer/fall chinook are a mixed-origin stock, but the three other chinook stocks are considered native by WDFW (1994a). Bridal Veil Creek fall chinook are genetically distinct from all other Snohomish basin and Puget Sound stocks sampled (WDFW and WWTIT 1994a). They spawn only in the lower forks of the Skykomish and in the lower 0.25 miles of Bridal Veil Creek and are not supplemented by hatchery stocks (WDFW and WWTIT 1994a).

Snohomish River fall chinook are the only chinook stock in the basin that has had recently increasing escapement levels (SBSRTC 1999). For Bridal Veil Creek fall chinook, escapement has dropped substantially since the mid-1970s (SBSRTC 1999). Snohomish River summer chinook escapement declined to its lowest recorded level in 1997 (SBSRTC 1999). Although the Wallace River summer/fall stock was considered healthy in 1993, recent escapements have been lower than those from 1965 to 1976 (SBSRTC 1999).

Nehlsen et al. (1991) classified Snohomish River spring chinook salmon as extinct and Tolt River summer steelhead at "high risk" of extinction. Spring chinook populations throughout the Puget Sound region are "depressed" (Myers and ten others 1998). Declining body size in coho salmon in the basin is a concern in part because reproductive output is closely related to body size. Between 1972 and 1993 the average size of fish (coho) in the terminal landings declined from an average of 4 kg to 2 kg. (Weitkamp 1995).

HATCHERY INFLUENCES

"The Snohomish River system is managed primarily for wild production and only secondarily for hatchery production of all species of salmonids," according to SBSRTC 1999. The WDFW operates a hatchery on May Creek near Goldbar where it propagates primarily summer/fall chinook and coho salmon (Williams et al. 1975). All coho stocks are considered to be of mixed native and hatchery origin, except for the non-native South Fork Skykomish stock (WDFW and WWTIT 1994a). While coho stocking occurs throughout the basin, it is much less intensive in southern basins. The following table demonstrates the relative contribution of hatchery versus "natural" (spawned in the wild) coho to terminal runs in north versus south Puget Sound basins:

Average terminal run sizes of coho salmon (Weitkamp 1995).

Region	*Natural*	*Hatchery*
South Sound	207,700	473,400
Stillaguamish / Snohomish	164,200	63,400

Although Snohomish River summer chinook are considered a native stock, the proximity of the primary spawning area to the Wallace River hatchery may lead to significant mixing of hatchery with wild fish (SBSRTC 1999). No hatchery chum have been introduced to the Snoqualmie River basin (WDFW and WWTIT 1994a). Both the Skykomish and Wallace chum stocks are considered native, although they have received hatchery plants (WDFW and WWTIT 1994a).

Both summer and winter steelhead are stocked in the basin. Summer steelhead in the North Fork Skykomish are apparently native (WDFW and WWTIT 1994a). Busby et al. (1996) cite Phelps et al. (1994) as concluding, based on genetic data, that North Fork Skykomish summer steelhead had limited hatchery introgression, but Busby et al. (1996) suggest that the conclusion be regarded as tentative (pp 37-38). Biologists are unclear about the persistence of native summer steelhead in the Tolt River (WDFW and WWTIT 1994a; Nelson 1996). Skamania hatchery summer steelhead are planted over native summer steelhead stocks in the basin (Crawford 1979 cited in Busby and six others 1996). Winter steelhead are stocked but have high harvest rates and little overlap in spawn timing with native fish, and all three winter steelhead stocks are considered native (WDFW and WWTIT 1994a). Hatchery fish compose 12 percent of the winter steelhead escapement in Snohomish River (Busby and six others 1996).

Johnson et al. (1999) stated that stocking of hatchery cutthroat trout had little or no effect on cutthroat abundance in northern Puget Sound streams and thus was discontinued in 1985. Non-native brook trout have been stocked in upland lakes and occur in some high-elevation lakes (WDFW 1998; DEA 1999b). Due to differences in distribution, they probably have little influence on anadromous fishes in the basin.

AREAS RECOMMENDED FOR WITHIN-BASIN REFUGIA DESIGNATION AND JUSTIFICATIONS

REFUGIA - ALTERED (CATEGORY 2)

SNOHOMISH RIVER SUB-BASIN:

Snohomish River mainstem - Thomas Creek (RM 11) to Snoqualmie/Skykomish Fork (RM 20.5)

This is an important spawning area for pink salmon. Pink salmon spawn throughout the segment, although we found some disagreement as to where the most spawning occurred. Snohomish River fish distribution maps indicate that even-year pink salmon spawn primarily from the Pilchuck River (RM 13.4) to Anderson Creek (RM 18.35) and odd-year pinks spawn from about RM 17.5 up into the North Fork. However, Hard (1996) states that both even- and odd-year pink salmon spawn in the mainstem between RM 13 and 21, but especially above RM 18. Some chinook salmon spawning occurs in the segment, although less than in the Skykomish and Snoqualmie Rivers (Nelson 1996). The upper portion of the segment is a primary winter rearing area for chinook salmon and also includes numerous important adult holding pools (Nelson 1996). Much of the segment is included in the Cathcart Drainages subwatershed as delineated by WDOE (Draft). It is identified as having problems with baseflows, but not with any of the other five processes investigated.

Pilchuck River - lower, middle, and tributaries

The lower Pilchuck River near Snohomish is an important spawning area for anadromous fishes from at least five stocks (Nelson 1996). The third-highest percentage (about 11 percent) of the total coho salmon production in the Snohomish River basin occurs in the lower Pilchuck River (Bilby et al. 1999). Included in this area are Dubuque, Catherine, Star, Little Pilchuck, and Panther creeks, which produce more coho than the upper Pilchuck River in spite of altered habitat (pers. comm. G. Pess). The Pilchuck River has a distinct native winter steelhead stock, according to the SASSI report (WDF et al. 1993). Concentrated spawning of odd-year pink salmon occurs in the lower Pilchuck River, particularly near the mouth (Nelson 1996). Furthermore, the Pilchuck River enters the Snohomish River in the middle of an important mainstem spawning reach for both odd- and even-year pink salmon (Nelson 1996). Primary spawning and winter rearing habitats for summer/fall chinook salmon occur in the lower and middle Pilchuck River up to about RM 18 (Nelson 1996). However, use by chinook is much lower than historical levels, and the habitat is degraded (Nelson 1996).

Gravel mining in the Pilchuck River has led to channel bed degradation and a decline in chinook salmon spawning use of the river (Bishop and Morgan 1996). Channel aggradation and widening has exacerbated the effects of "natural" low flows so that the Pilchuck River is an area of "special concern" with respect to flows (Bishop and Morgan 1996, and pers. comm. A. Haas). K. Nelson (memo Nov. 30, 1999) stated that extensive bank hardening, a lack of woody debris, and poor riparian conditions are problems in the lower river, and the low flows and sewage discharge (from the city of Granite Falls) can severely impact water quality.

Upper Pilchuck River

Based on fish distribution and intact watershed processes, WDOE (Draft) categorized the upper Pilchuck River as an existing refugia for chinook salmon. Although no major problems were identified with processes related to baseflow, peakflow, sediment, nutrients, toxins, or woody debris in the first draft of the WDOE report, K. Nelson (memo Nov. 30, 1999) thought that problems existed with sediment, woody debris, and low flows. About 6 percent of the coho salmon production in the Snohomish River basin occurs in the upper Pilchuck River (Bilby et al. 1999). Chinook salmon are believed to occur up to Wilson Creek, but it is unknown whether spawning occurs upstream of Worthy Creek (Nelson 1996). The Pilchuck River has a distinct native winter steelhead trout stock (WDF et al. 1993) that Huntington et al. (1996) classified as a healthy stock. The steelhead spawn in Worthy, Wilson, Kelly, and lower Miller creeks and an unnamed stream (number 0181 in Williams et al. 1975), all of which are tributaries to the upper Pilchuck River (Nelson 1996). Summer steelhead use the entire river; however, they are of hatchery origin (Nelson 1996). K. Nelson (memo Nov. 30, 1999) indicated that a diversion dam with a fish ladder creates passage problems for fish moving into the upper watershed.

SKYKOMISH SUB-BASIN:

Skykomish River - Mouth to above Woods Creek (RM 26.5)

The lower Skykomish near Monroe is an important spawning area for at least three anadromous species (Nelson 1996). The segment may include the best pink salmon spawning habitat in the sub-basin (Nelson 1996). A primary chinook spawning reach occurs where the river borders the town of Monroe, and some adult holding pools are located near RM 26 (Nelson 1996). Chinook salmon summer rearing occurs throughout the mainstem of the Skykomish River (Nelson 1996). Coho spawn in the segment but the lower and upper Skykomish each support less than 3 percent of the coho spawning in the basin (Bilby et al. 1999).

A variety of activities and land uses impact this segment. The town of Monroe borders the segment, creating urban impacts. Forestry impacts accrue from upstream. Much of the non-urban land is in agricultural or rural/residential use. WDOE (Draft) identified problems with nutrient and toxin loadings in the segment and predicted that both will worsen in the future. Also, in lower Woods Creek, a tributary entering within the segment, large woody debris recruitment was minimal (WDOE Draft).

Skykomish River - McCoy Creek (RM 33.3) to Gold Bar

This river segment provides important spawning area for five anadromous species, including summer/fall chinook, pink, chum, and some coho salmon and steelhead trout (Williams et al. 1975; Nelson 1996; MBSNF 1997). The most concentrated spawning of Skykomish fall chum salmon in the basin occurs in braided channels throughout this segment (WDFW and WWTIT 1994a; Nelson 1996; MBSNF 1997). In addition, sloughs from McCoy Creek to the town of Gold Bar are important summer and winter rearing areas for juvenile coho salmon (Nelson 1996; MBSNF 1997). Pink salmon spawning was historically intense from Monroe to Gold Bar, but has declined "notably" (Nelson 1996). Adult chinook hold in several pools near Sultan (Nelson 1996).

Land uses include agriculture in the wide valley, logging at higher elevations, rural residences, and several towns. Dikes were built in 1968 between the Skykomish and Wallace rivers and downstream of the Sultan River (Williams et al. 1975). Between RM 32 and 40, pools have been filling in over the past 20 years (Bishop and Morgan 1996). The Burlington Northern Railroad has substantially altered channel conditions in this segment (K. Nelson, memo Nov. 30, 1999).

Sultan River – lower (mouth to diversion dam RM 9.7)

Based on the distribution of chinook salmon and the predominantly intact watershed processes, WDOE (Draft) categorized the lower Sultan River as an existing refugia for chinook salmon. Coho, pink and chum salmon also spawn in the river, primarily downstream of RM 3, but to some degree up to the diversion dam at RM 9.7 (Williams et al. 1975). The lower tributaries are used primarily by coho salmon (Williams et al. 1975).

The lower three miles of the river flows through a relatively flat valley, but above that the river is confined in a steep canyon (Williams et al. 1975). Land uses in the basin are primarily forestry and recreation except in the lower three miles, where residences, farms, and the town of Sultan predominate. No major problems were identified with processes related to increased peakflows, sediment or nutrient loadings, toxins, or woody debris recruitment (WDOE Draft). However, hydrologic modification, including reductions of baseflows and severe flow fluctuations, are created by the upstream dams, and have created severe limitations to fish production in the past (Williams et al. 1975; WDOE Draft). The earth-fill Culmback Dam (RM 16.5) impounds 3-mile-long Spada Lake. At RM 9.7 the Everett diversion dam transfers water to Lake Chaplain. Extensive clearcuts and gravel removal downstream of the diversion dam prior to the mid-1970s degraded fish habitat (Williams et al. 1975).

Skykomish Forks / North Fork Skykomish area

This area includes the entire North Fork Skykomish River and tributaries and the South Fork Skykomish River to Sunset Falls (RM 51). Portions of the area are used by Bridal Veil chinook, coho, and chum salmon, summer and winter steelhead trout, and native char. Bridal Veil chinook salmon are a unique stock, both genetically and behaviorally. Eighty percent of the stock's production originates within a two-mile radius of the forks, including the lower 0.25 mile of Bridal Veil Creek and some area upstream of Sunset Falls (Nelson 1996). Bridal Veil Creek fall chinook use the lower 11 to 13 miles of the North Fork, but cannot ascend Bear Creek Falls (RM 13), according to one source (DEA 1999b). However, K. Nelson (memo Nov. 30, 1999) believes that coho, steelhead, and chinook can all ascend Bear Creek Falls under certain flow conditions. Concentrated spawning of the chinook in the North Fork Skykomish extends from the mouth to Lewis Creek (RM 2.8)(Nelson 1996). Juvenile chinook have been observed in the lower end of Salmon Creek (DEA 1999b). The North Fork Skykomish has been identified as a critical remaining habitat that should be preserved for recovery of chinook salmon (SBSRTC 1999).

Coho spawning and rearing in the North Fork occurs largely between RM 2.5 and 3.7, and other important spawning areas include the lower ends of Howard and West Cady creeks (MBSNF 1997). In the North Fork, winter steelhead occur up to Bear Creek (RM 13.1). North Fork summer steelhead are the only native summer steelhead in the basin, and they spawn the upper North Fork Skykomish River from Bear Creek to Goblin Creek (RM 18.4), where there is a barrier to anadromous fishes (MBSNF 1997). Ninety percent of the native char spawning habitat in the basin occurs in the same area of the North Fork and tributaries (MBSNF 1997). Native char occur in North Fork tributaries, including Troublesome, Silver, and Salmon creeks (WDFW 1998). The North Fork has been classified as a "well-functioning refugia for native char" (DEA 1999b). Native char are present but not abundant in the lower forks of the Skykomish (DEA 1999b). Bilby et al. (1999) predicted that habitat in the North Fork should be productive for coho salmon.

Habitat where North Fork summer steelhead spawn is generally in good condition, but is unstable during floods (WDFW and WWTIT 1994a). Habitat in the South Fork below Sunset Falls is in good condition (pers. comm. with J. Doyle, 1999).

Pink salmon spawn in the North Fork to RM 12 and in the South Fork to Sunset Falls (WDFW and WWTIT 1994a).

The headwaters of the North Fork originate in the Henry M. Jackson Wilderness. Ninety-four percent of the land is within the MBSNF (DEA 1999b). Land use is primarily forestry with clearcut logging having occurred in much of the area (DEA 1999b). Mining and recreation are other land uses (DEA 1999b). In a report to the Forest Service, DEA (1999b) considered the South Fork a refugia functioning "at risk" for Bridal Veil chinook salmon and considered the South Fork below the falls to be "functioning at unacceptable risk" for floodplain connectivity (DEA 1999b). In the North Fork, a county road on the floodplain limits hydraulic connectivity with side channels (DEA 1999b). Large woody debris frequency in the North Fork is "relatively high compared to more heavily logged basins, but low compared to basins with similar disturbance history," according to DEA (1999b).

SNOQUALMIE RIVER SUB-BASIN:

Mainstem - Harris Creek (RM 21.30) to Snoqualmie Falls (RM ~41.3)

The mainstem Snoqualmie River from Harris Creek to Snoqualmie Falls provides important spawning areas for chinook, chum, and pink salmon and steelhead trout, as well as rearing and spawning habitat for coho salmon (Williams et al. 1975; Nelson 1996). Gravel composition was "good to excellent" for spawning upstream of the Harris Creek confluence as of the mid 1970s (Williams et al. 1975). River channelization, diking, gravel removal and increased sedimentation have degraded habitat in the segment (Williams et al. 1975).

Harris Creek

Harris Creek has the fourth-highest coho production of surveyed areas in the Snohomish River basin (Bilby et al. 1999) and contains "outstanding" spawning and rearing habitat for coho throughout the stream (Nelson 1996). The stream is included in the Waterways 2000 list of high aquatic diversity basins.

The first draft of the WDOE report (Draft) characterized Harris Creek as having several impaired processes, including peak flows, sediment production, and large woody debris recruitment or retention and as having the potential for nitrogen and phosphorus loading problems in the future. K. Nelson (memo Nov. 30, 1999), however, suggested that the extensive wetland systems in the Harris Creek watershed would be expected to ameliorate problems with peak flows and excessive sediment production. Recent rapid development, which is predicted to continue in this drainage, has permanently altered much of the watershed, possibly making it susceptible to severe habitat damage and fish mortality during future floods, droughts, or other natural disturbances (pers. comm. B. Bilby).

Tolt River

Anadromous fish distributions extend up to waterfalls at about RM 1 on the North Fork Tolt River and RM 8 on the South Fork. Primary spawning area for chinook salmon in the Tolt River extends up to about RM 6.0, although some spawning occurs up to the falls on the North and South Forks (Nelson 1996). This primary spawning area on the Tolt River has been identified as a remaining critical habitat that should be preserved for recovery of chinook salmon (SBSRTC 1999). Holding areas for adult chinook occur in several areas below the fork (Nelson 1996). The lower 1 mile of the river includes some of the best pink salmon spawning habitat in the Snoqualmie sub-basin (Nelson 1996). Also, some of the best steelhead spawning in the Snoqualmie sub-basin is in the lower Tolt River (Nelson 1996), although it was not clear to which steelhead stock this applied.

"Outstanding" coho salmon spawning and rearing habitat occurs throughout the accessible areas of Stossel Creek, a tributary (Nelson 1996). As of 1975, Stossel Creek had several reaches containing beaver dams (Williams et al. 1975). Coho production in the Tolt River contributes 1 to 3 percent of the total documented coho production in the Snohomish basin.

The headwaters of the North Fork are in the MBSNF, and much of the upper watershed is managed as a water supply for Seattle (Williams et al. 1975). The lower river has been impacted by gravel removal operations and by riprapping and levees (although set back) below RM 4. Clearcuts in the upper watershed contributed to flash flooding and increased sedimentation (Williams et al. 1975). Massive landslides have occurred in the upper watershed (WDFW and WWTIT 1994a). A dam just upstream of a large waterfall on the South Fork Tolt River impounds the Seattle Water Supply Reservoir. WDOE (Draft) identified sediment problems in the North Fork Tolt, base flow problems in the South Fork, both above and below the dam, and peak flow problems in the Tolt River below the fork. Between 50 and 70 percent of the culverts in the drainage create complete or partial upstream passage barriers to fish (Bishop and Morgan 1996). However, as part of a larger restoration effort, Washington Trout and King County have been replacing culverts in the watershed.

Griffin Creek

Thirteen-mile-long Griffin Creek, a major tributary (Williams et al. 1975), is the largest documented producer of coho salmon in the Snohomish River basin (Bilby et al. 1999). From 1984 to 1998, coho spawners in Griffin Creek accounted for an average of more than 18 percent of the spawners counted in the entire basin (Bilby et al. 1999). The primary coho spawning area (prior to 1975, at least) was between RM 3.0 and 5.1, near the outlet of lower Swamp Lake (Williams et al. 1975), although recent maps show primary chinook spawning habitat throughout the creek (Nelson 1996).

Distributions of chinook and pink salmon and steelhead trout also extend into Griffin Creek (Nelson 1996). The Griffin Creek watershed was identified as important “critical remaining habitat” that should be preserved in order to assist recovery of chinook salmon (SBSRTC 1999).

The Waterways 2000 report listed Griffin Creek as a high aquatic diversity basin and identified two segments within the creek for conservation. One segment extended from the railroad bridge (RM 1.1) to RM 2.2. Coho and steelhead spawn in the segment, but spawning is not concentrated (Waterways 2000). An unidentified mollusk species also occurs in the segment (Waterways 2000). The other reach encompasses almost continuous beaver impoundments from RM 5.0 to 8.2, and includes the lower first mile of the East Fork and the lower 0.5 miles of tributary 0369 (Waterways 2000). Coho and steelhead rear in the beaver ponds, and cutthroat trout occupy the segment (Waterways 2000). Coho spawning is intense in the lower ends of the two tributaries, and some anadromous cutthroat trout also spawn in the East Fork (Waterways 2000). Two mollusk species occur in the East Fork (Waterways 2000). Red-legged frogs, Pacific giant salamanders, and Northwest salamanders are common in the segment (Waterways 2000). "The beaver ponds are probably the major factor in the continued productivity of the system," according to Waterways 2000. The tributaries appear to be important components of the thermal complexity in the segment.

Roads frequently run near or cross Griffin Creek. Between 50 and 70 percent of the culverts in the drainage create complete or partial upstream passage barriers to fish (Bishop and Morgan 1996). Houses and farms occur along the lower 2.2 miles of the drainage, and most of the remainder is used for commercial timber production and is largely owned by Weyerhaeuser. The basin includes many clearcuts (Waterways 2000). The first draft of the WDOE report considered Griffin Creek as having problems with the following processes: base flows, peak flow increases, and nutrient loading. As of 1975, the stream had many beaver dams above RM 5 (Williams et al. 1975), and K. Nelson (memo Nov. 30, 1999) suggested that the extensive wetland systems in the watershed would be expected to ameliorate problems with peak flows and base flows. Most of the upper watershed had been logged and the lower watershed contained many summer homes along the stream (Williams et al. 1975). The creek received a low rating (secondary restoration category) for protection or restoration of chinook salmon (WDOE Draft); however, the coho population appears to have been somewhat resilient to the land use changes to date. Recent rapid development, which is predicted to continue in this drainage, has permanently altered much of the watershed, possibly making it susceptible to severe habitat damage and fish mortality during future floods, droughts, or other natural disturbances (pers. comm. B. Bilby).

Patterson Creek

Patterson Creek is the fifth-largest documented producer of coho salmon in the Snohomish River basin (Bilby et al. 1999). Chinook and steelhead use Canyon Creek, and chum spawn in the Snoqualmie River near the mouth of Patterson Creek (Nelson 1996). Anadromous cutthroat trout spawn in Canyon Creek, especially above a cascade at RM 1.1 (Waterways 2000). Freshwater mussels occur in Canyon Creek, but may be declining (Waterways 2000). The creek is included in the Waterways 2000 list of highest aquatic diversity basins and includes segments identified for preservation in the program: Canyon Creek RM 1.1 to 1.9, including the headwater wetland; Tributary 0383 entering Patterson Creek from the south at RM 6.2; and mainstem RM 5.1-5.3, RM 6.1-6.3, and RM 7.7-8.0. The lower 0.2 miles of tributary 0383 has the largest concentration of spawning coho salmon in the Patterson Creek watershed and also has some freshwater mussels (Waterways 2000). The cool water from the tributary provides a thermal refuge for fish in Patterson Creek (Waterways 2000). Tributary 0383 is the least-disturbed waterway in the subwatershed.

Riparian forests in this subwatershed are second-growth. Much of the mainstem was straightened in the 1950s, but most agriculture has since ceased; the channel is reforming and riparian forests are regrowing (Waterways 2000). Problems with wood supply and sediment exist in Patterson Creek (WDOE Draft). Recent rapid development, which is predicted to continue in this drainage, has permanently altered much of the watershed, possibly making it susceptible to severe habitat damage and fish mortality during future floods, droughts, or other natural disturbances (pers. comm. B. Bilby). Future problems with peak flow increases and nutrient loading are predicted (WDOE Draft).

Raging River

Coho, chinook, and pink salmon and steelhead trout all use the Raging River to some degree. Chinook and steelhead spawn in the lower 4 to 7 miles of the Raging River, but their distributions extend well into the upper river, above I-90 (Nelson 1996). The primary chinook spawning area was included among a list of “remaining critical habitats” that should be preserved to further recovery of chinook salmon (SBSRTC 1999). Coho production in the upper river is comparable to some of the more productive areas in the Snoqualmie sub-basin (pers. comm. G. Pess).

Historically, the river produced many chinook, steelhead, and coho salmon, but the habitat has been heavily altered (pers. comm. J. Doyle). The river was placed in the "refugia – altered" category on the recommendation of both J. Doyle and G. Pess (pers. comm.).

POSSIBLE REFUGIA (CATEGORY 3)

SKYKOMISH SUB-BASIN:

Skykomish River – above Woods Creek to McCoy Creek, and several tributaries

The mainstem from above Woods Creek to McCoy Creek historically produced the most chinook salmon in the basin (pers. comm. G. Pess). The segment still has numerous off-channel habitats (pers. comm. G. Pess). The tributaries, Elwell, Youngs, and McCoy creeks, also historically produced chinook salmon, and currently are used by steelhead trout (pers. comm. G. Pess). G. Pess (pers. comm.) suggested that all of the above segments be classified as altered refugia, and K. Nelson (memo Nov. 30, 1999) suggested Elwell Creek be classified as an altered refugia.

Wallace River

The Wallace River near Sultan is an important spawning area for at least five anadromous species (Williams et al. 1975; Nelson 1996). The 1995 Snohomish fish distribution maps (Nelson 1996) indicate that chum salmon spawn throughout the river, although G. Pess (pers. comm.) said that passage is not provided above the hatchery rack. WDOE (Draft) identified the Wallace River as an "existing refugia" for chinook salmon, in spite of characterizing the river as having a phosphorous and nitrogen loading problem. Biologists identified the Wallace River as a "high density use area for all adult and juvenile salmon and steelhead" and in need of protection (Nelson 1996). The Wallace River, from RM 2.0 to 4.2, probably has the highest spawning density of chinook salmon in the basin (Nelson 1996), although we do not know to what extent this is due to the location of the hatchery. The best habitat for anadromous cutthroat trout in the basin occurs in the Wallace River, Woods Creek, and their tributaries (pers. comm. with C. Kraemer 1996, cited in MBSNF 1997).

The major factor preventing us from classifying the Wallace River as a refugia for native salmon is a hatchery and hatchery rack at RM 4.2. The extent of hatchery influence on the spawning populations in the river, in terms of fish passage and genetic influences was not described in any of the reports we reviewed. The only process identified by WDOE (Draft) as a problem in the watershed was nutrient loading. Due to our uncertainties about the operations and influence of the hatchery, we designated the entire stream a possible refugia.

Woods Creek -mouth to falls (RM 7.3) and lower ends of tributaries

The best habitat for anadromous cutthroat trout in the basin occurs in the Wallace River, Woods Creek, and their tributaries (pers. comm. with C. Kraemer 1996, cited in MBSNF 1997). Chinook, pink, chum, and especially coho salmon still use Woods Creek (pers. comm. G. Pess). The creek produces less than 3 percent of the total document coho production in the Snohomish basin (Bilby et al. 1999). In Woods Creek below the confluence with West Fork Woods Creek, recruitment or retention of large woody debris was classified as poor and future increases in peak flows and nutrient loading were predicted (WDOE Draft). However, WDOE (Draft) identified no process problems in Woods Creek above the confluence with West Fork Woods Creek. Between 50 and 70 percent of the culverts in the drainage create complete or partial upstream passage barriers to fish (Bishop and Morgan 1996). K. Nelson (memo Nov. 30, 1999) suggested that Woods Creek be categorized as an altered refugia. We classified it as a possible refugia because we are unsure about the influence of the hatchery on the fish populations in the lower river.

SNOQUALMIE SUB-BASIN:

Cherry Creek – RM 2.5 to headwaters

Primary spawning habitat for steelhead occurs throughout several miles of upper Cherry Creek coho spawning occurs in at least one segment of the upper creek (Nelson 1996). Pink and chinook distributions extend into the lower creek and the North Fork Cherry Creek (Nelson 1996). Although lower Cherry Creek is "heavily hydromodified," the upper creek produces many coho (pers. comm. G. Pess). Chronic low flows are a problem in the creek (Nelson 1996). A comment recorded during a general discussion in August 1995 by biologists working in the Snohomish basin indicates that a state-owned wildlife unit was blocking fish passage, but that above the blockage was "a large amount of suitable habitat for steelhead, coho, chum, and anadromous cutthroat trout" (Nelson 1996).

CRITICAL CONTRIBUTING AREAS (CATEGORY 4)

Bridal Veil Creek - above falls

Bridal Veil Creek is the outlet of Lake Serene. In general, the headwaters of Bridal Veil Creek are an area of high biodiversity (MBSNF 1997). Unique plant assemblages occur around Lake Serene, and the area contains a stable population of mountain goats (MBSNF 1997). Lake Serene is accessed by a trail, and some concern exists regarding the impacts on plants and goats of increasing recreational use (MBSNF 1997).

North Fork and tributaries above Goblin Creek

The majority of the area above Goblin Creek is in the Henry M. Jackson Wilderness, and is thus in nearly pristine condition. The habitat is important to maintaining processes in the refugia of the upper North Fork Skykomish River.

Tokul Creek above hatchery rack

The hatchery rack on Tokul Creek (RM 0.4) "is perceived by some to block use of good habitat above the hatchery for steelhead trout. If the blockage was removed, it is thought that many miles of good stream could be used," according to Nelson (1996). However, G. Pess (pers. comm.) indicated that a natural barrier occurs within about one mile of the hatchery rack. Therefore, we are somewhat uncertain about our designation of Tokul Creek as a "potential future refuge.". The historic existence of summer steelhead in the creek is a point of controversy (Nelson 1996). Between 50 and 70 percent of the culverts in the drainage create complete or partial upstream passage barriers to fish (Bishop and Morgan 1996).

TABLE 6. SNOHOMISH RIVER BASIN STREAMS AND STREAM SEGMENTS IN ONE OF THE REFUGIA CATEGORIES.

STREAM OR SEGMENT NAME	CATEGORY A	ALTERATION CLASS B	SOURCE TYPES C
SNOHOMISH SUB-BASIN			
Snohomish River mainstem - Thomas Creek to Fork	2	AFU	R
Pilchuck River - lower, middle (including some tributaries), and upper	2	FO	RP
SKYKOMISH SUB-BASIN			
Skykomish River - Mouth to above Woods Creek (RM 26.5)	2	AFU	R
Skykomish River - above Woods Creek to McCoy Creek, including Elwell, Youngs and McCoy creeks	3	AFU	P
Skykomish River - McCoy Creek to Gold Bar	2	AFI	R
Woods Creek – lower (mouth to falls, RM 7.3)	3	AFU	R
Sultan River - mouth to diversion dam (RM 9.7)	2	AFID	R
Wallace River	3	FHU	R
Skykomish Forks / North Fork Skykomish area	2	FO	R
Bridal Veil Creek - above falls	4	U	R
North Fork and tributaries above Goblin Creek	4	FU	R
SNOQUALMIE SUB-BASIN			
Mainstem - Harris Creek to Snoqualmie Falls	2	AIU	R
Cherry Creek, RM 2.5 to headwaters	3	AU	RP
Harris Creek	2	AFU	R
Tolt River - mouth to RM 1 on NF and RM 8 on SF, and Stossel Creek	2	DF	R
Griffin Creek	2	AF	R
Patterson Creek	2	AFIP	R
Raging River)	2	FIU	RP
Tokul Creek above hatchery rack (RM 0.4)	5	FH	R

[A] Stream categories: 1 = areas with high ecological integrity; 2 = anadromous salmonid refugia but with impaired integrity; 3 = possible refugia but more data are needed; 4 = critical contributing area; 5 = areas with exceptional habitat that is currently inaccessible to anadromous fishes due to an artificial barrier such as a dam or hatchery rack

[B] Categories of alterations: A = Agricultural/rural residential (often including diking); D = Dam influenced, either by passage issues downstream or flow issues from upstream (including diversions); F = Forestry; H = hatchery; I = Industrial or urbanized; E = Exotic invasive species; N = Not managed; O = Other; P = Planned development (e.g. platted subdivision); U = unknown

[C] Types of information sources that provide support for the category designations include: P = personal communications; R = reports or articles; S = WDFW spawner database; D = other data sets; O = other

LAKE WASHINGTON BASIN - WRIA 8

OVERVIEW

The Cedar River, Bear Creek, and Issaquah Creek are the predominant salmon producing streams in the Lake Washington basin (Lucchetti and Steward 1998). In addition, numerous smaller tributaries also support salmon. The Cedar River is accessible to anadromous fish up to about RM 21.3, (near Landsburg), where a pipeline crossing and the Seattle City Water diversion dam create blockages. About 14 miles upstream of the diversion dam is Masonry Dam, the lower of two additional dams. Approximately 13 miles of high-quality salmonid habitat exists and is presently inaccessible to upstream migrants between the diversion dam and the Cedar Falls powerhouse. Cedar Falls, located downstream of Chester Morse Lake, was a historic barrier to anadromous fishes (WDFW 1998). The upper two-thirds of the Cedar River (upstream of the diversion dam) is protected from most development because it is the municipal potable water supply for the City of Seattle.

Although the Sammamish River is highly urbanized, parts of the Sammamish River basin, including Issaquah Creek and some smaller tributaries, still support anadromous fish. Bear Creek, a tributary of the Sammamish River contains several unique stocks. Issaquah Creek has the most suitable spawning area in the Sammamish basin (Williams et al. 1975) and also has a large hatchery. Some large parks in the upper Issaquah Creek are protected from development.

The Cedar River and Lake Washington historically flowed into the Green-Duwamish River basin. In 1916, the completion of the Lake Washington Ship Canal and the H. M. Chittendon Locks created a new outlet for the lake to the north (Lucchetti and Steward 1998). The lower end of the Cedar River was channelized and diked so that it flowed directly into the lake. The Ship Canal and surrounding urbanization has resulted in a nearly complete loss of estuarine habitat for salmonids (Bishop and Morgan 1996). Anadromous fish must now navigate the locks or a fish ladder to pass upstream into Lake Union and then Lake Washington. Predation by California sea lions in the ship canal is apparently a substantial source of mortality for some anadromous fish stocks, particularly steelhead trout (e.g. Busby and six others 1996). In the mid- 1960s, 27 miles of the Sammamish River was shortened to 14 miles of diked channel (Lucchetti and Steward 1998).

Independent tributaries of Lake Washington historically provided quality production areas for anadromous fishes. However, most of the tributaries, as well as the shorelines, of Lake Washington and Lake Sammamish are now highly urbanized, creating a host of conditions that are detrimental to salmonids (Williams et al. 1975; WDFW and WWTIT 1994b). Impervious surfaces comprise about 18 percent of the Lake Washington/Cedar River subwatershed and 14 percent of the Lake Sammamish/Sammamish River watershed (Lucchetti and Steward 1998). Much of the Cedar River that is presently accessible to salmon is channelized (Bishop and Morgan 1996). At least the lower three miles of the Cedar River is heavily industrialized (Williams et al. 1975). About 27 percent of the Cedar River's flow is diverted for municipal water use (Lucchetti and Steward 1998).

No part of Issaquah Creek was listed as a priority area because of the very large influence of the Issaquah Creek hatchery on the anadromous fish stocks in the creek.

FISH

Chinook, coho, and sockeye salmon, as well as winter steelhead and anadromous cutthroat trout, use the Lake Washington basin (Williams et al. 1975). No chum or pink salmon stocks now occur in the Lake Washington basin (WDF et al. 1993; Phelps et al. 1995). Native char use the upper watersheds. Chinook salmon primarily use the larger rivers, including Cedar River and Issaquah and Bear creeks (Williams et al. 1975). Wild spawning above the hatchery in Issaquah Creek has been consistently allowed since 1990 (pers. comm. J. Kerwin). The other species historically used most accessible streams (Williams et al. 1975).

Hatchery fish are produced at the Issaquah Creek hatchery and, in small numbers, at the University of Washington hatchery. As of 1975, numbers of hatchery fall chinook and coho salmon returning to the Issaquah Creek hatchery approached or exceeded numbers spawning in the wild (Williams et al. 1975). Much smaller numbers of sockeye salmon are also produced (Williams et al. 1975). In spite of extensive stocking of hatchery fish, both the chinook salmon and steelhead trout in the Cedar River are apparently predominantly native (WDFW and WWTIT 1994b, and pers. comm. G. Lucchetti).

Nehlsen et al. 1991 listed Lake Washington winter steelhead as having a moderate risk of extinction. However, G. Lucchetti (Minutes of the Cedar/Sammamish Watershed Steering Committee, 24 June 1999) indicated that numbers have increased dramatically in the past four years, but did not define the role of hatchery fish in the increase. Based on genetic data, the Lake Washington winter steelhead that use the Cedar River appear to have had limited hatchery introgression (Busby et al. 1996 citing Phelps et al. (1994)). However, Busby (1996) suggested that the conclusion be regarded as tentative. Steelhead trout smolt stocking in the basin ended in 1992 (WDFW and WWTIT 1994b). Predation by California sea lions has been a significant source of mortality on adult steelhead trout (Nehlsen et al. 1991) in the Ship Canal, where an estimated 60 percent of the annual wild run is consumed (WDFW and WWTIT 1994b). The SASSI report noted that escapements to some tributaries were approaching zero in spite of little obvious change in habitat quality in the years recently preceding publication of the report (WDFW and WWTIT 1994b).

Prior to the major alterations of the Lake Washington basin, sockeye salmon runs are believed to have been quite small. Non-native sockeye salmon were first introduced into the basin in 1917, but a non-native population was not established until the late 1930s (WDFW and WWTIT 1994b; Hendry et al. 1996). While the majority of the sockeye salmon (e.g. those spawning in Cedar River, Lake Washington, and E.F. Issaquah Creek) in the basin today are primarily descended from the introduced stock, native fish apparently persist in the Bear Creek drainage (Hendry et al. 1996; Gustafson et al. 1997). Genetically, these fish are not similar to other sockeye salmon in the basin, nor are they similar to any probable non-native parent stocks (Gustafson et al. 1997). However, some hatchery plants have been made in Big Bear Creek, and it is not certain that they are a native stock (Gustafson et al. 1997). NMFS has designated the sockeye salmon in Big Bear Creek and its tributaries, Cottage Lake and Evans creeks, as a provisional ESU, although the Biological Review Team was divided on the issue (Gustafson et al. 1997). The Biological Review Team was also split as to the status of the provisional ESU; some concluded it was not in danger of extinction, others that it is likely to become endangered in the foreseeable future, and still others concluded that data were insufficient for making a status determination (Gustafson et al. 1997). A very small remnant native population of kokanee salmon may spawn on several beaches in Lake Sammamish (Lucchetti and Steward 1998, and pers. comm. G. Lucchetti).

A new sockeye salmon hatchery recently began operating on the Cedar River at the Landsburg Diversion Dam. Prior to construction of the hatchery, the Cedar River was one of the only major rivers in Puget Sound lacking a hatchery. One life-history type of fall chinook salmon remains in Lake Washington for up to three years before migrating to Puget Sound, and some males complete their life-cycle in freshwater (pers. comm. B. Fuerstenberg and J. Kerwin, 23 Nov. 1999). Concern exists over interactions between these fall chinook salmon and the large number of hatchery-produced sockeye salmon in Lake Washington (pers. comm. B. Fuerstenberg and J. Kerwin, 23 Nov. 1999).

Cutthroat trout have persisted in all but the most highly urbanized streams in the Lake Washington basin, possibly benefiting from declines in coho salmon populations (Lucchetti and Steward 1998; Johnson et al. 1999). Johnson (1999) reports the following densities (fish per 50 m) of cutthroat trout in Lake Washington basin tributaries (citing primarily Ludwa et al. 1997): Lyon Creek - 30, McAleer Creek – 8; Kelsey Creek - 4 to 5 in 1979 (citing Scott et al. 1986) and up to 23 in 1996.

Above Cedar Falls, habitat is excellent for bull trout, according to C. Steward (pers. comm.). Bull trout and Dolly Varden occur in the upper Cedar River basin and use Chester Morse Lake (WDFW 1998). Dolly Varden are occasionally reported in Lake Washington, and one report was made of bull trout in the headwaters of Issaquah Creek. No char are known to use the lower Cedar River (WDFW 1998).

AREAS RECOMMENDED FOR WITHIN-BASIN REFUGIA DESIGNATION AND JUSTIFICATIONS

REFUGIA - ALTERED (CATEGORY 2)

Bear Creek

This is the second-largest fish-producing watershed in the Lake Washington basin (pers. comm. C. Steward). Habitat is in relatively good condition, particularly in the upper portion (pers. comm. C. Steward). The stream is used by sockeye, coho, and chinook salmon and steelhead trout. Chinook salmon spawn between RM 4 and 11 (Williams et al. 1975). Coho salmon historically used all of the tributaries (Williams et al. 1975). Anadromous fish stocks appear to be, for the most part, native. Chinook salmon in Bear Creek are genetically distinct from those in Issaquah Creek and the Cedar River (Marshall 1995). The sockeye salmon in Bear Creek and its tributaries, Cottage Lake and Evans creeks, are thought to be a remnant native stock, although some hatchery plants were made in the basin (Hendry et al. 1996; Shaklee et al. 1996; Gustafson et al. 1997). The stock was designated as a provisional ESU by NMFS (Gustafson et al. 1997). The stock has had relatively high recent average escapement levels (10,000 to 20,000 spawners), although large fluctuations have occurred in stock abundance, ranging from a low of 1,800 in 1989 to 39,700 in 1994 (Gustafson et al. 1997). The Biological Review Team did not reach consensus on the status of this provisional ESU (see "Fish" section above) (Gustafson et al. 1997).

Freshwater mussels (*Margaretifera falcata*) are abundant in some reaches of Bear Creek and its tributaries. The most extensive mussel beds found in King County occur between RM 8.9 and 11.0 (King County 1999). Freshwater sponges that are typically rare are found commonly in the same segment. River otter, mink, muskrats, and a variety of birds and amphibians use Paradise Lake and associated wetlands (RM 10.5)(King County 1999). Beaver occur in many stream reaches (King County 1999).

The headwaters of Bear Creek are presently "for the most part unaffected by development" but are at high risk for future development (Lucchetti and Steward 1998). As of 1975, excellent spawning gravels and favorable cover existed upstream of the York Road crossing (about RM 4.1) (Williams et al. 1975). The urban influence has no doubt spread upstream since then.

Development is expanding in the watershed, including at least one proposed development near Welcome Lake (King County 1999). Fish must pass through the highly urbanized areas downstream, and estuarine rearing habitat is essentially gone (Bishop and Morgan 1996). Forestry and agriculture have occurred over most or all of the basin (Williams et al. 1975). Although development is scattered throughout the watershed, it is most concentrated in the lower end. Low summer flows, warm stream temperatures (due largely to the lakes), water quality deterioration and increased peak flows have been detrimental to salmon at least in the lower end of the creek (Williams et al. 1975).

Cedar River – mainstem RM 16 to pipeline crossing (RM 21.3)

Chinook, coho, and sockeye salmon, winter steelhead trout, and possibly anadromous cutthroat trout use the mainstem Cedar River. The chinook salmon and steelhead trout in the Cedar River watershed have apparently not introgressed substantially with hatchery stocks. The primary chinook spawning occurs in the mainstem between RM 5 and 20 (Bishop and Morgan 1996). The upper portions of the Cedar River segment downstream of the pipeline crossing are still productive for anadromous fishes (pers. comm. C. Steward). Nearly all of the lower watershed was logged, but forests have regenerated and the stream is in good condition (pers. comm. C. Steward).

Within the segment is a short reach identified as a priority area by King County (1999). The short reach includes a braided channel and a large gravel wall. The reach is "used extensively by spawning sockeye and chinook and ... provides rearing for coho and chinook during all seasons" (King County 1999). Black bear, river otter, and mink, and a variety of birds use the reach. Riparian forest is intact on the right bank (King County 1999). On the left bank, the plateau above a high "wall" has been clearcut. Downstream, some homes disrupt the riparian forest (King County 1999).

A hatchery produces non-native sockeye salmon in the basin. Chinook and coho salmon and steelhead trout are all stocked in the basin. Flows are regulated by upstream dams, and a substantial amount of water is withdrawn for use by the city of Seattle and surrounding areas. Forestry, agriculture, residences, and dikes all impact the lower river.

POSSIBLE REFUGIA (CATEGORY 3)

Rock Creek - including tributaries and wetlands

(We refer to the Rock Creek that enters the Cedar River from the south at RM18.15) Rock Creek, from RM 0.4 to RM 1.4 was identified by King County as a priority segment in the Waterways 2000 program. Rock Creek was also one of the smaller streams listed by Lucchetti and Steward (1998) as having significant habitat for anadromous fish. The creek is spring-fed, and rarely receives damaging floods (King County 1999). The stream is used primarily by coho salmon and resident cutthroat trout (King County 1999), with occasional use by sockeye salmon. The riparian area is essentially intact, composed largely of mature second growth forest (King County 1999). Some mature second growth and possibly old-growth forests occur in upland areas. B. Fuerstenberg (pers. comm.) described Rock Creek as the best of the lowland streams in the Cedar River drainage.

Some homes occur along the stream, but most are set back 100 to 200 feet. Two large developments are planned along the segment (King County 1999). Clearcuts of various ages occur throughout the watershed. A water diversion well for the city of Kent removes 40 % of the streamflow during some summers (pers. comm. B. Fuerstenberg). The influence of hatchery stocking on the coho salmon using the stream is unknown.

POSSIBLE REFUGIA RECOMMENDED DURING THE REVIEW PERIOD BUT WITHOUT SUPPORTING DOCUMENTATION OR REASONS (NOT MAPPED)

Cedar River - mainstem (RM 8.0 13.5)

This somewhat arbitrarily defined segment was suggested as a possible refugium by B. Fuerstenberg. He describes the diked segment as having fairly continuous riffles that provide good spawning habitat for sockeye salmon (non-native) and some chinook salmon spawning habitat. Short stretches (hundreds of feet) are in good condition, although large woody debris is minimal in the channel.

Kelsey Creek

This tributary to Mercer Slough on the east side of Mercer Lake was suggested as a possible refugium by J. Doyle.

POTENTIAL REFUGIA ABOVE ARTIFICIAL BARRIERS (CATEGORY 5)

Cedar River - pipeline crossing to Cedar Falls Powerhouse (RM 21.4 - 33.9)

This segment is presently inaccessible to anadromous fish due to barriers at both the Landsburg pipeline crossing and the Landsburg diversion dam (RM 21.8). The Cedar River and some of its tributaries in the segment have "considerable potential" for spawning and rearing of chinook, coho, and sockeye salmon (Williams et al. 1975). The only developments along the segment are those related to power production and water diversion. Some logging has occurred, but generally away from the river (Williams et al. 1975). The watershed contains roads and receives some recreational use (Williams et al. 1975). About 128 square miles of the upper Cedar River are in protected status as a municipal watershed for Seattle.

The City of Seattle has recently passed a 50-year watershed plan for the Cedar River Drainage. Provisions include providing passage for chinook and coho salmon and steelhead trout over the Landsburg diversion dam within the next several years and a prohibition against commercial logging in the municipal watershed (CRS Daily Summary, electronic news report). Sockeye salmon will not be allowed to pass the dam due to concerns by the City of Seattle about their influence on water quality.

Flows have been altered by the upstream dams. Successful future colonization is dependent, in part, on the installation of adequate passage facilities and effective screens on the diversion. Some logging and associated road construction has occurred in the basin. Increasing pressure to stock more hatchery fish in the segment seems likely in light of the recent hatchery constructed on the river.

TABLE 7. LAKE WASHINGTON BASIN STREAMS AND STREAM SEGMENTS IN ONE OF THE REFUGIA CATEGORIES.

STREAM OR SEGMENT NAME	CATEGORY[A]	ALTERATION CLASS[B]	SOURCE TYPES[C]
Bear Creek, upper including Cottage Lake and Evans creeks	2	ADP	R
Cedar River, below diversion dam (RM 16.0 - 21.3)	2	ADF	RP
Cedar River, above diversion dam (RM 21.4 – 33.9)	5	DF	RP
Rock Creek	3	ADFP	R

[A]Stream categories: 1 = areas with high ecological integrity; 2 = anadromous salmonid refugia but with impaired integrity; 3 = possible refugia but more data are needed; 4 = critical contributing area; 5 = areas with exceptional habitat that is currently inaccessible to anadromous fishes due to an artificial barrier such as a dam or hatchery rack

[B]Categories of alterations: A = Agricultural/rural residential (often including diking); D = Dam influenced, either by passage issues downstream or flow issues from upstream (including diversions); F = Forestry; H = hatchery; I = Industrial or urbanized; E = Exotic invasive species; N = Not managed; O = Other; P = Planned development (e.g. platted subdivision); U = unknown

[C]Types of information sources that provide support for the category designations include: P = personal communications; R = reports or articles; S = WDFW spawner database; D = other data sets; O = other

GREEN-DUWAMISH RIVER BASIN - WRIA 9

OVERVIEW

The Green-Duwamish River and five independent tributaries to Puget Sound constitute WRIA 9. The lower 10 miles of mainstem is considered to be the Duwamish River, whereas the remainder is the Green River (Morgan and Coccoli 1996). Historically, the Duwamish River drained a 1,642-square-mile watershed including the Green, White, and Black rivers. Of those drainages, only the

Green River continues to flow into the Duwamish River and the total drainage area is reduced to 483 square miles (Morgan and Coccoli 1996). The independent drainages (Longfellow, Miller, Bow Lake and Joes creeks and one unnamed creek) in the WRIA are small and frequently have long periods of low or intermittent flows (Williams et al. 1975). The basin is highly industrialized and urbanized along the lower reaches of the river. Much of the wetlands and marine nearshore habitats near the mouth of the river are gone, and fish kills are common in the lower river (WDFW and WWTIT 1994b). Morgan and Coccoli (1996) estimated that a 99 percent reduction in Duwamish River estuarine habitat had occurred since 1854. The river has been extensively diked up to RM 38 (WDFW and WWTIT 1994b). The City of Tacoma diversion dam at RM 61.0 blocks anadromous fish passage and together with Howard Hansen Dam (RM 64.5) alters natural downriver processes such as streamflow and transport of sediment and large woody debris. The dam at RM 61 has prevented anadromous fish access to the upper Green River since 1911. Area accessible to anadromous fishes in the basin has been reduced 93 percent from historic levels (Blomberg et al. 1988 cited in Morgan and Coccoli 1996).

Morgan and Coccoli (1996) cited Williams et al. (1975) as identified the main limiting factors (excluding harvest) affecting anadromous fish in the basin: passage blockage, hydrologic alteration (namely reduced flows), estuarine losses, high water temperatures in the Green River (especially below RM 30), excess fine sediment, and loss of riparian vegetation. Many of the small tributaries in the Green River basin have been severely degraded (Williams et al. 1975; WDFW and WWTIT 1994b). Much of the habitat in the upper watershed, above the dams, is degraded from logging, railroad construction, and flooding (MBSNF 1996b).

King County included the Puget Lowlands portion of the Green River in its assessment of basins to be selected for land preservation with the intent of salmon conservation. Criteria for basin selection included elements of watershed, riparian and biotic conditions (King County 1999). Our prioritization relied heavily on their assessment.

FISH

Anadromous fishes using the Green River include chinook, coho, and chum salmon; winter steelhead and cutthroat trout; and possibly native char (Williams et al. 1975). The primary chinook salmon stock is fall-run, although some spring and summer chinook spawn in the upper gorge segment of the mainstem (Williams et al. 1975). Both coho and chum salmon traditionally used all accessible tributaries in the basin (Williams et al. 1975). Hatchery production dominates the total production of chinook and coho salmon in the basin (Williams et al. 1975). The Green River Salmon Hatchery on Soos Creek produces chinook, coho, and occasionally chum salmon (Williams et al. 1975). For a period of five years, all chinook salmon attempting to pass a weir across the Green River upstream of Soos Creek were collected and spawned at the hatchery (pers. comm. B. Fuerstenberg, 23 Nov. 1999). Since 1990, hatchery operators have allowed some chinook and coho to pass upstream of the Soos Creek Hatchery rack, and prior to that, some fish were able to pass the rack during storms (pers. comm. J. Kerwin, 23 Nov. 1999). We did not consider Covington Creek a refugia because of the large influence of the Soos Creek Hatchery, even though the creek contains some good habitat. Beginning in 1972, chinook salmon were also produced at a hatchery on Icy Creek (RM 48.3) (Williams et al. 1975).

SASSI (WDFW and WWTIT 1994b) listed Newaukum Creek summer/fall chinook salmon as a distinct stock, pending genetic analyses. Draft run reconstruction data from 1989 to 1997 indicated that about 45 percent of the adult chinook in Newaukum Creek were hatchery released, and about 39 percent of the fish returning to the Soos Creek hatchery rack were progeny of wild spawners (pers. comm. T. Cropp to J. Kerwin cited in (Kerwin Draft-a). Genetic data from chinook salmon in Newaukum Creek and in the Soos Creek Hatchery failed to indicate a statistical difference between the groups (Marshall et al. 1995 –cited in Kerwin Draft-a). Escapement in Newaukum Creek "dropped considerably" in the early 1990s (WDFW and WWTIT 1994b). In the Green River, chinook escapement numbers were generally increasing from 1986 to 1991, but hatchery strays comprised a "significant portion" of the naturally spawning population (WDFW and WWTIT 1994b). Green River hatchery chinook salmon have been planted throughout Puget Sound (Williams et al. 1975; WDFW and WWTIT 1994b).

Both the Newaukum Creek and Green River coho salmon stocks are considered a mixture of hatchery and native stocks, with no ability to distinguish between the two (WDFW and WWTIT 1994b). Hatchery coho are released annually in the basin (Kerwin Draft-a). The Newaukum Creek stock had a severe short-term decline in escapement prior to 1991, and escapement of the Green River stock was lower in 1991 than in any year on record (1967 to 1991) (WDFW and WWTIT 1994b).

SASSI (WDFW and WWTIT 1994b) listed two steelhead trout stocks in the basin: a native, winter-run stock and a non-native summer-run stock. Both stocks receive hatchery supplements. Busby (1996) cites Phelps et al. (1994) as concluding, based on genetic data, that Green River steelhead had moderate to large amounts of hatchery introgression, but Busby (1996) suggests the conclusion be regarded as tentative (pp. 37-38). Natural escapement of winter steelhead averages about 1,500 fish, with 12 percent of those being hatchery fish (Busby et al. 1996). As of 1992, escapement of winter-run fish appeared to be fairly stable (WDFW and WWTIT 1994b).

Hood Canal stocks of chum salmon were widely planted in the Green River. The Green River chum salmon stock is now genetically indistinguishable from some Hood Canal fall chum stocks (Phelps et al. 1995). Nehlsen et al. (1991) considered Duwamish-Green River fall chum at high risk of extinction due to habitat loss and degradation. The SASSI report (WDFW and WWTIT 1994b) indicated that the chum salmon spawning in Crisp Creek are likely of Hood Canal origin, whereas a remnant native stock that is influenced by hatchery stocks may still spawn in the mainstem. However, the report acknowledged that the native stock may be extinct.

Howard Hanson Dam creates a complete barrier to upstream passage of anadromous fish at RM 61.0. However, juvenile hatchery chinook and coho salmon and steelhead trout are planted upstream of Howard Hanson Reservoir, and adult steelhead trout are trucked around the dams (MBSNF 1996b).

Sockeye salmon were "numerous" before 1911, and an average of 50 pairs (compared to a maximum of 200 pairs in 1988) are still seen annually at the diversion dam (MBSNF 1996b). Odd-year pink salmon were thought to have been extirpated from the Green River since the mid-1930s (Williams et al. 1975; Hard et al. 1996); however, some have been observed spawning in recent years (pers. comm. J. Kerwin). It is not known if these fish are remnant native pink salmon or fish recolonizing from other basins. Nehlsen et al. (1991) listed spring chinook salmon as extinct from the basin.

Native char have been documented in the Green River below Howard Hanson Dam (WDFW 1998). One fish, captured near RM 5 by the Muckleshoot Tribe, was identified as a bull trout and confirmed by genetic analysis (Kerwin Draft-a). We found no documentation of char spawning in the basin.

Small numbers of coho and chum salmon and anadromous cutthroat trout spawned in the independent streams as of the mid 1970s (Williams et al. 1975). However, due largely to the heavy, surrounding urbanization, we suspect that these streams no longer support substantial numbers of anadromous fishes. No recent work has been conducted in these streams (pers. comm. J. Kerwin).

AREAS RECOMMENDED FOR WITHIN-BASIN REFUGIA DESIGNATION AND JUSTIFICATIONS

REFUGIA - ALTERED (CATEGORY 2)

Green River, Middle - Auburn to the diversion dam (RM 32 to 61)

Within this segment, some sections are dredged and diked or otherwise modified; however, the segment as a whole represents the best remaining habitat in the basin that is accessible to anadromous fishes. As of the early 1970s, the most intensive chinook salmon spawning in the basin occurred between RM 30.5 and 46.5 (Williams et al. 1975). Mainstem coho salmon spawning occurred primarily in the gorge and near Burns Creek (RM 38) (Williams et al. 1975).

Upstream of Burns Creek (RM 38), tree and brush cover have been maintained along the banks (Williams et al. 1975). From RM 30.5 to 46.5, there were excellent spawning gravels and large trees (although sometimes beyond dikes) as of the mid-1970s (Williams et al. 1975). The segment from RM 31 to 47 is a floodplain segment that historically included more that 10 miles of braided channel, now reduced to less than 4 miles (Madsen 1999). Extensive gravel bars characterized the braided segment (Fuerstenberg et al. 1996 cited in Madsen 1999). Large woody debris loading is about 35 pieces per mile, well below expected historical levels (Madsen 1999). A combination of levees and revetments, prevention of flows greater than 12,000 cfs, and a reduction in sediment delivery from upstream due to Howard Hanson Dam have contributed to losses in both off-channel habitats and "active geomorphic surfaces" (Madsen 1999).

The King County assessment identified five stream sections within this segment that met most of their criteria. Brief descriptions of the sections follow. All descriptions are from (King County 1999), except where otherwise noted.

1) Auburn section RM 32-33. This is a meandering braided segment used by chinook, coho, steelhead and hatchery-origin chum salmon. On the south, the segment is bordered primarily by wetlands and on the north by forest. However, subdivisions encroach on the forest to the north.

2) O'Grady section RM38-40. The river "meanders wildly" through this segment, creating numerous off-channel habitats. Chinook, coho and chum salmon, steelhead trout, and anadromous cutthroat trout spawn and rear in the segment. On the south bank, “extensive”

riparian forests remain and include two forested tributaries. On the north, the riparian forest is sparser and is constrained by a road and homes.

3) Newaukum Creek confluence RM 40.7. This is "an area of intense physical and biological activity." Chinook and coho salmon and steelhead trout stage in this area. The area immediately upstream is an intense spawning area for salmon, including chums. The banks are forested on both sides, with some openings and homes on the north side. The forest on the south side extends upstream almost to the gorge.

4) Green River gorge RM 46-58. This segment is used by chinook and coho salmon (King County 1999) and steelhead trout (pers. comm. J. Kerwin). Elk, black bears, and cougars also occupy the gorge. The forest is continuous along the river and inner gorge. Lands bordering the gorge were primarily second-growth conifer and deciduous forest as of the 1970s (Williams et al. 1975). Patches of spawning gravels occur in the gorge, but gravel recruitment has been reduced since construction of Howard Hanson Dam (pers. comm. J. Kerwin). Large flows from springs occur between RM 48 and 50 (Williams et al. 1975). Chinook salmon spawn in the mainstem and coho spawn in the fringes of the mainstem (Williams et al. 1975).

5) Headworks section RM 58-60.7. Steelhead trout use this small, braided section of river (King County 1999), as do coho and chinook salmon (pers. comm. J. Kerwin). Mink and bears also use the area (King County 1999). The riparian forest is disrupted by a road on the south side of the river.

The entire middle segment of the Green River is influenced by the two upstream dams. Low flows are exacerbated by water diversion and peak flows are dampened. However, the operation of Howard Hanson Dam provides some augmentation of low summer flows (pers. comm. J. Kerwin). Downstream of Burns Creek, much of the river has been dredged and diked (Williams et al. 1975). Revetments occur in places, particularly in the lower portion of the segment. Much of the upland land use is agricultural and residential. Urbanization encroaches on the riparian area in places. The chinook and coho salmon stocks in the segment have been strongly influenced by hatchery fish (pers. comm. B. Fuerstenberg).

POSSIBLE REFUGIA (CATEGORY 3)

COVINGTON CREEK

As of 1975, this was an "excellent coho-type stream" with adequate riparian cover and good spawning gravels (Williams et al. 1975). The lower half of Covington Creek remains in good condition and contains some wetlands (pers. comm. B. Fuerstenberg, 23 Nov. 1999).

The hatchery influence on anadromous runs in the creek is presumably extreme (see "Fish" section). The creek enters Big Soos Creek upstream of the Soos Creek Hatchery, so salmon entry into the stream has been limited and controlled at the hatchery rack for many fish generations. Chinook and coho salmon adults have been passed upstream of the rack consistently since 1990 (pers. comm. J. Kerwin). Although habitat is in good condition, the large hatchery impact on the fish populations precluded this stream from being categorized as a refugium.

NEWAUKUM CREEK (MOUTH TO RM 4)

We found little current information about Newaukum Creek. However, the stream was suggested as a refugia during the review period for this report (Dec. 5, 1999 memo from I. Tinoco). The lower four miles of the creek passes through a forested ravine with "little stream adjacent development" (memo from I. Tinoco). On average, about 15 percent of the Green River chinook run spawns in this segment, as do "large numbers" of coho, chum, and steelhead (memo from I. Tinoco).

The plateau surrounding the lower stream segment is a "heavily developed farming community and most of the land is cleared" (Williams et al. 1975). Although mixed deciduous growth borders the lower five miles of stream, streamside vegetation was extremely sparse between RM 5 and 10 in the 1970s (Williams et al. 1975). As of the early 1970s, low summer flows and water quality were concerns in the creek (Williams et al. 1975).

POTENTIAL REFUGIA ABOVE ARTIFICIAL BARRIERS (CATEGORY 5)

The following tributaries of the upper Green River were suggested as candidates for the potential future refugia (if dam passage were provided) category: Twin Camps Creek, Snow Creek, Upper Sunday Creek, and Tacoma Creek (pers. comm. J. Doyle). Because many factors tend to hinder the establishment of anadromous fishes above long-standing, migration-blocking dams when passage is finally provided, we chose to include in this refugia category only areas that contain excellent habitat with high ecological integrity (see "Introduction"). Although we obtained only limited information about the upper basin, the only documentation we did review suggests that the habitat is not in excellent condition in the upper Green River and tributaries (MBSNF 1996). Twin Camp Creek and the Green River above Tacoma Creek have 32 and 46 percent, respectively, of their riparian reserve areas in "large structure class forests" (i.e. mature trees) (MBSNF 1996), whereas Tacoma and Snow Creeks have 29 and 17 percent, respectively. Sunday Creek has a "disproportionate amount of poor recruitment potential" for large woody debris (MBSNF 1996 citing Plum Creek watershed assessments in the upper Green River). Moreover, if the stocking of hatchery chinook, coho, and steelhead were to continue after fish passage was provided into the upper basin, we believe that the likelihood of self-sustaining, native stocks becoming reestablished would be further diminished. For these reasons, we did not include the above tributaries on our maps, but suggest they be considered further in basin-specific analyses.

TABLE 8. GREEN RIVER BASIN STREAMS AND STREAM SEGMENTS CLASSIFIED IN ONE OF THE REFUGIA CATEGORIES.

STREAM OR SEGMENT NAME	CATEGORY[A]	ALTERATION CLASS[B]	SOURCE TYPES[C]
Green River Mainstem RM 32-61	2	ADF	RP
Covington Creek	3	FH	RP
Newaukum Creek (RM 0-4)	3	AFU	P

[A]Stream categories: 1 = areas with high ecological integrity; 2 = anadromous salmonid refugia but with impaired integrity; 3 = possible refugia but more data are needed; 4 = critical contributing area; 5 = areas with exceptional habitat that is currently inaccessible to anadromous fishes due to an artificial barrier such as a dam or hatchery rack

[B]Categories of alterations: A = Agricultural/rural residential (often including diking); D = Dam influenced, either by passage issues downstream or flow issues from upstream (including diversions); F = Forestry; H = hatchery; I = Industrial or urbanized; E = Exotic invasive species; N = Not managed; O = Other; P = Planned development (e.g. platted subdivision); U = unknown

[C]Types of information sources that provide support for the category designations include: P = personal communications; R = reports or articles; S = WDFW spawner database; D = other data sets; O = other

PUYALLUP RIVER BASIN AND CHAMBERS, SEQUALITCHEW, AND HYLEBOS CREEKS - WRIAs 10 AND 12

OVERVIEW

The Puyallup River and its two major tributaries, the White and Carbon rivers, are all glacial rivers originating on the slopes of Mount Rainier. The White River was historically a tributary to the Green River, but a flood event in 1906 redirected the river into the Puyallup River basin. In 1914, a concrete diversion was constructed to prevent the White River from returning to the Green River.

The mouth and estuary of the Puyallup River are heavily urbanized and industrialized. Commencement Bay has lost more than 98 percent of its historical intertidal and subtidal habitat (Kerwin 1999). A variety of contaminants severely degrade water quality, and in 1981, Commencement Bay was listed as a federal Superfund site (Kerwin 1999). The Hylebos, Middle, and Thea Foss waterways remain Superfund sites. The lower mainstems of the Puyallup, White, and Carbon rivers are channelized and diked. Much of the upper Puyallup and White river basins that lie outside of Mt. Rainier National Park have been logged and roaded, causing increases in sediment and decreases in shading and large woody debris recruitment to the rivers and tributaries (Kerwin 1999). The White River, within the national forest boundaries, is designated as a FEMAT key watershed (FEMAT 1993).

Mainstem dams influence fish passage, river flows, timing of sediment discharge, and movement of materials in both the White and Puyallup rivers. On the Puyallup River, the Puget Sound Energy's Electron dam is near RM 41. Water is diverted by canal and returned to the river 11 miles downstream at the Electron Power Station. No minimum flows were established in the diversion reach until a 1997 agreement (Kerwin 1999). Presently, no fish passage is provided over the dam, but a fish ladder is scheduled to be in operation by the year 2000 (pers. comm. D. Nauer and B. Smith). On the White River, Mud Mountain Dam at RM 29.6 is a U.S. Army Corps of Engineers flood control dam. Five miles downstream is the Puget Sound Energy diversion dam (near Buckley). Water is diverted by the Puget Sound Energy dam to Lake Tapps and is returned to the river through the Dierenger Powerhouse, located at RM 3.5. Improved fish screens designed to meet current criteria were installed at the point of diversion in 1996 and are presently undergoing efficiency testing (Kerwin 1999). In 1995, juvenile bypass tunnels in Mud Mountain Dam were modified to reduce mortality of juvenile salmonids passing the dam (Kerwin 1999). Returning adult salmon are trapped at the diversion dam, trucked upstream of Mud Mountain Reservoir, and released in the White River. Mud Mountain Dam disrupts the natural sediment transport regime, reducing the typically high fine sediment load downstream during high flows and increasing it during low flows in the fall when the reservoir is flushed.

FISH

The Puyallup River basin contains native stocks of chum and pink salmon, winter steelhead, and perhaps chinook and coho salmon. Anadromous cutthroat trout that are presumably native (Johnson et al. 1999) also use the basin, but little information is available about them. White River spring chinook are considered a native stock but have been produced in hatcheries as part of an attempt to recover the stock. Puyallup fall chinook salmon appear to be strongly influenced by hatchery fish. Nehlsen et al. (1991) rated Puyallup River fall chinook salmon in the "special concern" category because of "threats posed by habitat damage from logging and development, overfishing, and large releases of hatchery fish.". Coho salmon have been stocked extensively in the basin, but the influence on native stocks is not known.

White River spring chinook are the only representative of the South Puget Sound spring chinook "genetic diversity unit" (Marshall et al. 1995). They are presently produced largely in hatcheries as a part of a program to rebuild the stock to self-sustaining levels. Nelson et al. (1991) considered Puyallup River spring chinook to be extinct. However, spring chinook salmon are occasionally observed in the Carbon River up to RM 25 and are apparently either a small remnant population or strays from the White River (Kerwin 1999). Puyallup fall chinook are largely influenced by Green River hatchery stocks (WDFW and WWTIT 1994b), and hatchery stocking is ongoing. The genetic distance between White River spring chinook and Puyallup fall chinook is "relatively large" (Marshall et al. 1995). Some coded-wire-tagged fall chinook of Green River origin have been recovered in the White River at the Buckley trap, and their spawn timing overlaps with White River Spring chinook (Marshall et al. 1995, and memo from B. Smith, 23 Nov. 1999).

Pink salmon appear to be genetically similar to stocks in the Skagit, Stillaguamish, and Snohomish, but due to their geographic isolation from those stocks, were placed in their own "genetic diversity unit" (Shaklee et al. 1995). The SASSI report rated Puyallup pink salmon as "healthy;" however "population trends within the past five years are not as optimistic" (Kerwin 1999).

In genetic analyses, Fennel Creek chum salmon cluster with Hood Canal fall chum stocks (source of documented stocking) (Phelps et al. 1995), and are considered a non-native stock (Kerwin 1999). The Carbon River chum salmon samples did not cluster with Hood Canal fish, but clustered with other southern Puget Sound fall- and summer-run populations or with northern Puget Sound populations, depending on the analysis (Phelps et al. 1995). These fish probably constitute a native stock.

The Puyallup River has the largest natural (hatchery-excluded) escapement of winter steelhead in southern Puget Sound, averaging about 1,900 fish annually (Busby et al. 1996). Native winter steelhead runs occur in the Puyallup, Carbon, and White rivers and tributaries (WDFW and WWTIT 1994b). The hatchery component of the total winter steelhead escapement is estimated at 5 percent (Busby and six others 1996). The SASSI report rated Puyallup and White river winter steelhead stocks as "healthy;" however, "population trends within the past five years are not as optimistic" (Kerwin 1999). Small numbers of summer steelhead are caught in the Buckley trap on the White River, but are thought to be strays from other systems (WDFW and WWTIT 1994b). These fish are not passed above Mud Mountain Dam (memo from B. Smith, 23 Nov. 1999).

The entire Puyallup system has been extensively stocked with coho salmon since at least 1952, and the influences on the native fish are not known (WDFW and WWTIT 1994b; MBSNF 1998). The Puyallup coho stock was considered "depressed" in the SASSI report. The White River coho stock was considered "healthy," at least upstream of Mud Mountain Dam, based on counts since 1940 at the dam (WDFW and WWTIT 1994b). Escapement index data from 1993 to 1997 for the Puyallup system indicated increases in escapement, with 1997 having the highest estimated escapement in the period of record, 1983-1997 (MBSNF 1998). Planting of hatchery coho in the upper White River was stopped in 1995 and record numbers of coho have returned since then (pers. comm. with C. Baranski, D. Nauer, and B. Smith). However, as of 1995, natural coho production in the White River below the dam did not appear to be increasing (MBSNF 1995a).

Native char (bull trout /Dolly Varden) occur in the Puyallup, Carbon, and White Rivers (WDFW 1998). Fish counts have been conducted periodically at the Buckley trap on the White River; a maximum of 45 native char were counted at the trap in one year (1994) (WDFW 1998). Char occur up to RM 65 (above Sunrise Creek) in the headwaters of the White River, to RM 11 (above Pyramid Creek) in the Greenwater River, and to RM 22 (near Tolmie Creek) in the Carbon River, according to the Limiting Factors report (Kerwin 1999), but extend further upstream in the White (to RM 68) and Carbon (to RM 31) rivers according to the Carbon River Watershed analysis (MBSNF 1998).

INDEPENDENT TRIBUTARIES

We did not identify any independent tributaries within these WRIAs as refugia.

Chambers Creek, along with the Nisqually River and McAllister Creek, support a genetically distinct winter chum stock that is the latest spawning chum run in North America (Phelps et al. 1995). Nehlsen et al. (1991) listed Chambers Creek coho salmon as having a high risk of extinction and chum salmon (summer-run) as having a moderate risk of extinction. The SASSI report (WDFW and WWTIT 1994b) listed the Chambers Creek summer chum as extinct (note that this is the only extinction listed for Puget Sound in the SASSI report). J. Kerwin (pers. comm.) noted that both a chinook and a coho salmon stock may also have been extirpated from the creek in recent years. Although Chambers Creek still has some good habitat in the lower end, it suffers from water quality problems, including high copper levels resulting from ongoing algae control efforts in Steilacoom Lake (pers. comm. with D. Nauer and B. Smith). Some excellent spawning and rearing habitat exists in the upper end; however, passage problems preclude anadromous fish access in most years (pers. comm. C. Baranski). Some of the blockages are scheduled to be modified to allow passage. WDFW transports several hundred adult coho salmon above the blockages each fall (pers. comm. C. Baranski). Little information is available about the degree of hatchery influence on chinook and coho salmon in the creek. The coho stock is classified as mixed origin in SASSI (WDFW and WWTIT 1994b).

Hylebos Creek chum salmon may be a unique stock (WDFW and WWTIT 1994b). Some coho salmon (pers. comm. J. Kerwin) anadromous cutthroat and steelhead trout use the system, and chum numbers are "fairly good" (pers. comm. with D. Nauer and B. Smith). Chinook were historically present in low numbers (pers. comm. J. Krewin). No habitat approaches pristine condition in the basin. West Fork Hylebos Creek is in the best condition and contains some lakes and beaver ponds (pers. comm. with D. Nauer and B. Smith). Habitat is in poor condition in mainstem Hylebos Creek. (pers. comm. with D. Nauer and B. Smith). Spring Valley is the most productive area for fish, but it contains housing developments and is in need of restoration (pers. comm. with D. Nauer and B. Smith). Hylebos Waterway, where the creek enters Commencement Bay, is a federal Superfund site, and juvenile salmon from the waterway show evidence of chemical contamination (Kerwin 1999 citing Collier 1998).

AREAS RECOMMENDED FOR WITHIN-BASIN REFUGIA DESIGNATION AND JUSTIFICATIONS

REFUGIA - ALTERED (CATEGORY 2)

PUYALLUP/CARBON-RIVER SUB-BASIN:

South Prairie Creek

South Prairie Creek, a tributary to the Carbon River, is unquestionably the most productive for anadromous salmonids of all mainstem reaches and tributaries in the Puyallup system (WDFW and WWTIT 1994b; Kerwin 1999, and pers. comm. with D. Nauer, B. Smith, and R. Ladley). The stream is used by native stocks of winter steelhead, and pink and fall chum salmon (WDFW and WWTIT 1994b; MBSNF 1998). The majority of pink salmon production and nearly half of the wild steelhead production in the Puyallup River comes from South Prairie Creek (WDFW and WWTIT 1994b; Kerwin 1999). Pink salmon spawn primarily between RM 1 and 13 (WDFW and WWTIT 1994b). Coho and fall chinook salmon and anadromous cutthroat trout also use the stream (MBSNF 1998; Kerwin 1999). Some coho salmon using the stream are late-spawning, suggesting little or no hatchery influence, whereas others have spawn timing similar to that of the Voight Creek Hatchery coho stock (memo from B. Smith, 23 Nov. 1999). Chinook salmon using the stream show some genetic uniqueness but are heavily influenced by hatchery stocking. Most of the known natural production of Puyallup fall chinook comes from South Prairie Creek (WDFW and WWTIT 1994b). The stream has been closed to recreational fishing since 1977. The segment from the mouth to the Burnett Bridge (State Highway 165 crossing) is the most productive for pink, chum, and chinook salmon reproduction and is also the most threatened by development. Resident cutthroat trout are present in South Prairie Creek up the headwaters (MBSNF 1998).

Spawning habitat is abundant in South Prairie Creek (pers. comm. with D. Nauer and B. Smith). Few dikes exist along the creek. The creek is highly productive for invertebrates. It is a clear-water creek, whereas much of the Puyallup system, including the Carbon River, is glacial. The lower watershed is primarily agricultural with some homes near the creek. The upper watershed is primarily privately owned tree farms. "Opportunities to protect and restore habitat are available in this creek," according to Kerwin (1999)

Habitat in South Prairie Creek is far from pristine. In USFS lands in the watershed, almost no mature or old-growth forest remains (MBSNF 1998). The lower end of the creek has a narrow riparian buffer strip (details in Kerwin 1999). There are five highway crossings along the creek. The entire creek is influenced by intensive logging in the upper reaches. South Prairie Creek is expected to be listed for exceeding Clean Water Act section 303(d) standards for water temperature, and was listed in 1996 for exceeding fecal coliform standards (Kerwin 1999). Considerable siltation has occurred in the lower watershed (Williams et al. 1975). Recruitment and retention of large woody debris in lower South Prairie Creek is low (Kerwin 1999).

The City of Buckley's water diversion dam at RM 15.7 blocks upstream fish passage. However, steep cascades at RM 15.0 may have historically limited passage by anadromous fish (Williams et al. 1975). The lower 5 miles of the creek have been channelized or leveed, but the levees have not been maintained for 20 years (Kerwin 1999). The creek is recapturing some of the historic floodplain.

Non-native brook trout occur in the East Branch of the South Fork of South Prairie Creek and in lakes within the system (MBSNF 1998). Potential exists for negative interactions between brook trout and native resident fishes.

Wilkeson Creek

This is the main tributary to South Prairie Creek. The lower 6.8 miles of the creek provide good spawning and rearing habitat (Williams et al. 1975, and pers. comm. with D. Nauer and B. Smith). Coho and fall chinook salmon, winter steelhead trout and anadromous cutthroat trout spawn in Wilkeson Creek (WDFW and WWTIT 1994b; Kerwin 1999). Habitat is in relatively good condition with constraints similar to those noted above for South Prairie Creek (pers. comm. with D. Nauer and B. Smith). Above the falls at RM 6.8, resident cutthroat trout populations occur (Kerwin 1999).

Land below the falls is used for residences and forestry, and the channel is incised (Kerwin 1999). Wilkeson Creek is expected to be listed for exceeding Clean Water Act section 303(d) standards for water temperature (Kerwin 1999). The lower first mile of the creek is channelized or has levees (Kerwin 1999). Recruitment and retention of large woody debris in lower Wilkeson Creek is low (Kerwin 1999).

Carbon River - upstream of Orting (RM 3.3) to the mouth of Lily Creek (RM 11.3)

This segment has the most productive mainstem spawning for all species of salmon and steelhead in the basin (pers. comm. with D. Nauer and B. Smith). It is the most productive segment in the Puyallup system for fall chum salmon and is used by steelhead trout, coho and fall chinook salmon (pers. comm. with D. Nauer and B. Smith). Pink salmon spawn in the lower 4 miles of the Carbon River (MBSNF 1998). The most productive area is between RM 3.3 and 6.0, but all the way to RM 11.0 (located at the mouth of a canyon) should be considered for protection (pers. comm. with D. Nauer and B. Smith).

Portions of the segment are unconfined, although other portions are restricted by levees (pers. comm. B. Smith). From RM 3.3 to 5.9, a levee exists on the left bank to protect the town of Orting.

However, the river channel is wide through this section and is highly productive for salmon. From RM 5.9 to 8.2, the channel is narrow with levees on both banks. From RM 8.2 to 11.3, the channel is wide and lacks dikes.

WHITE RIVER SUB-BASIN:

Mainstem - RM 8.9 to Buckley

All salmon species in the system, as well as steelhead trout, spawn in this segment. The river is unconfined and interacts with its floodplain. The segment contains numerous side channels, sloughs and springs.

Much of the land in the lower portion of the segment is in the Muckleshoot Indian Reservation, with some private land interspersed. The land in the upper end is owned by Puget Sound Energy.
This is the diversion reach below the Buckley diversion dam, and thus major flow problems exist. However, if a more natural flow regime is returned to the segment, habitat should be outstanding. In 1996, the segment from RM 0 to 29.6 exceeded Clean Water Act section 303(d) standards for fecal coliform, pH, and instream flows, and it is expected that temperature will be added to the list (Kerwin 1999). General problems related to the dams are discussed in the introduction. The City of Tacoma's water Pipeline Number 1 crosses the White River downstream of the mouth of Boise Creek. The pipeline, which disrupts upstream migrations of fish (especially chum salmon), was scheduled to be removed in 1999, but has been delayed for at least one year. Recruitment and retention of large woody debris in lower Wilkeson Creek is low (Kerwin 1999).

POSSIBLE REFUGIA (CATEGORY 3)

PUYALLUP/CARBON RIVER SUB-BASINS:

Fennel Creek - mouth to impassible falls (RM 2.0) – and Canyon Falls Creek

All salmon and steelhead species in the basin use this segment (pers. comm. with D. Nauer and B. Smith). It is an important spawning segment for native pink salmon (WDFW and WWTIT 1994b). Large numbers of chum salmon were planted over a small native stock (WDFW and WWTIT 1994b), and chum salmon from Fennell Creek are genetically influenced by Hood Canal hatchery-origin fish (Phelps et al. 1995). Rapid development is ongoing upstream with 10,000 homes planned between Fennel Creek and Orting (pers. comm. with D. Nauer and B. Smith).

Canyon Falls Creek is similar to Fennel Creek with regard to both species use and habitat limitations and should also be classified as a possible refugia (pers. comm. C. Baranski, with reported concurrence from D. Nauer).

Niesson Creek

Niesson Creek enters the diversion reach of the Puyallup River between the Puget Sound Energy diversion dam and the powerhouse. This creek supports a "good steelhead trout population and some coho salmon" (pers. comm. D. Nauer).

Coho salmon returns have been limited by low flows in the diversion reach that effectively prevent adult coho salmon access to Niesson Creek (pers. comm. D. Nauer).

Upper Puyallup mainstem above Electron Dam

Fish passage into this segment has been blocked by Electron Dam for 95 years; however, a fish ladder is scheduled to be installed in the year 2000. Wild winter steelhead have persisted just downstream of the dam and are expected to naturally recolonize the area above the dam. "The 11 tributaries accessible for anadromous fish within this sub-basin have the potential to produce chinook and coho salmon along with winter steelhead and cutthroat trout," according to Kerwin (1999). Native char occur in the upper Puyallup River and in the Mowich River (WDFW 1998; Kerwin 1999).

It is not known whether runs will be reestablished above the dam. Hatchery chinook and coho salmon are being planted upstream of the dam. Habitat is not pristine. Intensive logging has, and continues to, occur in the upper Puyallup River basin and has had adverse effects on peak flows, bedload movement, large woody debris recruitment, and slope stability (Kerwin 1999).

Kapowsin/Ohop Creek

Habitat is in good condition in this segment; however, few fish use the system (pers. comm. with D. Nauer and B. Smith). The SASSI report indicates that Kapowsin Creek was an important spawning area for pink salmon (WDFW and WWTIT 1994b). Coho net pens were used for a few years until three years ago (pers. comm. with D. Nauer and B. Smith).
The first return of coho from net-pen progeny (F2 generation) has been very successful, with numerous coho returning to the system this year (pers. comm. pers. comm. B. Smith, 1999).

WHITE RIVER SUB-BASIN:

Boise Creek

Below the barrier, Boise Creek is used by chinook and coho salmon and native steelhead trout (pers. comm. D. Nauer and B. Smith), and resident cutthroat trout occur above the barrier (pers. comm. J. Kerwin, 23 Nov. 1999). Boise Creek is the most productive chinook salmon stream in the White River basin (pers. comm. D. Nauer and B. Smith). Coho have been stocked extensively in the watershed, but have not been stocked for the past four years and are still returning (pers. comm. D. Nauer and B. Smith).

Habitat in the lower creek, below the falls, is not in good condition (pers. comm. D. Nauer and B. Smith), but continues to provide important overwintering habitat (pers. comm. J. Kerwin, 23 Nov. 1999). The creek has been dredged and ditched. Land use is primarily farms and a golf course, and there is development pressure on the farms. The habitat above the falls is owned by Weyerhaeuser and is in better condition (pers. comm. D. Nauer and B. Smith).

White River Upstream of Mud Mountain Dam

"The middle and upper segments of the White River and associated tributaries have the potential to be highly productive if significant passage problems ... can be successfully addressed and riparian areas are allowed to recover," according to Kerwin (1999).

Mainstem White River - Clearwater River to Greenwater River

This river segment is unconfined and in good condition. Few data exist on fish use because the glacial color makes visual surveys impractical for most species. Two years of radio tracking data for chinook salmon suggest that this may be an important spawning segment, but data are limited (pers. comm. D. Nauer and B. Smith). A watershed analysis also indicated that chinook salmon spawn in the upper White River (MBSNF 1995a). Native char occur in the upper White River up to Fryingpan Creek (MBSNF 1995a). Side channels off the mainstem occur in the segment (pers. comm. J. Doyle).

Intensive logging throughout much of the upper White River basin has degraded habitat quality from its historic condition in the river. The river exceeds the CWA section 303(d) standard for temperature (Kerwin 1999). Large woody debris recruitment and retention are poor (Kerwin 1999).

West Fork White River

Fish use of this river is poorly known because the glacial coloration makes observations of fish impractical for much of the year. At least some chinook use the mainstem (MBSNF 1995a, and pers. comm. D. Nauer and B. Smith). J. Doyle (pers. comm.) indicated that fall chinook, coho, and steelhead spawn in the mainstem and tributary channels. There is one chinook acclimation pond in the West Fork White River. Coho salmon also use the river (Kerwin 1999). Some wild steelhead use both the mainstem and tributaries (pers. comm. D. Nauer).

Habitat in tributaries Viola and Wrong creeks is in good condition, and the basins are in second-growth forest (pers. comm. with D. Nauer and B. Smith). Fair to good side channel habitat exists in the segment (pers. comm. J. Doyle). Land ownership is Park Service at the headwaters, Forest Service downstream, and Weyerhaeuser in the lower end.

We found little information on habitat conditions in the watershed, but the drainage is extensively roaded (MBSNF 1995a). Much of the upper West Fork White River outside of Mt. Rainier National Park has been heavily logged (pers. comm. J. Kerwin, 23 Nov. 1999). No timber harvesting has occurred in the past 10 years, however, and some roads are scheduled to be decommissioned (pers. comm. J. Doyle). J. Doyle noted that upland conditions are recovering from past timber harvesting and road construction.

Clearwater River

This tributary to the upper White River is used by pink, coho, and spring chinook salmon and steelhead trout (pers. comm. with D. Nauer and B. Smith). Chinook salmon numbers are increasing (pers. comm. with D. Nauer and B. Smith). The upper watershed is in the Clearwater Wilderness, and the lower watershed is primarily in Weyerhaeuser ownership.

Chum salmon passage to the Buckley trap is hindered by the previously described pipeline crossing the lower White River. Large woody debris recruitment and retention is severely limited in much of the Clearwater River (Kerwin 1999). The river exceeds the CWA section 303(d) standard for temperature (Kerwin 1999). A study conducted in 1995-96 during the salmon egg incubation period found that channel instability was high (Kerwin 1999). Ratings for fine sediments in spawning gravels have been "fair" to "good" (Kerwin 1999).

Greenwater River

This river is similar in most respects to the Clearwater River, but the habitat is in poorer condition (pers. comm. with D. Nauer and B. Smith). It produces more coho salmon than does the Clearwater River, and chinook salmon numbers are increasing. The lower 2/3 of the river appears to be providing spring chinook salmon refugia habitat (Doyle 1999b). Steelhead trout also use the system (pers. comm. J. Doyle). The Greenwater River is "thought to be a major bull trout/Dolly Varden tributary" (WDFW 1998). The upper 1/3 of the watershed is in designated wilderness.

In most of the sub-watersheds in the lower two-thirds of the Greenwater River, 50 to 90 percent of the area has been harvested in the past 30 years (Doyle 1999b). Although some quality spawning grounds exist (MBSNF 1996a), in general, habitat conditions in the lower two-thirds of the watershed are in poor condition. "Overall watershed conditions are functioning between at risk and at unacceptable risk," according to Doyle (1999b). Summer stream temperatures exceeded the CWA section 303(d) standards more often in the Greenwater than in the Clearwater River (Kerwin 1999). Floods in 1977 removed nearly all large woody debris from the Greenwater River (WDFW and WWTIT 1994b; WDFW, 1998 #16). Road densities average 3.25 miles/ square mile, with some tributary watersheds having densities as high as 6.0 miles/square mile (Doyle 1999b). USFS Road 70 lies almost completely within the river's floodplain, restricting hydraulic connectivity with the floodplain (Doyle 1999b). A recent land swap with Weyerhaeuser resulted in 95 percent of the watershed being administered by USFS (Doyle 1999b). The Greenwater River watershed has been targeted for restoration by the USFS. Three stream surveys conducted from 1989 to 1998 show habitat conditions improving in the mainstem (pers. comm. J. Doyle).

Huckleberry Creek (tributary to the upper White River)

Huckleberry Creek is a non-glacial system (pers. comm. J. Doyle). The creek supports many coho salmon. White River spring chinook salmon and steelhead trout also spawn in Huckleberry Creek (MBSNF 1995a, and pers. comm. with D. Nauer and B. Smith), as do native char (pers. comm. J. Doyle). While this basin has also been intensively logged, water temperatures were lower than in the Clearwater, Greenwater, and White rivers, and were in compliance with the CWA section 303(d) (Kerwin 1999). Habitat is recovering from past logging and road building (pers. comm. J. Doyle).

Mainstem White River - RM 57-61 and Snoquera Creek

Few data exist on fish use because the glacial color makes visual surveys impractical for most species. A watershed analysis indicated that chinook salmon spawn in the upper White River (MBSNF 1995a). Native char occur in the upper White River up to Fryingpan Creek (MBSNF 1995a). Coho salmon and native char are found in tributaries of the mainstem segment (pers. comm. J. Doyle). Snoquera Creek contained cutthroat trout in 1980 (MBSNF 1995a).

From about RM 57.0 to 59.5, the river is confined by mudflow deposits from Mount Rainier (MBSNF 1995a). From RM 59.5 to 61.0, the river is unconfined and has a braided channel. Habitat along the mainstem is in good condition (pers. comm. J. Doyle). From RM 57 to 61 is one of the few segments of the mainstem outside of the National Park where little disturbance has occurred in the channel or riparian zone. No timber harvest has occurred on the valley floor or along the river, and old-growth trees exist along a buffer of at least several hundred feet from the river in most places (MBSNF 1995a). Snoquera Creek, a tributary to the lower end of the segment, was harvested in the 1980s but has a buffer strip of old-growth conifers along the stream, and the stream channel is in good condition (MBSNF 1995a).

POSSIBLE REFUGIA RECOMMENDED DURING THE REVIEW PERIOD BUT WITHOUT SUPPORTING DOCUMENTATION OR REASONS (NOT MAPPED)

Silver Creek, lower – (on the upper White River) - J. Doyle

Carbon River and tributaries above Lily Creek - J. Doyle

CRITICAL CONTRIBUTING AREAS (CATEGORY 4)

Goat Creek

Goat Creek is a major tributary to Silver Creek, which enters the upper White River. Cutthroat and rainbow trout use the lower 0.6 miles of Goat Creek (MBSNF 1995a). Although this subwatershed has not been harvested, it is suspected that large woody debris was cleared from the stream in the 1970s (MBSNF 1995a). A 1992 stream survey report indicated that the stream was in "good, stable condition and supporting a healthy population of resident trout" (MBSNF 1995a).

Upper White River, above RM 61.0, and tributaries

Upstream of RM 61, the White River is in the national park. We have no information on river conditions within the park, but assume that the watershed is in relatively good condition upstream of the park boundary. However, the Mather Memorial Parkway continues to parallel the White River in the park. J. Doyle (pers. comm.) concurred that this should be classified as a critical contributing area.

POTENTIAL REFUGIA ABOVE ARTIFICIAL BARRIERS (CATEGORY 5)

Puyallup and Mowich rivers above Electron dam

Habitat upstream of Electron Dam is in relatively good condition. Given the paucity of high-quality habitat in the Puyallup and Carbon rivers, the area upstream of the dam could prove important to recovery of native, anadromous stocks in the basin. C. Baranski, D. Nauer, and B. Smith (pers. comm.) concurred with this assessment.

TABLE 9. PUYALLUP RIVER BASIN STREAMS AND STREAM SEGMENTS CLASSIFIED IN ONE OF THE REFUGIA CATEGORIES.

Stream or segment name	CATEGORY[A]	ALTERATION CLASS[B]	SOURCE TYPES[C]
PUYALLUP/CARBON			
Fennel and Canyon Falls creeks	3	P	RP
Kapowsin/Ohop creeks	3	U	P
Carbon River, RM 3.3 to RM 11.3	2	A	P
South Prairie Creek	2	AFD	RP
Wilkeson Creek	2	AF	RP
Puyallup and Mowich rivers above Electron dam	5	FD	P
WHITE			
White - RM 8.9 to Buckley	2	AD	P
Boise Creek	3	AF	P
White - Clearwater to Greenwater	3	FD	RP
West Fork White River	3	FD	RP
Clearwater River	3	FD	RP
Greenwater River	3	FD	RP
Huckleberry Creek	3	FD	RP
White - RM 57-61 and Snoquera Creek	3	FD	R
Goat Creek	4	O	R
White River, RM 61 to headwaters	4	FO	P

[A]Stream categories: 1 = areas with high ecological integrity; 2 = anadromous salmonid refugia but with impaired integrity; 3 = possible refugia but more data are needed; 4 = critical contributing area; 5 = areas with exceptional habitat that is currently inaccessible to anadromous fishes due to an artificial barrier such as a dam or hatchery rack

[B]Categories of alterations: A = Agricultural/rural residential (often including diking); D = Dam influenced, either by passage issues downstream or flow issues from upstream (including diversions); F = Forestry; H = hatchery; I = Industrial or urbanized; E = Exotic invasive species; N = Not managed; O = Other; P = Planned development (e.g. platted subdivision); U = unknown

[C]Types of information sources that provide support for the category designations include: P = personal communications; R = reports or articles; S = WDFW spawner database; D = other data sets; O = other

NISQUALLY RIVER BASIN AND MCALLISTER AND RED SALMON CREEKS - WRIA 11

OVERVIEW

The Nisqually River has the largest estuary in southern Puget Sound (Nisqually EDT Work Group 1999b) and the "last major undeveloped delta in Puget Sound" (Williams et al. 1975). The historic estuary area has been reduced about 30 percent by dikes (Nisqually EDT Work Group 1999b). Much of the riparian area along the lower river is already in protected status by the Nisqually National Wildlife Refuge, the Fort Lewis Military Reservation, and the Nisqually Indian Reservation. In addition, the Nisqually River Basin Land Trust has been purchasing land for conservation purposes since 1990. Along the 40 miles of mainstem accessible to anadromous fishes, 64 percent of the shoreline is in protected status.

The mainstem Nisqually River has three dams (Walter 1986). Tacoma City Light's LaGrande Dam at river mile 42.5 normally diverts the total flow of the river to its powerhouse at RM 40.8. The present upstream distribution limit of anadromous fishes is RM 41.4 (pers. comm. J. Kerwin). Alder Dam at river mile 44.2 impounds the 8-mile-long Alder Lake. A falls or cascade in the vicinity of the impoundments is thought to have prevented fish passage historically. The City of Centralia's diversion dam at RM 26.2 diverts up to 800 cfs, returning the water to the river at RM 12.7. Interim minimum flow guidelines for the LaGrande Dam were established in 1978 and amended in 1985, becoming "permanent operating requirements" for both dams in 1993 (Kerwin Draft-b). Fish passage facilities at the dam were renovated in 1985 and appear to have improved fish passage (pers. comm. with G. Walter).

FISH

The Nisqually River basin has several genetically unique stocks of salmon that have apparently been influenced minimally, if at all, by hatchery stocks. South Sound winter run chum, including fish from the Nisqually River and the independent streams Chambers and McAllister creeks are genetically distinct from all Puget Sound and Hood Canal summer- and fall-run fish sampled, and they have the latest run timing of any chum salmon in North America (Phelps et al. 1995). The Nisqually River pink salmon are also very genetically distinct from all others sampled (Shaklee et al. 1995). They have the latest run timing of any Washington populations of pink salmon studied (Hard et al. 1996). Cutthroat trout from the upper Nisqually River are "markedly genetically distinct from their nearest geographic neighbor;" however, hatchery cutthroat trout from several sources have been planted in the Nisqually River basin (Johnson et al. 1999). The amount of hatchery influence on winter steelhead trout and coho salmon is unknown, although the winter steelhead trout are thought to be primarily native (WDFW and WWTIT 1994b) and have not been stocked since 1982 (memo from G. Walter). Of major rivers in Puget Sound, the Nisqually River is the only one not receiving hatchery winter steelhead, and it has the smallest component (1 percent) of hatchery fish in the total wild spawner escapement (Busby et al. 1996). Summer steelhead trout, however, are stocked in the system (Busby et al. 1996). The fall chinook salmon probably have a strong genetic influence from hatchery fish (WDFW and WWTIT 1994b, Marshall et al. 1995, Nisqually EDT Work Group 1999a). Nisqually River-origin spring chinook salmon were extinct by 1955 (Kerwin Draft-b).

Chum and chinook salmon runs appear to be stable or increasing in the basin. The Nisqually Limiting Factors Report (Kerwin Draft –b) will have additional and more recent information on run size and hatchery issues. Huntington et al. (1996) listed the Nisqually River chum salmon population as a healthy native stock as of 1995. Chum constitute the major salmon run in the river with returns of up to 100,000 fish in recent years (memo from G. Walter). Nisqually River pink salmon have apparently always had a smaller run of about 2,000 to 10,000 fish (memo from G. Walter). Chinook salmon runs are increasing with recent returns of about 10,000 fish (memo from G. Walter), although "the bulk of these are hatchery returns" (pers. comm. J. Kerwin). Steelhead trout run sizes have been declining in recent years (from fewer than 5,000 to 1,000 fish) (memo from G. Walter) and indicate that the stock is depressed (Kerwin Draft-b). Coho salmon have also been declining in recent years, with runs now consisting of fewer than 5,000 fish (memo from G.

Walter). Native anadromous and resident cutthroat trout persist in the basin (pers. comm. with G. Reeves and D. Clouse), but we found no information on their abundance.

The Nisqually River basin hosts a large wintering population of bald eagles that feed nearly exclusively on chum salmon (96 percent of their food items identified) (Stalmaster and Kaiser 1997). The birds were concentrated primarily along the mainstem between river miles 5 and 11, at the mouth of Yelm Creek (river mile 13), and along the lower 2.5 miles of Muck Creek. Peak counts (in February) ranged from 83 to 155 birds on the mainstem and from 10 to 77 birds in Muck Creek. In Washington, larger winter populations apparently occur only in the Skagit and Nooksack basins and along the Columbia River.

AREAS RECOMMENDED FOR WITHIN-BASIN REFUGIA DESIGNATION AND JUSTIFICATIONS

Readers should note that more detailed descriptions of the river segments described below will soon be available when the limiting factors report (Kerwin Draft-b) is completed. We did not have sufficient time to include all relevant information from the draft report in our report.

REFUGIA - ECOLOGICAL INTEGRITY INTACT (CATEGORY 1)

Mainstem: BN railroad bridge to Centralia powerhouse

This is the "least impacted" segment of the mainstem Nisqually River (Nisqually EDT Work Group 1999b). This segment provides transportation, holding, rearing, and spawning habitat for chinook, chum, pink, and coho salmon; winter steelhead; and anadromous cutthroat trout (Walter 1986). The segment includes important side channels that are heavily used by chum and coho salmon for spawning and rearing (Walter 1986) and supports large concentrations of wintering bald eagles that feed primarily on adult chum salmon carcasses (Stalmaster and Kaiser 1997). Most riparian areas contain medium to large conifers and hardwoods (Nisqually EDT Work Group 1999b).

REFUGIA - ALTERED (CATEGORY 2)

MAINSTEM SEGMENTS

Mainstem: Mouth to I-5 bridge

This segment provides transportation, holding, rearing and spawning habitat for chinook, chum, pink, and coho salmon, winter steelhead and anadromous cutthroat trout (Walter 1986). It provides crucial freshwater to saltwater transition zone for anadromous fishes (Walter 1986). In the lower segment, the river "meanders freely over its estuarine floodplain" (Nisqually EDT Work Group 1999b).

A "substantial number" of dikes occur along the middle portion of the segment (Nisqually EDT Work Group 1999b). The riparian habitat consists of a narrow corridor of deciduous and hardwood trees and blackberry vines along the mainstem (Nisqually EDT Work Group 1999b, and pers. comm. J. Kerwin).

Mainstem: Centralia powerhouse (RM 12.7) to Murray Creek (RM 19.1))

Between the powerhouse and the highway bridge in McKenna (RM 21), various stream-side developments, including homes, exist along the segment, but much of the right bank and some of the left bank are within the Fort Lewis Military Reservation (Nisqually EDT Work Group 1999). The floodplain is confined in a canyon through much of the segment, although moderately wide floodplains exist in some areas (Nisqually EDT Work Group 1999; Kerwin Draft-b). Spawning gravel is abundant in the lower two miles of the segment (Nisqually EDT Work Group 1999). "Riparian conditions are generally good within the portions of this segment that is within the US Army– ort Lewis ownership, consisting primarily of second growth hardwoods and some second growth conifers, but some destruction of the riparian corridor has occurred elsewhere," (Nisqually EDT Work Group 1999; Kerwin Draft-b). We found no current information on fish use of this segment, but when finalized, the limiting factors report (Kerwin Draft-b) will include fish distribution maps.

Water is diverted from the river upstream at the Centralia Diversion Dam and not returned to the river until it reaches the Centralia Powerhouse at the downstream end of the segment. However, minimum flow requirements exist for the diversion reach (Kerwin Draft-b). The riparian forest along much of the segment provides a source of large woody debris, but large woody debris recruitment from upstream is limited (Kerwin Draft-b). Near McKenna and in Horn Creek (a tributary entering at RM 25.8), water quality is degraded by sediment and animal wastes originating from agricultural activities (Nisqually EDT Work Group 1999).

Mainstem: Confluence of Tanwax Creek to LaGrande powerhouse

The segment provides transport, holding, spawning, and rearing habitat for chinook, chum, pink, and coho salmon and winter steelhead (Walter 1986). In the lower part of the segment (Tanwax Creek to Ohop Creek) the river meanders across a wide valley and has many productive side channels and sloughs that provide "significant habitat for summer rearing and winter flood protection," according to Nisqually EDT Work Group (1999b). The riparian areas have second- and old-growth forests. In the upper part of the segment, the river flows through bedrock canyons and has some eroding sand/gravel bluffs. The segment is primarily in its natural condition (Nisqually EDT Work Group 1999b).

TRIBUTARY SEGMENTS

Muck Creek drainage

Muck Creek usually supports less than 25 percent of the chum production in the basin (Walter 1986). Coho, winter steelhead, and anadromous and resident cutthroat trout also use the creek (Walter 1986; Johnson and seven others 1999, pers. comm. G. Reeves and D. Clouse). Some planting of chum has occurred in Lacamas Creek, a tributary (Walter 1986). Tributaries at miles 2.3, 5.55 and 9.3, as well as mainstem gravel reaches, were important chum salmon spawning areas as of 1975 (Williams et al. 1975). Stream habitat is good up to about RM 9.5 (pers. comm. G. Walter). Some very good habitat exists upstream of Ft. Lewis (RM 14.5) in Muck and South creeks, but intermittent flows hinder access (pers. comm. G. Walter). Some late-run coho use upstream perennial areas when flows allow passage (pers. comm. D. Clouse). The area supports large wintering concentrations of bald eagles, except in years when low flows inhibit chum passage near the stream mouth (Stalmaster and Kaiser 1997).

The lower end of Lacamas Creek is perennial and provides good coho salmon, steelhead and cutthroat trout rearing habitat (Kerwin Draft-b) for 1.5 to 2.0 miles upstream (pers. comm. G. Walter). No development has occurred along the lower end of the creek.

Peak spawner counts for chum salmon in the WDFW database were available for 15 years between 1979 and 1998. We found no statistically significant decline over the period, and the counts appeared to be stable. The maximum chum salmon count was 534 in a 0.1-mile reach at Exeter Springs.

The creek becomes intermittent from June to December near the upstream boundary of Fort Lewis, but in recent years the intermittent zone is expanding upstream (pers. comm. with D. Clouse). Dense development is ongoing upstream of Ft. Lewis. Invasion by reed canary grass is a major problem in Muck Creek where it flows through Ft. Lewis; attempts to control the weed are ongoing (pers. comm. with D. Clouse). Heavy predation on salmonids by non-native centrarchids in the lakes is a concern (Walter 1986).

Mashel and Little Mashel rivers

The Mashel River is the largest tributary to the lower Nisqually River and supports chinook, pink, and coho salmon, as well as winter, and possibly summer, steelhead. This lower section has mature riparian forests, including some old-growth trees, and is scheduled for acquisition as a state park (Nisqually EDT Work Group 1999b). Winter, and possibly summer steelhead, also use the upper river, but good documentation is lacking (Walter 1986). Pink salmon historically used the lower 3.7 miles of the Mashel and made less than 100 redds/mile, but they declined in the late 1970s and early 1980s (Walter 1986).

We designated the Mashel River from RM 3.7 to 15.4 and the lower end of its tributary, Busywild Creek, as possible refugia, except for the area around Eatonville. The areas receive a "fair" amount of use by steelhead (pers. comm. with G. Walter, 23 Nov. 1999). Upstream of Eatonville, land is used primarily for timber production. A waterfall prevents fish passage above RM 15.4.

The Little Mashel River is used by coho salmon and steelhead trout for spawning and rearing up to an impassible falls at RM 0.8. Salmon use of Beaver and Busywild creeks is not well studied (Walter 1986). The riparian areas are mostly intact, consisting of medium-size hardwoods (Nisqually EDT Work Group 1999b). Upstream of the falls, land uses are primarily agriculture and tree farms (Nisqually EDT Work Group 1999b).

The town of Eatonville lies between RM 5.1 and 6.0 on the Mashel River, and the river is channelized and rip-rapped through town (Nisqually EDT Work Group 1999b). The town withdraws water at RM 5.7 and returns it to the river at RM 5.4, creating thermal and possibly adult passage problems (Nisqually EDT Work Group 1999b). Sediment load in the river is high from mass wasting and logging roads in poor condition in the headwaters (Nisqually EDT Work Group 1999b).

INDEPENDENT STREAMS

Red Salmon (Mounts) Creek

This 1.5-mile-long stream provides spawning and rearing habitat for coho and chum salmon and anadromous cutthroat trout (Walter 1986). The estuary is hydrologically connected to the Nisqually River estuary and "provides an important segment of the estuarine habitat of the Nisqually Delta" (Walter 1986). Some housing development is occurring at the upper end of the stream, but the stream habitat remains in good condition (pers. comm. with G. Walter).

Peak spawner counts for chum salmon in the WDFW database were available for 17 years between 1975 and 1997. With the exception of 1997, which had the lowest peak spawner count on record, the counts were stable or increasing over the period. The maximum chum salmon count was 625/0.1 mile in the reach from RM 1.2 to 1.5.

POSSIBLE REFUGIA (CATEGORY 3)

McAllister Creek

This independent tributary to the Nisqually Reach provides some spawning and good rearing habitat primarily for chum, but also for chinook, coho, sockeye salmon, steelhead trout, and anadromous cutthroat trout (Williams et al. 1975; Walter 1986). Spawning occurs primarily in springs. The stream produces fewer than 1,000 chum salmon per year (pers. comm. with G. Walter).

Peak spawner counts for chum salmon in the WDFW database were available for 26 years between 1969 and 1998. The counts were stable over the period. The maximum chum salmon count was 416 in a 0.1 mile reach at McAllister Springs.

The refugia function of the creek arises as much from its role as an important component of the Nisqually estuary as from salmonid production in the creek itself (G. Walter, pers. comm., 23 Nov. 1999). Downstream of the I-5 bridge, McAllister Creek is tidally influenced and lies entirely within the Nisqually Wildlife Refuge. Therefore, we assigned a higher ranking to the lower segment than to segments above the bridge, where more development and agricultural uses exist.

Access to some of the spring and side channel spawning areas has been prevented or inhibited. Flow has been reduced by water withdrawals for Olympia. Alteration of the river where I-5 crosses may have increased upstream siltation in spawning areas. A WDFW hatchery at RM 4.0 releases large numbers of fall chinook salmon (Walter 1986, and pers. comm. G. Walter). Intense agricultural activity on the largest tributary, Medicine Creek, has nearly eliminated its fish production (Walter 1986).

Water quality monitoring in the 1996-97 water year indicated that temperature, pH, and turbidity did not exceed state standards for class AA streams (Thurston County 1998). However, the dissolved oxygen standard was violated on all six sampling dates and fecal coliform levels sometimes exceeded the standard (Thurston County 1998). The low dissolved oxygen levels were attributed to the gradual stream slope and the tidal influence (Thurston County 1998).

Yelm Creek

Anadromous fish are limited to the lower 0.4 miles of the stream (Nisqually EDT Work Group 1999b). The segment is "well forested" with second-growth trees (Nisqually EDT Work Group 1999b). Peak spawner counts for chum salmon in the WDFW database were available for 15 years between 1961 and 1998. We found no statistically significant decline over the period, and the counts appeared to be stable. The maximum chum salmon count was 302/0.1 mile in the segment from RM 0.0 to 0.5. About 50 winter steelhead and coho also spawn in the segment (Walter 1986).

Winter congregations of eagles have been documented near the mouth of Yelm Creek (Stalmaster and Kaiser 1997). The eagles are dependent on chum salmon carcasses.

Streamside development upstream of the spawning reach is dense and is progressing rapidly (Nisqually EDT Work Group 1999b) and the stream has become intermittent downstream of the town of Yelm. However, flows appear to be adequate during the chum salmon spawning and incubation period (pers. comm. G. Walter, 23 Nov. 1999).

Peak spawner counts for pink salmon in the WDFW database were available for eight years between 1965 and 1985. Counts declined significantly (linear regression slope = -3.95×10^{-5} p-value = 0.002) over the period from a high of 7 fish/0.1mile to zero fish observed in 1979, 1981, and 1985. Pink salmon may have spawned in Yelm Creek due to dewatering of the mainstem, but returned to mainstem spawning when minimum flows were established in the mainstem (G. Walter, pers. comm. 23 Nov. 1999). If the explanation is correct, declines in numbers of pink salmon spawners over the 20-year period would be indicative not of habitat degradation in Yelm Creek, but of improving conditions in the mainstem. Water quality near the mouth of the creek was rated good (Thurston County 1998). The stream failed part of the state fecal coliform standard and nitrate levels were high in the 1996-97 water year (Thurston County 1998).

Ohop Creek (RM 8.9) to 25 Mile Creek (RM 1.0)

This segment extends from the upstream end of Ohop Lake to an impassible falls at RM 1.0 on Twentyfive Mile Creek. Wetlands dominate the segment along Ohop Creek (Nisqually EDT Work Group 1999). Land use along the lower mile of Twentyfive Mile Creek includes hobby farms, timber production, and a clay mine at RM 0.5 that was abandoned in 1994 (Nisqually EDT Work Group 1999; Kerwin Draft-b). Upstream land use is entirely timber production (Nisqually EDT Work Group 1999; Kerwin Draft-b). Good spawning gravels exist in the lower end of Twentyfive Mile Creek (Nisqually EDT Work Group 1999). Riparian conditions are wetland shrubs and some small- to medium-size hardwoods along Ohop Creek and medium-size, second-growth hardwoods along Twentyfive Mile Creek except in the lower 0.3 miles, where riparian vegetation is impacted by agriculture (Nisqually EDT Work Group 1999). Except for fine sediment levels, water quality appears to be good in the segment (Kerwin Draft-b).

Sediment delivery to Twentyfive Mile Creek from the abandoned clay mine is a concern, as are impacts from agriculture and rural residential development in the lower 0.3 miles of stream (Kerwin

Draft-b). Conditions in lower Ohop Creek, through which fish must migrate to get to and from the segment upstream of the lake, are not good (Kerwin Draft-b). Moreover, it is not known whether the low wooden weir that is used to control the level of Ohop Lake creates migration delays for fish (Kerwin Draft-b). Due largely to these downstream concerns, we designated the segment upstream of the lake only as a *possible* refugium.

TABLE 10. STREAMS AND STREAM SEGMENTS IN THE NISQUALLY RIVER BASIN AND NEARBY INDEPENDENT DRAINAGES CLASSIFIED IN ONE OF THE REFUGIA CATEGORIES.

STREAM OR SEGMENT NAME	CATEGORY[A]	ALTERATION CLASS[B]	SOURCE TYPES[C]
Mainstem Nisqually			
Mouth to I-5 bridge	2	AD	R
BN RR bridge to Centralia powerhouse	1	D	R
Centralia powerhouse to Murray Creek	2	D	PR
Tanwax Cr. to LaGrande powerhouse	2	FD	R
Tributaries			
Muck Cr.	2	EIPO	SRP
Yelm Cr. (mouth to RM 0.4)	*3*	FIP	SR
Ohop Cr (RM) to 25 Mile Cr (RM1)	2		
Mashel R. to mile 3.7	2	F	R
Mashel R. from RM 3.7 to 15.4 (except around Eatonville)	3	IFO	R
Little Mashel R. (mouth to RM 0.8)	3	IF?	R
Independents			
Red Salmon Cr.	2	IP	SRP
McAllister Cr.			
Mouth to I-5 bridge (tidally influenced zone)	2	H	RP
I-5 bridge to headwaters	3	AIH	SRP

[A]Stream categories: 1 = areas with high ecological integrity; 2 = anadromous salmonid refugia but with impaired integrity; 3 = possible refugia but more data are needed; 4 = critical contributing area; 5 = areas with exceptional habitat that is currently inaccessible to anadromous fishes due to an artificial barrier such as a dam or hatchery rack

[B]Categories of alterations: A = Agricultural/rural residential (often including diking); D = Dam influenced, either by passage issues downstream or flow issues from upstream (including diversions); F = Forestry; H = hatchery; I = Industrial or urbanized; E = Exotic invasive species; N = Not managed; O = Other; P = Planned development (e.g. platted subdivision); U = unknown

[C]Types of information sources that provide support for the category designations include: P = personal communications; R = reports or articles; S = WDFW spawner database; D = other data sets; O = other

SOUTHWEST PUGET SOUND INDEPENDENT DRAINAGES

OVERVIEW

This region consists of a complex system of streams, estuaries, and extensive marine inlets on the southwest section of Puget Sound. From south to north, Eld Inlet, Totten Inlet, Little Skookum Inlet, and Hammersley Inlet/Oakland Bay are the primary marine water bodies in this region. The character of the freshwater streams changes along a south-north gradient, owning to changes in topography, geology, and hydrology: the northern section is predominately a low-elevation glacial plain, whereas the south consists of a higher elevation of a crescent formation of marine basalts (Walsh et al. 1987, cited in Schuett-Hames et al. 1996). Accordingly, the northern streams are generally less steep and generally have more extensive wetland complexes than the mountainous areas to the south (Schuett-Hames et al. 1996). For all streams in this region, the extensive estuary mud flats along the inlets have been historically rich production areas for shellfish, as well as marine and anadromous fishes (Williams et al. 1975).

The Deschutes River, draining into Budd Inlet, is the largest of the southwest Puget Sound-area independent drainages, with a drainage area of about 166 square miles and a length of 52 miles (Haring and Konovsky 1999). Tumwater Falls, at RM 2, historically blocked upstream passage of anadromous fishes, but a fish passage facility has allowed access to the river since 1954 (Schuett-Hames and Child 1996). A dam at the mouth of the river has impounded the river below Tumwater Falls (creating Capitol Lake) since 1950 (Collins 1994). Deschutes Falls (RM 41) creates the present upstream distribution limit of anadromous fishes in the drainage (Haring and Konovsky 1999). Because anadromous fish are not native to the Deschutes River above Tumwater Falls and the two miles of historically accessible river habitat are now impounded, we did not consider any stream segments within the Deschutes River drainage as refugia for native anadromous fishes. Our rationale for excluding historically inaccessible areas from refugia status is explained in the Introduction. We acknowledge that the Deschutes River may provide important refugia for native resident fishes and that the habitat quality in the drainage may substantially influence conditions in Budd Inlet. However, these functions are beyond the scope of this analysis.

Although the majority of the land within this region is owned by the Simpson Timber Company and the Washington Department of Natural Resources (Williams et al. 1975), many areas are managed by various landowners (Schuett-Hames et al. 1996). The impacts of forestry and agricultural practices are prevalent throughout this region, as illustrated in Schuett-Hames et al's (1996) assessment of water quality and salmon habitat, which attributed problems in water temperature, wood debris retention, and spawning gravel embeddedness to poor management activities. Surveys by the Washington Department of Ecology and the Thurston County Environmental Health Division have indicated high levels of fecal coliform and other pollutants in areas with high agricultural or urban use (Thurston County 1998). The Kennedy Creek Watershed Analysis also acknowledged the impacts of logging on peak flow changes and habitat degradation in this region (Simpson Timber Company and WDNR 1995, cited in Schuett-Hames et al 1996).

Urban and rural residential development is an increasing threat to salmon conservation in this region. Industrial and municipal effluent from the city of Shelton has affected the salmon production in Oakland Bay (K. Seiders pers. comm.). Additionally, sections of several streams have been impounded to create artificial lakes for recreational use and housing developments, including

Cranberry Creek, Kennedy Creek, Gosnell Creek, Mill Creek, Campbell Creek, and Sherwood Creek (Williams et al. 1975). Although these developments have all impacted the quality and quantity of water in these systems, some streams have retained higher relative quality for salmon production (Schuett-Hames et al. 1996).

FISH

This region primarily supports coho, chum, and winter steelhead. Although chinook were historically produced in Deer and Sherwood Creeks (Williams et al. 1975), chronic low flows have severely curtailed chinook numbers (R. Bernard, pers. comm.). Fall chum are grouped by SASSI into six discrete stocks in this region (Eld Inlet, Totten Inlet, Skookum Inlet, Upper Skookum Creek, Johns/Mills Creeks, Goldsborough/Shelton Creeks), which are all classified as "healthy." With the exception of hatchery-influenced production in Skookum Inlet, all stocks are listed as "wild" production types (WDF et al. 1993). Moreover, the Eld Inlet, Totten Inlet, Upper Skookum Creek, and Goldsborough/Shelton chum stocks were acknowledged by Huntington et al. (1996) as healthy, native stocks. Phelps et al. (1995) speculated that the geographic complexity of the numerous inlets and bays of this region has encouraged reproductive isolation and the emergence of genetic diversity over time.

Summer chum within this region are listed by SASSI only for Hammersley Inlet, which enters into Oakland Bay near the city of Shelton. This stock is categorized as "native and healthy" with some hatchery-influenced production (WDF et al. 1993). Coho within this region are lumped into one stock by SASSI as "deep south sound tributaries" and categorized as a healthy stock with hatchery origins and hatchery-supported production. Winter steelhead are categorized with an "unknown" status for Eld, Totten, and Hammersley Inlets (WDF et al. 1993).

WDFW hatchery out-plants of coho and/or chum have been attempted in most streams within this region. Brood stock sources have included Minter Creek, Hood Canal, Green River, Nooksack River, and the Skagit River. The Squaxin Island Tribe also operates a coho pen-stock hatchery off Squaxin Island. R. Bernard (pers. comm.) estimates that 250 of the 2,500,000 Skykomish River coho released annually stray into streams within the Southwest Sound Independents region.

AREAS RECOMMENDED FOR WITHIN-BASIN REFUGIA DESIGNATION AND JUSTIFICATIONS

REFUGIA - ALTERED (CATEGORY 2)

Kennedy Creek

This stream flows into Totten Inlet's Oyster Bay after draining a low-gradient watershed for approximately 10 miles, originating along the north face of the Black Hills. Depending on flow conditions, anadromous salmonid use may be limited to below the steep cascades near RM 2.5. At RM 7, a stream from Summit Lake meets Kennedy Creek. The majority of this watershed is privately owned. However, state lands (Capitol State Forest) are located within the upper portions of the watershed. Simpson Timber Company is the largest landowner in this watershed. The importance of this stream for salmon has been long recognized (Williams 1975; J. Aimes pers. comm.). This stream currently supports a robust stock of chum salmon (WDFW Spawner database), which is self-sustaining, and of native origins (WDFW 1993). Huntington et al. (1996) reported that the Totten

Inlet stock of chum salmon were healthy, wild, and being supported at population levels at least two-thirds as abundant as what would be expected in the absence of human impacts. Kennedy Creek's fall chum run is generally the earliest in the region (Phelps et al. 1995).

Although reaches within Kennedy Creek did not meet targeted levels of canopy cover or large woody debris in one recent study, the stream was found to have good pool surface area and residual pool depth (Schuett-Hames et al. 1996). It is important to point out that the habitat shortcomings observed in this study were not limited to Kennedy Creek, but were systemic across their analysis area of the southwest Puget Sound independents. Recent riparian management standards developed by Simpson Timber Company may improve LWD recruitment and canopy cover for this stream (Simpson and WDNR in Schuett-Hames 1996). Agricultural and industrial development pressures are increasing in this area (Thurston County 1998).

Skookum Creek

Just north of the Mason-Thurston County line, Skookum Creek flows in an eastward direction and meets Little Skookum Inlet within an extensive estuary complex. Nearly all of this watershed is privately owned, with Simpson Timber Company as the primary landowner. This stream was historically important for chum salmon (Williams 1975) and currently shows evidence of stable/increasing population numbers of fall chum within spawner count survey index reaches (WDFW Spawner database). Canopy cover and pool ratio qualities rated poorly in Schuett-Hames et al's (1996) survey of this stream. However, satisfactory LWD levels (Schuett-Hames et al. 1996) and stable flow regimes (Williams 1975) have been reported.

Mill Creek

This stream flows 8.8 miles from Isabella Lake to the Hammersley Inlet, east of the town of Shelton. (Above the lake, the stream is called Gosnell Creek.). Simpson Timber Company is the largest landowner in the privately administered watershed. This stream has traditionally supported and currently maintains strong populations of fall chum (WDFW Spawner database), which are considered to be supported by wild production and native origin (WDFW 1993). Habitat structure within this stream includes frequent pools (Williams 1975; Schuett-Hames et al. 1996), but was not found to contain adequate amounts of large woody debris or canopy closure (Schuett-Hames et al. 1996). RM 6-7 may be affected by urban development around Shelton.

Goldsborough Creek

This low-gradient stream flows eastward to the town of Shelton, which it flows through before entering Oakland Bay. This is the largest watershed within the region. Simpson Timber Company is the primary landowner. Native, wild fall chum show a robust escapement trends within this stream (WDFW Spawner database). Huntington et al (1996) reported that Goldsborough Creek supports a healthy population native, wild chum. This stream supports good pool quality and fair fine sediment loading, but has shown low LWD counts (Schuett-Hames et al. 1996).

McLane Creek

McClane Creek is an independent tributary of Eld Inlet. It is 5.6 miles long, has a drainage area of 11.5 mi^2 and a maximum elevation of 1,864 feet (Schuett-Hames et al. 1996). Small, steep tributaries feed the main creek, which flows through a broad alluvial valley (Schuett-Hames et al.1996). Although some impairment of ecological integrity has occurred, McClane Creek warrants designation as a possible refugia for salmon due to its use by salmon (pers. comm. J. Konovsky). The creek contains a chum run as well as some coho salmon (Williams et al. 1975, and pers. comm. J. Konovsky, 1999).

Predominant land uses in the drainage include rural residential development, agriculture and forestry. Schuett-Hames et al. (1996) report on stream surveys conducted in a 1,323 m reach of McClane Creek and an 874 m reach of its tributary, Swift Creek. Riparian canopy closure was judged to provide insufficient shade for the stream to meet the state water quality standard of a maximum water temperature not exceeding 18 °C for class A streams. Total large woody debris was rated "good" in McClane Creek and fair in Swift Creek; however, both were rated "poor" for amount of "key pieces" (large pieces of wood–qualifying size is relative to channel width; see Schuett-Hames et al. 1996). Both reaches were rated "fair" for pool frequency and area and for the percentage of fine sediment (less than 0.85 mm) in spawning gravels. Water quality was rated as "good" in the 1996-97 water year, with no violations of fecal coliform standards and one violation of turbidity standards detected (Thurston County 1998).

Perry Creek, Schneider Creek

Perry Creek flows into Eld Inlet; further north, Schneider Creek flows into Totten Inlet. Both of these watersheds are primarily privately owned. Perry Creek does include state lands in its headwaters, however. Simpson Timber Company is large landowner in both of these watersheds. Fall chum show stable or increasing escapement trends in both of these watersheds (WDFW Spawner database). However, habitat issues may limit the utility of these watersheds as salmon refugia. In both watersheds, extensive urban and agricultural development has disproportionately impacted habitat quality, as reflected in Schuett-Hames et al's (1996) survey of the streams.

Johns Creek, Cranberry Creek

These streams flow south into the northern section of Oakland Bay. Most of these watersheds is privately owned. Robust populations of native, wild fall chum have been reported for each of these streams (WDFW Spawner database) but habitat quality may limit their values as refugia. More information on habitat quality is needed for these streams.

Deer Creek, Sherwood Creek

Deer Creek flows into the northern region of Oakland Bay; further west, Sherwood Creek flows into the North Bay of Case Inlet. Both of these low-gradient streams drain low-elevation watersheds. these watersheds are privately owned. Historically, these streams were unique because they supported the only chinook runs within this region (Williams 1975). Although chinook salmon are currently much less abundant than their historic levels within this region (R. Bernard pers. comm.), these streams may still provide some unique refugia values for salmon. More information is needed for these streams.

TABLE 11. STREAMS AND STREAM SEGMENTS IN THE SOUTHWEST PUGET SOUND INDEPENDENT DRAINAGES CLASSIFIED IN ONE OF THE REFUGIA CATEGORIES.

STREAM OR SEGMENT NAME	CATEGORY[A]	ALTERATION CLASS[B]	SOURCE TYPES[C]
McLane Creek	3	AF	PR
Perry Creek	3	AF	RS
Schneider Creek	3	AFI	RS
Kennedy Creek (RM 0-3)	2	AFI	PRS
Skookum Creek	3	AF	RS
Mill Creek	2	AFI	RS
Goldsborough Creek	2	AFI	R
Johns Creek	3	FI	RS
Cranberry Creek	3	DF	RS

[A]Stream categories: 1 = areas with high ecological integrity; 2 = anadromous salmonid refugia but with impaired integrity; 3 = possible refugia but more data are needed; 4 = critical contributing area; 5 = areas with exceptional habitat that is currently inaccessible to anadromous fishes due to an artificial barrier such as a dam or hatchery rack

[B]Categories of alterations: A = Agricultural/rural residential (often including diking); D = Dam influenced, either by passage issues downstream or flow issues from upstream (including diversions); F = Forestry; H = hatchery; I = Industrial or urbanized; E = Exotic invasive species; N = Not managed; O = Other; P = Planned development (e.g. platted subdivision); U = unknown

[C]Types of information sources that provide support for the category designations include: P = personal communications; R = reports or articles; S = WDFW spawner database; D = other data sets; O = other

EAST KITSAP PENINSULA

OVERVIEW

Streams within this region originate in the lowland hills of the Kitsap Peninsula and empty into several large inlets within western Puget Sound. Although this region contains no major river systems, many of these streams historically supported substantial salmon runs (Williams et al. 1975). Currently, several stream systems contribute significantly to the salmon production of this region, although nearly all watersheds on the eastern Peninsula have been impacted by some degree of land use (J. Zischke, pers. comm; C. May pers. comm; May and CTC 2000~~.~~). Because of this region is not affected by high-elevation snow melting events and is located within the rainshadow of the Olympic Mountains, low flows often limit salmon use within this region (Williams et al. 1975).

The East Kitsap Peninsula consists primarily of second- and third-growth forest cover (Williams et al. 1975) and an increasing amount of urban development (J. Zischke pers. comm.). As the primary land use of this area, forestry practices have degraded salmon habitat quality in many of these streams. However, accelerating urban and rural development around Bremerton and Port Orchard may pose an even greater threat to salmon conservation and has already impacted water quality and salmon habitat within this region (J. Zischke, pers. comm.). As notable exceptions, some areas have been protected to supply a municipal water source (Gorst Creek watershed) or as old-growth refugia (Chico Creek watershed).

FISH

Most streams in this region support populations of chum and coho. Steelhead stocks for East Kitsap are recognized within SASSI as a native stock of "unknown" status (WDF et al. 1993). Although Burley Creek (emptying into Henderson Bay near the town of Purdy) and Dogfish Creek (emptying into Liberty Bay near the town of Poulsbo) historically contained chinook runs (Williams et al. 1975), subsequent WDFW spawning surveys indicate that these streams no longer maintain historic levels of chinook production.

Although coho (Weitkamp 1995) and chum (Johnson et al. 1997) populations have been assumed to be relatively genetically homogenous due to natural straying and hatchery introductions throughout the East Kitsap region, some evidence suggests that unique evolutionary stocks may persist within this region. Genetic analysis by Phelps et al. (1995) recognized regionally distinct summer and fall chum populations for Blackjack Creek (draining into Sinclair Inlet near the city of Port Orchard). Although SASSI listed Blackjack Creek's summer chum as a "native, wild, healthy" stock (WDF et al. 1993), it did not recognize the fall chum populations distinguished by (Phelps et al. 1995) at this scale. Instead, SASSI identified fall chum within Sinclair Inlet and categorized this population as "native, wild, and healthy" (WDF et al. 1993).

Due to numerous historical and current out-plants from Coulter and Minter Creek Hatcheries, coho production in the East Kitsap Peninsula is generally supported by non-native fish (J. Zischke pers. comm.). SASSI recognized a single coho stock for this region and categorized it as a "healthy" stock with mixed origin and composite (i.e. hatchery-supported) production.

AREAS RECOMMENDED FOR WITHIN-BASIN REFUGIA DESIGNATION AND JUSTIFICATIONS

REFUGIA - ALTERED (CATEGORY 2)

Blackjack Creek

Blackjack Creek flows from its headwaters 6.9 miles north to the Sinclair Inlet. The lower sections of this stream run through the city of Port Orchard and the estuary is severely degraded (May and CTC 2000). This watershed is privately owned. SASSI (WDFW 1993) considered the summer chum run within this stream to be a "healthy" stock with native origin and wild production type. This stream also supports a robust fall chum population (WDFW Spawner database; J. Zischke pers. comm.), as well as coho, steelhead, and cutthroat trout (May and CTC 2000). Although the lower sections of this stream are impacted by Port Orchard, the habitat quality within the majority of Blackjack Creek is good (J. Zischke pers. comm.).

Chico/Lost/Wildcat/Dickerson Creeks

After emerging from headwaters on Green and Gold Mountains, these streams join and flow into Chico Bay near the community of Chico, west of Bremerton. This stream network is influenced by lakes that may act to mitigate the low flow problems otherwise characteristic of the East Kitsap region. Ownership is private. These streams can support very large runs of chum salmon. In 1998, this stream network supported the largest run of chum salmon on record for the Kitsap Peninsula (70,000 individuals) (J. Zischke pers. comm.). Lost Creek and Dickerson Creek show generally increasing numbers of chum salmon (WDFW Spawner database). The watersheds in this area contain some of the last old-growth forest on the Kitsap Peninsula. These forests are currently being purchased and protected by the Mountaineers Organization, based in Seattle (J. Zischke pers. comm. , May and CTC 2000).

Eglon and Silver Creeks

This is a small watershed south of Hansville. Most of the combined watershed area is forested, with little development impact. Extensive headwater wetlands and beaver ponds provide good rearing habitat. Both streams support populations of coho, cutthroat, and chum (May and CTC 2000).

Steele Creek

This stream enters Puget Sound near Brownsville, and supports good runs of chum, coho, and cutthroat; Historically, the creek may have also supported a small chinook run (May and CTC 2000). The stream is impacted by roads, agriculture, and rural residential development, but the in the South Fork intact headwater wetlands and other high-quality habitats remain (May and CTC 2000).

Barker Creek

Barker Creek flows south from Island Lake 3 miles to Dyes Inlet. Ownership is private. This stream was recognized as a historically important for chum and coho salmon. Escapement trends for chum salmon show consistent increases (WDFW Spawner database). The stream also presently supports coho, cutthroat trout, steelhead, and some use by chinook salmon (May and CTC 2000). More information is needed about habitat quality for this stream, but the stream is considered Category 1 on the strength of the chum salmon population trend. Development pressures are increasing in this region.

Olalla Creek

Olalla Creek watershed was historically the primary steelhead, chinook, coho, and chum stream in the southern Puget Sound side of the Kitsap Peninsula (May and CTC 2000). Despite some agriculture and residential impacts, the stream retains much of its natural ecological integrity. Headwater wetlands confer important hydrologic buffering and may help explain the persistence of salmon populations. The stream currently supports a healthy chum salmon population and runs of coho, cutthroat, and steelhead, and some chinook salmon (WADFW database~~,~~; May and CTC 2000).

POSSIBLE REFUGIA (CATEGORY 3)

Rocky Creek, Burley Creek

Rocky Creek flows south into Case Inlet; to the east, Burley Creek flows south into Carr Inlet. Ownership is private. Rocky Creek and Burley Creek are recognized as containing historically good salmonid spawning habitat (Williams 1975). Short-term trends of chum escapement show consistently increasing numbers (WDFW Spawner database). Huntington et al. (1996) reported that Case Inlet chum were wild, native, and healthy. Habitat limitations and the influence of hatchery out-plants from Minter Creek are uncertain.

Curley Creek

Location: Curley Creek flows eastward into Yukon Harbor near the community of South Colby. The influence of Long Lake (RM 2.5) may mitigate low flow limitations common in this region. Curley Creek was recognized as good historical coho spawning habitat (Williams 1975) and retains some of this quality (J. Zischke pers. comm.). The headwater portions off both major forks are disturbed by agricultural and residential development. More information on habitat conditions and population status is needed to assess the refugia potential for this stream.

Big Scandia Creek

This stream enters Liberty Bay, and recognized historically as an important coho/chum producer (Williams 1975). Based on a review of the WDFW Spawner database, Big Scandia Creeks contains a robust populations of coho salmon. May and CTC (2000) designated this watershed as a potential refuge, but it is in need of significant restoration

POTENTIAL REFUGIA ABOVE ARTIFICIAL BARRIERS (CATEGORY 5)

Coulter Creek

Coulter Creek was proposed in May and CTC (2000) as a focal watershed (FW) refugia. The upper watershed is in Kitsap County and lower watershed is in Mason County. A small timber company owns much of the watershed. Instream spawning and rearing habitat, as well as LWD is generally excellent in comparison to other Puget Sound streams. A riparian forest corridor is also in a relatively natural condition throughout much of the stream system. Headwater wetlands and beaver ponds are common. There is limited development in the watershed; however, a fish hatchery near the mouth is a partial barrier to fish passage.

TABLE 12. STREAMS AND STREAM SEGMENTS ON THE EAST KITSAP PENINSULA CLASSIFIED IN ONE OF THE REFUGIA CATEGORIES.

STREAM OR SEGMENT NAME	CATEGORY[A]	ALTERATION CLASS[B]	SOURCE TYPES[C]
Rocky Creek	3	AH	PRS
Burley Creek	3	AH	RS
Olalla Creek	2	AF	SR
Curley Creek	3	F	PR
Blackjack Creek	2	AFI	PR
Dickerson Creek	2	F	PS
Chico/Lost/Wildcat Creeks	2	F	PS
Barker Creek	2	AFI	PS
Big Scandia Creek	3	AF	S
Coulter Creek	5	HF	R
Eglon and Silver Creeks	2	AHF	R
Grovers Creek	2	AHF	R
Steele Creek	2	AHF	R

[A]Stream categories: 1 = areas with high ecological integrity; 2 = anadromous salmonid refugia but with impaired integrity; 3 = possible refugia but more data are needed; 4 = critical contributing area; 5 = areas with exceptional habitat that is currently inaccessible to anadromous fishes due to an artificial barrier such as a dam or hatchery rack

[B]Categories of alterations: A = Agricultural/rural residential (often including diking); D = Dam influenced, either by passage issues downstream or flow issues from upstream (including diversions); F = Forestry; H = hatchery; I = Industrial or urbanized; E = Exotic invasive species; N = Not managed; O = Other; P = Planned development (e.g. platted subdivision); U = unknown

[C]Types of information sources that provide support for the category designations include: P = personal communications; R = reports or articles; S = WDFW spawner database; D = other data sets; O = other

WEST KITSAP PENINSULA

OVERVIEW

The riverine systems of the West Kitsap Peninsula are significantly larger than those of the east side of the Peninsula (Williams et al. 1975) and include some of the most intact salmon habitat on the Peninsula (J. Kischke, pers. comm.). Major basins include Big Beef Creek, Dewatto River, Tayuha River, Big Mission Creek, and Union River. Unlike the rivers entering Hood Canal from the Olympic Peninsula side, streams of the West Kitsap region generally have more accessible spawning habitat (Point-No-Point Treaty Council and WDFW 1999)(Hood Canal Coordinating Council 1999) and more extensive estuaries (Williams et al. 1975). Thus, the west Kitsap region offers some of the best opportunities for conservation of intact salmon habitat in the Hood Canal area (M. Ereth, pers. comm.; Point-No-Point Treaty Council and WDFW 1999;Hood Canal Coordinating Council 1999; C. May pers. comm.).

Because streams of this region originate from low-elevation foothills and are not influenced by runoff from glaciers or snowpacks, low flows frequently limit salmon production (Williams et al. 1975). However, wetland headwater complexes may mitigate these impacts in several river systems (Point-No-Point Treaty Council and WDFW 1999; Hood Canal Coordinating Council 1999). Additionally, the impacts from more than a century of intensive logging and road building have degraded the streams and rivers of this region to varying degrees.

Although the intensity of urban and rural residential development decreases substantially from east to west across the Peninsula, the western region also faces accelerating pressures from urbanization (Amato 1996). From 1980 to 1990, the human population in West Kitsap County grew by 29 percent and is estimated to continue at this rate (Nelson et al. 1993, cited in Amato 1996). One emerging threat to productive capacity of these streams is a proposal from the City of Bremerton in east Kitsap to extract groundwater from west Kitsap watersheds to feed municipal water source demands. This action could jeopardize the hydrological function of West Kitsap (J. Zischke, pers. comm.), including groundwater-surface water interactions that are of importance to salmonid habitat (Stanford and Ward 1988).

FISH

This region supports fall chinook, summer chum, fall chum, coho, winter steelhead, and coastal cutthroat trout. Fall chinook are managed primarily as a hatchery stock in this region. Because of historical and current hybridization of introduced and wild fall chinook, Phelps et al. (1995) identified one genetic group for this region. Similarly, SASSI considered one stock of fall chinook in Hood Canal and categorized this stock as "healthy" stock (WDF et al. 1993), even though populations in the West Kitsap region are recognized as depressed.

Coho and fall chum have been divided into geographically similar stock units by SASSI, based on geographic distribution of spawning grounds for these species. In the northeast Hood Canal stocks, including the Big Beef Creek watershed, SASSI listed coho as a "depressed" stock of mixed origin and wild production type and fall chum as a "healthy" stock with hatchery influences. To the south, the Dewatto River and Southeast Hood Canal stocks were listed as "depressed" for coho and "healthy" for fall chum (WDF et al. 1993). Phelps et al. (1995) failed to distinguish between fall chum stocks at this scale, explaining that the original distinctions may have been blurred by extensive fall chum hatchery out-plants in this region.

SASSI identified two stocks of summer chum within the West Kitsap region: Hood Canal and Union River stocks (WDF et al. 1993). Although Phelps et al. (1995) recorded genetic evidence in support of a separate Union River stock, they did not consider this population to be a "genetic diversity unit." SASSI categorized the Union River stock as "native, wild, and healthy" but determined that the larger Hood Canal stock was "critical" in status. In March, 1999, the Hood Canal stock was listed as "threatened" under the Endangered Species Act.

Winter steelhead stocks are identified by SASSI as "depressed" for the Dewatto and Tahuya Rivers and "unknown" for the Union River (WDF et al. 1993). In a status review for the National Marine Fisheries Service, Busby et al. (1996) reported declining winter steelhead numbers for the Dewatto and Tahuya Rivers, with annual escapement estimates under 100 individuals for these rivers. Nehlsen et al. (1991) rated winter steelhead within the Dewatto River at a "high risk of extinction" and within the Tahuya River at a "moderate risk of extinction."

We attempted to make our recommendations consistent with those of May and CTC (2000) wherever possible. Some inconsistency occurs as a result of different criteria. We list here only those streams that meet the standards in May and CTC (2000) as "focal watersheds," and where present fish populations and fish access are not constrained by intensive hatchery operations.

AREAS RECOMMENDED FOR WITHIN-BASIN REFUGIA DESIGNATION AND JUSTIFICATIONS

REFUGIA - ECOLOGICAL INTEGRITY INTACT (CATEGORY 2)

Dewatto River

The Dewatto River drains the southwestern portion of the Kitsap Peninsula and enters Hood Canal approximately 5 miles north of the Great Bend. Ownership is private. This river is widely known as historically important for salmon (Amato 1996; C. Baranski, pers. comm. ; J. Zischke pers. comm. ; Williams 1975). Currently, two surveyed reaches of this river show robust coho salmon populations (WDFW Spawner database), and other reaches also reportedly support high coho spawner densities (M. Ereth pers. comm.). The lower 2 miles of this River are important for Hood Canal summer chum (Point-No-Point Treaty Council and WDFW 1999; Hood Canal Coordinating Council 1999). This watershed contains exceptional habitat quality, although evidence of historical disturbance is readily apparent (Point-No-Point Treaty Council and WDFW 1999), and the habitat is perhaps best characterized as recovering from past conditions. Within the Kitsap Peninsula and Hood Canal region, this river stands out with relatively high-quality conditions and important salmonid habitat (T. Labbe pers. comm.). Although large-scale developments do not imminently threaten in this watershed (J. Zischke pers. comm.), the land remains zoned for rural residential development and receives no special protection, and much of it appears to be presently offered for sale (M. Ereth pers. comm.). This watershed was recommended for American Fisheries Society's Aquatic Diversity Areas list by P. Wampler. Due to historical and current salmonid use, as well as relatively good quality habitat conditions, this watershed can be considered one of the best opportunities for salmon refugia in the region (C. Baranski pers. comm. , M. Rowse pers.comm., May and CTC 2000).

Union River

The Union River drains a relatively large watershed (24 square miles) and enters the Hood Canal at its eastern apex in Lynch Cove. Ownership is private. This river has historically supported large runs of coho, chum, and chinook salmon (Williams 1975). Currently, this watershed supports the only viable population of summer chum on the Kitsap Peninsula (Point-No-Point Treaty Council and WDFW 1999). Consistently large runs of fall chum are also currently supported in this river (WDFW Spawner database). Habitat quality is considered by some to be generally good within this watershed (C. Baranski, pers. comm. ; T. Labbe, pers. comm.), but others find that much of the mainstem is simplified and degraded (M. Rowse pers. comm.). Pool frequency and channel complexity were thought to be suitable for salmon use (Point-No-Point Treaty Council and WDFW 1999). Some toxins have been recorded from the East Fork of the Union River near the Olympic View Sanitary Landfill (Point-No-Point Treaty Council and WDFW 1999). This watershed was recommended for American Fisheries Society's Aquatic Diversity Areas list by P. Wampler, and recommended as a refuge in May and CTC (2000). The Union River watershed is under severe development pressure, as the upper portions lie within Mason County's designated Urban Growth Area (M. Ereth, pers. comm.).

Tahuya River

This River drains more than 45 square miles of the west side of the Kitsap Peninsula before entering Hood Canal near the community of Tahuya. Ownership includes private land and Tahuya State Forest (DNR). This river has historically supported large numbers of chum, coho, and chinook salmon. Currently, this river supports robust coho populations (WDFW Spawner database). Habitat quality is generally good (C. Baranski pers. comm.), although the impacts of logging have degraded the riparian zone integrity (Point-No-Point Treaty Council and WDFW 1999). Numerous wetland complexes may buffer low flows during the summer (Point-No-Point Treaty Council and WDFW 1999). This watershed was recommended for American Fisheries Society's Aquatic Diversity Areas list by P. Wampler, and as a salmon refuge in May and CTC (2000).

Big Beef Creek (RM 0-3)

Big Beef Creek is the largest tributary in the northwestern section of the Kitsap Peninsula. This stream. Headwater wetland complexes partially mitigate summer low flow effects (Frissell 1998; West Kitsap Watershed Analysis, 1993, may and CTC 2000). Ownership is mixed private and state (DNR). This stream was recognized as historically and presently important for coho and chum salmon and steelhead (Frissell 1998; Amato 1998). Summer chum are presumed to be extinct from this stream (Point-No-Point Treaty Council and WDFW 1999). SASSI (1993) categorizes the chum stock as "healthy."

Stavis Creek

This stream flows north into Hood Canal at Stavis Bay. Ownership is private and state land (DNR). Conservation easements are currently being negotiated to protect lands within this watershed (Point-No-Point Treaty Council and WDFW 1999). This stream historically produced coho and chum salmon (Williams 1975). Summer chum runs have been inconsistent in this stream (Point-No-Point Treaty Council and WDFW 1999). Habitat quality of this stream and watershed is exceptional. The Point-No-Point Treaty Council and WDFW (1999) considered this to be one of the three most intact streams in the region. There are complex wetland areas in the headwaters that provide hydrologic buffering (May and CTC 2000). Given the habitat potential within this watershed, more information on salmonid use of this stream is needed.

Stimson Creek, Caldervin Creek, Rendsland Creek

These independent streams flow into the Hood Canal after draining relatively small watersheds in the southwest corner of the Kitsap Peninsula. Each of these streams shows evidence of strong salmon populations (WDFW Spawner database, and May and CTC 2000) (Stimson: chum; Caldervin: coho; Rendsland: chum and coho salmon).

Seabeck Creek

This stream supports chum, coho, and cutthroat spawning and rearing habitat. The lower watershed has been impacted by past land-use practices (timber harvest) and current development along the Seabeck Highway corridor. The upper watershed has little relatively little development (May and CTC 2000).

Little Mission Creek

Little Mission Creek passes through the center of Belfair State Park, and hosts historically strong chum runs. The upper watershed, on private land, has little development and is heavily forested. The stream system has unusually stable flows for its drainage area (May and CTC 2000).

Big Mission Creek

The lower reach of Big Mission Creek flows through Belfair State Park and into Hood Canal via a heavily modified and diked estuarine delta (May and CTC 2000). The headwaters of this stream support coho and cutthroat populations. The headwaters begin in a forested area above Mission Lake and in wetlands northwest of Mission Lake. The upper and middle portions of the watershed comprise forests managed by the Washington Department of Natural Resources (WA-DNR) and other commercial forest landowners. The upper watershed contains patches of good habitat, but has been adversely impacted by forestry, agriculture, and residential development. Big Mission Creek was recommended by May and CTC (2000) as a high priority refuge, recognizing the need for some restoration, and M. Rowse (pers. comm.) strongly recommended this watershed as a well-established refuge for natural coho salmon on the basis of a detailed (unpublished) analysis of coho populations and habitat in Hood Canal.

Martha John Creek

This small stream watershed south of Hansville drains into the Hood Canal via Port Gamble Bay. Most of the combined watershed area is forested, with little development impact (May and CTC 2000). Extensive headwater wetlands and beaver ponds provide stable flows and high water quality. The system supports coho, cutthroat, and chum, and may also contain steelhead.

Little Boston Creek

Little Boston and Middle Creeks lie at the northwest corner of the Kitsap Peninsula. These streams support coho, cutthroat, and chum, and have potential for steelhead populations (May and CTC 2000). The majority of this forested reserve area is located on the Port Gamble S'Klallam Reservation. Culverts at the mouth of both streams may be partial barriers to fish reaching headwater rearing habitat (May and CTC 2000).

POSSIBLE REFUGIA (CATEGORY 3)

Gamble Creek

The largest watershed draining north into Gamble Bay, the creek supports coho, chum, and cutthroat, as well as potential steelhead habitat. The stream has been impacted by rural residential development and agriculture throughout the watershed, but retains much of its natural ecological structure and function. Major road crossings may be partial passage barriers and allow stormwater runoff to enter the creek (May and CTC 2000). Patches of mature riparian forest still exist in the upper watershed, providing good instream spawning and rearing habitat for coho and cutthroat (May and CTC 2000).

Kinman/Cougar Creek

A small stream located near Lofall on Hood Canal, it supports coho, chum, and resident and sea-run cutthroat, and the creek also has potential for steelhead (May and CTC 2000). Sedimentation and low summer flows appear to be the limiting factors. Coho runs have diminished significantly over the past decade (May and CTC 2000). The estuary has also been severely impacted by development within the past decade. The headwater wetlands are hydrologically linked to Dogfish Creek in the Big Valley area (May and CTC 2000). Rural residential development has begun to impact the watershed.

Little Beef Creek

This stream enters Hood Canal near Big Beef Creek, and supports coho and chum runs, as well as resident and sea-run cutthroat. The creek may support steelhead. Coho and chum populations are considered healthy (May and CTC 2000), but little is known about habitat conditions in Little Beef Creek, so we elected to list it as a "possible refuge" pending further study.

Big Anderson Creek

Big Anderson Creek flows west through a 5-square-mile watershed and enters the Hood Canal near the community of Holly. Ownership is mixed private state DNR land. This area was historically important for salmon production and served as a seasonal fishing camp for Twana and S'Klallam tribes (Amato 1996). Although this stream shows evidence of strong chum salmon production (WDFW Spawner database), habitat quality is relatively low, as the result of extensive logging and road building (Point-No-Point Treaty Council and WDFW 1999). More information is needed to understand the potential for this area as a salmon refuge.

TABLE 13. STREAMS AND STREAM SEGMENTS ON THE WEST KITSAP PENINSULA CLASSIFIED IN ONE OF THE REFUGIA CATEGORIES.

STREAM OR REACH NAME	CATEGORY[A]	ALTERATION CLASS[B]	SOURCE TYPES[C]
Union River	2	FH	PRS
Stimson Creek	2	FH	S
Tahuya River	2	FH	PRS
Caldervin Creek	2	F	S
Rendsland Creek	2	F	S
Dewatto River	2	F	PORS
Martha John Creek	2	A	R
Kinman/Cougar Creek	3	AF	R
Big Mission Creek	2	AF	R,P
Little Mission Creek	2	AF	R
Little Boston Creek	3	FA	R
Gamble Creek	3	FA	R
Big Anderson Creek	3	F	RS
Big Beef Creek	2	ADF	R,P
Stavis Creek	2	AF	R
Seabeck Creek	2	AF	R
Little Beef Creek	3	AF	R

[A]Stream categories: 1 = areas with high ecological integrity; 2 = anadromous salmonid refugia but with impaired integrity; 3 = possible refugia but more data are needed; 4 = critical contributing area; 5 = areas with exceptional habitat that is currently inaccessible to anadromous fishes due to an artificial barrier such as a dam or hatchery rack

[B]Categories of alterations: A = Agricultural/rural residential (often including diking); D = Dam influenced, either by passage issues downstream or flow issues from upstream (including diversions); F = Forestry; H = hatchery; I = Industrial or urbanized; E = Exotic invasive species; N = Not managed; O = Other; P = Planned development (e.g. platted subdivision); U = unknown

[C]Types of information sources that provide support for the category designations include: P = personal communications; R = reports or articles; S = WDFW spawner database; D = other data sets; O = other

SOUTHWEST HOOD CANAL

OVERVIEW

The southwest Hood Canal region extends from the Skokomish River basin in the south to the Dosewallips River basin to the north. This regional designation overlaps with the Washington Department of Fish and Wildlife's WRIA 16. With the exception of the Skokomish River system, streams of this region are characterized by steep gradients and numerous barriers to anadromous fish passage (Williams et al. 1975). In contrast, the Skokomish system drains a broad, low-gradient floodplain for 9 miles before meeting Hood Canal.

Although the headwaters of the Skokomish River emerge from protected Olympic National Park lands, the majority of this basin drains Olympic National Forest lands, which have been heavily logged and roaded (Frissell 1998). The lower nine miles of the mainstem of the Skokomish River have undergone extensive channelization, with additional impacts from agricultural, urban, and rural development (M. Ereth, pers. comm.). The Lower Cushman Dam on the North Fork of the Skokomish River restricts anadromous fish to below RM 17.3 and has impacted fish habitat downstream (Williams et al. 1975; WDF et al. 1993).

Historically, the entire Skokomish River system was an important fishing area for indigenous tribes in the region (Amato 1996). European settlers first arrived in the 1850s. By the 1880s, large-scale logging had begun and the Skokomish River was cleared of large woody debris and used for log drives (Amato 1996). Currently, industrial forestry is remains a primary land use within the basin. The Simpson Timber Company owns and manages much of the lower basin, including the North Fork of the Skokomish River. Currently, the development of Simpson Timber Company's Habitat Conservation Plan (HCP) might offer some hope for improvement of salmon habitat on the large blocks of Simpson ownership in the Skokomish basin (M. Ereth, pers. comm.).

North of the Skokomish River, several river systems and independent streams flow into the west side of Hood Canal. Principal river systems include the Hamma Hamma, Duckabush, and Dosewallips Rivers. Although anadromous barriers generally limit salmon spawning to the lower reaches of these streams and rivers (Williams et al. 1975), forestry in the upper reaches and agricultural and rural development in the lower reaches have significantly degraded the quality of salmon habitat, as determined by a recent Habitat Recovery Plan for Hood Canal summer chum (Point-No-Point Treaty Council and WDFW 1999).

FISH

Coho, pink, chum, and fall chinook salmon, as well as steelhead, coastal cutthroat trout, and bull trout or Dolly Varden are supported in this region. Spring chinook reportedly occurred historically in both forks of the Skokomish system as late as the 1950's, but, along with pink salmon in the Skokomish, are thought to be extirpated or nearly so today (M. Ereth pers. comm.).

Five coho stocks have been designated by SASSI within this region. For the Skokomish River, Southwest Hood Canal, Hamma Hamma River, and Dosewallips River, stocks were categorized as "healthy." Of these, only the Skokomish stock was not considered a wild production type (WDF et al. 1993; however late-returning run of putatively wild origin does remain in the Skokomish system, M. Ereth pers. comm.). The Duckabush River coho stock was listed as "depressed" by the SASSI report (WDF et al. 1993).

Although pink salmon have been historically produced by several hatcheries within the Puget Sound area, only the Hood Canal Hatchery (Finch Creek) currently continues its pink production program (Hard et al. 1996). However, wild production of even-year pink salmon also occurs in this region in the Hamma Hamma, Duckabush, and Dosewallips Rivers (Williams et al. 1975). SASSI classified these rivers as separate stocks and determined that the Hamma Hamma and Duckabush River stocks were "healthy" whereas the Dosewallips River stock was "depressed" relative to historic levels of production (WDF et al. 1993). Shaklee et al. (1995) concluded that, despite interspecific variation between populations, all even-year pink salmon should be classified as one ESU for purposes of restoration and management.

On the west side of Hood Canal, summer chum traditionally have utilized lower sections of larger rivers in this region, including the Hamma Hamma, Duckabush, and Dosewallips Rivers (Williams et al. 1975). Johns Creek (Hamma Hamma River basin) supported summer chum, despite its relatively small size (Williams et al. 1975). Other streams in the region apparently once supported populations of summer chum salmon that are now extirpated (M. Ereth, pers. comm.). SASSI identified one stock of summer chum within Hood Canal and determined that its status was "critical" (WDF et al. 1993). Hood canal summer chum were listed as "threatened" under the Endangered Species Act in March, 1999. SASSI identified one stock of summer chum within Hood Canal and determined that its status was "critical" (WDF et al. 1993). Hood canal summer chum were listed as "threatened" under the Endangered Species Act in March, 1999.

Seven stocks of fall chum were identified by SASSI (WDF et al. 1993) in this region: Southeast Hood Canal, Lower Skokomish River, Upper Skokomish River, West Hood Canal, Hamma Hamma River, Duckabush River, and Dosewallips River. With the exception of an "unknown" status for the Upper Skokomish fall chum, all stocks were categorized as "healthy" (WDF et al. 1993). The Lower Skokomish, Southeast Hood Canal, and West Hood Canal stocks were described as being partly hatchery supported, whereas the other stocks were "native and wild" (WDF et al. 1993). However, in their analysis of fall chum genetics, Phelps et al. (1995) found relative homogeneity between fall chum on the west and east side of the Hood Canal.

The SASSI bull trout/Dolly Varden appendix (WDFW 1998) indicates that "native, wild" stocks of bull trout and/or Dolly Varden are found within the South Fork and Upper North Fork of the Skokomish River system. Surveys by Dr. Robb Leary from the University of Montana confirmed the presence of bull trout in the South Fork mainstem of the Skokomish River. Additionally, US Forest Service surveys found bull trout and/or Dolly Varden in several tributaries of the South Fork (WDFW 1998). Although it is possible that fluvial, resident, and anadromous life histories may be present in the Skokomish River basin, data to this effect are currently unavailable.

AREAS RECOMMENDED FOR WITHIN-BASIN REFUGIA DESIGNATION AND JUSTIFICATIONS

REFUGIA - ALTERED (CATEGORY 2)

Skokomish River Estuary (RM 0-6)

This area includes one of the more intact estuaries of Puget Sound, despite significant areas of diking and diversion (G. Walter pers. comm., Frissell 1998). Extensive areas of cedar wetland and other naturally forested wetlands remain in the area. The estuary receives extensive use by all salmon species in the Skokomish system (Frissell 1998), and has been the focus of recent dike alteration efforts to restore natural connectivity and hydrology (M. Ereth, pers. comm.). Ownership is mixed private and Skokomish Reservation.

Richerts Springs Complex and mainstem Skokomish River (RM 7-8)

This short reach of the mainstem Skokomish River is associated with a series of large natural springs and floodplain channels and ponds that receive heavy use by salmon and steelhead, with especially heavy use by fall chum salmon (M. Ereth, pers. comm.; Frissell 1998). The area has relatively clean and stable gravel, and thermally buffered inflows (M. Ereth pers. com.). Ownership is private, and the present landowners are reportedly hostile to biological surveys of this area (M. Ereth, pers. comm).

South Fork Skokomish River mainstem (RM 13-21)

Although the upper sections of this basin drain relatively pristine areas within Olympic National Park (14 percent of entire watershed), many of the middle and lower reaches have been degraded from the cumulative effects of logging and road building on national forest and private timberland (Frissell 1998). This area contains patches of mature floodplain/riparian forest cover, floodplain wetland complexes, secondary or anabranched channels, and significant large woody debris accumulations (Frissell 1998). The area provides important habitat for winter steelhead, summer steelhead, bull trout, and possibly coho salmon (Ereth pers. comm.). It is also an important contributing area to chinook and chum salmon habitat downstream.

Dosewallips River mainstem (RM 4-12)

This area drains east into Hood Canal near the community of Brinnon. Habitat features of this region include secondary or anabranched channels, significant large wood debris accumulations, low road densities, and mature floodplain/riparian forest cover (Frissell 1998). This area is important habitat for native steelhead trout (winter and summer), coho, chinook (fall, possibly spring/summer), chum (fall, possibly late fall/winter), and pink salmon (Frissell 1998). Although hatchery outplanting has occurred in the basin, the lack of a local hatchery has decreased the relative impact of hatchery fish and suggests that this basin may offer more opportunities for conservation of native, wild salmon than more impacted systems (Frissell 1998). The area (lower 11.5 RM) was proposed as a "critical area" for the Aquatic Diversity Areas database of the American Fisheries Society, Oregon Chapter, by Phil Wampler.

Johns Creek

This basin drains north into the Hamma Hamma at RM 1.3. The basin is owned by a private landowner who actively manages the timber and mineral resources. Although landslides have impacted the fisheries resources in the watershed, this area supports some of the most important habitat for salmonids within the west side of Hood Canal (T. Labbe, pers. comm.). The stream is of particularly high quality and potential importance for coho salmon (M. Rowse, pers. comm. based on a detailed, unpublished study of coho habitat in Hood Canal tributaries). This stream system was severely altered from timber practices in the 1950s (Amato 1996).

POSSIBLE REFUGIA (CATEGORY 3)

Vance Creek and tributaries (Skokomish River)

This stream supports populations of coho and fall chum salmon, as well as winter steelhead, sea-run cutthroat trout , and char (dolly varden or bull trout) (M. Ereth pers. comm, Frissell 1998). Fall chinook salmon occasionally spawn in Vance Creek. The watershed has been severely impacted by logging , roadbuilding, and agricultural and rural residential development (Frissell 1998). The habitat may be recovering, but population trends are poorly known.

Lilliwaup Creek

This area was proposed as a "critical area" for the Aquatic Diversity Areas database of the American Fisheries Society by Phil Wampler. This area has been degraded (entirely logged by the 1930s (Amato 1996)) but may offer important salmon habitat, particularly for summer chum. The Hood Canal Coordinating Council (1999) recognized Lilliwaup Creek as "moderately degraded with areas of good habitat." Factors for summer chum decline in this stream system include riparian degradation, subestuarine habitat loss and degradation, and low channel complexity (Hood Canal Coordinating Council 1999).

Eagle Creek

Williams et al. (1975) identified this area as a historically important stream system for coho salmon. More information about the current status of this watershed is needed.

Hamma Hamma mainstem (RM 0-5)

This watershed is located on the west side of Hood Canal in Mason and Jefferson Counties. This area was proposed as a "critical area" for the Aquatic Diversity Areas database of the American Fisheries Society by Phil Wampler. Historical logging and bank armoring practices drastically altered the hydrology of the lower Hamma Hamma River (Amato 1996).

The Hood Canal Coordinating Council (1990) cites low channel complexity, subestuarine habitat loss and degradation, altered sediment dynamics, and riparian degradation as proximal causes for decline of summer chum in this system. This area offers important habitat for summer chum and pink salmon (C. Baranski, pers. comm.).

Fulton Creek

This watershed is located in southern Jefferson County, entering Hood Canal south of the Duckabush River. Fall chum runs were historically large (Williams et al. 1975) and remain robust in this stream (Washington State Spawner database). This stream contains "excellent reproductive area" below the anadromous barrier (RM 0.9) (Williams et al. 1975).

Duckabush River mainstem (RM 0-7)

This large watershed, greater than75 square miles flows east into Hood Canal near the community of Duckabush. This watershed has less pressure for industrial development, relative to other Hood Canal watersheds (Hood Canal Coordinating Council 1999). Most of this watershed is protected within the Olympic National Park in the upstream sections. The lower areas are comprised of national forest and private lands, both of which support forestry practices as the dominant land use. Extensive bank alteration and channel revetment impact the lower reaches of the river (M. Ereth pers. comm.). Overall density of roads in this watershed is "low," with roads concentrated in the lower sections of this watershed (Hood Canal Coordinating Council 1999) where they directly damage salmon habitat. The area was proposed as a "critical area" for the Aquatic Diversity Areas database of the American Fisheries Society by Phil Wampler.

Dosewallips River mainstem (RM 0-2.5)

This area was proposed as a "critical area" for the Aquatic Diversity Areas database of the American Fisheries Society by Phil Wampler. It is utilized by summer chum, fall chum, pink, and coho salmon as well as summer and winter steelhead (SASSI 1993). Off-channel habitat is limited in this reach and large woody debris is relatively scarce (Frissell 1998). This area was subjected to intensive splash damming and log drives from about 1918 to 1927 (Amato 1996). Residential development pressure is increasing in this section of the Dosewallips watershed (Hood Canal Coordinating Council 1999). More information is needed about the values of this reach and basin for native, wild salmon.

CRITICAL CONTRIBUTING AREAS (CATEGORY 4)

South Fork Skokomish mainstem (RM 21-headwaters)

The relatively pristine conditions of Olympic National Park benefit ecological processes and patterns downstream (Frissell 1998). The reach up to RM 22.6 is accessible to and used by summer steelhead and perhaps historically by spring chinook (M. Ereth, pers. comm.).

Dosewallips River mainstem (RM 12-headwaters)

This area supports secondary or anabranched channels, significant large wood debris accumulation, low road densities, and mature floodplain/riparian forest cover (Frissell 1998). The relative integrity of this watershed (draining Olympic National Park) benefits downstream conditions for salmonids. More information is needed about the current and potential fish use in the upper sections of this watershed.

TABLE 14. STREAMS AND STREAM SEGMENTS ALONG SOUTHWEST HOOD CANAL CLASSIFIED IN ONE OF THE REFUGIA CATEGORIES.

STREAM OR SEGMENT NAME	CATEGORY[A]	ALTERATION CLASS[B]	SOURCE TYPES[C]
SKOKOMISH RIVER			
Skokomish River Estuary (RM 0-6)	2	FHA	PR
Richerts Springs Complex and mainstem Skokomish River (RM 7-8)	2	FHA	PR
Vance Creek and tributaries-	3	FHA	PR
South Fork Skokomish River mainstem (RM 13-21)	2	F	PR
South Fork Skokomish River upper basin (RM 21-headwaters)	4	N	PR
INDEPENDENTS			
Lilliwaup Creek	3	F	R
Eagle Creek	3	F	R
HAMMA HAMMA RIVER			
mainstem (RM 0 - 5)	3	AFI	PR
Johns Creek	2	AF	PR
INDEPENDENT			
Fulton Creek	3	F	PR
DUCKABUSH RIVER			
mainstem (RM 0-7)	3	FI	PR
DOSEWALLIPS RIVER			
mainstem (RM 0-2.5)	3	AFI	RS
mainstem (RM 4-12)	2	F	PRS
mainstem (RM 12-headwaters)	4		

[A]Stream categories: 1 = areas with high ecological integrity; 2 = anadromous salmonid refugia but with impaired integrity; 3 = possible refugia but more data are needed; 4 = critical contributing area; 5 = areas with exceptional habitat that is currently inaccessible to anadromous fishes due to an artificial barrier such as a dam or hatchery rack.

[B]Categories of alterations: A = Agricultural/rural residential (often including diking); D = Dam influenced, either by passage issues downstream or flow issues from upstream (including diversions); F = Forestry; H = hatchery; I = Industrial or urbanized; E = Exotic invasive species; N = Not managed; O = Other; P = Planned development (e.g. platted subdivision); U = unknown

[C]Types of information sources that provide support for the category designations include: P = personal communications; R = reports or articles; S = WDFW spawner database; D = other data sets; O = other

NORTHWEST HOOD CANAL-EAST STRAIT OF JUAN DE FUCA

OVERVIEW

This region was identified as Water Resource Inventory Area 17 by the Washington Department of Fish and Wildlife. Extending from Marple Creek in the Hood Canal to Johnson in Sequim Bay

(Strait of Juan de Fuca), this region includes the northeastern corner of the Olympic Peninsula. The topography of this region varies dramatically from south to north: in the south, volcanic basalt ridges of Buckthorn Mountain and the Quilcene Range form the Little and Big Quilcene River basins (Olympic National Forest and WDNR 1994); the remainder of the region consists primarily of low-elevation, low-gradient streams. As the largest lotic system in this region, the Big Quilcene River historically supported spring and fall chinook (Williams et al. 1975). However, spring chinook have been largely extirpated from this basin and fall chinook are supported by hatchery out-plants (Olympic National Forest and WDNR 1994) to the extent which they may not be of interest in conservation of native, wild salmon.

Forestry is the major land use of the southern portion of this region. The middle and lower reaches of the Quilcene basins have been extensively logged and roaded; only the headwaters of the Big Quilcene River remains pristine as part of the Olympic National Park and the Buckthorn Wilderness Area (Olympic National Forest). Owing to the inherently erosive geology and soils of this region (Williams et al. 1995) and the intensity of logging operations, forestry practices have substantially degraded salmonid habitat through sedimentation and aggradation (Olympic National Forest and WDNR 1994).

Forestry and agricultural uses dominate the northern portion of this region. In his assessment of anadromous fish habitat and use in the region, Lichatowich (1993) documents historical manipulation and damage to streams and the consequent declines in salmon productivity. A chronic limiting factor for this region is low flows resulting from perennially low rainfall and compounded by land use practices (Lichatowich 1993; McHenry et al. 1996). A recent assessment of Hood Canal summer chum habitat also highlighted problems with water temperature, sediment loading, channel complexity, riparian condition, and flood plain loss within this region (Point-No-Point Treaty Council and WDFW 1999).

In both the northern and southern sections of this region, rural and urban development poses immediate and long-term threats to the health of watersheds and salmon (C. Baranski, pers. comm.). In the Chicamum Creek watershed, development activities are estimated to have reduced winter rearing habitat by 97 percent and summer rearing habitat by 94 percent (Pacific Fisheries Management Council 1997). McHenry (1996) recognized Chimacum, Snow, and Salmon Creeks as some of the most highly altered streams systems as the result of channelization and urbanization within the northern Olympic Peninsula.

FISH

Rivers and streams within this region are utilized by chum and coho salmon, as well as steelhead and cutthroat trout. Of the 10 stocks identified by SASSI (WDF et al. 1993), only the Chicamum Creek coho stock is considered "healthy," even though its escapement numbers are maintained by hatchery efforts. Coho stocks in Sequim Bay (Bell, Johnson, Dean, and Jimmycomelately Creeks) and the Quilcene/Dabob Bays (Big and Little Quilcene Rivers and Tarboo Creek) was classified as "depressed." Coho stocks in Discovery Bay (Snow, Salmon, and Eagle Creeks) were designated with a "critical" status (WDF et al. 1993). All of these stocks have been influenced by hybridization with hatchery fish (WDF et al. 1993) to the point where identification of native stocks is increasingly difficult and unlikely (Weitkamp 1995). However, Lichatowich (1993, cited in Olympic National Forest and WDNR 1994) suggested that there is little straying and/or inbreeding between coho in the Quilcene Rivers based on temporal differences in peak spawning.

For streams of this region that drain into the Strait of Juan de Fuca, Phelps et al. (1995) used genetic and life history data to group fall chum into a single "genetic diversity unit." However, SASSI did not identify a fall chum stock for this geographic location (WDF et al. 1993), although chum salmon are historically known to utilize these streams (Williams et al. 1975). For streams draining into Hood Canal and Dabob Bay, SASSI recognized one stock of fall chum with a "healthy" status and composite (i.e. hatchery-supported) production (WDF et al. 1993). Genetically similar stocks of summer chum were found within Discovery and Sequim Bays in the eastern Strait of Juan de Fuca (Phelps et al. 1995). SASSI listed the status of these stocks as "critical" and "depressed," respectively. Both of these stocks are of native origin and neither is supported by hatchery out-plants (WDF et al. 1993).

Winter steelhead stocks are recognized by SASSI for Discovery Bay, Sequim Bay, and Quilcene/Dabob Bays. The Discovery Bay stock is listed as "depressed" and the others are of "unknown" status (WDF et al. 1993). Although the origin of the Quilcene/Dabob Bays stock is disputed in SASSI (WDF et al. 1993), a report on Olympic National Forest by the WDNR 1994 treats this stock as an introduced species to the area.

Sea-run cutthroat trout are listed as a "species of special concern" by USDA Forest Service for the Big Quilcene Water Administrative Unit (Olympic National Forest and WDNR 1994). In the southern portion of this region, several streams are recognized as containing either resident or anadromous cutthroat trout populations, including Penny, Townsend, Spencer, Jackson, and Marple Creeks (Olympic National Forest and WDNR 1994). To the north, cutthroats can be found in several stream systems, although their numbers are generally declining (Lichatowich 1993).

AREAS RECOMMENDED FOR WITHIN-BASIN REFUGIA DESIGNATION AND JUSTIFICATIONS

POSSIBLE REFUGIA (CATEGORY 3)

Spencer Creek

This small watershed drains the west side of Mount Walker into Hood Canal just south of Quilcene Bay near Frenchman's Point. This stream supports a self-sustaining population of cutthroat trout and is considered to be a "locally significant aquatic habitat for salmonids" (Big Quilcene Watershed Analysis 1994). However, this system is used to support an intensive outplantings of coho hatchery fish from the Quilcene National Fish Hatchery (Lichatowich 1993).

Tarboo Creek

Although this stream system has been severely degraded by agricultural practices, it still supports relatively robust populations of coho and chum salmon (C. Baranski pers. comm.). Chum salmon utilize the lower half of the stream; coho salmon utilize the stream to its headwaters (pers. comm. C. Baranski). This stream was a historically important salmon stream (Lichatowich 1993; Williams et al. 1975). More information is needed about the habitat quality and security of this watershed.

POTENTIAL REFUGIA ABOVE ARTIFICIAL BARRIERS (CATEGORY 5)

Penny Creek

This watershed contains the most significant opportunities for preservation of native, wild salmon habitat in the Quilcene basin (Frissell 1998). The mouth of Penny Creek (into the Big Quilcene River) is obstructed by the Quilcene National Fish Hatchery. Chum (summer, early fall, late fall/winter) and coho salmon, as well as steelhead and coastal cutthroat trout are known to have historically used this area (Frissell 1998; Big Quilcene Watershed Analysis 1994). Frissell (1998) discussed the potential heuristic value for protection and restoration of this as an experimental restoration effort. This stream supports a "highly productive population of resident cutthroat trout" and has the "potential for natural coho production" (Big Quilcene Watershed Analysis 1994).

TABLE 15. STREAMS AND STREAM SEGMENTS OF THE NORTHWEST HOOD CANAL AND EAST STRAIT OF JUAN DE FUCA AREAS CLASSIFIED IN ONE OF THE REFUGIA CATEGORIES.

STREAM OR SEGMENT NAME	CATEGORY[A]	ALTERATION CLASS[B]	SOURCE TYPES[C]
BIG QUILCENE RIVER			
Penny Creek	5	FH	PR
INDEPENDENT			
Spencer Creek	3	FH	R
Tarboo Creek	3	AFH	PRS

[A]Stream categories: 1 = areas with high ecological integrity; 2 = anadromous salmonid refugia but with impaired integrity; 3 = possible refugia but more data are needed; 4 = critical contributing area; 5 = areas with exceptional habitat that is currently inaccessible to anadromous fishes due to an artificial barrier such as a dam or hatchery rack

[B]Categories of alterations: A = Agricultural/rural residential (often including diking); D = Dam influenced, either by passage issues downstream or flow issues from upstream (including diversions); F = Forestry; H = hatchery; I = Industrial or urbanized; E = Exotic invasive species; N = Not managed; O = Other; P = Planned development (e.g. platted subdivision); U = unknown

[C]Types of information sources that provide support for the category designations include: P = personal communications; R = reports or articles; S = WDFW spawner database; D = other data sets; O = other

DUNGENESS-ELWHA RIVER BASINS AND INDEPENDENT DRAINAGES

OVERVIEW

This region consists of Water Resource Inventory Area 18 (Williams et al. 1975) and is dominated by two large basins: the Dungeness and the Elwha rivers. Both of these rivers flow generally northward from headwaters in the Olympic National Park, through Olympic National Forest lands, and into the Strait of Juan De Fuca. Although anadromous fishes can access more than 20 miles of spawning habitat within the Dungeness basin (DAWACT 1995), anadromous fish use of the Elwha is limited to the lower 4.9 miles due migration blockage by the lower Elwha Dam.

In the Dungeness basin, land use intensifies from the headwaters to the mouth of the river. In the headwaters of the system, most watersheds are protected from commercial logging and development, including a large protected area in the Gray Wolf River. Further downstream, the middle reaches have been degraded through forestry practices (Lichatowich 1992; Orsborne 1994; DAWACT 1995). In the lower sections of the river, land use has been most intense, including agricultural impacts, forestry, and rural/urban development (DRRWG 1997). In particular, construction of numerous irrigation diversions, dikes, and roads has altered river movement patterns and flow regimes (Orsborne 1994; DAWACT 1995; DRRWG 1997).

These land uses have dramatically degraded the historical salmon production capacity of the lower Dungeness River (Lichatowich 1993; Orsborne 1994; DRRWG 1997; Frissell 1998). Independent streams have been subjected to a similar array of land use practices, with the same deleterious consequences for salmonids (C. Baranski, pers. comm.; T. Labbe pers. comm.). These anthropogenic impacts may be exacerbated as the result of characteristically low levels of rainfall within this section of the Olympic rainshadow.

FISH

The Dungeness-Elwha River region historically supported large populations of chinook, pink, coho, and chum salmon (WDF et al. 1993) as well as coastal cutthroat trout, bull trout, Dolly Varden, and steelhead trout (Busby and six others 1996; WDFW 1998; Johnson and seven others 1999). Currently, no identified stocks of wild, naturally reproducing salmon are considered to be healthy. Moreover, numbers of native and wild trout have declined and are generally limited to non-anadromous populations within the boundaries of Olympic National Park (WDF et al. 1993). These declines in population numbers and genetic integrity can be attributed to land use decisions (Bishop and Morgan 1996; McHenry et al. 1996) and the influence of some hatcheries (Bishop and Morgan 1996). In response, native stock restoration programs are being instigated by the Lower Elwha Klallam Tribe (P. Crain, pers. comm.) and the (DRRWG 1997).

In the Dungeness River system, SASSI (WDF et al. 1993) identified stocks of spring chinook, coho, chum, and pink salmon, as well as winter and summer steelhead stocks. With the exception of the hatchery-supported coho runs, the status of all of these stocks is categorized as either "depressed," "critical," or "unknown" (WDF et al. 1993). Similarly, Nehlsen et al. (1991) rated the Dungeness populations of spring and fall chinook with a "high risk of extinction." However, native and wild populations of bull trout/Dolly Varden appear to be stable in the higher reaches of this system (WDFW 1998).

The pink salmon populations deserve special attention in the Dungeness River system (Lichatowich 1993). Based on genetic and life history information, two stocks of odd-year pink salmon have been identified (WDF et al. 1993; Shaklee et al. 1995; Hard et al. 1996). The earlier-timed run spawns above RM 10 of the mainstem Dungeness River and lower nine miles of the Gray Wolf River, whereas the later-timed run generally remains in the lower three miles of the mainstem Dungeness River (WDF et al. 1993). Given that the earlier (summer) run exhibits a unique run timing in the State of Washington (Hard et al. 1996), this population holds local and regional significance for conservation. Although both stocks are experiencing recent declines in abundances (Hard et al. 1996), the upper (earlier-timed) run appears to be less threatened than the lower (later-timed) run (WDF et al. 1993).

The lower section of the Elwha River system supports “healthy” stocks of fall chinook and coho salmon, which are both maintained by annual out-plants of hatchery fish (WDF et al. 1993). However, the status of natural production salmon is less optimistic: SASSI classified the status of pink salmon as “critical” and the chum salmon as “unknown” (WDF et al. 1993). Historical runs of spring chinook may be extinct (Nehlsen et al. 1991) and were not recognized in SASSI (WDF et al. 1993). It has been long been recognized that the Elwha River dams are a principal limiting factor to salmon production in this river system (Bishop and Morgan 1996; McHenry et al. 1996) and that relatively pristine salmon habitat occurs above the dams (Williams et al. 1975, and P. Crain pers. comm.).

Independent streams in this region vary considerably in salmon productivity. Morse Creek supports the highest abundance and richness of salmon (McHenry et al. 1996). In other relatively large streams such as McDonald and Siebert Creeks, low flows and culvert passage problems may limit salmon use and reproduction (C. Baranski pers. comm.). All of the independent streams have been affected to some extent by logging and agricultural practices (McHenry et al. 1996).

AREAS RECOMMENDED FOR WITHIN-BASIN REFUGIA DESIGNATION AND JUSTIFICATIONS

REFUGIA - ECOLOGICAL INTEGRITY INTACT (CATEGORY 1)

Gray Wolf River (RM 0-9)

Most of this basin is protected within the Buckthorn Wilderness (Olympic National Forest). This river supports populations of bull trout (WDFW 1998), coastal cutthroat trout, and steelhead trout (winter and summer), as well as coho, spring/summer chinook, fall chum, and early pink salmon (Frissell 1998). This basin supports one of the most robust early pink salmon populations in the Puget Sound region (Frissell 1998; Lichatowich 1993). The watershed maintains mature floodplain/riparian forest cover, low road densities, and significant accumulations of large woody debris (Frissell 1998). In an evaluation of potential salmon refugia for Olympic Peninsula and Hood Canal. Frissell (1998) described this basin as the most secure watershed identified.

REFUGIA - ALTERED (CATEGORY 2)

Elwha River (below RM 4.9)

The Elwha River drains a large basin (321 mi2) and flows into the Strait of Juan De Fuca at Freshwater Bay. With construction of mainstem hydroelectric dams in 1913 (RM 4.9) and 1927 (RM 13.4), anadromous salmon use of the Elwha River was drastically altered. The dams not only prevented upstream passage, but also altered the organic matter and gravel recruitment as well as temperature regimes in the remaining accessible reaches (McHenry et al. 1996). WDFW (1993) described the chinook hatchery program on the Elwha (Elwha Hatchery) as a native fish program. Although the Elwha historically supported massive salmon runs (McHenry et a. 1996), the coho, chum, and chinook salmon populations are currently showing relatively low numbers (C. Baranski pers. comm.). In particular, the lack of fine material recruitment and side channel complexity (as the result of the dams and also revetments and other alterations in the lower river miles) may limit habitat for coho salmon (C. Baranski pers. comm.).

Dungeness River mainstem (RM 0-5 and 10-18.8)

With a large watershed, the Dungeness River flows north into the Strait of Juan De Fuca between the city of Port Angeles and the town of Sequim. The lower section (RM 0-5) supports essential habitat for a distinct early pink run (Lichatowich 1993) as well as an important early chum run which has generally not received much attention (C. Baranski pers. comm.). The lower reach has been damaged by diking and two bridges which have constricted the channel (Dungeness River Restoration Work Group 1997). The upper section (RM 10-18) supports pink, chinook (Lichatowich 1993), coho, and chum salmon use (Frissell 1998). Aggradation from large landslides in Gold Creek has impacted the quality of spawning habitat of this region (Orsborne and Ralph 1994), but complex habitat remains in off-channel sites on forested floodplains (Frissell 1998).

POSSIBLE REFUGIA (CATEGORY 3)

Matriotti Creek

This stream drains from west to east into the Dungeness River near RM 2. Juvenile mortality from irrigation screens may limit the potential salmon production within this stream system (C. Baranski pers. comm.). Agricultural and urban development pressures are increasing within this watershed (C. Baranski, pers. comm.). More information about possible salmon use of this area is needed. There are verbal accounts of high densities of chum salmon spawning in spring-fed reaches of the Matriotti Creek complex (M. McHenry, Jamestown S'Klallam tribe, Jamestown, pers. comm.).

Morse Creek

Morse Creek flows north into the Strait of Juan De Fuca two miles east of Port Angeles.. This stream was historically an important salmon stream (Williams et al. 1975) and currently supports robust populations of pink, chum, coho, and fall chinook salmon (C. Baranski pers. comm.). However, some stocks have been lost from this stream: McHenry et al. (1996) point out that the loss of spring chinook salmon from this stream was an "irreparable loss of a unique genetic stock." Currently, the City of Port Angeles operates two hydropower dams on Morse Creek, but times use to minimize impacts on anadromous salmonids (McHenry et al. 1996). McHenry et al. (1996) recommended that Morse Creek pink salmon be managed as a distinct stock. Although the headwaters of this stream contain late seral forests, the lower elevations have been cleared and impacted (McHenry et al. 1996). However, in general, the habitat quality for salmonids in this stream is considered to be good (C. Baranski pers. comm.).

CRITICAL CONTRIBUTING AREAS (CATEGORY 4)

Gray Wolf River (RM 9-headwaters)

Given its nearly pristine nature, the upstream areas within this basin may benefit downstream ecological processes and patterns.

POTENTIAL REFUGIA ABOVE ARTIFICIAL BARRIERS (CATEGORY 5)

Canyon Creek

This stream meets the Dungeness River at RM 12. This watershed is thought to be important for winter steelhead trout (S. Ralph and M. Reed, pers. comm. in Frissell 1998). Access to this stream from the Dungeness River is blocked by a water diversion. Further information about the quality of the habitat and importance for salmonid conservation is needed for this watershed.

ELWHA RIVER SYSTEM (ABOVE RM 13.4)

McHenry et al. (1996) and others have recommended removing the lower and upper dams as an appropriate and cost-effective way to restore the Elwha River fishery. Given that the potential habitat above the dams is abundant (P. Crain pers. comm.) and considering the currently depressed status of salmon populations in the lower Elwha River (C. Baranski pers. comm.), we agree with the conclusions of McHenry et al. (1996).

TABLE 16. STREAMS AND STREAM SEGMENTS IN THE DUNGENESS, ELWHA AND NEARBY INDEPENDENT DRAINAGES CLASSIFIED IN ONE OF THE REFUGIA CATEGORIES.

STREAM OR SEGMENT NAME	CATEGORY[A]	ALTERATION CLASS[B]	SOURCE TYPES[C]
DUNGENESS RIVER			
Matriotti Creek	3	AF	RP
mainstem (RM 0-5; 10.0-18.8)	2	AFHI	PRS
Canyon Creek	5	FH	R,P
Gray Wolf River (RM 0-9)	1	FH	PRS
Gray Wolf River (RM 9-headwaters)	4	None	PR
ELWA RIVER			
mainstem (RM 0-4.9)	2	ADFHI	PRS
upper Elwha (RM 13.4-headwaters)	5	AF?	R
INDEPENDENT			
Morse Creek (RM 0-4.9)	3	ADFHI	PRS

[A]Stream categories: 1 = areas with high ecological integrity; 2 = anadromous salmonid refugia but with impaired integrity; 3 = possible refugia but more data are needed; 4 = critical contributing area; 5 = areas with exceptional habitat that is currently inaccessible to anadromous fishes due to an artificial barrier such as a dam or hatchery rack

[B]Categories of alterations: A = Agricultural/rural residential (often including diking); D = Dam influenced, either by passage issues downstream or flow issues from upstream (including diversions); F = Forestry; H = hatchery; I = Industrial or urbanized; E = Exotic invasive species; N = Not managed; O = Other; P = Planned development (e.g. platted subdivision); U = unknown

[C]Types of information sources that provide support for the category designations include: P = personal communications; R = reports or articles; S = WDFW spawner database; D = other data sets; O = other

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ACKNOWLEDGEMENTS

Steve Willer, Ben Sabold and Ryan Hopkins (Pacific Biodiversity Institute interns) worked hard during the summer of 1999 to create the detailed subwatershed layer used in all of these analyses. Jason Karl and Teresa Allen (Pacific Biodiversity Institute staff) provided essential support to the project.