FINAL REPORT

PRIORITIZATION OF MARINE SHORELINES OF WATER RESOURCE INVENTORY AREA 9 FOR JUVENILE SALMONID HABITAT PROTECTION AND RESTORATION

Prepared for

Water Resource Inventory Area 9 Technical Committee

With funding provided by

King Conservation District

Washington State Salmon Recovery Funding Board

Prepared by

Anchor Environmental, L.L.C.

1423 Third Avenue, Suite 300

Seattle, Washington 98101

May 2006

ANCHOR ENVIRONMENTAL, L.L.C.

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EXECUTIVE SUMMARY ES-1

1 INTRODUCTION 1
1.1 Project Goal 3
1.2 Project Area 4

2 SALMONIDS AND THE MARINE NEARSHORE 5
2.1 Summary of Salmonid Stocks Originating in the Project Area 5
2.2 Juvenile Salmonid Ecological Needs 8

3 PROJECT APPROACH AND METHODS 11
3.1 Habitat Features Considered 12
3.2 Habitat Function Model 13
3.3 Consideration of Landscape Processes 16
3.4 Final Steps in Priority Area Determinations 17
3.5 Spatial Scales of Priority Area Recommendations 17

4 HABITAT FUNCTION MODEL RESULTS 20
4.1 Current Function 24
4.2 Rehabilitation Potential 24
4.3 Restoration Potential 24

5 PRIORITY AREAS AND SUBAREA RECOMMENDATIONS 25
5.1 General Project Area Habitat Needs 25
5.1.1 Conservation 25
5.1.2 Restoration 26
5.1.3 Rehabilitation 26
5.1.4 Substitution 27
5.2 Study Area Priority Recommendations 27
5.3 Subareas 32
5.3.1 Magnolia 33
5.3.1.1 Habitat Needs and Goals 33
5.3.1.2 Priority Recommendations 33
5.3.2 Elliott Bay 36
5.3.2.1 Habitat Needs and Goals 36
5.3.2.2 Priority Recommendations 36
5.3.3 West Seattle to Burien 39
5.3.3.1 Habitat Needs and Goals 40
5.3.3.2 Priority Recommendations 40
5.3.4 Three Tree Point to Des Moines 43
5.3.4.1 Habitat Needs and Goals 43
5.3.4.2 Priority Recommendations 43
5.3.5 Des Moines to Federal Way 46

5.3.5.1 Habitat Needs and Goals 46
5.3.5.2 Priority Recommendations 47
5.3.6 East Maury Island 49
5.3.6.1 Habitat Needs and Goals 49
5.3.6.2 Priority Recommendations 49
5.3.7 East Vashon Island 52
5.3.7.1 Habitat Needs and Goals 52
5.3.7.2 Priority Recommendations 52
5.3.8 North Vashon Island 55
5.3.8.1 Habitat Needs and Goals 55
5.3.8.2 Priority Recommendations 56
5.3.9 West Vashon Island 58
5.3.9.1 Habitat Needs and Goals 58
5.3.9.2 Priority Recommendations 58
5.3.10 West Quartermaster Harbor 61
5.3.10.1 Habitat Needs and Goals 61
5.3.10.2 Priority Recommendations 61
5.3.11 Inner Quartermaster Harbor 64
5.3.11.1 Habitat Needs and Goals 64
5.3.11.2 Priority Recommendations 64
5.3.12 East Quartermaster Harbor 67
5.3.12.1 Habitat Needs and Goals 67
5.3.12.2 Priority Recommendations 67

6 CONCLUSIONS 70

7 REFERENCES 71

List of Tables

Table ES-1 Overall Project Area Recommendations ES-1
Table 1 SASSI Reports Status of Anadromous Salmonid Stocks Originating in the Project Area 8
Table 2 Summary of Ecological Functions Affected by Habitat Features Used in Nearshore Assessment 13
Table 3 Data Used in the Evaluation of the Ecological Function of Habitats 15

List of Figures

Figure 1 Conceptual Model of Ecological Processes and Salmon Responses 11

List of Maps

Map ES-1 Study Area and Subarea Recommendations 2
Map 1 Vicinity Map 2
Figure 1 Conceptual Model of Ecological Processes and Salmon Responses 11
Map 2 Subareas and Drift Cells 19
Map 3 Existing Habitat Function 21
Map 4 Rehabilitation Potential 22
Map 5 Restoration Potential 23
Map 6 Study Area and Subarea Recommendations 28
Map 7 Magnolia Subarea and Priority Recommendations 35
Map 8 Elliott Bay Subarea and Priority Recommendations 38
Map 9 West Seattle to Burien Subarea and Priority Recommendations 42
Map 10 Three Tree Point to Des Moines Subarea and Priority Recommendations 45
Map 11 Des Moines to Federal Way Subarea and Priority Recommendations 48
Map 12 East Maury Island Subarea and Priority Recommendations 51
Map 13 East Vashon Island Subarea and Priority Recommendations 54
Map 14 North Vashon Island Subarea and Priority Recommendations 57
Map 15 West Vashon Island Subarea and Priority Recommendations 60
Map 16 West Quartermaster Harbor Subarea and Priority Recommendations 63
Map 17 Inner Quartermaster Harbor Subarea and Priority Recommendations 66
Map 18 East Quartermaster Harbor Subarea and Priority Recommendations 69

List of Appendices

Appendix A Field Data Collection Report
Appendix B Final GIS Data Layers (data CD)
Appendix C Scoring System for Habitat Function Model

EXECUTIVE SUMMARY

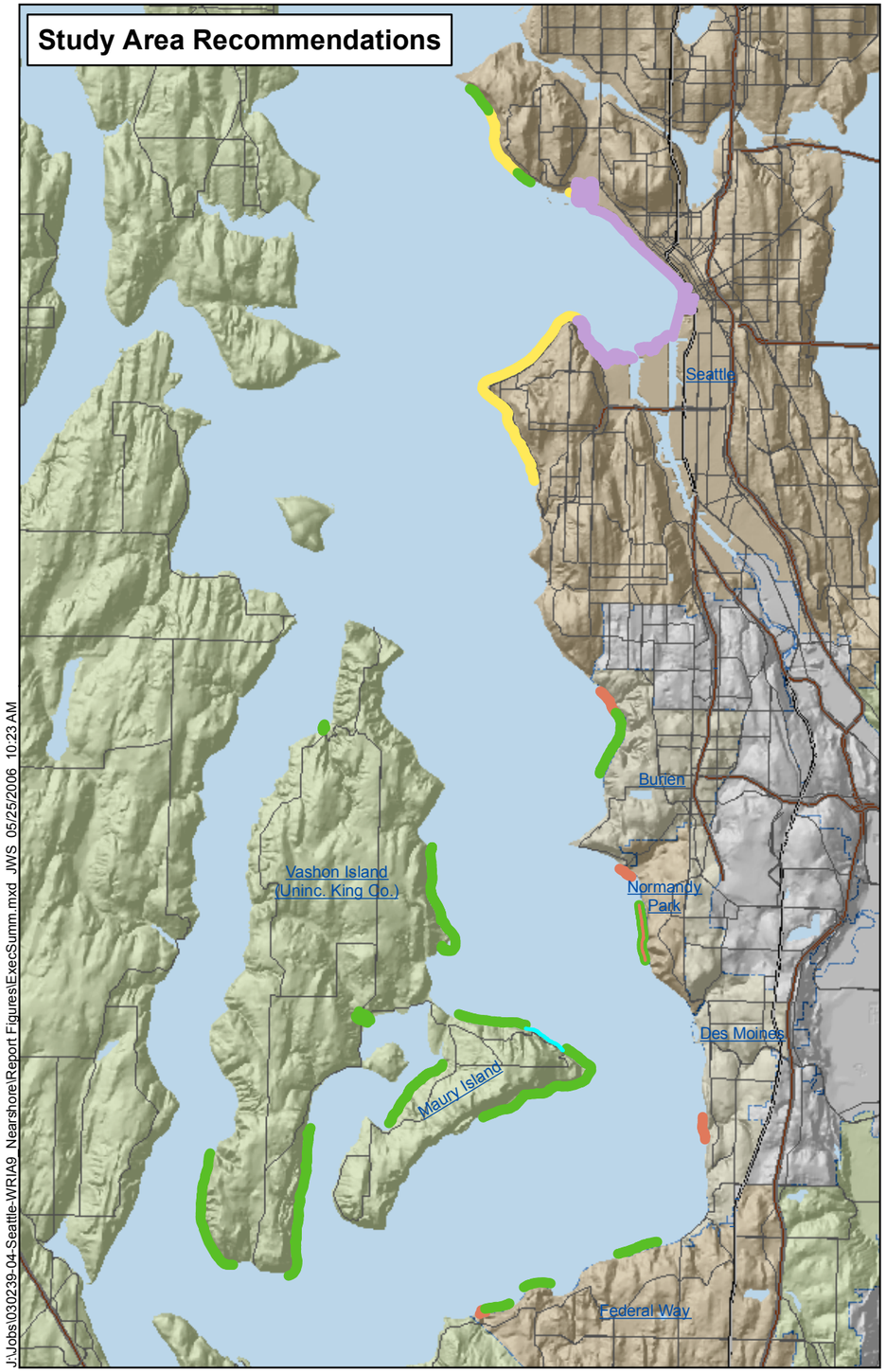
This report presents the results of a project that identified and prioritized habitat management areas and actions to promote salmonid survival along the marine shorelines of the Green/Duwamish and Central Puget Sound Watershed (Water Resource Inventory Area 9 [WRIA 9]). This information will help guide regional salmon recovery planning resulting from the recent Endangered Species Act (ESA) listing of Puget Sound Chinook salmon and the proposed listing of steelhead and coho salmon. This project used habitat features to characterize marine shoreline habitats of WRIA 9 and to select priority habitat action areas through a science-based prioritization process. The general strategies of conservation, restoration, rehabilitation, and substitution were used for prioritization, consistent with the WRIA 9 Steering Committee and the Puget Sound Technical Recovery Team's (Puget Sound TRT's) recommendations for the management of current and potential salmonid habitat in Puget Sound (WRIA 9 2005; Puget Sound TRT 2003).

The project area encompassed the marine shoreline of WRIA 9. This covered approximately 90 miles of shoreline, including the marine shorelines of the municipalities of Seattle (south of West Point), Burien, Normandy Park, Des Moines, and Federal Way, as well as the shorelines of Vashon and Maury Islands

For juvenile salmon that rear and migrate in the marine nearshore after their outmigration from the region's rivers, the physical and biological features of the habitat can influence their growth and survival. This link to overall marine survival, coupled with the urgency of salmon recovery due to the ESA listings, assigns great importance to providing high functioning marine nearshore habitats to support juvenile salmon. In this project, a Geographic Information System (GIS)-based habitat function model was developed to characterize the level of function provided for the ecological needs of juvenile salmon; function was characterized by assigning scores based on the presence, absence, or condition of specific physical and biological habitat features that contributed to habitat function. Priority areas were identified in two spatial extents: first, at the extent of the entire project area; and second, at the extent of each of 12 subareas comprising the project area. Table ES-1 and Map ES-1 provide an overview of the recommendations in specific areas identified by the model and the prioritization process. The full report provides further habitat enhancement recommendations.

Table ES-1
Overall Project Area Recommendations

Area	Recommendation
Magnolia Bluffs	*Conserve* the unarmored bluffs and stands of trees in the riparian zones along the northern and southern Magnolia bluffs. *Rehabilitate* areas between north and south Magnolia bluffs by removing groins and areas of protruding fill that impede longshore sediment transport.
Elliott Bay	*Substitute/Rehabilitate* habitat throughout Elliott Bay from the Elliott Bay Marina in the north to the Duwamish Head in the west in order to create and improve habitat for juvenile salmonids. Similar types of activities could be conducted along the western shoreline from West Waterway to the Duwamish Head in order to provide higher functioning habitat. Along the downtown Seattle Waterfront from Myrtle Edwards Park to the East Waterway, substitution activities to create shallow water and protected habitat offshore from the seawall would provide improved rearing habitat for juvenile salmonids.
Duwamish Head	*Rehabilitate* Schmitz Creek by daylighting the mouth of the creek to allow it to flow across the intertidal zone. *Rehabilitate* longshore sediment transport from Alki Point to the south end of Me Kwa Mooks Park by removing groins and areas of fill that protrude into the intertidal zone. *Rehabilitate* marine riparian vegetation from Duwamish Head to the Me Kwa Mooks Park seawall.
Seahurst Park	*Restore* the northern and central sections of Seahurst Park by removing armor and allowing landslide materials to feed the intertidal zone. *Conserve* unarmored feeder bluff sections north and south of Seahurst Park—including intact, mature riparian vegetation and large woody debris (LWD) across the intertidal zone.
Three Tree Point	*Restore* the mouths of Miller/Walker Creeks and McSorley Creek at Saltwater State Park to create high functioning pocket estuaries. The mouth of McSorley Creek could be restored by removing armor and pulling back the shoreline to provide an open, more naturally meandering channel across the intertidal zone. Restoration of the park shoreline north of the creek to reconnect the sediment supply and riparian vegetation to the intertidal zone is also a priority. *Conserve*/*Restore* sediment supply along the extended reach south of Three Tree Point that currently has a mix of armored and unarmored feeder bluffs with mature riparian vegetation. Remove patchy armoring in a section of well-vegetated and lightly developed shoreline south of Three Tree Point.
Federal Way	*Conserve* two extended sections of unarmored feeder bluffs west of Dumas Bay that have mature riparian vegetation. *Restore* the tributary mouth at Dash Point State Park. *Conserve* an extended reach east of Dumas Bay that has unarmored feeder bluffs that have mature vegetation.
Point Heyer – Vashon Island	*Conserve* the lagoon at Point Heyer (also known as KVI because of the radio tower on site) and the unarmored feeder bluffs providing sediment to the point.
Northern and Eastern Shoreline of Maury Island	*Conserve* intact feeder bluffs and mature riparian vegetation in two reaches along the northern and eastern shorelines of Maury Island.
Mouths of Shinglemill and Judd Creeks – Vashon Island	*Conserve* the unarmored mouths of Shinglemill Creek and Judd Creek, the two largest salmon producing tributaries on the islands.
Southwestern Vashon Island	*Conserve* unarmored feeder bluffs, intact riparian vegetation, and LWD across the intertidal zone.
West Shoreline of Entrance to Quartermaster Harbor	*Conserve* unarmored feeder bluffs, intact riparian vegetation, and LWD across the intertidal zone.
East Quartermaster Harbor	*Conserve* unarmored feeder bluffs and wide corridors of intact riparian vegetation in the drift cell north of Dockton.



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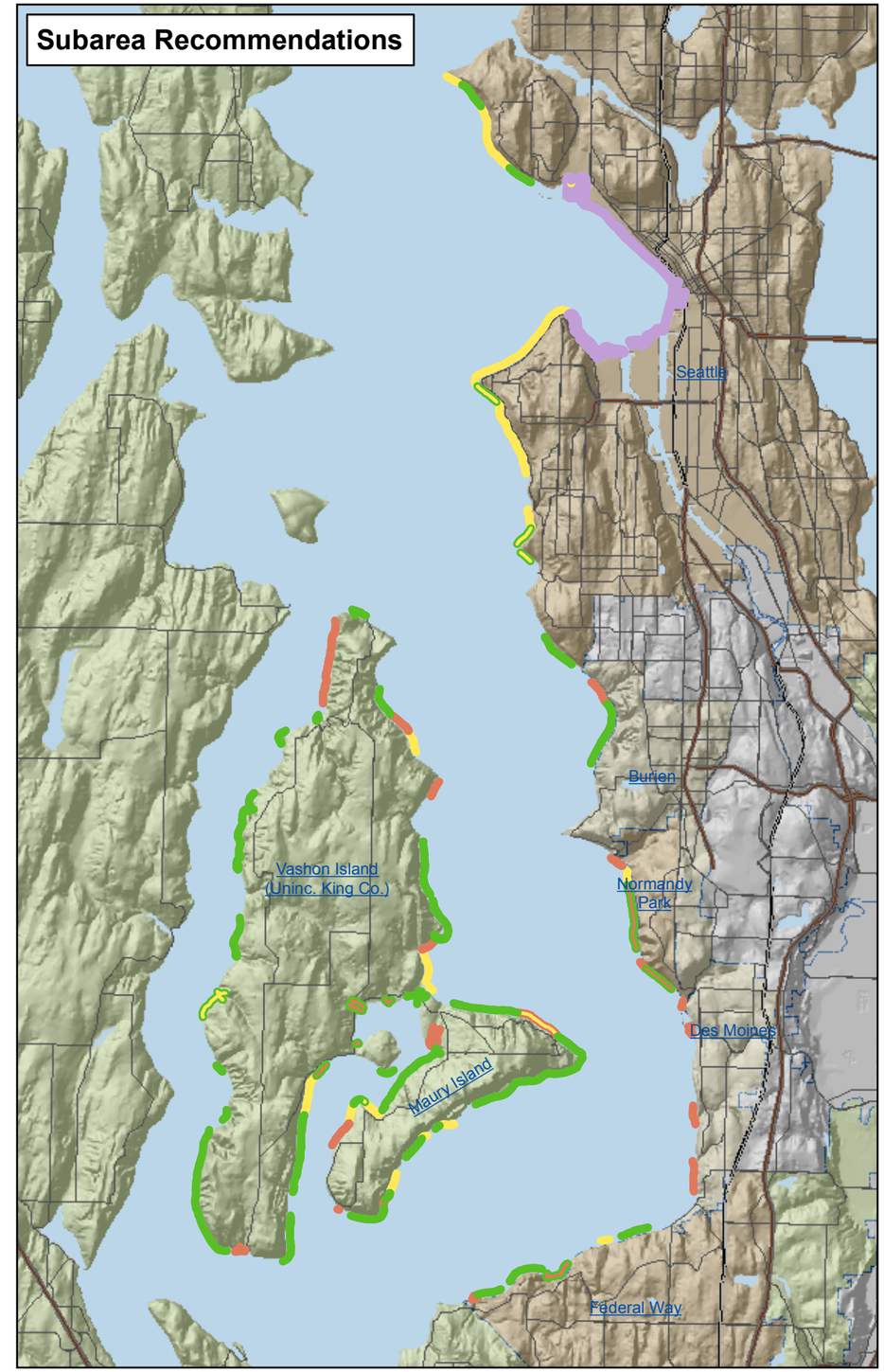
LEGEND

Study Area Recommendations

- Conserve
- Conserve/Restore
- Rehabilitate
- Substitute
- Restore

Subarea Recommendations

- Conserve
- Conserve/Rehabilitate
- Conserve/Restore
- Rehabilitate
- Substitute
- Rehabilitate/ Restore
- Restore



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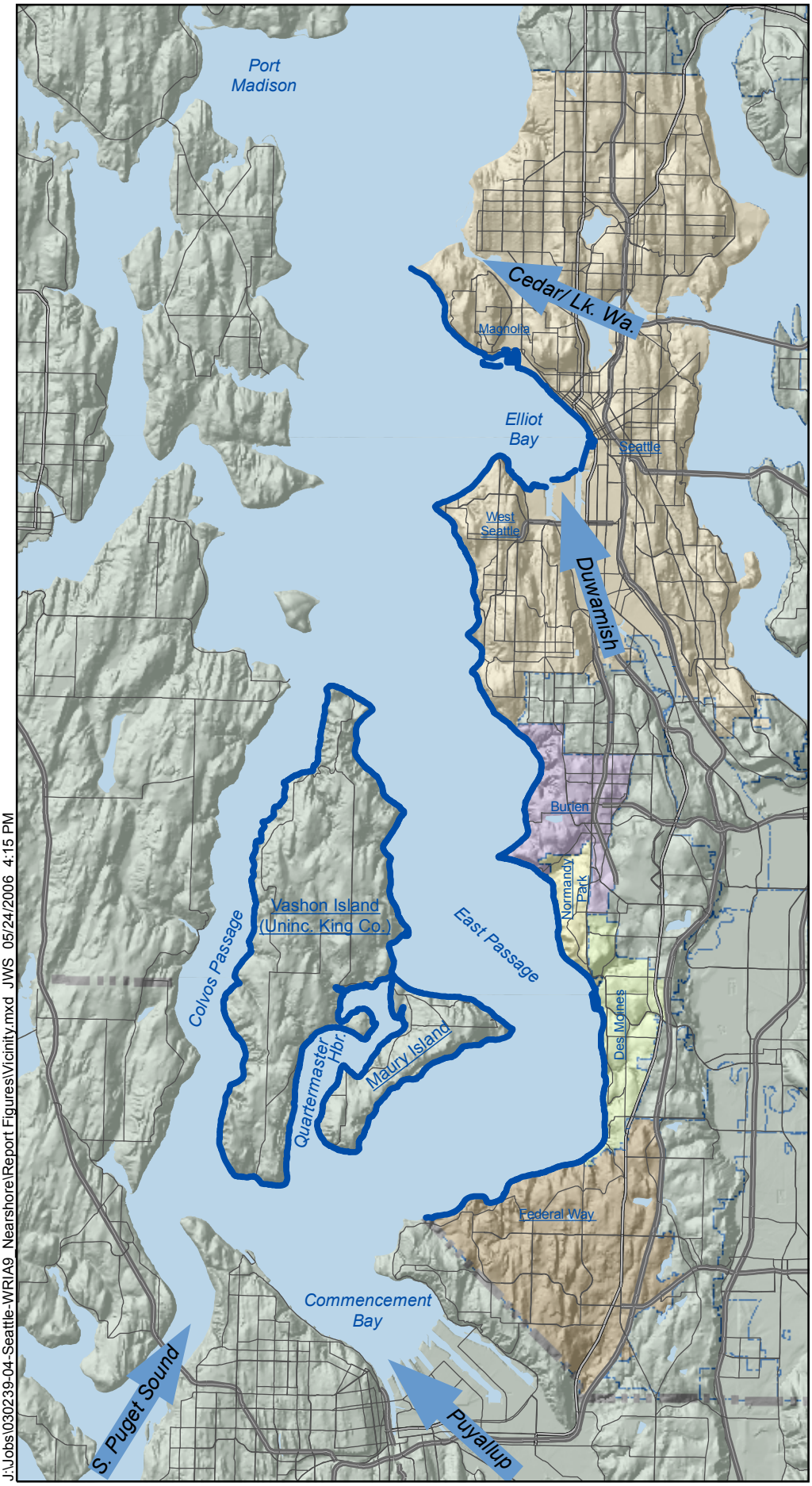
Map ES-1
Study Area and Subarea Recommendations
Identification of Priority Areas
WRIA 9 Nearshore Habitat Assessment

1 INTRODUCTION

Recent Endangered Species Act (ESA) listings of salmonid[1] stocks in Puget Sound have initiated significant salmonid recovery planning efforts throughout the area, including those in the Green/Duwamish and Central Puget Sound Watershed (Water Resource Inventory Area 9 [WRIA 9]). A key aspect of these planning efforts is to identify and increase the number and quality of habitats that promote salmonid survival. While salmonid recovery planning aims to support all phases of salmonid life history, supporting the juvenile phase is crucial because they are more vulnerable to habitat degradation due to limited mobility. The marine nearshore (shallow water) areas are the first habitats encountered by juvenile salmonids as they outmigrate from the region's rivers. They are particularly vulnerable during this early marine residence as their bodies complete adaptations to saltwater and they encounter new habitat types and food resources. Some species, especially Chinook salmon and chum salmon (*O. keta*), are highly dependent upon shoreline habitats for growth and survival. There is evidence that juvenile salmon growth during this period determines their overall marine survival trends (Holtby et al. 1990; Hargreaves 1997; Beamish and Mahnken 1998; Murphy et al. 1998; Tovey 1999).

WRIA 9 contains approximately 90 miles of marine shoreline in central Puget Sound that supports juvenile salmonid rearing and migration (Map 1). Therefore, maintaining and improving the quality of nearshore habitats has become an important component of salmonid recovery efforts for this area, beginning with the identification of priority nearshore areas that offer high potential to benefit juvenile salmonid survival. This report presents the methods and results of a prioritization that was completed for the project area.

[1] The Puget Sound/Strait of Georgia coho salmon (*Oncorhynchus kisutch)* Evolutionarily Significant Unit (ESU) is currently listed as a Candidate Species/Species of Concern under the ESA. The Puget Sound Chinook salmon (*O. tschawytscha)* ESU is currently listed as threatened under the ESA. The Puget Sound steelhead (*O. mykiss*) ESU is currently proposed to be listed as threatened under the ESA.



LEGEND

- Study Area
- County Limit
- City Limit

Cities in WRIA 9

- Seattle
- Burien
- Normandy Park
- Des Moines
- Federal Way
- Major Salmon Source

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0 0.5 1 2 3 4
Scale in Miles

Map 1
Vicinity Map
Identification of Priority Areas
WRIA 9 Nearshore Habitat Assessment

1.1 Project Goal

The project goal was to use a science-based approach to identify priority areas for conservation, restoration, rehabilitation, and substitution actions that support juvenile salmon growth and survival in the marine nearshore of WRIA 9. In one of the development steps to support this objective, guidance documents from regional salmonid recovery teams in the Puget Sound area were consulted. The WRIA 9 Steering Committee has prepared a Salmon Habitat Plan (Plan) that outlines the landscape-level and site-specific actions for the WRIA (WRIA 9 2005). The Plan is based on the Puget Sound Technical Recovery Team's (Puget Sound TRT's) proposed general habitat management strategies, including protection, restoration, rehabilitation, and substitution, that are to be used by watershed groups and others working for regional salmonid recovery (Puget Sound TRT 2003). Following is the definition of each type of habitat management strategy:

- Conservation: to be applied where habitat is presently functioning at a high level and supports natural habitat-forming or -sustaining processes. For example, conserve the natural sediment delivery processes from a feeder bluff to the intertidal zone by keeping that section of shoreline unarmored.
- Restoration: to be applied where habitat is impaired but natural processes can be recovered. For example, restore the natural sediment delivery processes from a feeder bluff to the intertidal zone by removing shoreline armoring that currently prevents bluff material from eroding and entering the intertidal zone.
- Rehabilitation: to be applied where habitat is impaired and restoration of full function and supporting processes appears infeasible; however, limited improvements to functions and supporting processes can be achieved through partial re-establishment of ecosystem processes or functions. For example, rehabilitate the delivery of sediment from a feeder bluff to the intertidal zone in areas where armoring cannot/will not be removed, by moving any sediment that erodes from the bluff over the armoring and into the intertidal zone.
- Substitution: to be applied where habitat function is lost through anthropogenic degradation and restoration and/or rehabilitation are not possible, but creation of habitat features to replace lost function can be accomplished. For example, substitute the delivery of sediment from a feeder bluff to the intertidal zone in areas where armoring cannot/will not be removed, by importing sediment and placing it in the intertidal zone to "nourish" the beach.

1.2 Project Area

The project area encompassed the marine shoreline of WRIA 9 (see Map 1). This covered approximately 90 miles of shoreline, including the marine shorelines of the municipalities of Seattle (south of West Point), Burien, Normandy Park, Des Moines, and Federal Way. The marine shorelines of Vashon and Maury Islands are officially part of WRIA 15, but for planning purposes are treated as part of WRIA 9, and thus were included in the project area.

The marine nearshore includes aquatic and upland features. The aquatic portion extends up rivers and streams to the upstream limit of tidal influence and out to approximately the 65-foot-deep bathymetric contour, which is considered the outer margin that may potentially receive sufficient sunlight to support aquatic vegetation (Shared Strategy 2005). The upland portion extends to those areas that directly influence conditions in the aquatic region.

The project area generally exhibits a high degree of urban development, and the vast majority of shoreline reaches have been modified or altered from the original condition (see Anchor 2004 and the Geographic Information System [GIS] data in Appendix B). Modifications common within urbanized areas include, among others, removal of vegetation and placement of riprap, bulkheads, overwater structure, fill, piling, and dwellings in and adjacent to the intertidal and riparian zones. Outside urbanized areas and within WRIA 9, shoreline development is still common, but it is less widespread on the more remote parts of the project area, chiefly Vashon and Maury Islands. A large number of shoreline reaches on the Vashon/Maury Island complex remain either lightly modified or unmodified from original conditions. Marine riparian vegetation there is more intact, and anthropogenic shoreline modifications are less intrusive overall.

2 SALMONIDS AND THE MARINE NEARSHORE

Many salmonids use the marine nearshore habitats of WRIA 9, including those from watercourses originating both in and outside the project area. Inside the project area, the Green/Duwamish River system[2], with tributaries including Soos Creek, Crisp (Keta) Creek, and Newaukum Creek, supports numerous stocks representing six anadromous salmon species. Outside the project area, the Cedar River watershed and the Puyallup River are the other major salmon-bearing watercourses draining to Puget Sound[3] within approximately 5 miles south and 5 miles north of the project area, respectively. Anadromous salmonids are not limited to these watercourses, however, as numerous smaller tributaries to Puget Sound have also been documented to contain anadromous salmonid spawning occurrences.

2.1 Summary of Salmonid Stocks Originating in the Project Area

According to the Washington Department of Fish and Wildlife (WDFW) Salmon and Steelhead Stock Inventory (SASSI) reports (WDF et al. 1993; WDFW 1998, 2000, and 2002), streams originating in the project area produce coho salmon, chum salmon, and Chinook salmon as well as steelhead, sea-run coastal cutthroat trout (*O. clarki clarki*), and bull trout/Dolly Varden (*Salvelinus malma*). Pink salmon (*O. gorbusha*) have also been documented in the Green/Duwamish River system in recent years (Kerwin and Nelson 2000; Nelson et al. 2004), although the SASSI reports do not indicate that pink salmon are present in the river system.

Chinook salmon are the most abundant anadromous salmonid in the Green/Duwamish River system, largely due to supplementation by a large number of hatchery fish (Kerwin and Nelson 2000). Chinook stocks are comprised mostly of summer/fall run fish produced in the mainstem Green River below the Tacoma Diversion Dam (River Mile [RM] 61), Soos Creek (RM 33.6), and Newaukum Creek (RM 40.7) (Kerwin and Nelson 2000). Chinook runs within the project area are comprised of two stocks: the Green/Duwamish fall stock and the Newaukum Creek summer/fall stock. These populations belong to the Puget Sound ESU that is listed as threatened under the ESA. The Green/Duwamish stock is the more productive of the two, ranging in abundance from 2,027 to 10,059 adult fish in the time

[2] The lower 10 miles of the Green/Duwamish River system is known as the Duwamish River. The rest of the river, upstream of these 10 miles, is known as the Green River.
[3] The Cedar River drains to Puget Sound via Lake Washington and the Ballard Locks

period 1986 to 1997[4] (Kerwin and Nelson 2000). The Chinook population is heavily supplemented by hatchery releases from two WDFW facilities and one Muckleshoot Indian Tribe facility. In 2003, approximately 3.7 million Chinook were released into the Green River basin, including approximately 3 million fingerlings into Soos Creek, 0.4 million fry above Howard Hanson Dam (RM 64), and 0.32 million yearlings from Icy Creek (Anchor and NRC 2005). Other than the Green/Duwamish River system, the SASSI reports document Chinook salmon presence in only Judd Creek on Vashon Island. Chinook are not considered to utilize the numerous smaller tributaries in the project area, except the lowermost reaches that may form pocket estuaries. Such non-natal pocket estuaries (i.e., those associated with streams other than those in which the fish originated) are considered to be highly important juvenile salmon rearing habitats, and recent studies have documented juvenile salmonid utilization of this type of habitat (Hirschi et al. 2003; Beamer et al. 2003).

Coho salmon, comprised of Green/Duwamish and Newaukum Creek stocks, are the second most abundant anadromous salmonid in the Green/Duwamish River system, ranging in abundance from 700 to 12,500 adult fish in the period 1967 to 1998 (Kerwin and Nelson 2000). These populations belong to the Puget Sound/Strait of Georgia coho ESU and are a species of concern under the ESA. Large numbers of hatchery-origin coho are also released to the Green River or produced in net pens in Elliott Bay. In 2003, approximately 1.5 million coho were released in the river and bay (Anchor and NRC 2005). Coho salmon utilize small tributaries more than any of the other anadromous salmonids, and the SASSI reports have documented coho in numerous tributaries throughout the project area. As described above, non-natal pocket estuaries formed from the multiple independent tributaries in the project area are considered to be highly important juvenile salmon rearing habitats, and recent studies have documented juvenile salmonid utilization of this type of habitat (Hirschi et al. 2003; Beamer et al. 2003).

Winter steelhead in the project area maintain relatively low numbers in the Green/Duwamish River system—spawning numbers ranged between approximately 1,000 to 2,500 fish from 1977 to 1998 (Kerwin and Nelson 2000). The winter steelhead are comprised of a native, wild spawning population and an early timing hatchery stock.

[4] Naturally spawning fish, including hatchery strays.

Summer steelhead in the basin are managed for recreational fishing and are almost entirely hatchery supported (Kerwin and Nelson 2000). All of these steelhead belong to the Puget Sound steelhead ESU that the National Marine Fisheries Service (NMFS) recently proposed for listing as threatened under the ESA. Formal listing of this species is pending a public review process (Federal Register Vol. 71, No. 60, p 15666 – 15680).

Two stocks of fall chum spawn in the Green/Duwamish River system (WDFW 2002). The status of Duwamish/Green fall chum stock is unknown, but past spawner numbers have been in the hundreds. The Crisp (Keta) Creek fall chum stock was considered healthy in 1992 (WDF et al. 1993), but its status was unknown in 2002 (WDFW 2002). The Crisp Creek escapement numbers ranged from as low as 71 to 1554 between 1982 and 1991 (Kerwin and Nelson 2000). Large numbers of hatchery chum subyearlings are released annually to Crisp Creek. In 2003, the Muckleshoot Indian Tribe released 1.2 million subyearling hatchery chum to Crisp Creek (Anchor and NRC 2005).

Anadromous coastal cutthroat trout inhabit the lower and middle mainstem of the Green/Duwamish River system and its major tributaries, including Springbrook, Hill, Soos, and Newaukum Creeks (WDFW 2000). The stock status is unknown, but population numbers are believed to be low. No hatchery supplementation of coastal cutthroat trout occurs in the project area.

Very few reports of bull trout have been documented in the Green River (WRIA 9 and KC 2004). In recent years, there have been reports of a handful of adult bull trout being captured by sport fisherman near RM 33.8 and several sightings of bull trout near the mouth of Newaukum Creek (WRIA 9 and KC 2004; Goetz and Jeanes 2004). No studies have been conducted of bull trout habitat use or potential spawning. Small numbers of bull trout have been documented in the Duwamish River estuary, but it is unclear what their river of origin was.

Pink salmon are not listed in any of the SASSI reports, as they have been previously characterized as extinct from the watershed. However, in recent years, pink salmon have been observed in the mainstem Green River (Kerwin and Nelson 2000; Nelson et al. 2004).

The SASSI reports status of anadromous salmonid stocks originating in the project area, including stocks that are ESA-listed, is summarized in Table 1.

Table 1
SASSI Reports Status of Anadromous Salmonid Stocks Originating in the Project Area[1]

Species	Stock	Origin[2]	Production[3]	SASSI Status
Bull Trout/Dolly Varden	Green/Duwamish	Native	Wild	Unknown
Fall Chinook	Green/Duwamish	Native	Composite	Healthy
Summer/Fall Chinook	Newaukum Creek	Mixed	Wild	Healthy
Coho	Deep South Sound Tributaries	Mixed	Composite	Healthy
Coho	Green River/Soos Creek	Mixed	Composite	Healthy
Coho	Newaukum Creek	Mixed	Composite	Healthy
Coho	East Kitsap[4]	Mixed	Composite	Healthy
Fall Chum	Duwamish/Green	Mixed	Composite	Unknown
Fall Chum	Crisp (Keta) Creek	Non-native	Cultured	Unknown
Coastal Cutthroat	Green/Duwamish	Native	Wild	Unknown
Summer Steelhead	Green/Duwamish	Non-native	Composite	Depressed
Early Winter Steelhead	Green/Duwamish	Non-native	Cultured	Healthy
Winter Steelhead	Green/Duwamish	Native	Wild	Healthy
Pink[5]	Green/Duwamish	Native	Wild	Unknown

Notes:

1 WDF et al. 1993; WDFW 1998, 2000, and 2002

2 Native = An indigenous stock of fish that have not been substantially impacted by genetic interactions with non-native stocks, or by other factors, and is still present in all or part of its original range.
Mixed = A stock whose individuals originated from co-mingled native and non-native parents, and/or by mating between native and non-native fish, or a previously native stock that has undergone substantial genetic alteration.
Non-native = A stock that has become established outside of its original range.

3 Composite = A stock sustained by both wild and artificial production.
Cultured = A stock that depends on spawning, incubation, hatching, or rearing in a hatchery or other artificial production facility.

4 Coho found in Shinglemill Creek and other creeks on Vashon and Maury Islands are part of the East Kitsap stock.

5 Pink salmon are not listed in the SASSI reports. They were previously characterized as extinct from the watershed, but in recent years have been observed in the mainstem Green River (Kerwin and Nelson 2000; Nelson et al. 2004).

2.2 Juvenile Salmonid Ecological Needs

The transition that juvenile salmonids make from freshwater areas into the estuarine nearshore is a critical lifestage for all anadromous salmonids (Simenstad 1983; Aitkin 1998; Williams et al. 2001). During this time, juvenile salmonids complete their physiological adaptation to saltwater and encounter new habitat types, different potential prey resources, and different potential predators. The extent to which the different species and runs utilize the marine nearshore is variable. Fall Chinook and chum tend to utilize nearshore habitats

for more extended rearing periods (on the order of weeks to months) than other salmonid species (Simenstad et al. 1982; Healey 1982).

During their residence in the marine nearshore, the survival of juvenile salmonids reflects the cumulative ability of the habitat to support four main ecological functions (Simenstad 1983; Williams and Thom 2001; Shared Strategy 2005):

- Foraging and growth
- Avoidance of predators
- Physiological transition
- Migration to the ocean

Each of these ecological functions are highly interrelated, and are summarized in Shared Strategy 2005, which outlines regional nearshore and marine aspects of salmon recovery in Puget Sound. For example, the growth of juvenile salmonids depends upon the energy demands and foregone foraging opportunities that result from predator avoidance actions. The importance of juvenile salmonid access to high quality marine nearshore habitat that supports each of these ecological functions is becoming increasingly apparent in investigations of salmon survival in the marine environment. There is mounting evidence that the early marine residence is a critical period and that juvenile salmon growth during this period determines their overall marine survival trends (Holtby et al. 1990; Hargreaves 1997; Beamish and Mahnken 1998; Murphy et al. 1998; Tovey 1999; Duffy 2003).

Juvenile salmon, particularly fall Chinook and chum, depend upon shallow water habitats to avoid predators and grow rapidly (Shared Strategy 2005; Kerwin and Nelson 2000). In general, juvenile Chinook and chum occupy progressively deeper habitats as they increase in size (Shared Strategy 2005). Thus, the smallest juvenile salmon will be primarily associated with the shallowest habitat. For smaller fish, very shallow water offers a refuge from predation, as larger piscivores cannot access those areas. During a rising tide, the shallow water along the waterline can provide a source of upper intertidal and terrestrial prey items that are inundated by the rising water and supplied to the water column and surface as prey. In addition, these habitats provide protection from high energy wave action. Recent work has documented the widespread utilization of non-natal estuaries (pocket estuaries) by juvenile salmonids (Hirschi et al. 2003; Beamer et al. 2003).

Recent research has documented that juvenile salmon in the nearshore depend heavily on prey from a detritus-based food web in these shallow-water habitats. Brennan et al. (2004) found that a significant portion of juvenile salmon diets were highly influenced by prey from terrestrial sources (especially in the summer and early fall), as well marine benthos and marine zooplankton. Juvenile salmon feed opportunistically on these various prey, depending on habitat, season, and fish size (Shared Strategy 2005).

In addition, juvenile salmon, especially Chinook and chum, undergo most of their transformation from a saltwater- to freshwater-adapted animal while they are migrating through the nearshore (Shared Strategy 2005). The nearshore provides tributary and river mouths with deltas that contain a salinity gradient, which eases this transition.

These fish also depend on shallow nearshore waters as a migratory pathway on their journey to the ocean. Because multiple species and multiple life histories of salmonids use this pathway, diversity in these habitats and connections between high quality habitats are important in order to provide the various conditions that migrating fish can use (Simenstad and Cordell 2000).

3 PROJECT APPROACH AND METHODS

The degree to which marine nearshore habitats provide the main ecological functions needed by juvenile salmonids depends upon ecosystem processes and natural controls on these processes, as well as human stressors (Shared Strategy 2005). This is illustrated in the simple conceptual model shown in Figure 1. Human stressors include shoreline alterations, land use, and fishery and hatchery management. Given the relationship between human stressors, habitat, and (ultimately) salmon viability, minimizing the impacts of shoreline alterations is a critical aspect of salmon recovery efforts.

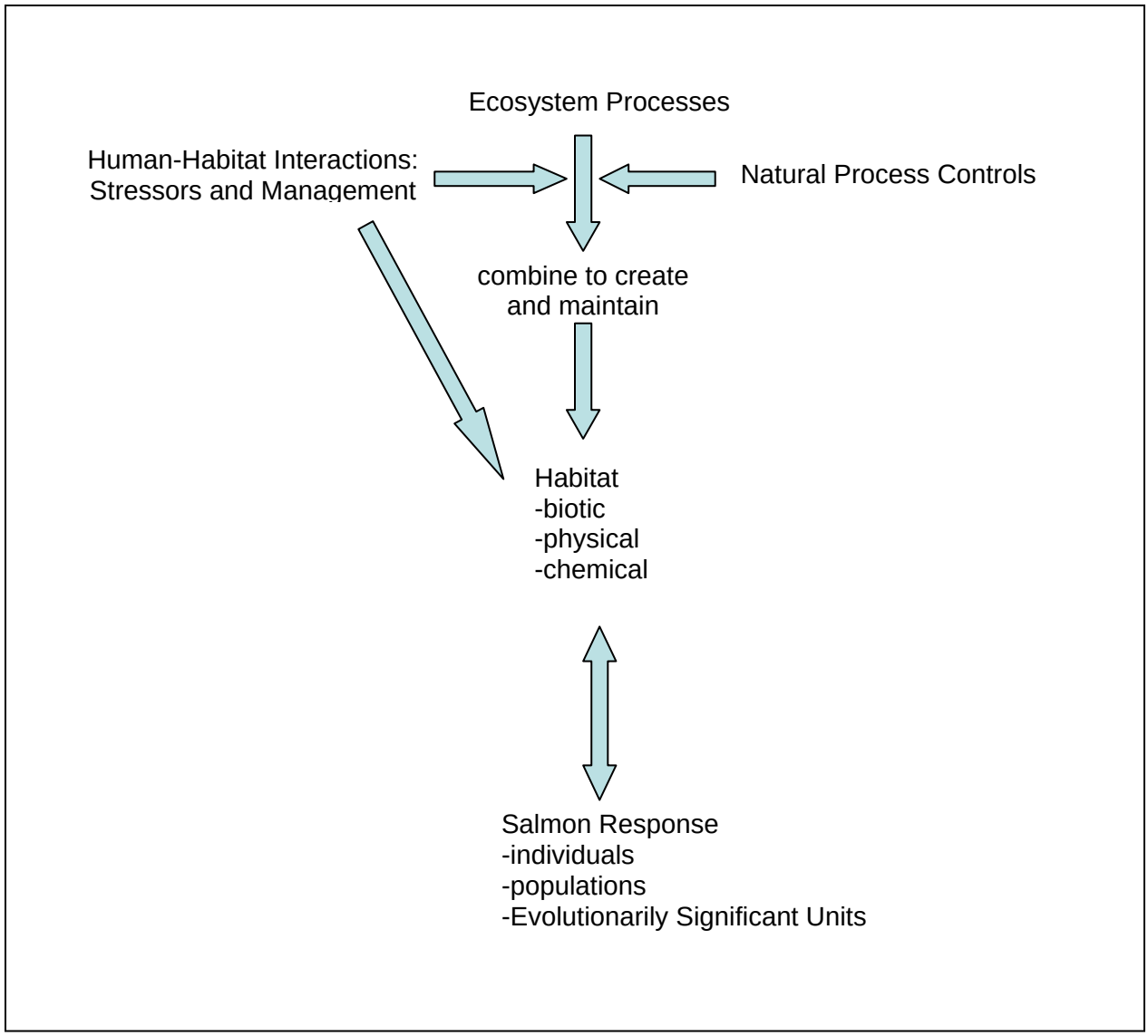


Figure 1
Conceptual Model of Ecological Processes and Salmon Responses (modified from Shared Strategy 2005)

In this project, we focused on the physical and biological habitat conditions in the nearshore and the role of shoreline alterations in determining those conditions. Relying upon the scientific literature on salmonid ecology in the marine nearshore, including habitat utilization and feeding habits, we developed an evaluation approach for characterizing habitat function of discrete shoreline reaches and interpreting landscape and drift cell scale processes.

To conduct a shoreline reach evaluation, a feature-based habitat function model was developed. This model relied on GIS mapping tools to organize habitat information for all shoreline segments and apply the habitat model scoring system. The following sections describe how this model was developed and was combined with landscape considerations and some measure of project feasibility to determine priority areas and recommendations.

3.1 Habitat Features Considered

The first step in evaluating habitat function and determining priority areas was to identify relevant habitat features for characterizing habitat function for salmon. The shoreline features used in this evaluation were selected for their contribution to providing or affecting one or more of the essential ecological functions for juvenile salmonids. The following habitat features were included in the habitat function model:

- Shore type, including consideration of shoreline armoring (e.g., presence/absence and toe elevation relative to Ordinary High Water [OHW])
- Obstructions to longshore sediment transport
- Aquatic vegetation
- Forage fish spawning
- Beach width
- Shoreline armor in intertidal zone
- Overwater structures
- Riparian vegetation, including large woody debris (LWD)
- Marshes
- Stream mouths

Table 2 illustrates the main ecological functions for juvenile salmonids that are provided for, influenced by, or indicated by each of these features.

Table 2
Summary of Ecological Functions Affected by Habitat Features Used in Nearshore Assessment

Habitat Feature	Ecological Function			
	Foraging and Growth	Avoidance of Predators	Physiological Transition	Migration to the Ocean
Shore type	✓	✓		✓
Obstructions to longshore sediment transport	✓			✓
Aquatic vegetation	✓	✓		✓
Forage fish spawning	✓			
Beach width	✓	✓	✓	✓
Shoreline armor in intertidal zone	✓	✓	✓	✓
Overwater structures	✓	✓		✓
Riparian vegetation, including LWD	✓	✓		✓
Marshes	✓			
Stream mouths	✓	✓	✓	✓

3.2 Habitat Function Model

The second step toward priority area determinations was to compile and organize data on the habitat features described above. To do this, data were organized using GIS to include data specifically collected for this project (Appendix B, Anchor 2004), as well as existing data from Johannessen et al. (2005), King County, Washington Department of Ecology, and Washington Department of Natural Resources. Data sources were selected for their ability to provide coverage of the entire study area and to describe the structure and process of the nearshore habitat in terms of the ecological function that habitat provides to juvenile salmon. These data were analyzed using a habitat function model, in terms of the following three components of the nearshore:

1. Sediment supply – the availability of sediment from naturally occurring processes such as coastal erosion and stream transport, and the integrity of the process in transporting that sediment along the shore to nourish and create broad, shallow water beaches and to support aquatic vegetation
2. Migration corridor – the quality and continuity of the shallow subtidal and intertidal corridor used by juvenile salmon to migrate along the shore, including the ability of the corridor to provide refuge from high energy conditions and predators
3. Riparian corridor – the quality of the riparian corridor as it influences the availability of terrestrial or freshwater prey resources and organic matter from the vegetative

canopy, and as it provides shade (cover from predators and protection for spawning forage fish)

Separate model scoring systems were developed to characterize current habitat function, potential habitat function through implementation of rehabilitation activities, and potential habitat function through implementation of restoration activities. Substitution opportunities were identified through consideration of current habitat function and potential restored habitat function, as well as the apparent feasibility of restoration given an area's infrastructure constraints. In keeping with the Puget Sound TRT definitions (Puget Sound TRT 2003), restoration was considered to include the removal of barriers (e.g., bulkheads) to sediment delivery to the intertidal zone. Rehabilitation was considered to include such actions as removing barriers to sediment transport (e.g., groins and boat ramps), removing overwater structures (docks), and making some improvements to the condition of riparian vegetation and stream mouths. Substitution included such actions as creating shallow water habitat by adding fill material or excavating tidal embayments, as well as placing sediment in the intertidal zone to nourish the beach.

The model scoring systems were developed by the project team with collaboration of scientists from multiple entities in WRIA 9. The scoring systems quantify the relative contribution (positive or negative) of each data input to the overall ecological function of the shoreline. Scores were assigned relative to one another based on current biological research and were adjusted based on the shoretype assigned in an evaluation of sediment supply for the project area (Johannessen et al. 2005). Appendix C describes each model scoring system and the scientific justification for each habitat parameter used in the model. Table 3 lists habitat feature descriptors used to characterize each nearshore component and the data sources for these features.

Table 3
Data Used in the Evaluation of the Ecological Function of Habitats

Nearshore Component	Habitat Feature	Habitat Feature Descriptor	Data Source
Sediment Supply	Shore type (including consideration of shoreline armoring [e.g., bulkheads, rock riprap, and seawalls])	Sediment process shore type	Johannessen et al. (2005) with additional armor information from Anchor (2004)
	Obstructions to longshore sediment transport	Presence of groins, boat ramps, and marine rails	Anchor (Appendix A)
Migration Corridor	Aquatic vegetation	Presence of eelgrass, macroalgae, or kelp	ShoreZone (WDNR 2001)
	Forage fish spawning	Documented forage fish spawning	Priority Habitats and Species Data (provided by King County, 2003, from WDFW 2003)
	Beach width	Intertidal beach slope	ShoreZone (WDNR 2001)
	Shoreline armor in intertidal zone	Shoreline armor toe depth	Anchor (Appendix A)
	Overwater structures	Presence of piers, docks, or houses over the water	Anchor (2004)
Riparian Corridor	Riparian vegetation	Condition of riparian vegetation, including vegetation type, location, and continuity	Anchor (2004)
	Marshes	Presence of supratidal salt marsh	Anchor (Appendix A)
	Stream mouths	Location and condition (e.g., piped, armored, unarmored) of stream mouths and use of stream for spawning by anadromous salmonids	Nelson et al. (2004), Johannessen et al. (2005), Washington Trout (2001), Anchor (Appendix A)

To determine current, rehabilitated, and restored habitat function, data were input to the model and snapped to the topology of the Mean Higher High Water (MHHW) line of the shoreline modified from the Washington State ShoreZone Inventory (WDNR 2001). Discrete shoreline segments were created by inserting a line break at the point that any feature or attribute of the data changed. Each shoreline segment was given a discrete score for current, rehabilitated, and restored habitat function. The resulting output was a single polyline shapefile with segments of varying lengths, each of which represented a homogeneous condition in relation to all the data describing that segment's habitat function and contained information on current, rehabilitated, and restored habitat function. The scores for the each of the model scoring systems are described in detail in Appendix C.

In interpreting the current function model, areas of greatest conservation value were those with the highest current function scores. Areas of greatest potential habitat function improvement through rehabilitation were those areas with the highest rehabilitation potential score. Similarly, areas with the greatest potential habitat function improvement through restoration were those areas with the highest restoration potential score. Substitution opportunities were identified in areas with low current function, where restoration could markedly improvement habitat function, but where restoration appeared to be infeasible due to the magnitude of modifications that have occurred to limit natural processes. In this way, substitution opportunities were identified for Elliott Bay (specifically the Elliott Bay Marina along the northern shoreline of Elliott Bay to the Duwamish Head along the western Elliott Bay shoreline), where restoration of natural feeder bluff or fluvial sediment supply processes appear infeasible.

In a similar fashion as that used to determine the current function, scoring systems were developed to characterize the potential habitat function gained through restoration and rehabilitation. Substitution opportunities were identified based on the rehabilitation model results.

3.3 Consideration of Landscape Processes

The third step in determining priority habitat recommendations was to consider the scores from the model output in combination with several landscape-scale factors, including proximity to the mouth of major salmon sources (rivers and south Puget Sound), drift cell length, position within a drift cell, and connectivity to neighboring habitats. The proximity of habitat actions to major salmon-bearing rivers is important because the mouths and natal estuaries of the three closest major river systems that support salmon populations (see Map 1) are all heavily modified and function-impaired. Including this consideration was important because it informed the likelihood of shoreline use by juvenile salmonids and the expectations of fish size at the time of first encountering a stretch of shoreline.

Length of a drift cell and position within a drift cell were important considerations in selecting priority areas because this information is indicative of the length of shoreline that may be influenced by sediment supply and transport conditions at specific locations within the drift cell.

Connectivity to neighboring habitats was considered in order to take into account the amount of quality habitat in the vicinity of a shoreline segment. This included considering habitat diversity, especially in areas without plentiful habitat, because fish needs for refuge, prey, and migration corridors can differ with such variables as fish growth stage, energy regime in the nearshore (storms), and predator abundance.

3.4 Final Steps in Priority Area Determinations

Lastly, the development of priority areas included a consideration of the measure of feasibility and timing. Feasibility was used to identify large areas where substitution appeared more likely than restoration. Otherwise, feasibility was not a major factor in the identification of priority areas, but was used to refine and distill recommendations from a list of possible actions. Often, where restoration would entail the removal of large numbers of residences or infrastructure, and rehabilitation could be achieved without such costly measures, rehabilitation was recommended instead. However, deference was not always given to existing structure and infrastructure, as these factors may change given a foreseeable shift in shoreline needs and conditions that will occur over the long-term (e.g., feeder bluff subsidence, shoreline erosion, and sea-level rise). In addition, feasibility was considered in a lesser regard for conservation actions than for restoration or rehabilitation actions; conservation areas were created as intentionally large areas that may contain smaller scale areas with lower habitat function within them.

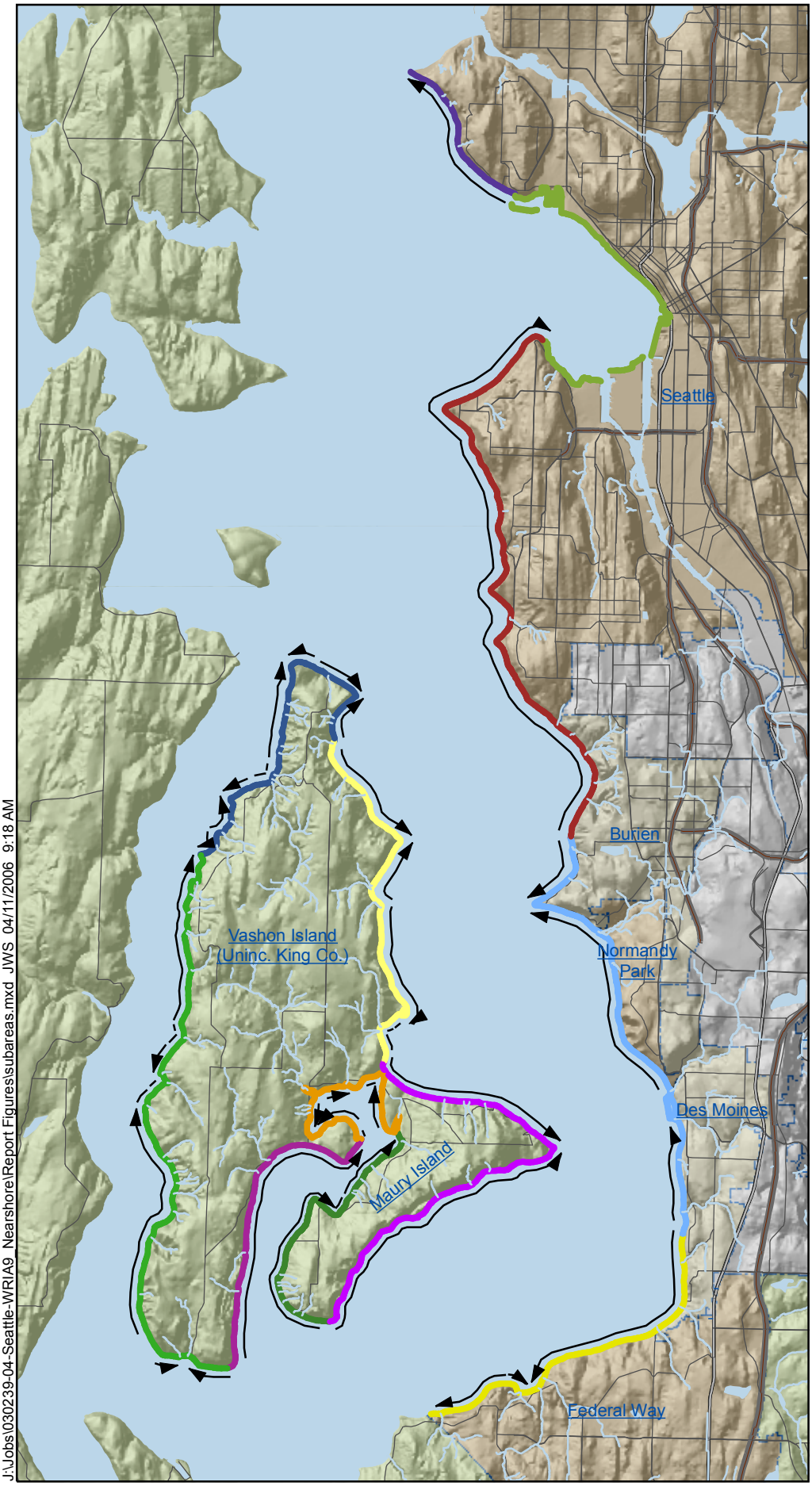
The timing of potential implementation of recommended habitat actions was considered in order to provide room for immediate application as well as future work. In addition, recommended projects may be interrelated in time. For example, the removal of nearshore sediment supply obstructions near the start of a drift cell will contribute to beach-building material near the end of the drift cell as longshore sediment supply sources are brought back to function. Moreover, following removal of all sediment obstructions in a drift cell, it would be expected that areas near the start of the drift cell would begin to show signs of accumulating sediment first, and then effects would move down the drift cell.

3.5 Spatial Scales of Priority Area Recommendations

Priority area recommendations were made on two scales: the general project area scale, and within each of 12 subareas within the general project area (Map 2). The overall project area

priorities are those considered to be the most significant projects in terms of order of implementation and magnitude of long-term benefit, but subarea priority recommendations are also significant actions to support salmon recovery. In subareas, key and unique habitat types that occur at a smaller scale, such as small estuaries and tidal marshes, were more often identified as recommendations to provide ecological function. It is important to note that numerous additional potential opportunities exist in the subareas, but have not been included because of the current perceived infeasibility of implementation or the limited effect of the action relative to other potential projects of a larger size. For example, the recent assessment of sediment supply conditions in the project area (Johannessen et al. 2005) included the identification of numerous smaller projects entailing actions such as removal of piling and small failing bulkheads that would contribute to improve the nearshore, but are generally of smaller individual size/impact than opportunities identified in this report. Cumulatively, the projects identified by Johannessen et al. (2005) would certainly improve habitat a great deal.

Special consideration was given to Elliott Bay due to its context in the urban downtown of Seattle. At both scales, within Elliott Bay, sediment transport processes were not identified by Johannessen et al. (2005), nor included in this analysis. Recommendations for this area were based largely on opportunistic actions that arise as facilities and infrastructure are modified, maintained, or improved.



LEGEND

Reach

- Magnolia
- Elliott Bay
- West Seattle to Burien
- Burien to Des Moines
- Des Moines to Federal Way
- East Maury
- East Vashon
- North Vashon
- West Vashon
- West Quartermaster
- Inner Quartermaster
- East Quartermaster
- Net Shore Drift Adapted from Johannessen (2005)

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0 0.5 1 2
Scale in Miles

Map 2
Subareas and Drift Cells
Identification of Priority Areas
WRIA 9 Nearshore Habitat Assessment