Ecosystem Restoration Opportunities in the Snohomish River Valley, Washington

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TULALIP TRIBES

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Working together for people, streams & fish.

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Cover Photo: Blind tidal channels in the Snohomish estuary. *Sean Edwards, 2000*

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INTRODUCTION

Given the substantial habitat losses that have occurred since the mid-19th century in the Snohomish River valley (Haas and Collins, 2001) and the threatened status of chinook salmon (*Oncorhynchus tshawytscha*) and bull trout char (*Salvelinus confluentus*) under the Endangered Species Act (ESA), the prevention of further habitat destruction is a prudent first step toward stabilizing listed stocks and helping prevent additional stock listings. Habitat preservation will require regulations based on science, improved enforcement of regulations, education and land acquisition, but these measures alone will not promote recovery. Preserving restoration opportunities and implementing them is necessary to move beyond halting the decline of listed species toward recovery of natural ecosystem productivity of salmonids.

This report describes restoration opportunities to address habitat and salmon productivity losses documented by Haas and Collins (2001) in the Snohomish River valley (Figure 1). Although it describes specific benefits for chinook and coho salmon (*Oncorhychus kisutch*), the identified restoration opportunities provide multi-species benefits because historical reference conditions are used as a template for restoration of natural habitat-forming processes and ecosystem function. Salmonid stocks evolved to the suite of habitat conditions available in the river basin, thus maximizing stock diversity and productivity. Therefore, to maximize salmonid recovery, it is important to address the full range of habitat losses.

Most opportunities described below involve restoring off-channel habitat and the riparian environment and reconnecting them with the Snohomish River, because the greatest habitat alterations and smolt production losses have occurred as a result of this disconnection. Other proposed enhancements address small tributary modifications and diminished habitat quality. Restoration of tidal marsh within the estuary is a critical component of chinook recovery. Chinook smolt production estimates show that the estuary commonly acts as a bottleneck, particularly in years when survival to smolt stage is high (Haas and Collins, 2001). An historical assessment of coho smolt production capacity shows an order of magnitude loss in coho production from off-channel habitats in the Snohomish valley, most notably due to diking and draining of vast floodplain marshes at Marshland and along French Creek (Haas and Collins, 2001). In the main

stem, bank armoring and wood removal have reduced rearing capacity for both coho and chinook salmon by over 50 percent (Haas and Collins, 2001).

All identified restoration opportunities described below are based on the concept of restoring natural processes that create and maintain habitat because this approach is more likely to be effective over the long-term, than simple attempting to replace physical habitat structure. For example, breaching a dike may restore side-channel formation, channel migration, wood recruitment processes and edge habitat. The long-term benefit of such a project is a self-sustaining dynamic ecosystem. This contrasts with the long-term effectiveness of a restoration project that attempts to control nature, such as anchoring wood in a stream. When the wood dislodges during a flood, the habitat benefit is lost, and nothing has changed.

We extrapolate regional rearing density, and when available, smolt production estimates for chinook and coho over the anticipated gain in usable habitat area (Reeves *et al.*, 1989; Beechie *et al.*, 1994, Hayman *et al.*, 1996; Beamer and Henderson 1998, Pess *et al.*, 1999; Swales and Levings, 1989). Rearing capacity is defined as the expected number of parr that available habitat can support. Smolt production capacity is defined as the expected number of smolts that could be produced from available habitat (Beechie *et al.*, 1994). Numbers generated in this analysis should be considered rough estimates and are based on the assumption that rearing habitat is limiting.

This report does not identify all potential restoration opportunities. Its purpose is to inform decision-makers of restoration opportunities and act as a catalyst for action. Most opportunities described below will require land acquisition and partnerships with landowners within the valley. Interested landowners and willing sellers have not yet been identified and restoration opportunities have not been prioritized. The development of an overall restoration strategy for the Snohomish River valley and a feasibility study to identify interested landowners, explore site restoration alternatives, estimate costs and prioritize restoration opportunities are critical next steps.

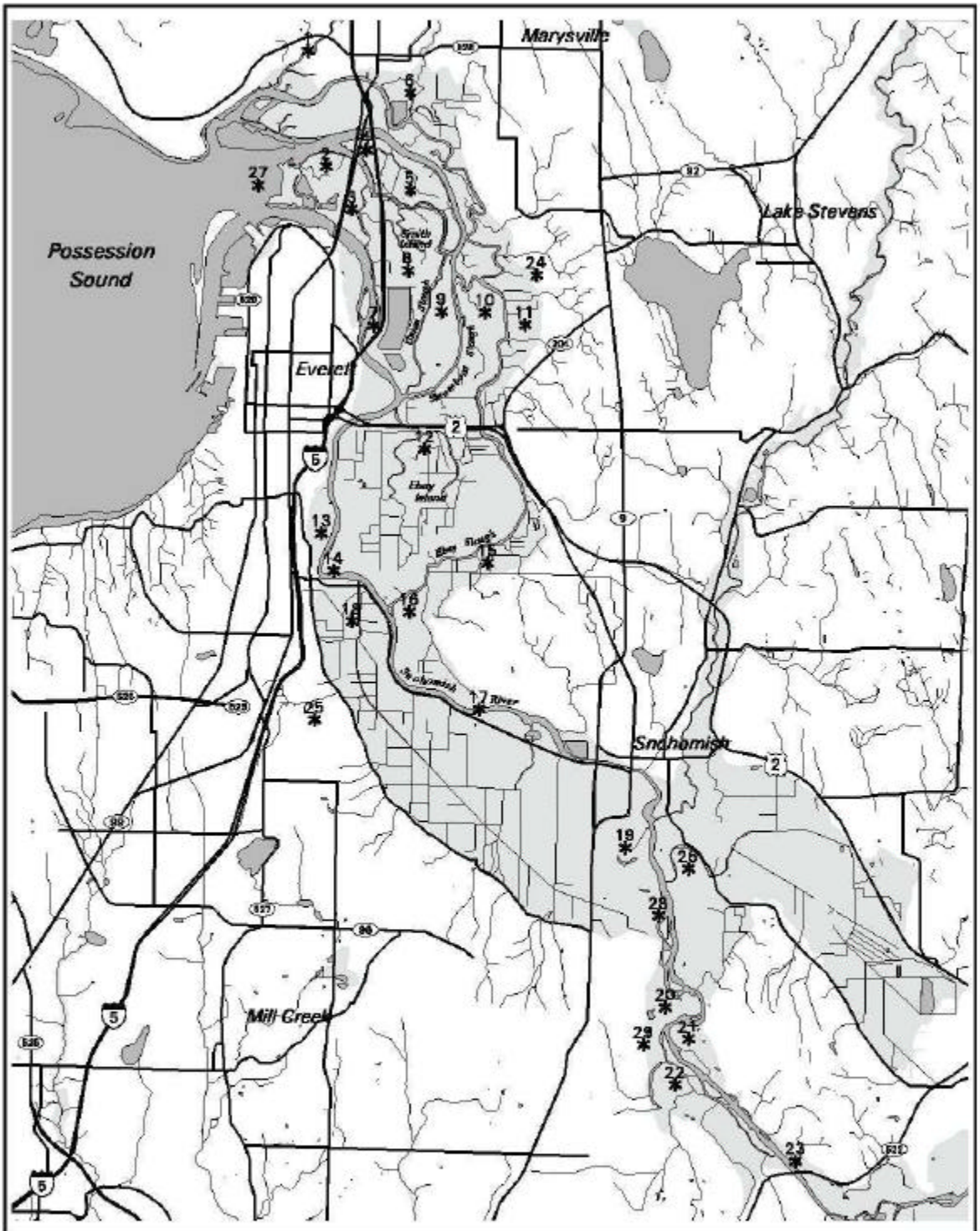

Figure 1: Restoration Opportunities

Roads
Watercourses
Waterbodies
Mid 19th Century 100 Year Floodplain
Restoration Opportunities

RESTORATION OPPORTUNITIES

Lower Estuary

1. Quilceda Creek barging site

Area: 2+ hectares
Restoration opportunity: Dike breaching
Habitat gained: Tidal marsh within the emergent/forested transition (EFT) zone
Potential production gain: 5,000 chinook smolts/year
Description: A small, undeveloped, diked site adjacent to an industrial barging site on the Tulalip Indian reservation could be breached, potentially without constructing a cross-dike. It would provide rearing and staging habitat and restore connectivity with adjacent marshes.

2. Smith Island along Steamboat Slough

Area: 47 hectares
Restoration opportunity: Dike breaching
Habitat gained: Tidal marsh within the emergent/forested transition (EFT) zone
Potential production gain: 110,000 chinook smolts/year
Description: This property, located north of the wastewater treatment facility along Steamboat Slough, is the largest undeveloped, diked property within the lower estuary. It is one of the most promising tidal marsh restoration sites in the EFT zone because many of the other sites are substantially constrained by a capped landfill, wastewater treatment facilities, transportation corridors and utility crossings. Breaching the dike and reconnecting a remnant blind tidal channel that traverses the site would increase critical rearing and staging habitat for juvenile salmonids within the freshwater/saltwater mixing zone. A portion of the property has been filled, which may increase restoration costs.

3. Smith Island cutoff distributary slough

Area: 6 hectares (surface water)
Restoration opportunity: Remove tide-gate, reconnect channel at one or both ends
Habitat gained: Distributary slough
Potential production gain: 130,000 chinook smolts/year
Description: An unnamed slough historically bisected Smith Island, connecting Union Slough and the Snohomish River. Dikes were constructed along its banks in the late 19th century, and it was disconnected in the mid-20th century. Currently, a tide-gate restricts access into the slough at the north end and a boat storage facility blocks access on the southern end. Reconnecting the slough would provide excellent rearing and staging habitat for juvenile salmonids within the most productive component of the estuary for chinook smolts, as well as increased connectivity between sloughs. Restoring tidal action to an undeveloped site adjacent to the channel mouth on the northern end would increase habitat quantity and quality. In order to reconnect the

channel without flooding adjacent properties, it would be necessary to bring relict dikes up to code.

4. North Spencer Island between Interstate Route 5 and State Route 529

Area: 19 hectares
Restoration opportunity: Dike breaching
Habitat gained: Tidal marsh within the emergent/forested transition (EFT) zone
Potential production gain: 23,000 chinook smolts/year
Description: The property between I-5 and SR 529 is diked but undeveloped. It includes a broad cut-off slough channel. The Port of Everett plans to restore a portion of the property along Union Slough as mitigation. Restoration will involve removing a section of dike and constructing a cross-dike along I-5. Habitat value and connectivity would increase if dikes were breached or removed along both Steamboat and Union sloughs.

5. North Spencer Island east of Interstate Route 5

Area: 157 hectares
Restoration opportunity: Dike breaching
Habitat gained: Tidal marsh within the emergent/forested transition (EFT) zone
Potential production gain: 190,000 chinook smolts/year
Description: An undeveloped section of North Spencer Island east of I-5 is located within the heart of the estuary between Union and Steamboat sloughs. It is an important restoration opportunity because of its size and location in the highly productive but heavily impacted EFT zone. If a short cross-dike is constructed along I-5 large sections of dike along Union and Steamboat sloughs could be removed to restore tidal exchange and access. A large blind tidal slough that has been disconnected but not filled increases the site's restoration potential.

6. Drainage District 3

Area: 130 hectares
Restoration opportunity: Dike breaching, tide-gate removal
Habitat gained: Tidal marsh within the emergent/forested transition (EFT) zone
Potential production gain: 160,000 chinook smolts/year
Description: The Tulalip Tribes purchased 90 percent of Drainage District 3 including Allen Creek Slough to restore tidal marsh. The Tribes have proposed to breach the dike along Ebey Slough and remove the tide-gates on Allen Creek. A cross-dike would need to be constructed to protect an industrial development along the northern and western edges of the district.

7. Langus Park slough reconnection

Area: 3 hectares (surface water)
Restoration opportunity: Reconnect remnant channel
Habitat gained: Large blind tidal channel/distributary slough
Potential production gain: 66,000 chinook smolts/year

Description: A remnant of one of the largest blind tidal channels in the Snohomish is located between Langus Park and I-5. It could potentially be reconnected as a blind tidal channel or as a distributary slough. In order to reconnect it as a distributary slough, dredge spoils would need to be removed. Restoration of the site is a high priority because of the lack of off-channel habitat and restoration opportunities along the Snohomish River main stem in the lower estuary.

8. Smith Island north of Everett sewage treatment plant

Area: 207 hectares
Restoration opportunity: Dike breaching
Habitat gained: Tidal marsh within the emergent/forested transition (EFT) zone
Potential production gain: 250,000 chinook smolts/year
Description: The property is an important restoration opportunity because of its size and location in the highly productive but heavily impacted EFT zone. It contains the remnants of two of the largest blind tidal slough channels in the Snohomish estuary. An ornamental tree farm encompasses almost half the property, and the rest is largely undeveloped. A cross-dike would need to be constructed to protect the city of Everett sewage lagoons and I-5, if the Union Slough dike is breached to restore tidal marsh.

9. South Spencer Island restoration site

Area: 140 hectares
Restoration opportunity: Dike breaching
Habitat gained: Tidal marsh within the forested riverine/tidal (FRT) zone
Potential production gain: Unknown
Description: The majority of South Spencer Island is managed as a non-tidal wetlands. While this may benefit some bird species, it is inconsistent with the objective of restoring a properly functioning estuary ecosystem. Monitoring of the breached portion to the south of the cross-dike has documented substantial use by multiple species of juvenile salmonids, including bull trout char and chinook salmon. Juvenile salmonids may access the diked portion through tide-gates, but this has not been documented. Even if juveniles access this area, conditions are not likely to be as favorable as a tidal marsh because the lack of tidal exchange may increase water temperature and decrease dissolved oxygen. Maintaining surface water at a constant level also could impact juvenile salmonids by sustaining a predatory fish population (i.e. bass, cutthroat trout). Maintaining a dike around the property also eliminates the opportunity to restore edge habitat complexity adjacent to the site along Union and Steamboat sloughs.

10. North tip of South Ebey Island

Area: 232 hectares
Restoration opportunity: Dike breaching
Habitat gained: Tidal marsh within the forested riverine/tidal (FRT) zone
Potential production gain: 20,000 chinook smolts/year
22,000 coho smolts/year summer
54,000 coho smolts/year winter
Description: Snohomish County owns the northern tip of South Ebey Island, and several properties to the south are largely undeveloped. Breaching the dike

along Snohomish County's property would create hundreds of hectares of tidal marsh. If several properties to the south are acquired, a much larger area could be restored and a shorter cross-dike would be required to protect adjacent landowners against flooding.

11. Right bank of Ebey Slough north of State Route 2

Area: 243 hectares
Restoration opportunity: Dike breaching
Habitat gained: Tidal marsh within the forested riverine/tidal (FRT) zone
Potential production gain: 21,000 chinook smolts/year
23,000 coho smolts/year summer
56,000 coho smolts/year winter
Description: The diked agricultural land north and south of the Lake Stevens sewage lagoon and water treatment facility along the right bank of Ebey Slough provides an excellent restoration opportunity. Dike breaching would restore hundreds of hectares of tidal marsh. It would provide unrestricted fish access to several hillside drainages, and numerous remnant sloughs could be reconnected. Restoration would involve removal of large portions of the dike along Ebey Slough and construction of short cross-dikes to protect the sewage treatment facility and Hewitt Avenue. A pipeline that traverses the property poses a significant challenge for restoration.

12. Deadwater Slough and South Ebey Island

Area: 540 hectares
Restoration opportunity: Dike breaching, tide-gate and pump-station removal
Habitat gained: Tidal marsh within the forested riverine/tidal (FRT) zone
Potential production gain: 46,000 chinook smolts/year
52,000 coho smolts/year summer
126,000 coho smolts/year winter
Description: A pump-station blocks anadromous fish access into Deadwater Slough and contributes to high summer temperatures and low dissolved oxygen levels through the restriction of tidal exchange and flushing. One potential restoration alternative would be to retrofit the tide-gate to allow fish access and limited tidal exchange. Riparian planting would enhance the restoration effort by increasing shade and wood recruitment to the slough over the long-term. Another alternative would be to acquire adjacent properties between Deadwater Slough, Ebey Slough and a large forested property owned by the Washington Department of Fish and Wildlife and remove the tide-gate and large sections of dike along Ebey Slough. A cross dike would need to be constructed (perhaps along Home Acres Rd and Hewitt) to protect adjacent properties. A pipeline that traverses the property poses a significant challenge for restoration.

13. Simpson Lee mill site

Area: 55 hectares
Restoration opportunity: Dike breaching
Habitat gained: Tidal marsh within the forested riverine/tidal (FRT) zone
Potential production gain: 5,000 chinook smolts/year
5,000 coho smolts/year summer
13,000 coho smolts/year winter
Description: Bigelow Creek enters the Snohomish River through a partially filled wetland complex north of Lowell along the left bank. The Tulalip Tribes

have documented use by juvenile salmonids. The dike could be breached, blind tidal slough remnants reconnected and fill removed to enhance off-channel rearing habitat. Restoration of the site is a high priority because of the lack of off-channel habitat and restoration opportunities along the Snohomish River main stem in the lower estuary.

14. Southwest corner of South Ebey Island near Lowell

Area: 20 hectares
Restoration opportunity: Dike breaching
Habitat gained: Tidal marsh within the forested riverine/tidal (FRT) zone
Potential production gain: 2,000 chinook smolts/year
2,000 coho smolts/year summer
5,000 coho smolts/year winter
Description: Most of this property was never diked because the natural levee is high enough to prevent tidal inundation, but a plug dike across a remnant blind tidal network prevents regular access into a marsh behind the natural levee. Removal of the plug dike would reconnect off-channel refuge and rearing habitat. Restoration would presumably be easier than at many other sites because it would not require new dike construction. Restoration of the site is a high priority because of the lack of off-channel habitat and restoration opportunities along the Snohomish River main stem in the lower estuary.

15. Drainage District 6

Area: 94 hectares
Restoration opportunity: Dike breaching
Habitat gained: Tidal marsh within the forested riverine tidal zone
Potential production gain: 8,000 chinook smolts/year
9,000 coho smolts/year summer
22,000 coho smolts/year winter
Description: Snohomish County has acquired the majority of Drainage District 6 located along Ebey Slough and developed a restoration plan to restore tidal action to 233 acres. The plan includes removal of large sections of dike and reconnection of several remnant blind tidal channels.

16. Swan Trail Slough

Area: 2 hectares (surface water)
Restoration opportunity: Tide-gate removal or retrofit
Habitat gained: Large blind tidal/distributary slough
Potential production gain: 6,000 chinook smolts/year
6,000 coho smolts/year summer
16,000 coho smolts/year winter
Description: Swan Trail Slough is a large blind tidal/distributary slough with an intact riparian zone. Restoration would consist of removal or retrofitting the pump-station and tide-gate to restore connection with Ebey Slough. Sub-surface flow from the hillslope and shade into the slough may help maintain cool water temperatures, thus providing a thermal refuge for juveniles.

Floodplain Process/Connectivity

17. Snohomish River habitat complexity

Restoration opportunity: Dike setbacks and removal, log jams, riparian planting
Habitat gained: Pools, edge habitat complexity, side-channels
Potential production gain: Not quantified
Description: Diking, floodplain clearing and wood removal have significantly reduced habitat quantity and quality in the Snohomish River. The feasibility of removing selected bank armoring and dikes could be investigated. Where removal is infeasible, setting back dikes coupled with riparian forest re-establishment would increase wood recruitment, shade, edge habitat complexity, jam formation and off-channel rearing area. The larger the setbacks, the more channel migration and riparian functions that can be achieved. Fast growing firs and cottonwood planted in the floodplain could potentially contribute functioning wood within 50 years if the river is allowed to migrate. Engineered logjams (Abbe *et al.*, 1997) could jump-start the recovery efforts by providing cover, initiating the accumulation of wood and forming pools.

18. Marshland

Area: 310 hectares of floodplain, access to 22 small hillside streams and 76 kilometers of streams and ditches within the floodplain
Restoration opportunity: tide-gate retrofit or removal, dike breaching
Habitat gained: Summer and winter rearing habitat, off-channel refuge
Potential production gain: Not quantified
Description: The conversion of the Marshland marsh for agricultural uses in the 1880s was the largest single loss of off-channel rearing habitat in the entire Snohomish River basin. Even under conservative estimates of summer and winter rearing capacity, the historic marsh at Marshland would have provided more rearing capacity for coho and chinook than the total rearing capacity of all remaining off-channel habitat within the Snohomish River floodplain between the head of Ebey Slough and the confluence of the Snoqualmie and Skykomish rivers. Currently, a pump-station blocks access to habitat within the floodplain and twenty-two small streams. A significant first step to restoring Marshland would be to retrofit (or remove) the pump-station and tide-gates to allow fish access to adult and juvenile salmonids. The northwestern portion of the historic marsh by Lowell may have the greatest potential for marsh restoration (approximately 16% of the historic marsh). A cross-dike could be constructed at the natural constriction of the floodplain between Wood Creek's alluvial fan and the river. Dikes could be breached along the Snohomish River, and Wood Creek could be placed back in its historic channel. Wood Creek, the largest and least disturbed of the Marshland tributaries, would provide spawning habitat and a perennial water source to the restored floodplain wetlands. A water pipeline, the Lowell River Road and railroad tracks pose significant challenges for restoration.

19. Hanson and Batt's sloughs

Area: 27 hectares
Restoration opportunity: Barrier removal, riparian planting
Habitat gained: Summer and winter Rearing, off-channel refuge

Potential production gain: Not quantified
Description: Salmonids have accessed Batt's Slough on occasion, but generally, a tide-gate restricts access. Hanson Slough has been partially filled and cultivated. The feasibility of removing or modifying tide-gates to allow access into these sloughs could be investigated. If opened, these sloughs would provide off-channel significant rearing and refuge for salmonids. Riparian planting would improve rearing habitat quality.

20. "Thomas's Eddy"
Area: 140 hectares
Restoration opportunity: Dike breaching
Habitat gained: Summer and winter rearing, off-channel refuge
Potential production gain: Not quantified
Description: The dike surrounding a Snohomish County park at "Thomas's Eddy" is preventing the natural migration of the Snohomish River into a former channel. Rearing habitat for juvenile salmonids on the site is degraded due to restricted access and flow and the introduction of exotic predatory fishes. Reforesting the site and breaching the dike to allow increased flow through Shadow Lake and associated wetlands would improve rearing habitat quantity and quality. Removing large portions of the dike would likely maximize smolt production over the long-term, because it would restore natural habitat forming processes such as channel migration and wood recruitment.

21. Inside of meander bend across from "Thomas's Eddy"
Area: 62 hectares
Restoration opportunity: Remove bank armoring, riparian planting
Habitat gained: Summer and winter Rearing, off-channel refuge
Potential production gain: Not quantified
Description: Several side-channels and floodways are evident across this bend in the 1933 aerial photos. Subsequent to these photos the bank was armored to reclaim land for agriculture. If land is acquired, than the riparian forest could be enhanced, bank armoring removed to allow channel migration, and off-channel ponds reconnected. The site is adjacent to several properties owned by Snohomish County.

22. Floodplain/islands/sloughs between State Route 522 and "Thomas's Eddy"
Area: 221 hectares
Restoration opportunity: Remove berm, riparian planting
Habitat gained: Summer and winter rearing, off-channel refuge
Potential production gain: Not quantified
Description: Between the confluence of the Snoqualmie and Skykomish rivers and Thomas's Eddy, the Snohomish River has been prevented from migrating laterally through its floodplain over the last 100+ years by wood removal, dredging, berms and bank armor since the 19th century. Oxbows indicate that the river migrated more broadly through this area at one time. Opportunities exist to enhance riparian conditions, channel migration, and connectivity between off-channel habitat in the floodplain, and habitat complexity within floodplain tributaries. Conditions in Lake Beecher, an oxbow lake, could be enhanced through riparian planting. Anderson, Elliott,

and Evans creeks also could be improved through riparian planting, as well as restoration of natural channel sinuosity.

23. Twin Rivers Quarry
Area: 64 hectares
Restoration opportunity: Dike breaching
Habitat gained: Summer and winter rearing, off-channel refuge
Potential production gain: Not quantified
Description: Rural property on the right bank of the main stem downstream of the State Route 522 bridge provides an excellent restoration opportunity. It is a prime location at the confluence of the Snoqualmie and Skykomish rivers. An intermittent creek flows into a cutoff side-channel slough along the base of a steep forested hillslope. The side-channel slough could be reconnected to the main stem below or just down stream of the State Route 522 bridge. The use of engineered logjams (Abbe *et al.*, 1997) to protect bridge supports from scour and to divert flow into the side-channel slough could be investigated.

Tributaries

24. Ebey Slough tributaries (Sunnyside Hill)
Area: Not calculated
Restoration opportunity: Tide-gate retrofit, culvert replacement
Habitat gained: Spawning and rearing for coho
Potential production gain: Not quantified
Description: A half dozen small creeks drain into Ebey Slough. Tide-gates restrict or block anadromous fish access on all these creeks. The Tulalip Tribes have identified several blocking culverts upstream as well.

25. Marshland tributaries
Area: 12+ kilometers of stream
Restoration opportunity: Barrier removal, erosion control, riparian planting
Habitat gained: Spawning, rearing, and off-channel refuge
Potential production gain: Not quantified
Description: The condition and accessibility of Marshland tributaries could be addressed concurrently with the proposed retrofit or removal of the pump-station and tide-gates. Twenty-two small streams drain into the Marshland floodway channel. Sediment settling ponds at the base of the hill slope block fish. Wood, Larimer, and Thomas creeks contain significant coho habitat. Increases peak flows, decreased summer low flow levels, and high sedimentation rates related to high levels of impervious surface in the headwaters may be a problem. Salmonid habitat could be improved in the floodplain by purchasing conservation easements from farmers along floodplain creeks and riparian planting.

26. French Creek access
Area: Not calculated
Restoration opportunity: Tide-gate and pump-station retrofit
Habitat gained: Spawning and rearing for coho and chinook

Potential production gain: Not quantified
Description: The French Creek pump-station restricts adult migration and blocks juvenile access for multiple salmonid species. Not enough water flows through the fish ladder to pass fish during the low flow period, and the facility was not designed to pass juveniles. The pump-station also exacerbates poor water quality conditions in lower French Creek, further stressing aquatic species and impeding salmonid access and migration. Redesigning, bypassing or removing the tide-gate and pump-station to address these problems would open tens of kilometers of spawning and rearing habitat throughout the French Creek sub-basin.

Habitat Quality

27. Log rafting and storage
Area: Not applicable
Restoration opportunity: Restricting log rafting
Habitat gained: Improved primary production, rearing habitat and water quality
Potential production gain: Not quantified
Description: Extensive log rafting and storage has occurred in the lower estuary for over 100 years. The practice has been found to reduce benthic infauna through sediment compaction, bark accumulations on the substrate, and shading (Pease, B. C., 1973). Low dissolve oxygen levels and high concentrations of wood leachates were also observed in areas of log rafting (Pease, B. C, 1973). Restriction or elimination of log rafting would greatly improve habitat conditions for juvenile salmonids in the estuary.

28. Cattle access
Area: Not applicable
Restoration opportunity: Restricting cattle access
Habitat gained: Improved instream habitat and water quality
Potential production gain: Not quantified
Description: Hundred of cattle access the Snohomish River between French Creek and the city of Snohomish and along Ebey Slough causing bank erosion and degrading water quality. These problems could be addressed through fencing and revegetation of denuded banks.

29. Exotic predatory fishes
Area: Not applicable
Restoration opportunity: Control of non-native predatory fishes
Habitat gained: Decreased mortality, increased rearing
Potential production gain: Not quantified
Description: Sport fishermen have planted bass and other game fish in off-channel habitats. The extent of exotics is widespread throughout the Snohomish floodplain. Removal of exotic game fish, which prey upon and compete with juvenile salmonids, would improve the quality of rearing habitat.

NEXT STEPS

The next steps are to investigate landowner interest at potential restoration sites, analyze restoration feasibility and develop an overall restoration strategy for the Snohomish River valley. A preliminary feasibility analysis would answer the following questions:

1. Which restoration sites have cooperative landowners or willing sellers?
2. How would restoration impact adjacent properties?
3. What are the hydrologic flow pathways and characteristics of each site?
4. What is the site elevation and topography?
5. Is there any site contamination?
6. Is the site fully or partially filled?
7. How is the site oriented in relation to existing channel geometry and other conservation properties?
8. Does the site contain utility crossings, transportation right-of-ways or other infrastructure?
9. What length of cross-dike (if any) would be necessary to construct relative to the length of dike that could be breached and acreage restored?
10. What are the restoration design alternatives?
11. What is the total project cost?
12. What is the smolt per unit cost estimate of restoration?

Once the preliminary feasibility analysis is completed for all identified sites, detailed feasibility/design work could then be conducted for sites with the greatest smolt production benefits, highest feasibility and landowner interest.

REFERENCES CITED

Abbe, T. B., D. R. Montgomery, C. Petroff. 1997. Design of stable in-channel wood debris structures for bank protection and habitat restoration: an example from the Cowlitz River, WA. In Wang, C. C., E. J. Langendoen, and F. D. Shields (Editors). Proceedings of the Conference on Management of Landscapes Disturbed by Channel Incision. Univ. of Mississippi. Oxford, MISS. pp. 809-814.

Beamer, E. M., R. A. Henderson. 1998. Juvenile Salmonid Use of Natural and Hydromodified Stream Banks in the Mainstem Skagit River, Northwest Washington. Prepared for the United States Army Corps of Engineers, Seattle District. Skagit System Cooperative, LaConner, WA.

Beechie, T. E. Beamer, L. Wasserman. 1994. Estimating coho salmon rearing habitat and smolt production losses in a large river basin, and implications for restoration. North American Journal of Fisheries Management, 14: 797-811.

Hayman, R. A., E. M. Beamer, and R. E. McClure. 1996. FY 1995 Skagit River chinook restoration research, Skagit System Cooperative, LaConner, WA.

Haas, A. D., and B. D. Collins. 2001. An historical analysis of habitat alterations in the Snohomish River valley, Washington since the mid-19th century: implications for chinook and coho salmon. Prepared for the Tulalip Tribes and Snohomish County Department of Public Works.

Pease, B. C. 1973. Effects of log dumping and rafting on the marine environment of southeast Alaska. Final Report for Period July 1, 1972 – August 30, 1973. College of Fisheries, University of Washington, Seattle Washington.

Pess, G. R., B. D. Collins, M. Pollock, T. J. Beechie, A. Haas, and S. Grigsby. 1999. Historic and current factors that limit coho salmon (Oncorhynchus kisutch) production in the Stillaguamish River basin Washington State: implication for salmonid habitat protection and restoration. Prepared for Snohomish County Department of Public Works and the Stillaguamish Tribe.

Reeves, G. H.; F. H. Everest; and T. E. Nickelson. 1989. Identification of physical habitats limiting the production of coho salmon in western Oregon and Washington. U.S. Forest Service General Technical Report PNW-245.

Swales, S. and C. D. Levings. 1989. Role of off-channel ponds in the life cycle of coho salmon (*Oncorhynchus kisutch*) and other juvenile salmonids in Coldwater River, British Columbia. Canadian Journal of Fisheries and Aquatic Science, Vol. 46 p 232-242.