SKAGIT WATERSHED COUNCIL

A Community Partnership for Salmon

Skagit 2020 Monitoring & Adaptive Management Report

Approved March 16, 2021

Executive Summary

Skagit 2020 Monitoring & Adaptive Management Report

This report was compiled from many independent research and monitoring projects completed between 2000 and 2016. The purpose of this Monitoring and Adaptive Management (M&AM) report is:

1. To present an adaptive management framework for collective decision-making;
2. To present a summary of the status and trends (where available) of explicit and implied habitat indicators from the Skagit Chinook Recovery Plan (2005); and
3. To make recommendations for future monitoring and adaptive management.

This report provides a comprehensive framework for quantifying indicators of key ecological attributes for multiple ecosystem components important to Skagit River Chinook Salmon viability, including 2005 habitat status, available current habitat status and trends data, and the desired future status where proposed. Ecosystem components in the report include natal Chinook estuaries (referred to as the tidal delta), pocket estuaries, large and small freshwater channels, off-channel lakes and wetlands, and uplands. This report does not include salmon monitoring nor does it attempt to link salmon performance and habitat.

These data summaries and conclusions represent complex ecosystems influenced by many variables, some of which we have limited knowledge about their interactions. These data represent our best assessments at this time, but with very few years of information care should be taken in how status and trends are interpreted and acted upon.

Technical recommendations were provided by the Skagit Watershed Council M&AM Subcommittee by category, including for improving monitoring; research; habitat protection & restoration strategies; and scientific hypotheses and desired future conditions. It is up to other committees, organizations, and communities to determine what to do with the strategy, hypotheses, and desired future condition recommendations.

<u>Tidal Delta Habitat Conclusions</u>

Chapter 3 quantifies five indicators (*shown in italics*). Overall, one was moving in a positive direction, one was negative, and the remaining three have not yet reported sufficient data.

- *Tidal delta extent* is the sum of the area of all habitat types within the vegetated Skagit tidal delta and *distributary/blind channel area* is the sum of the area of channel habitat types within the vegetated Skagit tidal delta. They were both mapped and classified for the year 2004, while tidal delta extent was repeated for the year 2013, allowing a trend analysis for the latter. In general, we are gaining tidal delta habitat faster than we are losing it, with an overall increase of 83 hectares (ha). About 122 ha were gained through active restoration projects and another 28 ha gained through natural progradation and a passive dike breach, while about 67

ha were lost predominantly through “natural” bayfront erosion and invasive spartina removal.
    - Active restoration projects are working, and often improve habitat quality outside and “downstream” of the dike removal areas.
    - Regulatory protections have minimized further losses of tidal delta habitat.
    - When including “natural” loss of mostly bayfront habitat due to erosion, current rates of restoration do not meet desired future conditions until sometime around the year 2100, 95 years after the Recovery Plan was adopted. If current conditions persist (or get worse) then future restoration work will need to continue even past 2100 to offset erosion.
    - The sooner desired future conditions are met, the less habitat restoration and agricultural land conversion will be needed to offset erosion over time.
- Skagit *tidal delta progradation* is the rate of change in habitat along the seaward boundary of the vegetated tidal delta. These progradation rates declined, and habitat was lost, even during a period of increasing timber harvest, subsequent landslides, and sediment delivery since the mid-19th century.
    - This suggests that relative sea level rise and sediment re-routing within the tidal delta are responsible for the “natural” erosion and decline in the formation of tidal delta habitat.
- *Blind channel landscape connectivity* is a measure of the length and complexity of the pathway a juvenile salmon must follow to access this rearing habitat. Connectivity was highest in the South and North Forks and lowest in Swinomish Channel/Padilla Bay. The report notes significant historic reduction in connectivity to the latter and to Central Fir Island due to historic changes in fish migration pathways through Fir Island and McGlinn jetty & causeway, respectively. No contemporary trend data is reported here.
- *Habitat Connectivity/Fragmentation* was intended when proposed in 2005 to assess continuity and scale of available habitat in the tidal delta. This report documents that it is difficult to conclude tidal delta habitat is not currently continuous, but that the estuarine wetland zone extent and width are so dramatically reduced that it may present minimum threshold concerns.

<u>Tidal Delta Habitat Recommendations:</u>
Monitoring recommendations include continuing tidal delta extent trend monitoring at 5-year intervals, including adding the unvegetated part of the tidal delta and tidal delta progradation rates as indicators. Refine functional vs. nonfunctional habitat extent and the connectivity/fragmentation indicators. Complete a GIS habitat census error assessment. And add new indicators for monitoring overwater structures and shoreline armoring.

Five tidal delta habitat recommendations are made for reassessing our strategies in this area. Strategies should explicitly address the global-scale stressor of carbon pollution and landscape-scale stressors such as sediment re-routing in the lower river and tidal delta. Restoration site locations and the overall approach to the tidal delta restoration strategy should be re-evaluated for risk from sea level rise and disrupted sediment regimes,

including the timeline and its cost effectiveness implications. Continue habitat protection strategies to protect habitat that currently exists.
Finally, a research recommendation includes launching a coordinated, comprehensive, and funded habitat and fish linkage program to address critical uncertainties and further improve current efforts.

Pocket Estuary Conclusions:
Chapter 4 quantifies four indicators (*shown in italics*). Pocket estuaries are partially enclosed embayments found along the shoreline, often exhibiting depressed salinity compared to adjacent marine waters due to freshwater inflow. Overall, three of the four indicators were moving in a positive direction, with no trend data reported for the fourth.

- The *count of pocket estuaries accessible to salmon* is defined as those pocket estuaries in the Whidbey Basin that have tidal connection at least some of the time. Pocket estuary count increased by one between 2005 and 2014 (from 24 to 25) due to a 94 ha restoration at Crescent Harbor.
- The *pocket estuary area/extent of functional channels accessible to juvenile salmon* are the sum of accessible areas that include tidal and subtidal habitats between tidal stages of Mean Low Water and Mean Higher High Water. Total habitat area increased by 104.8 ha due primarily to restoration, including the 94 ha project at Crescent Harbor and two smaller projects at Lone Tree Lagoon and Turner's Bay. Differences in mapping methods, image resolution, and surveyor differences between the two years likely contributed as well. Fifteen out of 25 pocket estuaries had smaller intertidal footprints than occurred historically/naturally due to human activity. Tidal channel function evaluation found 4 out of 25 mapped pocket estuaries had impaired tidal channels in 2015.
- The landscape position of pocket estuaries is important to determining availability and connectivity of these habitats to outmigrating juvenile Chinook salmon. It is assessed via two indicators, the *median distance between pocket estuaries* and *median distance of pocket estuaries from natal estuaries*. The landscape position of pocket estuaries improved because of the addition of one pocket estuary which decreased the median distance between pocket estuaries. This is not reported specifically (calculated) , but follows qualitatively from what is reported.

Pocket Estuary Recommendations:
Monitoring recommendations for pocket estuaries include continuing efforts on a 5-year interval for all indicators. Two research recommendations include conducting assessments of both climate change vulnerability and opportunity for drift cell scale sediment dynamics and coastal landform translation.

Freshwater Ecosystems Conclusions:
Chapter 5 quantifies nine freshwater ecosystem indicators (*shown in italics*). Overall, two of nine indicators were moving in a positive direction, one was moving in a negative direction, and the remaining either showed no direction or did not report sufficient data.

- *Floodplain extent* is quantified from a geomorphic floodplain polygon dating to 1998. It has been held constant since then as the basis for the following indicator calculations.
- *Large river floodplain structure and connectivity* is the area of all habitat types exposed to river hydrological processes, including channels and floodplains. Hydromodification and road data were used to determine level of connectivity, including functional, shadowed, or isolated. Total new area exposed to floodplain processes between 1998 and 2015 was 352 ha, which reduced percent impaired floodplain from 31% to 28% overall, <u>which is a positive trend</u>. Most of this new floodplain area is attributed to 1) newly mapped eroded areas, 2) changes in road presence, and 3) changes in hydromodification mapping and presence.
- Additional indicators under the umbrella of floodplain structure and connectivity include:
    - *Mainstem edge length* remained about the same between 1998 and 2015 after accounting for variation in methods and river flow/stage, increasing from 500.7 km to 501.2 km.
    - *Mainstem hydromodified edge length* (hydromods include riprap bank armoring and levees) decreased from 49.4 km in 1998 to 41.4 km in 2006 to 39.9 km in 2015, <u>which is a positive trend</u>. Some of the difference is due to passive (natural erosion) and active (anthropogenic restoration) removal of hydromodifications, but some of the difference is also due to mainstem channel migration away from the hydromods resulting in researchers not capturing it in subsequent surveys.
    - *Mainstem backwater perimeter length* (backwaters are low gradient areas of high quality rearing habitat) decreases from 23.7 km to 20.1 km between 2006 and 2015, <u>which is a negative trend</u>.
    - *Floodplain channel area* (defined as polygonal areas of mainstem, backwater, braids, and side/secondary channels) for each dataset was nearly identical: 2,415 ha in 2006 and 2,428 ha in 2015.
    - *Floodplain channel length* (defined as the length of all floodplain channels in unconfined reaches) totaled 371.1 km in 2005 but did not report trend data.
    - *Connectivity of large river floodplain habitats* (defined as the count of and distance between backwaters and floodplain channels) was reported as fragmented in the 2005 Skagit Chinook Plan with 20 mainstem reaches with gaps in habitat availability that may be priority areas for restoration. This analysis has not been repeated since the Skagit Chinook Recovery Plan so no trends reported.
    - *Tributary connectivity and structure* includes natural and artificial barriers to fish passage. Barrier assessment is currently underway.
    - *Tributary length* assessment has been started, but only exists for current conditions. Habitats are shown sorted first by gradient class and accessibility, and then by watershed position and accessibility.

<u>Freshwater Ecosystems Recommendations:</u> Seventeen freshwater habitat monitoring recommendations are made. Repeat floodplain, hydromodification, and channel

monitoring protocols on a five to ten year period, updating protocols and databases where appropriate. Refine the original 1998 channel data to make it more comparable to recent time stamps. Utilize LiDAR-derived Relative Elevation Modeling to better map floodplain features for both M&AM and protection/restoration planning purposes. Revisit 2006 and 2015 time stamps to measure floodplain channel lengths. Develop and measure a new indicator for alluvial fans (where tributaries enter the mainstem floodplains). Field verify fish barriers. Incorporate channel width estimates into the hydro layer in order to re-run the intrinsic potential models with updated fish distribution layers. Make estimates of large woody debris recruitment and trends therein. Create a new freshwater implementation monitoring framework and connect to broader ambient monitoring to understand how our actions are working in context to other trends. Improve indicator linkage to Chinook benefit.

<u>Riparian Habitat Conclusions</u>:
Chapter 6 develops and quantifies one riparian indicator, *spatial extent & continuity*, and recommends another be further developed, *community structure & function*. Desired future condition is currently defined as protecting existing riparian functions and continuing to restore degraded riparian functions within at least 40m of anadromous salmon habitat. Overall, riparian spatial extent & continuity are moving in a positive direction within SWC's priority Target Areas. While about 280 acres of functional riparian land cover was lost to anthropogenic activities (mostly from logging) between 2006 and 2013, about 1,170 acres were replanted by riparian project sponsors and landowners between 1998 and 2016. This increase of about 880 acres increases functional riparian areas by about 3.1% in WRIA 3 and about 1.1% in WRIA 4, attributed to current strategies of steady voluntary and regulatory protection coupled with voluntary riparian planting.

<u>Riparian Habitat Recommendations</u>:
Nine riparian recommendations are made, including five monitoring recommendations. Repeat land cover classification on a decadal time period while updating the SWC riparian action and WDFW high resolution change detection databases every two years. Improve hydrography layer accuracy. Monitor riparian planting effectiveness. Develop a new community structure indicator by comparing canopy heights across decades. And explore other indicators such as canopy cover and functional stream shading.

Toward improving the framework for M&AM, this report recommends more explicitly outlining desired future conditions and goals to better track progress in relation to them.

This report makes three strategy recommendations including clarifying recommended geographic extent of riparian target areas including in the context of mobile channels; generating technical guidance for how planting can provide most benefit for climate change adaptation; and sharing best practices and lessons learned among practitioners.

Potential future indicators for freshwater ecosystems and riparian habitats include large woody debris. Possible indicators and methods have been examined with two recommendations for future monitoring include quantifying LWD in mainstems and linking LWD, riparian, and sediment metrics to better characterize habitat processes.

Table of Contents

1.0 Introduction

1.1 Background

The Skagit Chinook Recovery Plan (2005) emphasized the need to protect and restore freshwater rearing habitats, and the processes that formed these habitats at the watershed, floodplain, and reach levels. It set up goals of no net loss (protection) plus habitat improvement (restoration) in the Skagit Basin. It also recognized the need to monitor the status and trends of these processes and subsequent habitat values. Comparing current and historic data is a means by which we can establish a common framework for understanding and communicating habitat trends. It highlights the pressures and stressors that degrade habitat, and provides insight into which areas require attention, thereby directing future adaptive management efforts. To date, efforts to monitor progress in habitat quality, quantity and productivity, relative to defined goals for chinook recovery, have been diffuse and unorganized. Therefore, informed understanding of how the condition and extent of Skagit habitat quantity and quality was increasing or decreasing over time has been lacking. To address the need for more coordinated and focused monitoring efforts, the Skagit Watershed Council Monitoring and Adaptive Management Subcommittee is developing a basin wide Monitoring and Adaptive Management Plan with the following objectives:

1) Fill gaps in metrics and protocols.
2) Generate additional time steps of habitat status to collect trend information and build on the existing monitoring priorities in the recovery plan.
3) Use alternative planning resources (e.g. causation analyses, course corrections to strategies) to integrate outcomes into future iterations of the monitoring plan.

Tracking the status and trends of salmon habitat is part of the regional effort to develop and implement Monitoring and Adaptive Management Plans (MAMP) for all local chapters of the Puget Sound Chinook Recovery Plan, including the Skagit Chinook Recovery Plan. The MAMP process is being led by the Puget Sound Partnership (PSP) but implemented at the local watershed level (Lead Entities). A set of Common Indicators for monitoring Puget Sound Chinook salmon habitat (e.g., Fore 2015) has been generally accepted by Lead Entities to guide and make monitoring consistent across all of Puget Sound. In Phase I of the project (2013 – 2014) each watershed team translated their unique recovery plans into common terms, based on the Open Standards for the Practice of Conservation approach. The resulting individual frameworks allow for comparison and roll-up of ecosystem and fish population status and an assessment of common pressures and recovery strategies throughout Puget Sound. As part of Phase I, the Skagit M&AM Subcommittee of the Skagit Watershed Council (Skagit and Samish Lead Entity) prepared the Skagit Chinook Monitoring and Adaptive Management Framework that identified the ecosystem components, key ecological attributes and indicators and desired future conditions (DFC) that were described in the 2005 Skagit Chinook Recovery Plan and Skagit Chinook Monitoring Plan.

The Skagit Watershed Council Monitoring and Adaptive Management Subcommittee based their indicators on the Skagit Chinook Recovery Plan (2005). Subsequently, the Puget Sound Partnership drafted their list of common indicators, and NOAA released a list of indicators as well (Beechie et al. 2015). In some cases, the indicators were explicit, with associated desired future conditions necessary for Chinook recovery (Table 1). In addition to the indicators in Table 1 there were many habitats and ecological processes described in the plan that Chinook depend on that did not have specific indicators and desired future conditions acknowledged. In this case, the most relevant key ecological attribute was identified. A complete list of implicit habitat components and associated key ecological attributes (KEAs) can be found in a comprehensive Miradi database file available from the Skagit Watershed Council. That, together with the Phase 1 report, provide the basis for the Skagit M&AM Framework.

Two additional efforts at the regional level further developed habitat indicators. The Puget Sound Partnership convened two groups of monitoring experts (freshwater and marine) to recommend the most appropriate Common Indicators to be reported upon throughout Puget Sound. The National Marine Fisheries Service also released a list of indicators and methods but went further by collecting and analyzing data at the regional and Major Population Group scales. Skagit's M&AM Framework (Phase 1) and Skagit M&AM Reports (Phase 2 and beyond) align with regional efforts while providing data and a management decision framework at the watershed scale.

1.2 Purpose

The purpose of this M&AM report is to present a summary of the status and trends (where available) of explicit and implied indicators from the Skagit Chinook Monitoring Plan (2005), to make recommendations for future monitoring and adaptive management work, and to present a recommended adaptive management framework. This and future reports will serve as a repository for which indicator status and trend information can be added to over time as monitoring and analysis is completed, and as a procedure through which recommendations are vetted, approved, and documented. Each chapter covers a suite of indicators related to one or more related habitat components.

It is important to note that this report only presents information on a subset of habitats and ecological processes that were presented in the 2005 Chinook Plan as important for Chinook recovery. However, the ultimate goal in Skagit Chinook recovery is to improve productivity and abundance of the 6 Chinook populations. The habitat status and trends information serve as a surrogate to assess progress until the appropriate time and number of projects allows for Chinook productivity and abundance information to reflect recovery effectiveness.

2.0 Skagit Habitat Indicators and Desired Future Conditions

The Skagit Chinook Recovery and Monitoring Plan (2005) provided habitat indicators, their current condition, and in many instances their desired future conditions. SWC's M&AM Subcommittee aligned those with ecosystem components and Key Ecological Attributes (KEAs) as a part of the development of the Skagit M&AM Framework. Tables 1 and 2 provide the parameters which were explicitly documented in the Skagit Chinook Recovery Plan in marine and freshwater habitats, respectively. Appendix 1 provides the parameters which were in the Skagit Chinook Recovery Plan, both explicit and implied, as identified in Phase 1. Appendix 2 provides viability assessment outputs from Phase 1 captured in the Miradi database. A primary task for the M&AM Subcommittee is to move implied indicators and their trends into an explicit status, as well as nest them into the framework of desired future outcomes, hypotheses, and strategies.

Table 1. Estuarine and pocket estuary habitat components, key ecological attributes and associated indicators developed in M&AM Phase I for the Skagit Chinook Recovery Plan (2005). NS = "not specified" which is presumed to be no net loss unless it is associated with another indicator and DFC.

Ecosystem Component	Key Ecological Attribute	Indicator	Details	2005 Status	Desired Future Status
Natal Chinook estuaries	Tidal channel formation and maintenance	Blind channels	Blind channels exposed to tidal and/or freshwater hydrology (Habitat zone). Pages 12 (historic, current) & 41 (planned restore) of Appx. D	62.7 km	110.8 km
	Habitat connectivity condition	Blind channels landscape connectivity	Blind tidal channel systems - increase in median landscape connective of blind tidal channel systems (page 36 (Existing) and page 41 (planned restore) of Appx D)	.0190	.0246
	Tidal channel formation and maintenance	Distributary channels	Distributary channels exposed to tidal and/or freshwater hydrology (Habitat zone)	851.7 hectares	895.8 hectares
	Freshwater hydrology - condition	Minimum instream flows	Recommendation 2 1.02 Page 81	NS	NS
	Estuarine habitats - distribution	Tidal delta habitat connectivity	All habitat types exposed to tidal and/or freshwater hydrology (Habitat zone) - Landscape context Pages 10 & 11 (historic, current) & 41 of Appx. D for connectivity restoration projects	Fragmented	Not Fragmented
	Estuarine habitats - extent	Tidal habitat; tidal delta		3,118 hectares	4,232 hectares

Ecosystem Component	Key Ecological Attribute	Indicator	Details	2005 Status	Desired Future Status
		footprint, all types			
Pocket estuaries	Tidal circulation – extent of dependent biological activity	Accessible pocket estuary area	Increase area within pocket estuaries that are accessible to juvenile Chinook salmon rearing. Pages 13 & 42 of Appx. D Could update with March 2011 data	47.5 hectares	311.5 hectares
	None specified	Length of riparian edge consistent with BAS	Protection 1.44 Buffer regulations consistent with BAS 1.45 Include BAS in existing CAO and SMP regulations 1.46 Include BAS in CREP and Farm Plans 1.47 Remove small Landowner riparian exemptions (code H7)	NS	NS
	Habitat connectivity - condition	Median distance between pocket estuaries	Decrease median distance between pocket estuaries. - Page 15 of Appx. D Existing 2005 was corrected with updated data Feb 2011.	3.49 km	NS
	Estuarine habitats - extent	Number of pocket estuaries accessible to juvenile Chinook salmon rearing	Increase number of pocket estuaries accessible to juvenile Chinook salmon rearing from 8 to 12. Historic is 22. Pages 40 & 42 of Appx. D Existing 2005 was corrected with updated data Feb 2011.	8	12

Table 2. Freshwater habitat components, key ecological attributes and associated indicators developed in M&AM Phase I for the Skagit Chinook Recovery Plan (2005). NS = "not specified" which is presumed to be no net loss unless it is associated with another indicator and DFC.

Ecosystem Component	Key Ecological Attribute	Indicator	Details	2005 Status	Desired Future Status
Large (Non-wadable) channels	Floodplain-channel interactions – Structure & Function	Area of all channel types in unconfined reaches	Floodplain channel Hydrologic regime Floodplain structure & function, Used Table 3, page 28 of Beamer et al 2010 for current Used spreadsheet for projects in Ch. 10 for restored	559.57 hectares	628 hectares
	Floodplain-channel interactions – Structure & Function	Length of all channel types in unconfined reaches	Floodplain channel Hydrologic regime Floodplain structure & function	371,089 meters	
	Floodplain-channel interactions - connectivity	Floodplain connectivity area	Large river floodplain footprint (including non-tidal delta) Area of all habitat types exposed to river hydrological processes, including channels and floodplains. Pages 98, 113-114 for historic and current Used spreadsheet for projects in Ch. 10 for restored	10,510 hectares	12,813 hectares
	Floodplain-channel interactions - connectivity	Floodplain connectivity fragmentation	Connectivity of large river floodplain Count and distance between all backwaters and floodplain channels Fragmented = 20 gaps in backwater	Fragmented	Not fragmented

Ecosystem Component	Key Ecological Attribute	Indicator	Details	2005 Status	Desired Future Status
			and floodplain channel opportunity for Chinook use along river corridor (page 112)		
	Floodplain-channel interactions - structure	Large mainstem backwaters	Perimeter of large mainstem backwaters. Pages 113-114 for current Used spreadsheet for projects in Ch. 10 for restored	63.2 km	97.3 km
	Habitat connectivity	Length of all edge types		589.4 km	623.5 km
	Habitat connectivity	Length of hydro modified edge type		98,559 meters	
	Hydrology – high flow regime	Frequency, duration and magnitude of peak flows	Protection 3.09 G39 Page 83	NS	NS
	Hydrology – high flow regime	Frequency, duration and magnitude of peak flows	Protection 3.09 G39 Page 83	NS	NS
	Floodplain-channel interactions - connectivity	Frequency, duration and magnitude of habitat connectivity flows	Protection Recommendation 15 Page 84 2.15	NS	NS

Ecosystem Component	Key Ecological Attribute	Indicator	Details	2005 Status	Desired Future Status
	Floodplain-channel interactions - structure	Frequency, duration and magnitude of habitat creation flows	Recommendation 15 Page 84 2.15	NS	NS
	Hydrology – low flow regime	Interday flow variability; high flow or low flow	Recommendation 9 Page 83 3.09	NS	NS
	Hydrology – high flow regime	Interday flow variability; high flow or low flow	Protection 3.09 G39 Page 83	NS	NS
	Sediment dynamics – sediment delivery	Sediment supply	Current sediment supply vs historic supply ratio.	NS	NS
Small (wadeable) channels	Habitat connectivity	Interday flow variability; high flow or low flow	Protection 3.09 G39 Page 83	NS	NS
	Habitat connectivity	Length of connected habitat	Protection 1.53 New passage structures must meet design criteria 1.54 Federal Regulatory requirements for passage 1.55 Enforce State Statues regarding passage 1.56 Identify and remove barriers on government lands	371.1 km	442.6 km
	Nutrient supply – water quality	# of 303d listed parameters	Recommendation 21 2.23 Farm program consistency with WQ Standards 2.25 Increase funding to WQ	NS	NS

Ecosystem Component	Key Ecological Attribute	Indicator	Details	2005 Status	Desired Future Status
			Improvement 2.26 Apply WQ standards to potential habitats 2.27 Improve Non-point protections in the CWA 2.28 Take action on WQ violations page 87		
	Floodplain – channel interactions – floodplain connectivity	Length of all channel types	Small mainstems and tributaries - Used Table 3, page 28 of Beamer et al 2010 for current	125 km	125 km
	Floodplain – channel interactions – floodplain connectivity	Length of mainstem natural edge, all types	Pages 113-114 for current Used spreadsheet for projects in Ch. 10 for restored	589.4 km	623.5 km
Non-channel lakes and wetlands	Floodplain-channel interactions - connectivity	Unisolated floodplain area	Recommendation 15 2.15 page 84	NS	NS
	Floodplain-channel interactions - connectivity	Floodplain connectivity area		10,510 hectares	12,813 hectares
	Habitat connectivity	Floodplain connectivity fragmentation		Fragmented	Not Fragmented

Ecosystem Component	Key Ecological Attribute	Indicator	Details	2005 Status	Desired Future Status
Uplands	Sediment dynamics – sediment delivery	Sediment supply- Mass wasting.	Poorly designed or maintained forest roads can reduce spawning and rearing habitat quality by increasing sediment delivered to streams through surface erosion and mass wasting processes. Sediment supply as measured by volume delivered to streams per sq km per year. The indicator metrics are a ratio of current vs historic or natural sediment supply. Rated as functioning where average sediment supply is <100 m3/km2/yr. Where average sediment supply is >100 m3/km2/yr, but is <1.5 times the natural rate, is also functioning. Where average sediment supply is >100 m3/km2/yr and is >1.5 times the natural rate, process is rated impaired. Page 104, Chapter 9; Appendix B of Plan	2269.9 miles of road treated	4325.7 miles (2,055.8 remaining to treat)
	Hydrologic processes	Total watershed pervious area	Recommendation 14 1.14 page 84		93+% nonimpervious condition for each WAUs

3.0 Skagit Natal Chinook Estuary

The Skagit River delta is a prograding to neutral fan delta with numerous distributary channels. The entire geomorphic Skagit River delta extends from Camano Island northward and includes Samish Bay. However, to understand changes in estuarine tidal delta habitat most directly relevant to Skagit Chinook salmon populations, the 2005 Skagit Recovery Plan looked at only that portion of the geomorphic Skagit River delta extending from southern Padilla Bay to Camano Island that was historically influenced by tidal hydrology. This portion of the geomorphic Skagit River delta was historically contiguous and directly connected to the Skagit River, the primary source of Chinook salmon for this area.

For the estuarine indicators, there were two salmon recovery strategies identified in the 2005 Skagit Chinook Recovery Plan: tidal delta restoration, and protection of habitat quality and habitat structure. The recovery strategies for restoration and protection of natal estuary is within the context of a portfolio of Skagit Chinook salmon recovery actions that includes strategies for freshwater habitats and watershed processes as well as actions related to non-habitat factors (e.g., hatchery and harvest management). The indicators below in Table 3 give the most recent information on tidal delta. For all indicators, detailed method information and data origin can be found in Beamer et al, 2015.

Table 3. Skagit tidal delta indicators and methods

Skagit Chinook Plan Indicator	PSP Common Indicator	Skagit Method/Data Type
Tidal delta habitat extent	Functional estuary surface area	
Distributary and blind channel area	Extent of tidal channels	GIS census of natal estuary (polygon data)
Tidal delta progradation rate	No Common Indicator identified, *but recommended as a new Common Indicator*	
Blind channel landscape connectivity	No Common Indicator identified	GIS census of blind channels (points) integrated with GIS representation of fish migration pathways (lines)
Tidal delta habitat connectivity/fragmentation	No Common Indicator identified	Uses polygon and line data listed above

3.1 Tidal Delta Habitat Extent and Distributary/Blind Channel Area

Description of Indicator

Tidal delta habitat extent is the sum of the area of intertidal/subtidal habitat polygons within the vegetated Skagit tidal delta (i.e., Delta zones are estuarine emergent marsh, estuarine scrub shrub, or riverine tidal). Distributary/blind channel area is the sum of the area of intertidal/subtidal channel? habitat polygons within the vegetated Skagit tidal delta. Changes and trends for the tidal delta are described below as individual metrics.

Methods

The tidal delta was mapped in GIS using the best available aerial photos, and classified into the following habitat types:

- Blind channel
- Distributary channel
- Impoundment
- Boat harbor
- Intertidal wood
- Intertidal rock
- Low tide terrace
- Tidal marsh
- Tidal scrub shrub
- Riverine tidal forest

Status and Trends

The Skagit River tidal delta had 3,384.65 hectares of total habitat exposed to tidal and riverine hydrologic processes in 2004 (Table 4). An additional 6.47 hectares of area was classified as intertidal fill and is not counted within the "tidal delta habitat extent" indicator. Please note results for intertidal wood is an underestimate within the 2004 polygon data due to incomplete classification of the intertidal wood habitat type. Some vegetated tidal wetland areas should be reclassified as intertidal wood. The Skagit tidal delta in 2004 had 109.14 and 859.11 hectares of blind channel and distributary channel, respectively.

Table 4. Results for tidal delta habitat extent and distributary/blind channel measures

Groupings of habitat types	Habitat type	Delta zone			Row total
		Estuarine emergent marsh	Estuarine scrub shrub	Riverine tidal	
Channels & other water types	blind channel	74.82	20.68	6.37	**101.87**
	boat harbor	27.83	0.00	0.19	**28.02**
	distributary channel	444.68	102.06	284.36	**831.09**
	impoundment	3.32	3.46	0.50	**7.27**
	Subtotal	**550.65**	**126.20**	**291.41**	**968.25**
Non channel intertidal habitats	intertidal rock	0.05	0.00	0.00	**0.05**
	intertidal wood	0.15	0.00	0.00	**0.15**
	low tide terrace	7.98	0.00	0.00	**7.98**
Vegetated tidal wetlands	riverine tidal forest	0.00	0.00	328.51	**328.51**
	tidal marsh	1630.59	0.00	0.80	**1631.39**
	tidal scrub shrub	0.00	447.24	1.08	**448.31**
Non channel subtotal		**1638.77**	**447.24**	**330.39**	**2416.40**
Grand total		**2189.41**	**573.44**	**621.80**	**3384.65**

3.2 Tidal Delta Progradation

Description of Indicator

Tidal delta progradation is the rate of change in tidal delta habitat extent along the seaward boundary of the vegetated tidal delta. Progradation is a positive change in tidal delta habitat extent while erosion is a negative change.

Methods

See Hood 2015.

Status and Trends

In Hood (2015), tidal delta progradation rate was calculated for three of the five sub-delta polygons, North Fork, South Fork, and Central Fir Island. Over the aerial photo period of record, Skagit tidal delta progradation rates for all areas within the vegetated tidal delta have been in decline (Figure 1, top panel). For two of the three areas (Central Fir Island, South Fork) in the Skagit tidal delta progradation rate is currently negative which means habitat is being lost along the Skagit Bay front faster than it can be formed. The North Fork tidal delta progradation rate was last measured at zero, but the trend is negative, suggesting that soon habitat in the North Fork tidal delta will be lost faster than it forms too. Skagit tidal delta progradation rate declined even during a period of increasing timber harvest, subsequent landslides, and sediment delivery (Figure 1, bottom panel). This suggests that relative sea level rise and sediment re-routing within the tidal delta are responsible for the decline in the formation of tidal delta habitat.

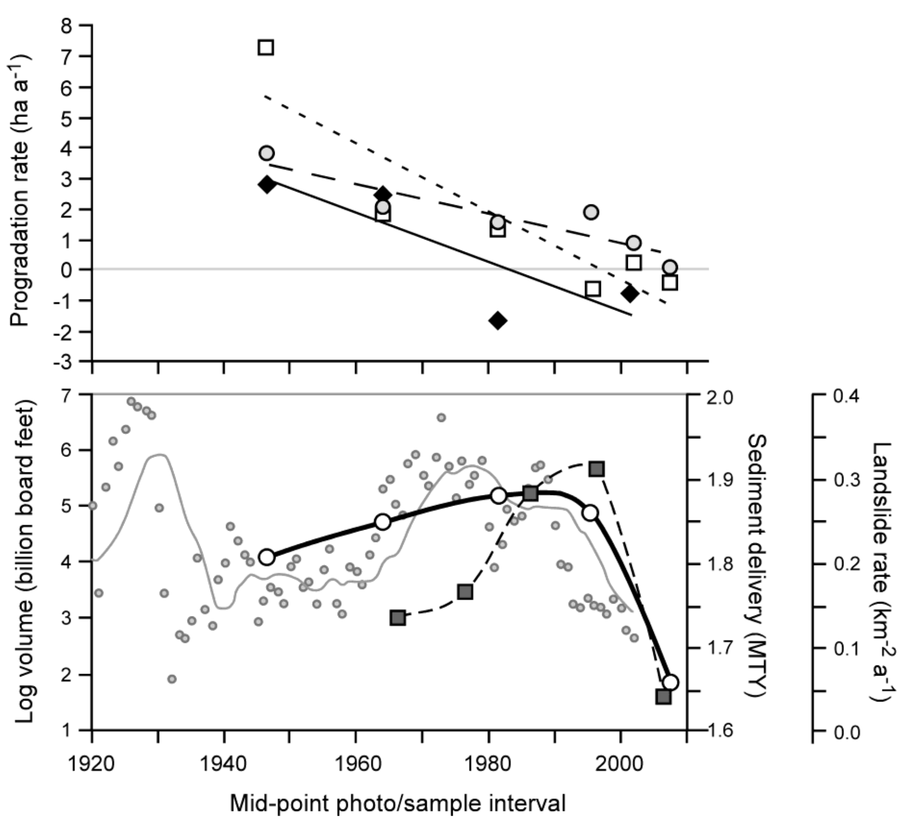

Figure 1 [Top frame] Progradation rates calculated from historical aerial photos, for the North Fork sub-delta (gray circles and dashed line; y = -0.0476x + 96.1; R2 = 0.82); the South Fork sub-delta data (open squares and dotted line; y = -0.1118x + 223.3; R2 = 0.81); and the bay-fringe marsh (black diamonds and solid line; y = -0.0804x + 159.5; R2 = 0.70). Negative values represent net erosion. [Bottom frame] Skagit Basin landslide rates (dark squares) and sediment delivery to Skagit Bay (white circles) plotted for similar photo intervals as for observed progradation rates and compared to Western Washington timber harvest (small gray circles; gray fitted line is the 10-yr moving average). Figure is from Hood et al (2015).

3.3 Blind Channel Landscape Connectivity

Description of Indicator

Landscape connectivity is defined as a function of both the length and the complexity of the pathway that juvenile Chinook salmon must follow to access tidal delta blind channels.

Methods

Blind tidal channel networks were mapped in GIS as lines with points at every intersection and mouth of channels. Blind channel connectivity is represented by the intersection point and the order of that point (branches). Points were attributed with the channel order (number of branches). Connectivity was calculated following methods in Green and Beamer 2006. Note that this is a ratio and no units are necessary.

Status and Trends

Landscape connectivity results were calculated for all 643 GIS points representing blind tidal channel networks in the Skagit tidal delta and some Skagit Bay pocket estuaries. For Skagit tidal delta blind channels (n=634), average landscape connectivity is 0.02752. However, average landscape connectivity varies as much as four times by the six spatial strata (areas of the delta) within the greater Skagit River estuary (Figure 2). Spatial strata within the Skagit River tidal delta (i.e., sub-delta polygons) were identified for planning restoration and monitoring juvenile Chinook salmon population response to restoration as part of the Skagit IMW (Greene & Beamer 2006; Greene et al 2015).

North Fork blind channels have the highest average landscape connectivity with South Fork blind channels ranking second for the six spatial strata (Figure 2). Blind channels in Central Fir Island (along the Skagit Bay front) average about one half the average value of the North Fork and are intermediate of all six spatial strata. The three remaining spatial strata (Stanwood-Camano, Swinomish Channel/S. Padilla Bay, and Skagit Bay pocket estuaries) are all similarly low in average landscape connectivity. Blind channels within the Swinomish Channel/S. Padilla Bay sub-delta polygon have the lowest average landscape connectivity due mainly to fish pathway modification caused by the North Fork Jetty and McGlinn Island Causeway fill at the junction of the North Fork and Swinomish Channel. Similarly, average landscape connectivity for Central Fir Island blind channels is lower than North Fork and South Fork delta areas due to loss of historic fish migration pathways through relic sloughs along central Fir Island (e.g., Browns, Hall, and Dry Sloughs).

Both North Fork and South Fork blind channels have a large range of connectivity values due to the length of their respective main distributary channels as well as extensive channel branching in the downstream areas of these sub-delta regions (Figures 2). However, blind channels are relatively rare in the upstream (riverine tidal forested) portions of each channel compared to the downstream estuarine scrub shrub and emergent marsh zones, so very limited opportunity currently exists for fish to colonize blind channel habitat in the upper parts of these sub-delta polygons.

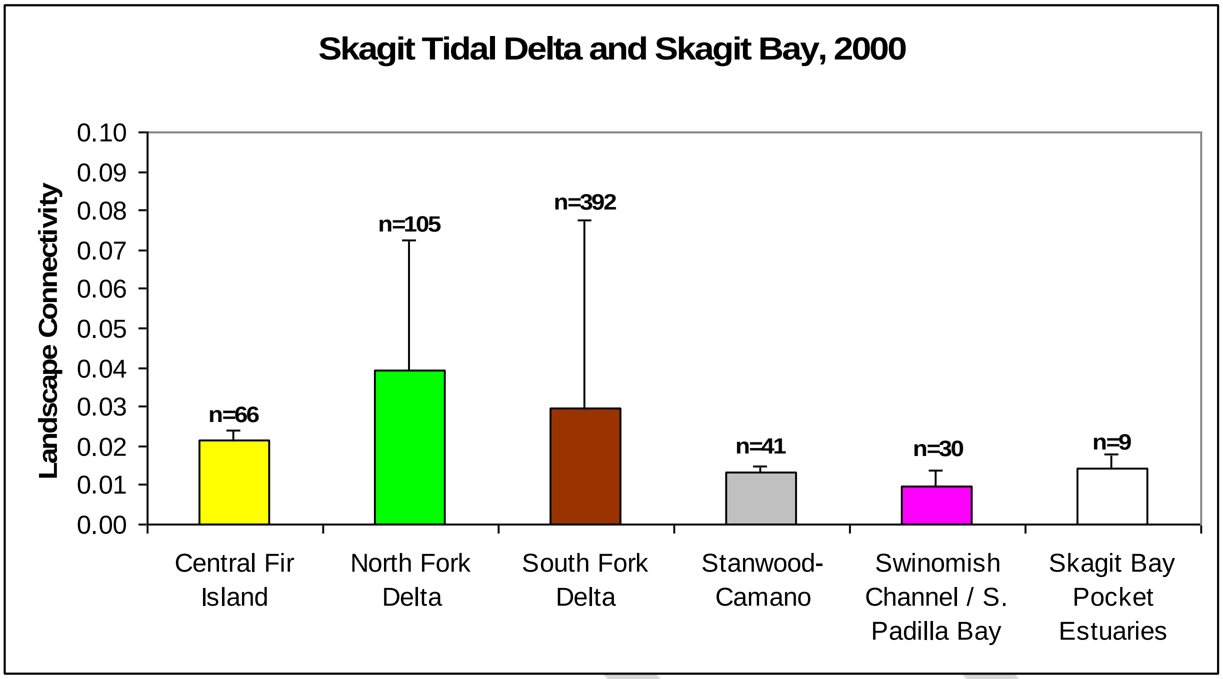

Figure 2. Average, standard deviation, and sample size of landscape connectivity measurement by spatial strata identified for planning restoration and monitoring juvenile Chinook salmon population response to estuary recovery actions (Greene & Beamer 2006).

3.4 Habitat Connectivity/Fragmentation

Description of Indicator

Tidal delta habitat connectivity/fragmentation is intended to track important changes in connectivity and presence/absence/extent of expected estuarine wetland zones (i.e., Delta Zone in the polygon dataset) at the scale of sub- delta within the Skagit tidal delta. Skagit Phase I translation of tidal delta fragmentation concepts are problematic for developing a non-subjective methodology for a single indicator related to tidal delta habitat connectivity/fragmentation. The Skagit Phase I translation states current conditions of the Skagit tidal delta are fragmented (3 separate delta habitat patches) while the historic condition (and desired recovery condition) of the Skagit tidal delta was not fragmented (one contiguous delta habitat patch). It is difficult to conclude that the Skagit tidal delta is not contiguous in its contemporary (years 2000 or 2004) condition (Figure 3). What is easily observable is a large change in estuarine wetland zone extent and width. Possibly, some rule on a minimum threshold estuarine wetland zone width could be the basis for determining whether a tidal delta is 'fragmented' or 'not fragmented.' The recommendations section below suggests using a new table to track the concept of Skagit tidal delta fragmentation articulated in the 2005 Skagit Recovery Plan. Watershed-level decision makers for recovery plan implementation need to decide which indicators are necessary to track through the Chinook monitoring and adaptive management process.

Methods

See Beamer, E. and K. Wolf. 2017.

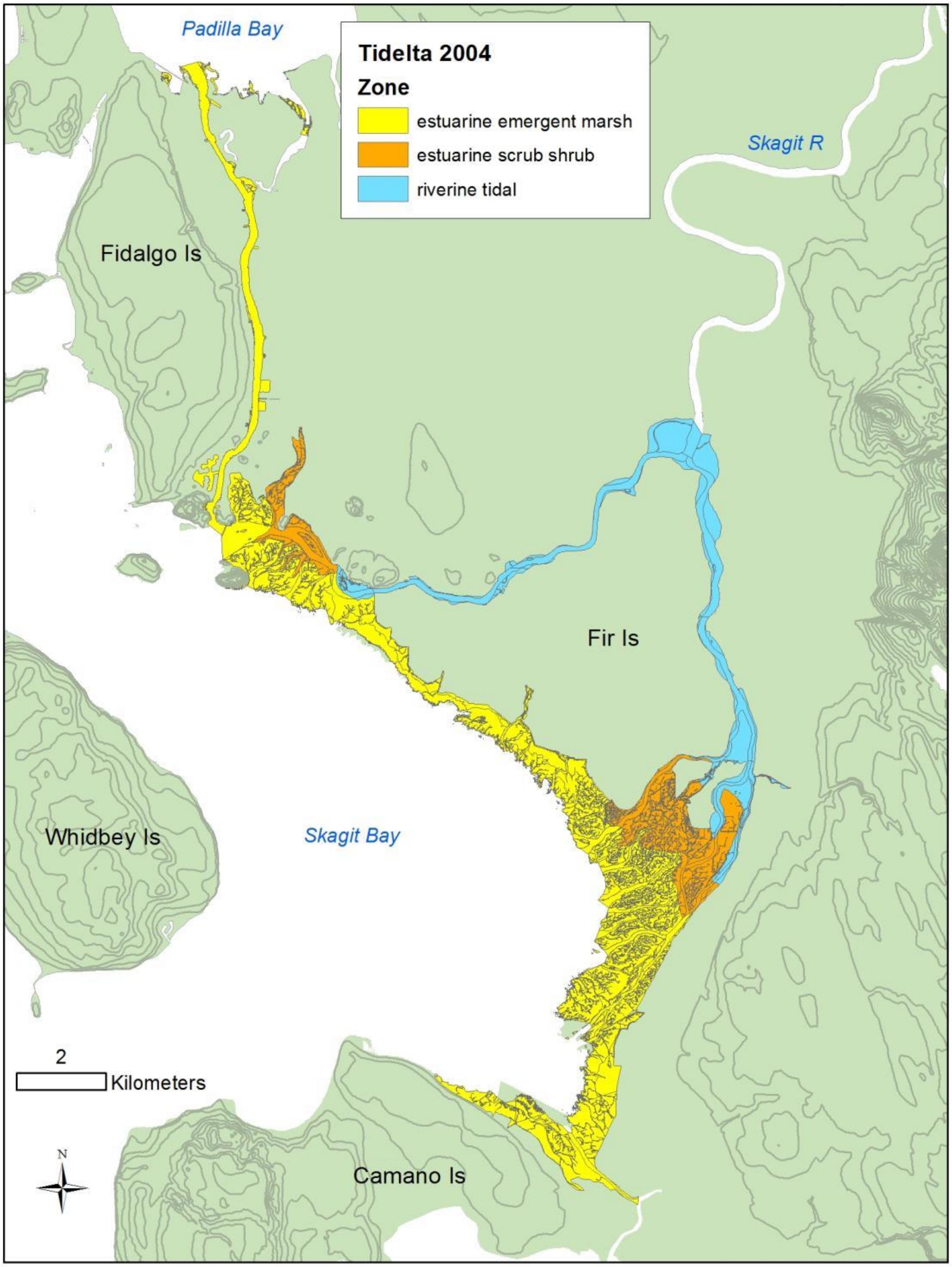

Figure 3. The Skagit River tidal delta in 2004 displayed by estuarine wetland zone

Status and Trends

Results

Between 2004 and 2013 the net change in the Skagit's tidal footprint is an increase in 83 hectares of intertidal footprint (Table 5, Figure 4). Human and natural causes of habitat change were detected over the 9-year period, but restoration outpaced both natural and human causes of lost tidal delta extent. We are not losing tidal delta habitat faster than we are gain it. Completed restoration projects are the primary reason for a net increase in tidal delta extent (Tables 5 and 6). In fact, a total of 122 hectares was restored over the nine-year period, averaging 13.6 hectares restored per year.

Two unique habitat changes were detected. The first is a 15 hectare gain in habitat from a passive failure of a levee which was not repaired. The site is located along West Pass (Figure 4). The second site is also located along West Pass and is an area of extensive spartina marsh removal (Beamer et al 2009). Spartina is an invasive plant for west coast estuaries that colonizes mudflat. In 2004 this area was mapped as (unnatural) marsh and in 2013 unvegetated and thus shows as a loss per our reporting methods.

Direct human causes of lost tidal delta extent were minor (Table 5). One incident of lost habitat due to a human cause was detected, a loss of 0.33 hectare due to a levee repair along the North Fork Skagit River near the Forks. The only other incident of habitat loss was a 0.04 hectare filled channel as part of the Fisher Slough Restoration Project which helped re-meander Fisher Creek and create a blind channel lobe. Overall, direct human caused losses of tidal delta extent was less than 0.04 hectare per year from 2004-2013. Natural changes in tidal delta extent occurred over the 9-year period with a net loss in tidal delta extent, primarily along the bayfront (Figure 4), with in 12.6 hectares gained but 29.9 hectares lost. Overall, natural-caused change of tidal delta extent was a loss of 1.9 hectare per year.

Table 7 shows recent (2000, 2004, and 2013) conditions relative to both desired future and historical conditions. Historical context is presented to stress that the 2005 Plan aspires to restore historic tidal delta extent from 29.6% in 2004 to 37.0% as the desired future condition.

Table 5. Gains and losses of Skagit tidal delta extent by cause 2004 - 2013

Cause of change		**gain (ha)**	**loss (ha)**	**net change (ha)**
General	**Specific**			
human	channel filled in		0.041	-0.041
	levee repair		0.354	-0.354
	restoration	121.917		121.917
	invasive sp. (spartina) removal		36.295	-36.295
natural	passive dike breach	15.071		15.071
	erosion and progradation	12.621	29.889	-17.269
	Total	**149.608**	**66.580**	**83.028**

Table 6. Gains and losses of Skagit tidal delta extent by restoration project for the period 2004 through 2013.

Restoration Project	gain (ha)	loss (ha)	net change (ha)
Fisher Sl restoration	18.657	0.041	18.615
SF Dike Setback restoration	8.369		8.369
Smokehouse restoration	26.902		26.902
Swinomish Channel fill removal	3.366		3.366
Wiley Sl restoration	64.623		64.623
total	**121.917**	**0.041**	**121.876**

Table 7. Skagit tidal delta extent indicator results and recovery plan targets

Source	Year	Status (ha)	% of DFC	Desired Recovery Condition (ha)	Historic Condition (ha)
Skagit Phase I (source[1])	2000	3,118	73.7%		
Skagit Monitoring Pilot[2]	2004	3,384.65	80%	4,232.6	11,438
SRSC Habitat Status & Trends Program[3]	2013	3,467.68	81.9%		

[1]Page 7 (historic, Year 2000) & page 41 (DFC) of Beamer et al 2005; [2] Beamer et al 2015
[3] Beamer and Wolf 2017

Spatial extent is presented in Figure 4. These results apply to the Skagit indicator: *Tidal delta habitat extent* for the vegetated Skagit tidal delta, excluding any changes to low density marsh which cannot reliably be delineated through remote sensing. There is some future work to ensure all data layers used for status and trends analysis (Historic, 2000, 2004, 2013, any future periods) are using the exact same spatial extent (Beamer and Wolf, 2017).

Variability of habitat types within tidal delta extent

These results only apply to the indictor: *Tidal delta habitat extent* and do not account for changes in specific habitat type (e.g., extent of blind and distributary channel) which have not been completely delineated yet in the 2013 data layer. It is important to completely divide the data layer into habitat types and track the channel metrics because large changes in intertidal footprint by restoration can have downstream or 'outside the dikes' benefits (Hood 2004) and restored habitats do not necessarily remain the same over time as natural processes interact with the site.

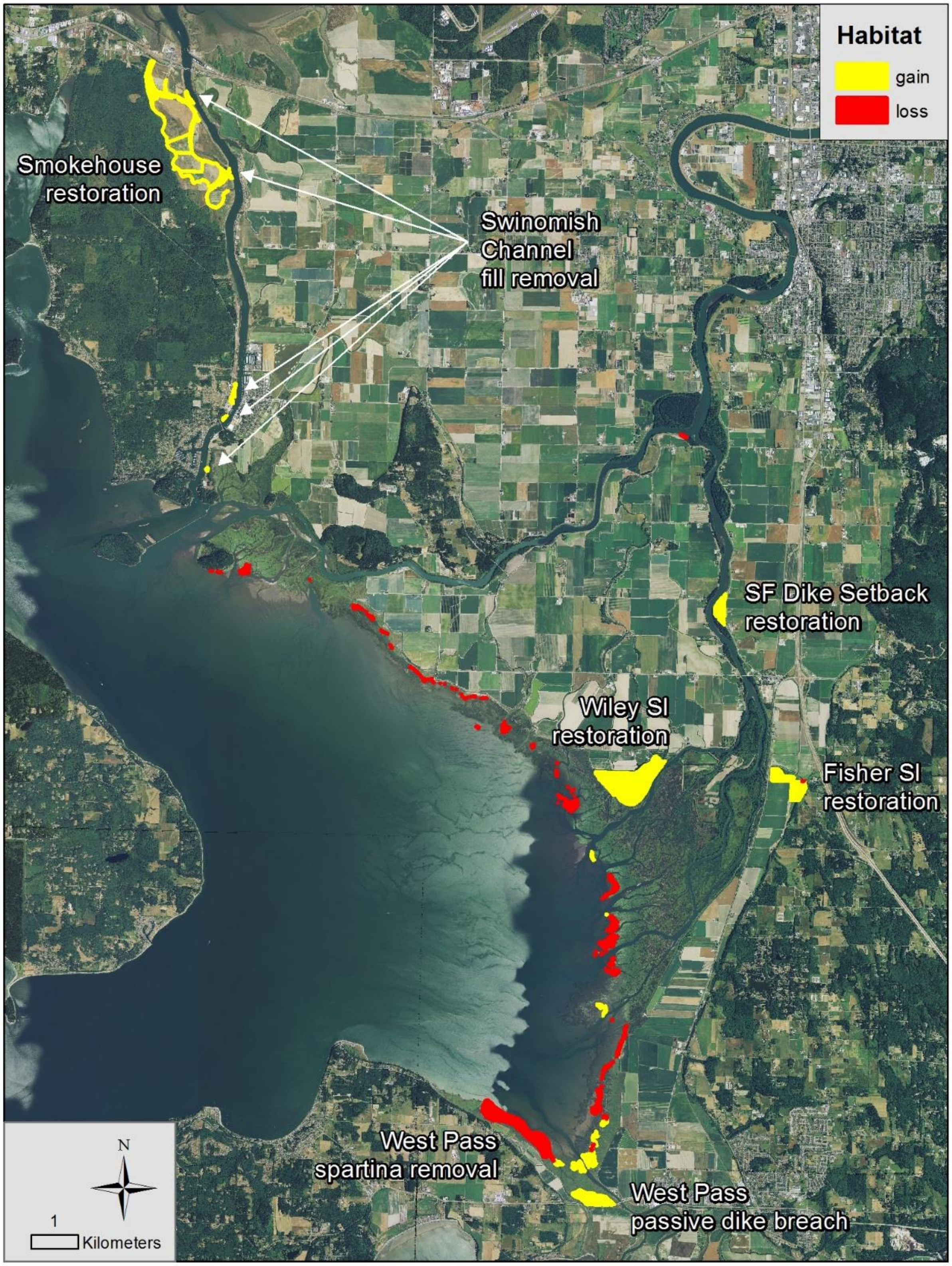

Figure 4. Map of gains and loss of tidal delta extent for the Skagit tidal delta 2004 - 2013.

Only the Wiley Slough restoration project accounted for in the 2013 dataset is expected to have significant downstream or 'outside the dikes' increases in tidal channel extent. The approximately 52-hectare tidal footprint of Fir Island Farm Restoration Project (not accounted for in this dataset because the restoration occurred in the summer 2016) also is expected to have significant downstream or 'outside the dikes' increases in tidal channel extent.

Conclusions

These status and trends results provide both 'good news' and 'bad news' related to implementation of the Skagit Chinook Salmon Recovery Plan's tidal delta restoration and protection strategies and associated monitoring plan. Taken together, these observations lead to several recommendations for adaptively managing our monitoring plans, strategies, and research plans. Our monitoring results demonstrate it will be the net sum of natural- and human- caused gains and losses of delta habitat over time that will achieve the Skagit tidal delta's DFC of 4,232.6 hectares. If overall gains and losses (i.e., net result of Table 7) continue at the same pace as observed between 2004 and 2013 – including the two unique habitat changes described above – the Skagit's DFC for tidal delta extent will not be achieved until year 2096, 91 years after Chinook Recovery Plan implementation started. Moreover, once DFC has been achieved, periodic tidal delta restoration, at the rate of 19 hectares per decade, will be required to maintain DFC assuming the observed rate of natural delta habitat loss remains the same. However, large scale spartina infestation in the Skagit tidal delta has been eradicated and dike failures are usually repaired or become official restoration projects, so we excluded the effects from these two unique observations to more realistically estimate three scenarios of how long it could take to achieve Skagit tidal delta DFC. The scenarios are: 1) fastest observed restoration pace, 2) slowest observed restoration pace, and 3) achieve DFC at the midpoint of a 50-year recovery plan. The rates used for restoration and natural habitat losses are shown in Table 8.

All values, except the rate of restoration needed to achieve Scenario 3, are from observed data. Table 8 shows results for: (a) the year when DFC is achieved; (b) the amount of restoration required to achieve DFC; (c) the amount of additional restoration required to maintain DFC through year 2106; and (d) the total amount of restoration needed to achieve and maintain DFC through 2106. Year 2106 is the year when DFC is achieved by Scenario 2, the slowest of the three scenarios to achieve DFC.

Under Scenario 1 the Skagit's DFC for tidal delta extent is achieved in year 2045, 40 years after Chinook Recovery Plan implementation started (Table 8). Under Scenario 2, DFC is achieved in year 2106, over 100 years after Chinook Recovery Plan implementation started. Under Scenario 3 DFC is achieved in year 2030, but it takes an average of 47 hectares per year of restoration, nearly a doubling of the fastest observed restoration pace to date. Interestingly, achieving DFC sooner requires less total restoration to achieve and maintain DFC. Moreover, it is likely that costs for completing large capital projects such as tidal delta restoration will increase over time. Together these two issues suggest it is more cost effective overall to achieve DFC sooner rather than later.

Table 8. Summary of scenarios for achieving Skagit tidal delta extent DFC.

DFC scenario	DFC achieved (year)	Restoration amount needed (2014-DFC)	Additional restoration to maintain DFC though year 2106	Total restoration to achieve and maintain DFC
Scenario 1: Fastest observed restoration pace Restoration pace = 25.8 ha/yr Natural gain/loss rate = -1.9 ha/yr	2045	825.6 ha	117.1 ha	942.7 ha
Scenario 2: Slowest observed restoration pace • Restoration pace = 10.2 ha/yr • Natural gain/loss rate = -1.9 ha/yr	2106	948.6 ha	0.0 ha	948.6 ha
Scenario 3: DFC by mid-point of a 50 year recovery plan • Restoration pace = 47.0 ha/yr • Natural gain/loss rate = -1.9 ha/yr	2030	799.0 ha	145.9 ha	944.9 ha

3.5 Recommendations for Tidal Delta Habitat

Monitoring Recommendations

Recommendation 1: Continue monitoring of *tidal delta extent* (and other habitat extent indicators) for the Skagit tidal delta at 5 year intervals, in keeping with monitoring of other geomorphic systems.

Recommendation 2: Monitor the area of the unvegetated part (distal edge/mudflats) of the Skagit Tidal Delta at 5 year intervals.

Recommendation 3: Adopt Tidal Delta Progradation Rate as an Indicator and determine its desired future condition. This was not an explicit indictor in the 2005 Skagit Plan.

Recommendation 4: Monitor functional habitat separately from habitat that is impaired (dredged, tidally muted, armored, and/or covered with overwater structures) based on methods shown in chapter 4 of Beamer et al. (draft, 2015).

> *Consideration:* Skagit tidal delta and pocket estuary habitat extent results include areas of channels that are dredged, tidally muted, armored, and/or covered with overwater structures – each of which is inconsistent with the idea of functional habitat.

Recommendation 5: Include monitoring location and area of overwater structures and location and length of shoreline armoring for natal estuaries and the nearshore system.

Recommendation 6: Complete GIS Habitat Census Error Assessment.

Recommendation 7: Refine the indicator for tidal delta connectivity/fragmentation.

Hypotheses and Desired Future Conditions Recommendations

Recommendation 8: The 2005 Skagit Chinook Recovery Plan hypothesized that one desired future condition for achieving Chinook recovery was to restore additional smolt capacity of 1.35 million in the tidal delta. We recommend no changes to these desired future conditions.

Strategies Recommendations

Recommendation 9: It now appears that sea level rise and systemic channelization in the tidal delta have reduced extant habitat capacity and resiliency for future habitat evolution. As a result, the location of future habitat restoration should be evaluated for risk from sea level rise and disrupted sedimentation. In cases where the proposed restoration is likely to be diminished as a result of these stressors, we need to adjust or relocate the proposed action to account for this risk.

Recommendation 10: Update the timeline for meeting and maintaining estuary rearing DFC given pace of restoration for 2005 to 2019 and other factors. Updated restoration strategies may need to do more than just increase the pace and magnitude of individual restoration projects within the delta.

Recommendation 11: Expand strategies to also focus on global and landscape-scale stressors (e.g., sediment routing and carbon pollution) referenced above into our framework in the Skagit Chinook Salmon Recovery Plan that expands our restoration focus beyond site-scale hypotheses of isolation by diking.

Recommendation 12: Continue habitat protection strategies, as they seem to be working with respect to tidal delta extent.

Recommendation 13: Explicitly incorporate predicted climate change impacts such as sea level, storm surge, etc., and sediment routing within the Skagit tidal delta into an updated strategy for the Skagit tidal delta.

> *Consideration:* Update the restoration strategy and conceptual projects to realistically achieve the DFC in the updated timelines from recommendation 2, given the understanding of current and future context in the Skagit delta.

Research Recommendations

Recommendation 14: There is no coordinated, comprehensive, funded effort to further research sediment dynamics and tidal delta formation in the Skagit, though there are early hypotheses that this trend will accelerate as sea level continues to rise and the predicted Skagit River sediment budget increases into the future. This gap should be addressed.

3.6 References

Beamer, E., J. Haug, C. Rice, and K. Wolf. 2009. Nearshore fish assemblages in reference and Spartina removal sites located in south Skagit Bay. Skagit River System Cooperative, LaConner, WA. Available at: www.skagitcoop.org.

Beamer, E., A. McBride, C. Greene, R. Henderson, G. Hood, K. Wolf, K. Larsen, C. Rice, and K. L. Fresh. 2005. Delta and nearshore restoration for the recovery of wild Skagit River

Chinook salmon: Linking estuary restoration to wild Chinook salmon populations. Supplement to Skagit Chinook Recovery Plan, Skagit River System Cooperative, LaConner, WA. Available at: www.skagitcoop.org.

Beamer, E, A McBride, K Wolf, A Hook, and WG Hood. 2015. Skagit Monitoring Pilot Project: Methods and results for estuarine and nearshore habitat targets identified in the 2005 Skagit Chinook Recovery Plan. Skagit River System Cooperative, LaConner, WA.

Beamer, E. and K. Wolf. 2017. Skagit Chinook Habitat Monitoring Fact Sheet: Change in Tidal Delta Habitat Extent, 2004 – 2013. Skagit River System Cooperative, La Conner, WA.

Hood, W. G. (2004), Indirect environmental effects of dikes on estuarine tidal channels: Thinking outside of the dike for habitat restoration and monitoring, Estuaries, 27, 273–282.

Hood, W.G., E.E. Grossman, and C. Veldhuisen. 2016. Assessing tidal marsh vulnerability to sea-level rise in the Skagit Delta. Northwest Science 90(1):79-93. 2016. doi: http://dx.doi.org/10.3955/046.090.0107.

4.0 Nearshore Pocket Estuaries

Pocket estuaries are partially enclosed embayments found along the shoreline that are created by coastal landforms and/or antecedent geology and topography (stream valleys, coastal lowlands), and that often have depressed salinity compared to adjacent marine waters due to small streams, ground water, and surface runoff. Pocket estuaries are typically made up of low energy habitats, including tidal channels, salt marshes, large driftwood accumulation, and impoundments. The habitats within the pocket estuary are maintained by a variable combination of wave, tidal, and fluvial processes that determine the specific pocket estuary types. Pocket estuaries and small coastal streams draining into the nearshore within the Whidbey Basin are important rearing habitat for fry migrant Chinook salmon originating from the three Chinook salmon bearing rivers of the Whidbey Basin (Beamer et al 2003, Beamer et al 2006b, Beamer et al 2013). Because of the importance of pocket estuaries to Chinook salmon, restoration and protection of pocket estuaries has been a priority for Skagit and Island counties and other Whidbey Basin Chinook salmon recovery plans in the following strategies: Tidal delta restoration, and Protection of habitat quality, and habitat structure.

A set of Common Indicators for monitoring Puget Sound Chinook salmon habitat (e.g., Fore 2015) has been generally accepted by Lead Entities in order to guide and standardize monitoring across all of Puget Sound (Table 9). Indicators measured for pocket estuaries are: 1) count of pocket estuaries accessible to juvenile salmon, 2) the extent of accessible pocket estuary habitat by type, and 3) relative landscape position or connectivity. Connectivity of pocket estuaries is expressed as two separate metrics: distance between pocket estuaries and distance from nearest Chinook salmon natal river. All Chinook salmon utilizing pocket estuaries must find them via migration pathways, traveling from their natal river estuary into pocket estuary habitats associated with the adjacent marine basin. These pathways are used to describe connectivity between habitats.

Table 9. Crosswalk of indicators for pocket estuaries from the 2005 Skagit Recovery Plan and PSP Common Indicator list

Skagit Chinook Plan Indicator	PSP Common Indicator	Skagit Method/Data Type
Count of pocket estuaries accessible to juvenile salmon	Pocket estuary count	GIS census of pocket estuaries (points)
Pocket estuary area/extent accessible to juvenile salmon	Pocket estuarine habitat area that is accessible Extent of connected tidal wetlands Extent of functional tidal channels	GIS census of pocket estuaries (polygon data)
Median distance between pocket estuaries	No common indicator identified	GIS census of pocket estuaries (points)
Median landscape connectivity	No common indicator identified	integrated with GIS representation of fish migration pathways (lines)

This report presents Whidbey Basin pocket estuary habitat count, extent, and connectivity as of 2014 (current status) and the 2005-2014 trend for pocket estuary habitat count, extent, and connectivity. Natal use of Whidbey Basin pocket estuaries and small streams is possible for chum and coho salmon depending on stream size and other watershed characteristics (Beamer et al 2013). For all four indicators, detailed method information and data origin can be found in Beamer et al, 2015.

4.1 Count of Pocket Estuaries Accessible to Juvenile Chinook Salmon

Description of Indicator

Pocket estuaries accessible to juvenile Chinook salmon are defined as those pocket estuaries that have tidal connection at least some of the time.

Methods

Accessible pocket estuaries were digitized heads-up on a Wacom DTU-2231 interactive pen display tablet in ArcGIS (v. 10x) where the point was placed at the mouth of the pocket estuary outlet channel. Digitizing scale of points varied based on the actual size of the pocket estuary (Figures 5 and 6). Remote sensed imagery shows whether pocket estuaries exist and whether there is a tidal hydrologic connection. When both characteristics are observed, i.e., pocket estuary habitat is present and tidal connection is present, then we infer juvenile salmon have access to the pocket estuary. If fish sampling has been conducted at the site and the results verify juvenile salmon presence, then we attribute the pocket estuary point as a site where salmon presence is known (Table 10). To our knowledge, no fish sampling has occurred at six Whidbey Basin sites (Ika Lagoon, Gedney Island Northeast, Mariners Cove, Mueller Park Lagoon N, Mueller Park Lagoon S, North Bluff Cr Lagoon).

Status and Trends

In 2005, 24 accessible pocket estuaries were mapped in the Whidbey Basin. Of the 24 accessible pocket estuaries, nine were within one day's migration from the Skagit River tidal delta by fry migrant Chinook salmon (i.e., in Skagit Bay) (Figure 5). Fourteen of the 24 pocket estuaries accessible to juvenile salmon in the Whidbey Basin have documented juvenile salmon presence results. We found 25 pocket estuaries accessible to juvenile salmon in the Whidbey Basin in 2014 (Figure 6). The 25 accessible pocket estuaries within the Whidbey Basin include one more than was identified in 2005 (Beamer et al 2015) and is due to restoring connectivity to Crescent Harbor Saltmarsh. Of the 25 accessible pocket estuaries, 17 have known juvenile salmon presence (Table 10).

Figure 5. Whidbey Basin pocket estuaries that were accessible to juvenile Chinook salmon in 2005. Red lines are fish migration pathways used for landscape position analysis and blue stars represent river

Figure 6. West Whidbey Island and Whidbey Basin pocket estuaries that were accessible to juvenile Chinook salmon in 2014. Red lines are fish migration pathways used for landscape position analysis and blue stars represent river mouths.

Table 10. Pocket estuaries accessible to juvenile salmon with known juvenile Chinook salmon use. Names of pocket estuaries coincide with names on Figures 5 and 6.

Basin	Pocket Estuary	Reference
Whidbey	Ala Lagoon	Beamer 2007a
	Arrowhead Lagoon	Beamer et al 2006b
	Crescent Harbor	Beamer et al 2016
	Elger Bay	Heatwole 2004; Kagley et al 2007b
	English Boom Lagoon	Beamer et al 2009a
	Grassers Lagoon	Beamer et al 2006b
	Harrington Lagoon	Beamer et al 2006a; Kagley et al 2007a
	Iverson Marsh	Beamer et al 2006b
	Kiket Lagoon	Beamer et al 2014
	Lone Tree Lagoon	Beamer et al 2003; Beamer et al 2006b; Beamer et al 2009b
	Maylor Marsh	Heatwole 2004
	Race Lagoon	Heatwole 2004; Henderson et al 2007
	Strawberry Point Lagoon	2016 SRSC unpublished data
	Sunnyshore Acres	Beamer et al 2006b
	Triangle Cove	Beamer et al 2006b
	Tulalip Bay	Beamer et al 2006b
	Turners Bay	Beamer et al 2006b; Beamer et al 2007b

4.2 Accessible Pocket Estuary Area and Extent of Functional Tidal Channels

Description of Indicator

Accessible pocket estuary area and extent of functional tidal channels accessible to juvenile Chinook salmon only include tidal and subtidal habitats at tidal stage approaching Mean Low Water (MLW). The extent of pocket estuary habitat by type is measured as the area of polygons mapped remotely. Only pocket estuaries that are determined to be accessible to juvenile salmon are measured.

Methods

We digitized pocket estuary features heads-up on a Wacom DTU-2231 interactive pen display tablet in ArcGIS (v 10x) at a scale ranging from 1:150 to 1:1,500. We digitized pocket estuary feature types as polygons according to the nested scale classification developed by the RITT Common Framework (i.e. Bartz et al 2013) which has been adopted by the PSP for tracking implementation of Chinook recovery plans. Possible pocket estuary attributes for polygons are shown in Table 11. Habitat areas can be summarized by any polygon type, but generally the pocket estuary habitat area accessible to juvenile Chinook salmon would only include intertidal and subtidal polygons.

Table 11. Classification of pocket estuaries based on RITT Common Framework (Bartz et al 2013) used to attribute GIS polygons within pocket estuaries (see definitions in Appendix 2).

<table>
<tr><th>Broad habitat</th><th>System type</th><th>System subtype</th><th>Shoreline type</th><th>Habitat type</th></tr>
<tr><td rowspan="3">Nearshore marine</td><td rowspan="2">Drift cell</td><td>Coastal landform</td><td>• Barrier beach</td><td rowspan="3">• Backshore berm
• Backshore colluvium
• Backshore dune
• Backshore wood
• Built
• Channel (intertidal or subtidal)
• Fill (intertidal or subtidal)
• Impoundment (intertidal or subtidal)
• Intertidal wood
• Intertidal fill wood
• Low tide terrace
• Rocky beach
• Rocky platform
• Tidal marsh
• Tidal scrub shrub
• Tidal forest</td></tr>
<tr><td>Pocket estuary</td><td>• Created
• Drowned channel lagoon
• Longshore lagoon
• Stream delta lagoon
• Tidal channel lagoon
• Tidal channel marsh
• Tidal delta lagoon
• Modified</td></tr>
<tr><td>Rocky shoreline</td><td>Rocky pocket estuary</td><td>• Created
• Pocket beach estuary
• Pocket beach lagoon
• Pocket beach tidal marsh
• Modified</td></tr>
</table>

For the 2005 habitat mapping we used digital imagery or georeferenced aerial photographs from 2000-2004, including: 1) 2000 Resource management project by Triathlon for the Swinomish Indian Tribal Community color infrared digital orthophotos with 1-ft pixel resolution, 2) 2000 Nearshore mapping project by Triathlon for Skagit River System Cooperative true color digital orthophotos with 2-ft pixel resolution, 3) 2001 Resource management project by WA Department of Natural Resources true color aerial photos, scanned and georeferenced in-house with 1-ft pixel resolution, and 4) 2004 Resource management project by Triathlon for the Swinomish Indian Tribal Community color infrared digital orthophotos with 0.5-ft pixel resolution

For the 2014 update we used four different image datasets to digitize pocket estuary habitat in 2012-2015 depending on the geographic coverage of each. The images are: 1) Island County 2014 4-band orthophotos for true color and color infra-red (CIR) images (0.15m pixel size); 2) Skagit County 2013 and 2015 pictometry images (0.15m and 0.1 m pixel size, respectively); 3) Snohomish County 2012 orthophotos for true color (0.3m pixel size), and 4) 2015 National Agriculture Imagery Program (NAIP) orthophotos (1m pixel size) for color infra-red (CIR) images outside of Island County. The time period represented by this polygon data layer of Whidbey Basin and west Whidbey pocket estuaries represents approximately ten years of Puget Sound Chinook recovery plan implementation (circa 2014).

The basic on-screen habitat mapping of individual pocket estuaries was done at a scale between 1:300 and 1:800 and followed a series of 4 steps to improve accuracy over what is apparent from orthophoto images alone. The steps are:

1. We used high resolution LiDAR (1m pixels) displayed at 1/3-meter intervals to identify unclear boundaries between intertidal vs backshore, backshore vs upland. We generally mapped areas below 3m NAVD88 as intertidal and above 3m as backshore; above 4m was considered upland and not mapped unless it was a known modification within the historic pocket estuary. In such cases, the polygon type may be: 'intertidal fill', 'created', or 'built' depending on the circumstance.
2. We used pictometry's oblique view to better interpret boundaries between habitat types that may be obscured in the normal aerial view. Specific examples include overhead tree canopy or houses on docks which can give a false sense of habitat boundaries.
3. We used Google Earth to aid in mapping boundaries between impoundment vs low tide terrace or tidal marsh vs floating vegetation by examining different air photos taken over the past several years at different tide levels. Having consistency in tidal stage between photo series used to map tidally influenced habitat is important. Specifically, for pocket estuary mapping having photos taken at a tidal stage approaching Mean Low Water (MLW) allows the surveyor to clearly see channel/impoundment, tidal wetlands, and unvegetated tidal flats. Having photos taken at Mean Lower Low Water (MLLW) or extreme low water (ELW) was not necessary for our purposes.
4. We used 2015 NAIP 4-band orthos displayed as CIR (color-infrared) to aid mapping of vegetated areas vs non-vegetated.

For the indictor 'pocket estuary area accessible to juvenile salmon' we summed the Table 11 habitat types: beach face, channel, impoundment, intertidal wood, low tide terrace, tidal forest, tidal marsh, and tidal scrub shrub for all pocket estuary shore types. These are the habitat types that are tidally inundated and thus where juvenile fish could live and access prey resources when flooded. We do not count habitats at elevations higher than MHHW or habitats seaward of barrier beaches as 'pocket estuary area accessible to juvenile salmon.'

Pocket estuary habitat extent results include areas that may be tidally muted, dredged, filled, armored, and/or covered with overwater structures – each of which is inconsistent with the idea of fully functional habitat for salmon. Moreover, many Whidbey Basin and West Whidbey pocket estuaries bear a human disturbance signal compared to their historic condition. Often this is in the form of truncating the system to some remnant of its historic extent. We utilized findings from an allometric analysis of tidal channel characteristics to address the question whether reducing the size of a pocket estuary from its historic extent is reason to classify the site functionally impaired for salmon.

Hood (2007) found no difference in relationships of physical tidal channel metrics with tidal marsh area for tidal marshes adjacent to levees compared to reference marsh sites. The sites adjacent to levees in the Hood study are equivalent to our truncated sites. Thus, under our definition of 'functional' tidal wetland systems, including pocket estuaries, can be considered 'functional' habitat even though they may be reduced from their historic extent, i.e., are truncated. To infer habitat functionality, we documented the presence or absence of four habitat disturbances: tidal muting structures, dredging, armoring, and over water structures. According to our classification, functional habitat for salmon in pocket estuaries:

- is not hydrologically muted,
- does not have significant wetted areas dredged or tidal wetlands filled, and
- is without extensive coverage of overwater structures or armoring.

We did not quantify the four disturbances for the 25 pocket estuaries monitored, but we did document which sites had tidal muting and extensive modification to their tidal footprint and/or outlet/inlet channel.

Status and Trends

In 2004-2006, the 24 Whidbey Basin pocket estuaries accessible to juvenile salmon ranged in their habitat extent from 0.55 hectares (Priest Point Lagoon) to 93.85 hectares (Triangle Cove). The nine pocket estuaries accessible to juvenile salmon within Skagit Bay had 8.71 hectares of channel and impoundment combined and a total of 34.90 hectares of habitat exposed to tidal hydrology (Table 12). The remaining 15 pocket estuaries had 54.59 hectares of channel and impoundment combined and a total of 203.40 hectares of habitat exposed to tidal hydrology. Total pocket estuary habitat accessible to juvenile salmon for the Whidbey Basin in 2004-2006 was 63.30 hectares of channel and impoundment combined and a total of 238.30 hectares of habitat exposed to tidal hydrology.

Table 12. Summary of habitat area (ha) by type within Whidbey Basin pocket estuaries 2004-2006

Habitat	Skagit Bay	Whidbey Basin Outside Skagit Bay	All Whidbey Basin
channel	1.08	14.40	15.49
impoundment	7.63	40.19	47.82
Total channel & impoundment	**8.71**	**54.59**	**63.30**
beach face	0.67	1.02	1.68
intertidal wood	1.05	19.08	20.13
low tide terrace	20.34	72.79	93.13
tidal salt marsh	10.39	109.51	119.90
tidal scrub-shrub	2.46	1.00	3.46
Total Intertidal	**34.90**	**203.40**	**238.30**
backshore berm	1.25	2.77	4.01
backshore wood	0.39	0.64	1.04
fill	0.50	0.84	1.34
Total Backshore	**2.13**	**4.25**	**6.39**
Grand Total	**45.75**	**262.24**	**307.99**

Total habitat area accessible to juvenile salmon for the 25 Whidbey Basin pocket estuaries during 2014 was 409.30 hectares with the smallest site (Strawberry Point Lagoon) having only 0.36 hectares and the largest site (Triangle Cove) having 94.56 hectares (Table 13). Since the 2005 inventory, the one new pocket estuary accessible to juvenile salmon – Crescent Harbor Saltmarsh – added another 94.13 hectares of habitat while two other systems (Lone Tree Lagoon, Turners Bay) increased in size due to restoration activities occurring after 2005. Appendix 3 shows each of the Whidbey Basin pocket estuary mapped at the habitat and shore type levels. Text in Appendix 3 associated with each map figure describes trends and disturbances at each site.

Overall impairment: Three of the 25 pocket estuaries accessible to juvenile salmon were impaired in 2014 based on extensive dredging, filling, armoring, and overwater structures (Camano Country Club, Gedney Island Northeast, Mariners Cove). One of the impaired sites had tidal muting (Camano Country Club).

Outlet/inlet channel condition: Nineteen of the 25 pocket estuaries accessible to juvenile salmon had natural outlet channels that were open to full tidal hydrology in 2014 (Table 14). Of the remaining four, one had a completely created outlet (Strawberry Point Lagoon). Mariners Cove, Camano Country Club, and Gedney Island Northeast outlets are dredged deeper than natural. Crescent Harbor's outlet channel is modified with bridge abutments and likely narrower than a natural channel would be for a 90+ hectare tidal system. Mueller Park Lagoon N appears to be artificially impounded at its mouth with a small built or intertidal fill area.

Tidal footprint condition: Ten of the 25 pocket estuaries accessible to juvenile salmon had a natural tidal footprint in 2014, meaning the area exposed to tidal hydrology was not reduced significantly by human causes such as diking or filling (Table 14). Of the remaining pocket estuaries, six had tidal footprints significantly reduced in size by human causes, one site was created, and three sites were extensively dredged, filled, and armored. It was outside our scope of work to estimate how much the tidal footprint was reduced from historic condition for the truncated sites. Our task was to measure the amount of habitat present in 2014. Also, for our method of classifying pocket estuary functionality, sites can be considered 'functional' habitat even though they may be reduced in size from their historic extent.

Table 13 Summary of pocket estuary habitat area accessible to juvenile salmon (ha) by habitat type and site within the Whidbey Basin, 2014.

Basin	Site	beach face	intertidal wood	low tide terrace	tidal forest	tidal marsh	tidal scrub shrub	channel	impoundment	Total
Whidbey Basin	Ala Lagoon	0.608	0.149	5.869		0.337		0.073	0.013	7.048
	Arrowhead Lagoon		0.185	0.177		1.741		0.115	0.133	2.350
	Camano Country Club			1.534		0.044			3.734	5.312
	Crescent Harbor		2.677	55.798		9.168	12.326	2.180	11.985	94.133
	Elger Bay	0.032	15.069	1.764	0.256	8.437	1.322	0.699	0.071	27.650
	English Boom Lagoon		0.552	0.022		0.660		0.042	0.076	1.353
	Gedney Island NorthEast								1.843	1.843
	Grassers Lagoon	0.190	0.109	5.318		0.715		0.066	1.347	7.745
	Harrington Lagoon		0.074	0.374		0.375		0.043	2.594	3.460
	Ika Lagoon		0.519			5.798	0.471	0.072	0.003	6.862
	Iverson Marsh	0.012	0.490	1.198		7.508		0.402		9.609
	Kiket Lagoon			0.114		0.310		0.005	0.746	1.174
	Lone Tree Lagoon			0.200		0.726		0.199	1.313	2.438
	Mariners Cove			2.250				0.015	2.205	4.470
	Maylor Marsh		0.708	1.170		20.396		0.683	0.830	23.787
	Mueller Park Lagoon N			0.093		0.052		0.016	0.845	1.006
	Mueller Park Lagoon S		0.018	0.045		0.209		0.058	1.131	1.461
	North Bluff Cr Lag	0.039	0.469	0.397		2.103		0.085	1.009	4.102
	Priest Point		0.154	0.501		0.340		0.053		1.048
	Race Lagoon	0.070	1.630	2.223		4.096		0.917	6.276	15.212
	Strawberry Point Lagoon	0.201	0.022	0.032		0.002		0.002	0.103	0.363
	Sunnyshore Acres		2.508	0.547		1.693		0.181	0.015	4.944
	Triangle Cove		1.877	79.351		5.779		7.476	0.072	94.556
	Tulalip Bay	0.075	0.484	52.386		0.755		0.248	10.933	64.881
	Turners Bay	0.078	0.873	15.192		4.978	0.012	0.509	0.850	22.492

Table 14 Summary of pocket estuary outlet/inlet and tidal footprint conditions in 2014. Pocket estuaries shown in bold font are significantly impaired for juvenile salmon habitat function.

Basin	Site	2014 condition	
		Outlet/inlet channel condition	Tidal footprint compared to historic
Whidbey Basin	Ala Lagoon	natural	natural
	Arrowhead Lagoon	natural	truncated
	Camano Country Club	**modified**	**extensively dredged, armored, &filled**
	Crescent Harbor	modified	truncated (partially filled)
	Elger Bay	natural	natural
	English Boom Lagoon	natural	truncated
	Gedney Island NorthEast	**modified**	**extensively dredged, armored, &filled**
	Grassers Lagoon	natural	truncated
	Harrington Lagoon	natural	truncated
	Ika Lagoon	natural	natural
	Iverson Marsh	natural	truncated
	Kiket Lagoon	natural	truncated
	Lone Tree Lagoon	natural	natural
	Mariners Cove	**modified**	**extensively dredged, armored, &filled**
	Maylor Marsh	natural	truncated
	Mueller Park Lagoon N	modified	natural
	Mueller Park Lagoon S	natural	natural
	North Bluff Cr Lag	natural	truncated
	Priest Point	natural	truncated
	Race Lagoon	natural	natural
	Strawberry Point Lagoon	created	artificial
	Sunnyshore Acres	natural	natural
	Triangle Cove	natural	natural
	Tulalip Bay	natural	natural
	Turners Bay	natural	truncated

Between 2005 and 2014 Whidbey Basin pocket estuary tidal footprint changed from 304.523 hectares in 2005 to 409.299 hectares in 2014, an increase of 104.776 hectares (Table 15). Three completed restoration projects are the primary reason for a net increase in pocket estuary habitat. A total of 97.61 hectares was restored over the nine-year period primarily from three projects (Crescent Harbor, Turners Bay, and Lone Tree Lagoon) with Crescent Harbor restoring 94 hectares of historic saltmarsh alone. Gedney Island Northeast increased pocket estuary tidal footprint, but its 0.4-hectare expansion was of a boat harbor through dredging. Restoration at Ala Spit appears to have reduced the tidal footprint of Ala Lagoon. The removal of rock groins at the south end of the spit may have contributed to increased overwash sediment and thus helped to build the barrier beach thereby reducing the lagoon's size slightly. A natural change at North Bluff Creek Lagoon was detected where the spit lengthened approximately 60 meters northward between 2005 and 2014 creating new pocket estuary channel area. It is noteworthy that additional intertidal filling was not detected between the 2005 and 2014 time period.

Differences in mapping methods between years are likely contributing to the 2005 – 2014 trend result for pocket estuary habitat change. The issue of a methods-based explanation for habitat change can be explored with nineteen sites where only mapping methods changed (i.e. there was no obvious natural or human caused change at the site between 2005 and 2014) (Table 15). For these sites we observed a median percent change of 5.74% (±2.99 95% CI) (Figure 7) and a decline in percent change by site size (Figure 8). Also, most (15 of 19) of the percent change values were in the positive direction, meaning the 2014 mapping effort generally found more habitat than the 2005 mapping effort.

The differences between 2005 and 2014 results for these 19 sites are likely caused by: 1) mapping methods, 2) orthophoto image resolution, and 3) surveyor differences. Obviously, using higher resolution images in 2014 (0.15m pixel size compared to 1.0m) improves accuracy in habitat delineation. The four additional methods steps developed for the 2014 survey also improve accuracy and consistency of mapping. These two improvements alone lead us to believe the 2014 results are more accurate than the 2005 results. Separate experiments using the exact same methods and images, but different surveyors would reveal possible surveyor influence on results but are not available. We suspect surveyor variability adds a small amount of noise in results that may hinder small scale (i.e. at the individual habitat polygon level) and small magnitude (e.g., < 0.1 hectares) interpretation of results but would likely not be a factor in detecting effects of restoration projects or habitat loss signals at the full site or basin level.

Table 15 Whidbey Basin pocket estuary trend for habitat area accessible to juvenile salmon 2005 – 2014.

Change type	Site	Hectares of habitat			% change	Comments
		Year 2005	Year 2014	Change		
Mapping Methods	Harrington Lagoon	3.457	3.46	0.003	0.1%	
	Mariners Cove	4.461	4.47	0.009	0.2%	
	Tulalip Bay	64.725	64.881	0.156	0.2%	
	Priest Point	1.061	1.048	-0.013	1.2%	
	Triangle Cove	93.212	94.556	1.344	1.4%	
	Grassers Lagoon	7.540	7.745	0.205	2.7%	
	Elger Bay	26.823	27.65	0.827	3.1%	
	Ika Lagoon	6.619	6.862	0.243	3.7%	
	Iverson Marsh	9.194	9.609	0.415	4.5%	
	Mueller Park Lagoon S	1.382	1.461	0.079	5.7%	
	Camano Country Club	5.706	5.312	-0.394	6.9%	
	Maylor Marsh	22.197	23.787	1.590	7.2%	Between 2011 and 2014 pilings were removed but the action had no detectable influence on tidal footprint extent
	Strawberry Point Lagoon	0.337	0.363	0.026	7.6%	
	Arrowhead Lagoon	2.162	2.35	0.188	8.7%	
	Kiket Lagoon	1.289	1.174	-0.115	8.9%	
	Sunnyshore Acres	4.503	4.944	0.441	9.8%	
	Race Lagoon	13.714	15.212	1.498	10.9%	
	Mueller Park Lagoon N	1.138	1.006	-0.132	11.6%	
	English Boom Lagoon	1.067	1.353	0.286	26.8%	Some restoration of connectivity was completed at the site circa 2006/7 but it had no detectable influence on tidal footprint extent
Mapping Methods and Real Change	Ala Lagoon	8.206	7.048	-1.158	14.1%	**Restoration:** removed rock groins which may have contributed to overwash sediment building the barrier beach in places thus reducing pocket estuary extent
	Crescent Harbor	0.000	94.133	94.133	NA	**Restoration**: tide gate replaced with bridge in 2009
	Gedney Island Northeast	1.439	1.843	0.404	28.1%	**Dredging**: boat harbor area expanded by 0.4333 hectares between 2011 and 2012
	Lone Tree Lagoon	2.216	2.438	0.222	10.0%	**Restoration**: restored 0.125 ha in 2006 (blocking culvert replaced with bridge)
	North Bluff Cr Lag	3.330	4.102	0.772	23.2%	**Natural change**: spit lengthened ~ 60 meters north creating new channel area; backshore was better mapped as intertidal wood in the 2014 survey
	Turners Bay	18.745	22.492	3.747	20.0%	**Restoration**: road removal circa 2008 restored 3.352 hectares to tidal inundation
	Total	**304.523**	**409.299**	**104.776**	**34.4%**	

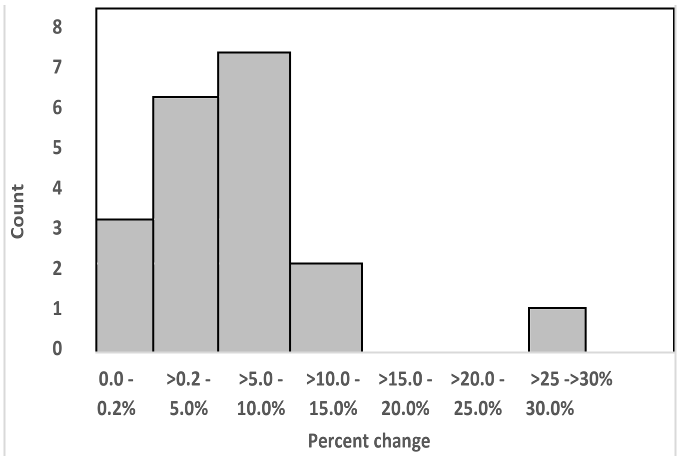

Figure 7. Frequency distribution of 'percent change' values for 19 pocket estuaries where only mapping methods changed and there was no obvious natural or human caused change at the site between 2005 and 2014.

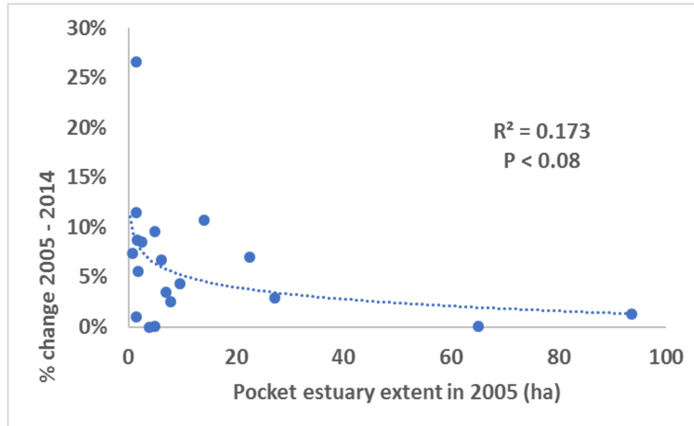

Figure 8. Relationship of 'percent change' and pocket estuary extent for 19 pocket estuaries where only mapping methods changed and there was no obvious natural or human caused change at the site between 2005 and 2014.

4.3 Landscape Position of Pocket Estuaries

Description of Indicators

We measured two indicators under the topic of landscape position of pocket estuaries:

1) *distance of pocket estuaries from natal Chinook salmon estuaries*, and
2) *distance between pocket estuaries*.

Both metrics are measurements of juvenile salmon habitat connectivity. All indicators are measured only for pocket estuaries that are accessible to juvenile salmon. Pocket estuary distance indicators account for the pathway distance a fish must travel between pocket estuaries or from its natal river estuary to a pocket estuary. These distance indicators do not account for the complexity (i.e., branching, alternative pathways) of said pathway. We only report the shortest and most direct pathway for distance metrics.

Methods

To quantify pocket estuary distance indicators, we use GIS line data to depict the pathways fish must take to go from one place to another (e.g., a river mouth to a pocket estuary; one pocket estuary to another pocket estuary). Line data are digitized based on prevailing tidal current direction within the landscape according to a PNNL hydrodynamic model (Yang & Khangaonkar 2007) and the assumption that fry-sized juvenile salmon follow shoreline areas once in the nearshore. Chinook salmon fry movement assumptions are discussed in section 6.1 of Beamer et al (2005). The fish migration pathways used to quantify pocket estuary distance for Whidbey Basin and West Whidbey pocket estuaries in year 2014 are shown as lines in Figure 6.

Status and Trends

Nearest natal Chinook salmon river: For the Whidbey Basin, the distance from a natal Chinook salmon river to an individual pocket estuaries ranges from 0.9 to 54.4 km (Figure 9, left panel). Ika Marsh is the closest to a natal river while Race Lagoon is the furthest. North Bluff Cr Lagoon, Harrington Lagoon, and Race Lagoon are all more than 50 km from the nearest Chinook salmon river within the Whidbey Basin. The median distance of pocket estuaries to the nearest natal Chinook salmon river is 13.9 km for the Whidbey Basin. (Figure 9). Fifteen of the 25 Whidbey Basin pocket estuaries are nearest to the Skagit River whereas only six and four pocket estuaries are nearest to the Snohomish and Stillaguamish Rivers, respectively (Table 16).

Table 16. Count of pocket estuaries by basin to their nearest natal Chinook salmon river.

Closest River	Number of Pocket Estuaries Whidbey Basin
Skagit	15
Snohomish	6
Stillaguamish	4

Nearest neighboring pocket estuary: For the Whidbey Basin, the distance between nearest individual pocket estuaries ranges from 0.2 to 22.3 km (Figure 9, left panel). Mueller Park Lagoons North and South are the closest together at 0.2 km. Elger Bay is furthest from any other pocket estuary, with Sunnyshore Acres its closest neighbor at 22.3 km away. The median distance between pocket estuaries is 3.96 km.

Habitat connectivity is important to Chinook salmon recovery because the ease with which juvenile salmon can find available habitat influences their survival. Juvenile Chinook salmon have been shown to move from one pocket estuary system to another adjacent pocket estuary system (Beamer et al 2013), suggesting connectivity of pocket estuaries within a larger landscape is important ecologically. Also, the location of pocket estuaries in proximity to the source of outmigrating Chinook salmon fry (i.e. their natal river) explains much of the variability in juvenile Chinook salmon abundance and presence in pocket estuaries (Beamer et al 2006b) and in small streams draining into the nearshore system (Beamer et al 2013). Sites closer to the source of fish have more fish and higher presence incidents. Tracking connectivity of pocket estuaries is an important habitat status and trend metric.

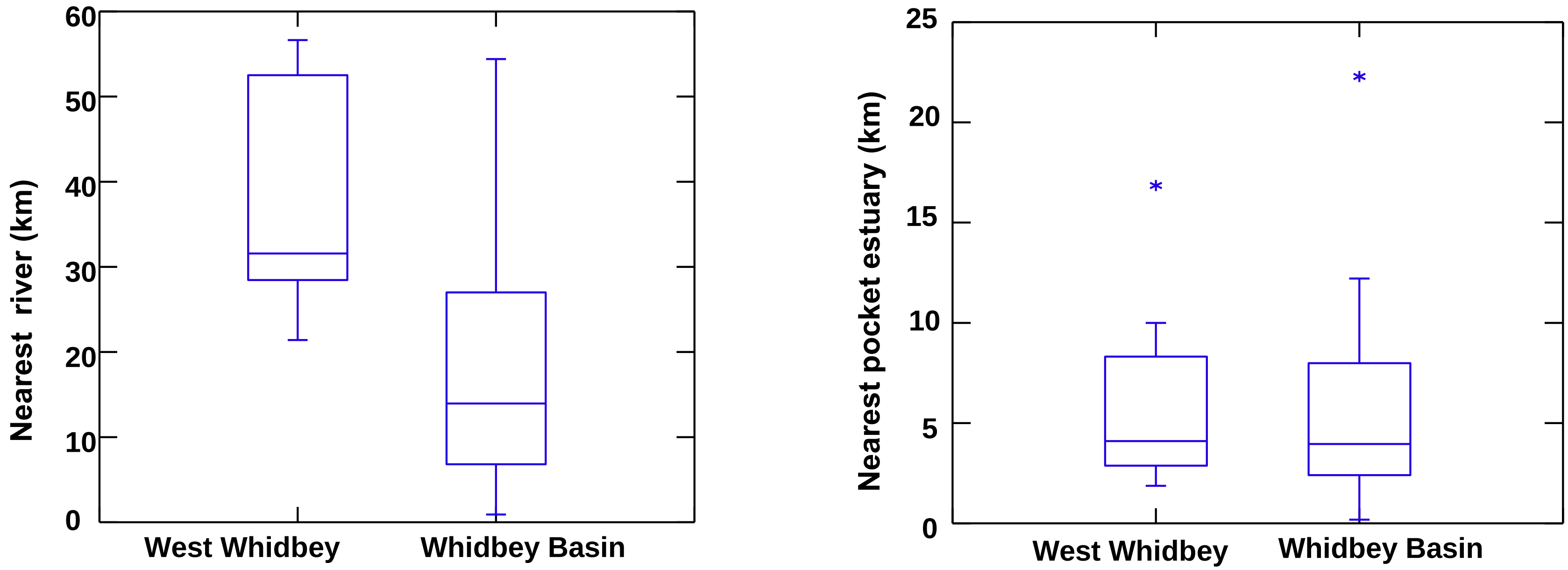

Figure 9. Boxplot results for pocket estuaries accessible to juvenile salmon in 2014: distance from nearest natal river left panel) and distance between pocket estuaries (right panel). Boxes show the median, 25th and 75th percentiles within the 'box.' Whiskers show the 5th and 95th percentiles. Stars are observations that are still within the full distribution. West Whidbey results shown here do not apply to this M&AM Report.

4.4 Recommendations for Pocket Estuary Habitat

Monitoring Recommendations

Recommendation 15: Continue monitoring pocket estuary number, habitat area, accessible habitat and connectivity on 5 year intervals.

Research Recommendations

Recommendation 16: Monitor change of coastal landforms in addition to changes in area to assess coastal landform translation related to climate change/storm wave processes. Observing the direction of net movement of landforms will assist in prioritizing which drift cells are most vulnerable to habitat loss as sea level rise and storm waves effect mobile sediments.

Recommendation 17: Conduct LiDAR analysis to identify potential future pocket estuary habitat within existing systems as sea level rises.

4.5 References

Bartz, K., and coauthors. 2013. Puget Sound Chinook salmon recovery: A framework for the development of monitoring and adaptive management plans. NOAA National Marine Fisheries Service, Northwest Fisheries Science Center, NOAA Technical Memorandum NMFS-NWFSCdraft, Seattle.

Beamer, E., A. McBride, R. Henderson and K. Wolf. 2003. The importance of non-natal pocket estuaries in Skagit Bay to wild Chinook salmon: an emerging priority for restoration. Skagit River System Cooperative Research Report. Available at: www.skagitcoop.org.

Beamer, E., A. McBride, C. Greene, R. Henderson, G. Hood, K. Wolf, K. Larsen, C. Rice, and K. L. Fresh. 2005. Delta and nearshore restoration for the recovery of wild Skagit River Chinook salmon: Linking estuary restoration to wild Chinook salmon populations. Supplement to Skagit Chinook Recovery Plan, Skagit River System Cooperative, LaConner, WA. Available at: www.skagitcoop.org.

Beamer, E., A. Kagley, and K. Fresh. 2006a. Juvenile salmon and nearshore fish use in shallow intertidal habitat associated with Harrington Lagoon, 2005. Skagit River System Cooperative, LaConner, WA. Available at: www.skagitcoop.org.

Beamer, E., A. McBride, R. Henderson, J. Griffith, K. L. Fresh, T. Zackey, R. Barsh, T. WyllieEcheverria, and K. Wolf. 2006b. Habitat and Fish Use of Pocket Estuaries in the Whidbey Basin and North Skagit County Bays, 2004 and 2005. Skagit River System Cooperative, Stillaguamish Tribe, Samish Nation, Tulalip Tribes, and NOAA Fisheries. Available at: www.skagitcoop.org.

Beamer, E. 2007a. Juvenile salmon and nearshore fish use in shoreline and lagoon habitat associated with Ala Spit, 2007. Skagit River System Cooperative Research Program, LaConner, WA. Available at: www.skagitcoop.org.

Beamer, E., R. Henderson, and K. Wolf. 2007b. Juvenile salmon and nearshore fish use in shoreline and lagoon habitat associated with Turners Bay, 2003-2006. Skagit River System Cooperative, LaConner, WA. Available at: www.skagitcoop.org.

Beamer, E., J. Haug, C. Rice, and K. Wolf. 2009a. Nearshore fish assemblages in reference and Spartina removal sites located in south Skagit Bay. Skagit River System Cooperative, LaConner, WA. Available at: www.skagitcoop.org.

Beamer, E., R. Henderson, and K. Wolf. 2009b. Lone Tree Creek and pocket estuary restoration: Progress report for 2004-2008 fish monitoring. Skagit River System Cooperative, LaConner, WA. Available at: www.skagitcoop.org.

Beamer, E.M., W.T. Zackey, D. Marks, D. Teel, D. Kuligowski, and R. Henderson. 2013. Juvenile Chinook salmon rearing in small non-natal streams draining into the Whidbey Basin. Skagit River System Cooperative, LaConner, WA. Available at: www.skagitcoop.org.

Beamer, EM, J Demma, and R Henderson. 2014. Kukutali Preserve Juvenile Chinook salmon and forage fish assessment. Report prepared for Swinomish Indian Tribal Community Planning Department. Skagit River System Cooperative. LaConner, WA.

Beamer, E, A McBride, K Wolf, A Hook, and WG Hood. 2015. Skagit Monitoring Pilot Project: Methods and results for estuarine and nearshore habitat targets identified in the 2005 Skagit Chinook Recovery Plan. Skagit River System Cooperative, LaConner, WA.

Beamer, E, B. Brown, K. Wolf, R. Henderson, and C. Ruff. 2016. Juvenile Chinook salmon and nearshore fish use in habitat associated with Crescent Harbor Salt Marsh, 2011 through 2015. Report to U. S. Department of the Navy, Whidbey Island Naval Air Station. Skagit River System Cooperative, LaConner, WA. Available at: www.skagitcoop.org.

Carman, R., Taylor, K., and Skowlund, P., 2010, Regulating Shoreline Armoring in Puget Sound, *in* Shipman, H., Dethier, M.N., Gelfenbaum, G., Fresh, K.L., and Dinicola, R.S., eds., 2010, Puget Sound Shorelines and the Impacts of Armoring—Proceedings of a State of the Science Workshop, May 2009: U.S. Geological Survey Scientific Investigations Report 2010-5254, p. 49-54.

Fore L., S. Suter, and S. Vynne. 2015. July 10 Memo to Puget Sound Salmon Recovery Council regarding Common Indicators

Herrera Environmental Consultants Inc. 2007. Functional assessment and historical analysis: Crockett Lake at Ebey's Landing National Historical Reserve. Herrera Environmental Consultants Inc, Seattle.

Heatwole, D. 2004. Insect-habitat associations in salt marshes of northern Puget Sound: Implications of tidal restriction and predicted response to restoration. Master's thesis. University of Washington, Seattle.

Henderson, R., and coauthors. 2007. Juvenile salmon and nearshore fish use in shallow intertidal habitat associated with Race Lagoon, 2006 and 2007. Skagit River System Cooperative, LaConner, WA. Available at: www.skagitcoop.org.

Hood, W.G. 2007. Scaling tidal channel geometry with marsh island area: a tool for habitat restoration, linked to channel formation process. Water Resources Research 43, W03409, doi:10.1029/2006WR005083.

Judge, M. 2011. A Qualitative Assessment of Implementation of the Puget Sound Chinook Salmon Recovery Plan. Report to NMFS. Task Order 2002 Puget Sound Chinook Recovery Tracking. 45 pages. Available http://treatyrightsatrisk.org/wp-content/uploads/2012/11/implement-rpt.pdf

Kagley, A., J. Marcell, K. Fresh, and E. Beamer. 2007a. Juvenile salmon and nearshore fish use in shallow intertidal habitat associated with Harrington Lagoon, 2006. Island County Planning & Community Development, Coupeville, WA. Available at: www.skagitcoop.org.

Kagley, A., T. Zackey, K. Fresh, and E. Beamer. 2007b. Juvenile salmon and nearshore fish use in shoreline and lagoon habitat associated with Elger Bay, 2005-2007. Skagit River System Cooperative, LaConner, WA. Available at: www.skagitcoop.org.

Northwest Indian Fisheries Commission. 2012. State of Our Watersheds Report: WRIAs 1-23. 339 pages. Available http://nwifc.org/publications/sow/.

Park, J. 2014. Technical Memorandum Crockett Lake, SR 20 at Keystone Harbor Geomorphic Pre-History. Washington Department of Transportation, Olympia.

Phillips C.H., K.D. Anderson, T.O. Ketel, and L.D.K. Udo. 2008. Spartina Eradication Program 2007 Progress Report. AGR PUB 850-214 (N/1/08). Available at: http://agr.wa.gov/PlantsInsects/Weeds/Spartina/

Washington State Department of Agriculture. 2017. Spartina Eradication Program 2016 Progress Report. AGR PUB 809-505 (R/1/17). Available: http://agr.wa.gov/PlantsInsects/Weeds/Spartina/

Wait M., T. Buehrens, and B. Trim. 2007. West Whidbey Nearshore Fish Use Assessment 20052006. Wild Fish Conservancy.

Yang, Z., and T. Khangaonkar. 2007. Development of a hydrodynamic model of Puget Sound and Northwest Straits. Battelle's Pacific Northwest National Laboratory, PNNL-17161, Richland, WA.

5.0 Freshwater Ecosystems

This chapter focuses on status and trends for habitat indicators of freshwater Skagit basin habitat throughout the anadromous fish zone. Metrics mapped from 2015 data repeated the measurements of the extent and connectivity of the large river floodplain, area of floodplain channels, and lengths for various types of mainstem edge habitats and hydromodifications. We used 2015 USDA-NAIP orthophotography to map habitats into categories consistent with previous mapping efforts in 1998 and 2006 for the Skagit Chinook Recovery Plan (SRSC and WDFW 2005), the Skagit Yearling Study (Beamer et al 2010), and the SWC Strategy and Application (Beamer et al 1998). Identified trends were assessed in the context of the 2005 Skagit Chinook Recovery Plan, NOAA status & trends monitoring program and Puget Sound Partnership common indicators. This study supports the implementation of the Skagit Monitoring and Adaptive Management Strategy and a forthcoming update to the 2005 Chinook Recovery Plan. It will also support the 2017 Skagit Steelhead Recovery Plan.

5.1 Floodplain Extent

Description of Indicators

The Skagit Chinook Recovery Plan (SRSC and WDFW 2005) identified floodplain areas as important for the freshwater rearing of juvenile Chinook salmon because of the habitats available for foraging and refugia, including complex mainstem edge, backwaters, and off channel sloughs and side channels. Floodplain habitat formation can be impeded by hydromodifications (bank hardening through the use of rip-rap and levees) that simplify edge habitat and prevent channel-forming processes.

Metrics for measuring the achievement of freshwater habitat objectives were first introduced in the Skagit Chinook Recovery Plan to identify and understand freshwater habitat restoration opportunities. These metrics included a measurement of the extent and connectivity of the large river floodplain, area of floodplain channels, and lengths for various types of mainstem edge habitats and hydromodifications.

SRSC delineated a geomorphic floodplain GIS layer. This floodplain extent data layer forms the basis by which metrics for floodplain connectivity, structure and function are applied by the Skagit Watershed Council Monitoring and Adaptive Management Subcommittee (Table 17; Beamer 2017). A comparable NOAA Regional Indicator is “Area of connected floodplain”, and the Puget Sound Partnership Common indicator is “connectivity” under the question “What is the 100-year flood extent and active width of connected floodplain”.

Table 17. Relationship of floodplain extent indicators and KEAs

Skagit Chinook Plan Indicator	Related Phase I KEA (s)	Skagit Method/Data Type
Large river floodplain footprint (including non-tidal delta)	Floodplain connectivity	GIS representation of connected and isolated floodplain area (polygon data)

	Floodplain structure & function	Completed for 1998, 2006 & 2015

Methods

In 1998, as a part of the effort to generate the Skagit Watershed Council Strategy and Application, the SRSC delineated a geomorphic floodplain extent that encompassed the eight unique rearing ranges of Skagit Chinook salmon (Figure 10). The floodplain layer, which included some adjacent low terraces, was developed using 1998 aerial photographs and other data, including FEMA maps, USGS topographic quadrangles, and Department of Natural Resources (DNR) and United States Forest Service (USFS) orthophotography and a field survey of hydromodifications along the mainstem of the Skagit River and its major tributaries – the Cascade, Sauk, and Suiattle Rivers (Beamer et. al. 2000). That floodplain extent and its associated metrics were also utilized and described in Chapter 10 and Appendix C of the Skagit Chinook Recovery Plan (SRSC and WDFW 2005), and the Skagit Yearling Study (Beamer et al 2010). The yearling report updated mainstem and floodplain habitats in a GIS primarily using 2006 orthophotography from the United States Department of Agriculture – National Agricultural Inventory Project (USDA-NAIP).

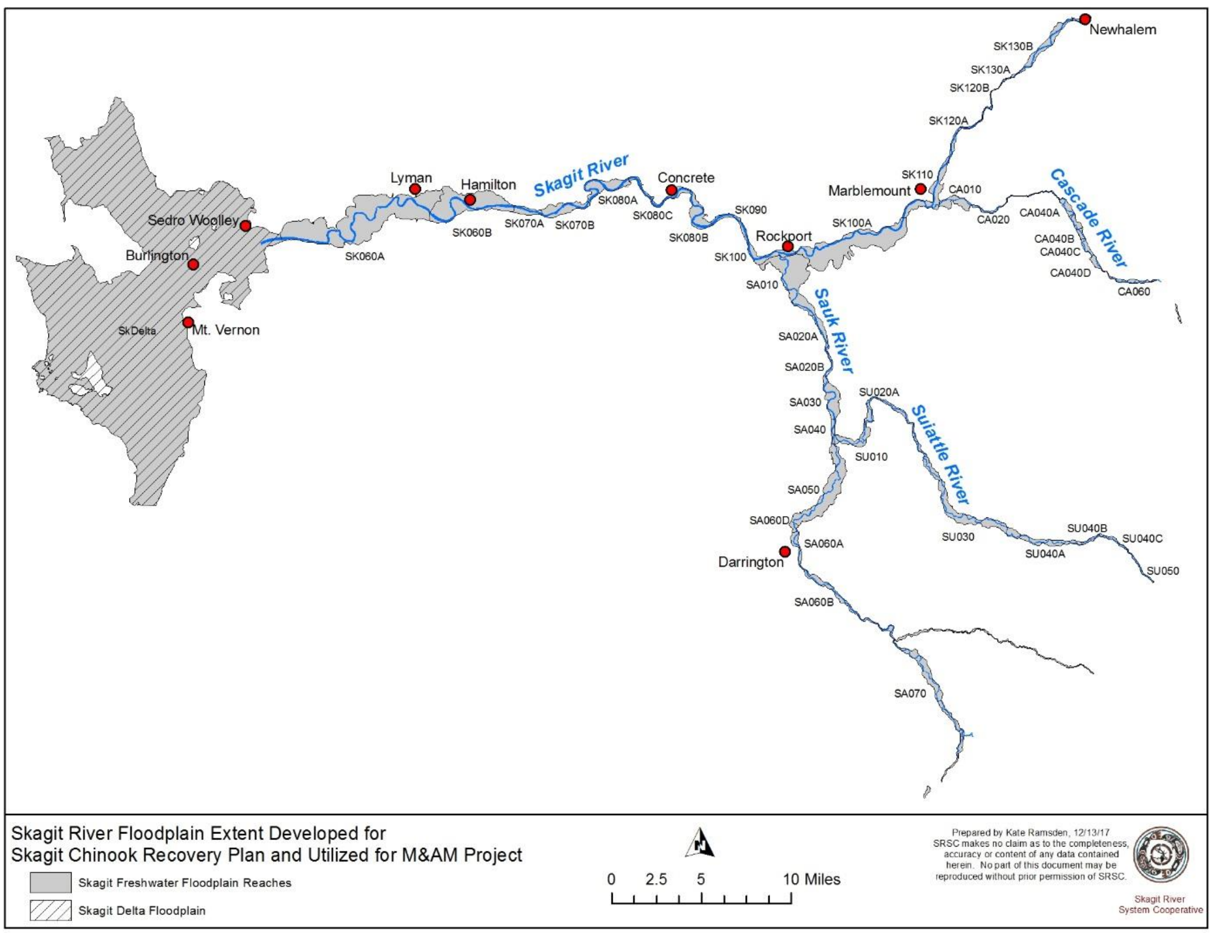

Figure 10. Skagit River floodplain extent developed for Skagit Chinook Recovery Plan (SRSC and WDFW 2005).

For this M&AM report, SRSC staff evaluated alternative floodplain interpretations from USGS (Konrad 2015) and FEMA's Flood Insurance Rate Maps (FEMA 1996) to determine whether an alternative layer may improve spatial boundaries. Each account had slight differences from the footprint that was first devised by SRSC (1998, 2000, 2010). Most deviations were isolated to the downstream reaches as the valley-wall-confined floodplain gives way to the delta floodplain.

Status and Trends

The floodplain extent developed as described here is used as the basis for comparisons in following freshwater sections. Status and trends for changes to the floodplain are described in detail for each floodplain metric below.

5.2 Large River Floodplain Structure and Connectivity

Description of Indicator

The large river floodplain structure and connectivity is the area of all habitat types exposed to river hydrological processes, including both channels and floodplains. Hydromodification and road data were used to determine the level of connectedness or impairment.

Methods

We started with the SRSC floodplain layer described in section 5.1 above. The floodplain layer represented the 100-year floodplain and areas that may be subject to channel migration. Appendix C of the Skagit Chinook Plan describes floodplain metrics included in the GIS layer. Data developed previously for the Application of the Skagit Watershed Council's Strategy (Beamer et al 2000) using 1991 aerial photographs were used to determine the non-tidal delta area for the Skagit Chinook Recovery Plan. Mainstem habitat (including many mainstem braided channels) and other land cover/land use features (agriculture, forest, clear-cut, urban/rural residential, etc) were digitized into the layer. Roads were cut into the layer using a buffered DNR road layer. The road information, along with a 1998 hydromodification layer that was previously developed by SRSC, were used to further delineate the floodplain layer into levels of disturbance, including "isolated" areas completely surrounded by roads and/or hydromodifications, "shadowed" areas located behind roads or hydromodifications but not completely enclosed, and "connected" areas not directly influenced by roads or hydromodifications. To take into consideration the direction and flow of water in the floodplain, the angle of the lines delineating the shadowed features were drawn as follows:

- Roads: A line was drawn at the downstream end of the road parallel to the floodplain direction in the immediate upstream alignment, down to the next river meander, where the line was then drawn parallel to the river in the immediate upstream alignment to the outer edge of the floodplain.
- Hydromodifications: The line on the upstream end of the hydromodification was drawn perpendicular to the floodplain flow/direction, and the line on the downstream end of the hydromodification was drawn perpendicular to the river flow/direction. The shadowed polygon behind the hydromodification was extended

all the way to the outer edge of the floodplain. Shadowed areas were ended after one meander length for polygons that would have other extended beyond that.

This effort was repeated for the year 2015 using USDA-NAIP orthophotography, updated DNR and Skagit County road layers, and hydromodification surveys completed from 2010-2015 by the Upper Skagit Indian Tribe (Hartson and Shannahan 2015). Minor revisions were made in areas where the river had clearly migrated outside of the previously mapped floodplain (evident on 2015 aerial photography and recent LiDAR data sets), and the updated road and hydromodification layers were used to delineate the floodplain layer into levels of disturbance, following the same methods utilized in the Skagit Chinook Plan. No changes were made to the non-tidal delta area.

Status and Trends

The results of the Skagit Chinook Plan (2005) show that the total floodplain area exposed to hydrologic processes in 1998 totaled 10,510 ha, and approximately 31% of the floodplain was impaired or isolated by roads or hydromodifications (Table 18). In 2015, the total floodplain area exposed to hydrologic processes totaled 10,861.8 ha, and approximately 28% of the floodplain was impaired by roads or hydromodifications (Figure 11). Total new area exposed to floodplain processes was 352 ha. Most of this new area exposed to hydrological processes can be accounted for by 1) newly mapped eroded areas, 2) changes in road presence, and 3) changes in hydromodification mapping and presence.

Table 18. Comparison of 1998 and 2015 floodplain footprint metrics.

	Total Floodplain Area (ha)	FP Area Disconnected from River Hydrology (ha)	% Impaired	Total area exposed to hydrological processes (ha)*
1998 (Skagit Chinook Plan)	14,618	4,489	31%	10,510
2015 (Status and Trends Update)	14,657	4,176	28%	10,862

*includes non-tidal delta area of 381 ha

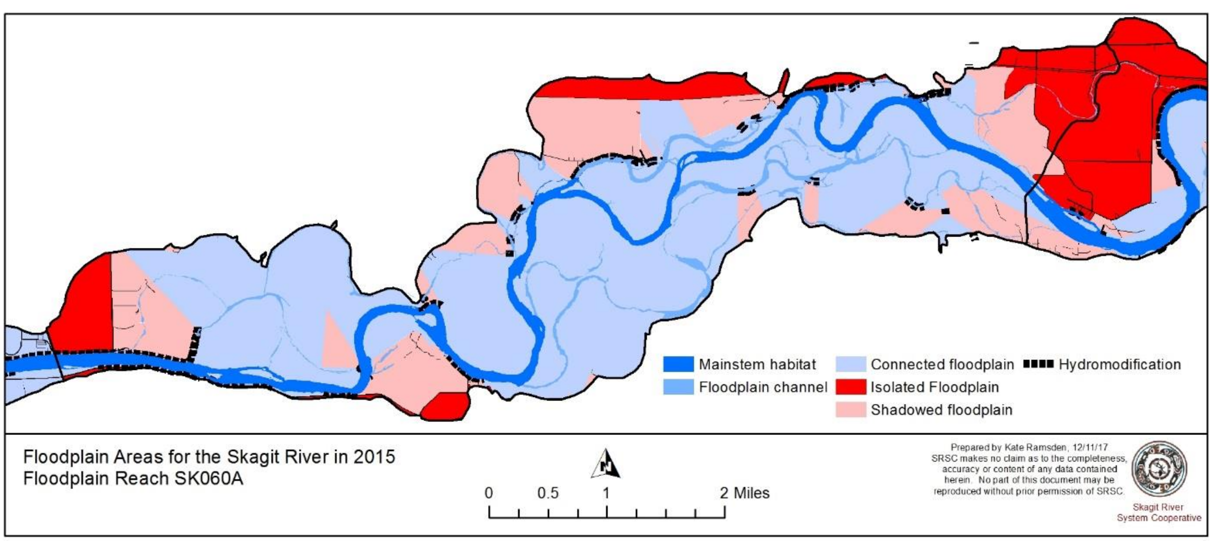

Figure 11. Example of 2015 Skagit River floodplain extent layer from Floodplain reach SK060A.

For the 2015 mapping effort, there were areas where the river had clearly migrated outside of the previously mapped floodplain footprint, primarily due to mainstem or side channel migration. This occurred most often in the Sauk and Suiattle Rivers. The newly added floodplain area totaled 38 ha. A change in road presence also accounts for some of this difference. In 2015, fewer roads were observed on the aerial photographs than appeared in the 1998 aerial photographs, particularly farm roads and forest roads. Updated county, DNR, and USFS road layers were consulted in addition to newer LiDAR data, which helped provide evidence of road presence in forested areas. In addition, in some cases it was clear the road had been removed by channel migration.

The change in mapping methods for the updated hydromodification data may also account for some of the difference. For the 1998 hydromodification layer, SRSC staff field-mapped hydromodifications by hand-drawing the structure on printed orthophotos, then later digitized them in a GIS. From 2010-2015, the Upper Skagit Indian Tribe (USIT) repeated the inventory by field-mapping hydromodifications that were clearly visible from a boat with a GPS unit in the Skagit, Sauk, and Suiattle (Hartson and Shannahan 2015). Some variability may be accounted for with the different mapping techniques, variable field conditions such as visibility of the hydromodification at different river stages, and/or actual erosion or removal of the rip-rap or levee.

Table 19. Relationship of floodplain channel interaction indicators and KEAs.

Skagit Chinook Plan Indicator	Related Phase I KEA(s)	Skagit Method/Data Type
Large mainstem edge length	Floodplain connectivity Floodplain structure & function	GIS representation of mainstem edge types (polyline data)
Large mainstem hydromodified edge	Floodplain connectivity Floodplain structure & function	
Large mainstem backwaters perimeter	Floodplain connectivity Floodplain structure & function	
Floodplain channel area	Floodplain connectivity Floodplain structure & function	GIS representation of off channel habitat (polygon data) Completed for 2006 & 2015
Floodplain channel length	Floodplain connectivity Floodplain structure & function	GIS representation of off channel habitat (polyline data) Not completed in same format for 2006, 2015.
Connectivity of large river floodplain	Floodplain connectivity	GIS representation of distance between off channel and backwater outlets (point and polyline data) Not completed for 2006, 2015

5.3 Large Mainstem Edge Length

Description of Indicator

The large mainstem edge length is described as the total length of all edge types along the mainstem channel.

Methods

To assess edge condition for the Recovery Plan, the mainstem habitat polygons that were delineated into the floodplain condition shapefile were converted to polyline features in a GIS. The polylines were then split into different edge types using 1998 aerial photographs. Edge types included bank, bar, and backwater. Banks were defined as a generally vertical/steep slope into the river and was usually vegetated. Bars were described as having generally a gentle slope into the river and was typically sandy rather than heavily vegetated. Backwaters were described as roughly the same elevation as the river, where water has flowed back into a depression, but without a sill separating it from the river. In addition, the 1998 hydromodification data was used to define the edge as hydromodified, or not, which is described more fully in the section on hydromodified edges.

For trend analysis edge habitat conditions were mapped in GIS for 2006 and 2015 using USDA-NAIP orthophotos. For 2006, edge habitat polylines were extracted from the mainstem and floodplain habitat mapping that was completed as part of the Skagit Yearling Study (Beamer et al 2010). The polylines were split into different edge types as described above using the 2006 orthophotos. Backwater edges were also further defined as being either bank or bar types. Edge condition was mapped in the same way for 2015 using the habitat polygons developed for this M&AM project and 2015 USDA-NAIP orthophotos. Hydromodification presence was also included in the edge habitat mapping for 2006 and 2015 and is described more fully in that section below.

Status and Trends

The Skagit Chinook Plan mapping shows that mainstem edge totaled 589.4 km. That 1998 result included the edge length of the non-tidal delta (57,390 m) in the total which was not included in 2006 and 2015 mapping, but it does not include edge length for some reaches in the Cascade and Suiattle Rivers (Figure 12; Table 20). The 1998 mapping effort also included more braided channels as mainstem habitat while the 2006 and 2015 mapping efforts did not. The mainstem channel length was reported to be 230 km in the Skagit Chinook Plan (1998 data), not including the non-tidal delta length.

The results of the 2006 and 2015 data are more directly comparable to each other, having the same extent (Table 21). Mainstem channel length for 2006 and 2015 were very similar to each other, 234 km and 235 km, respectively. However more edge habitat was mapped in 2015 than in 2006 (30.7 km more). In the Skagit floodplain reach SK060A – SK100, for example, the 2006 aerial photographs were taken at a higher level of flow, ranging from 10,300-13,000 cfs at the Concrete gage (with most of the reach landing on the higher flow day) and 10,500-13,300 cfs at the Mt Vernon gage, than were the 2015 aerial photographs, when the flow level was measured at 9,700-10,200 cfs at Concrete and 8,760-9,720 cfs at Mt Vernon. Thus, more gravel bars were exposed on the 2015 aerial photographs and more braids were mapped and included in the edge length total. It is possible to exclude braid lengths from the 2006 and 2015 edge data, calculating only the total for the mainstem channel. The totals in this case are much closer, 500.7 and 501.2 km respectively.

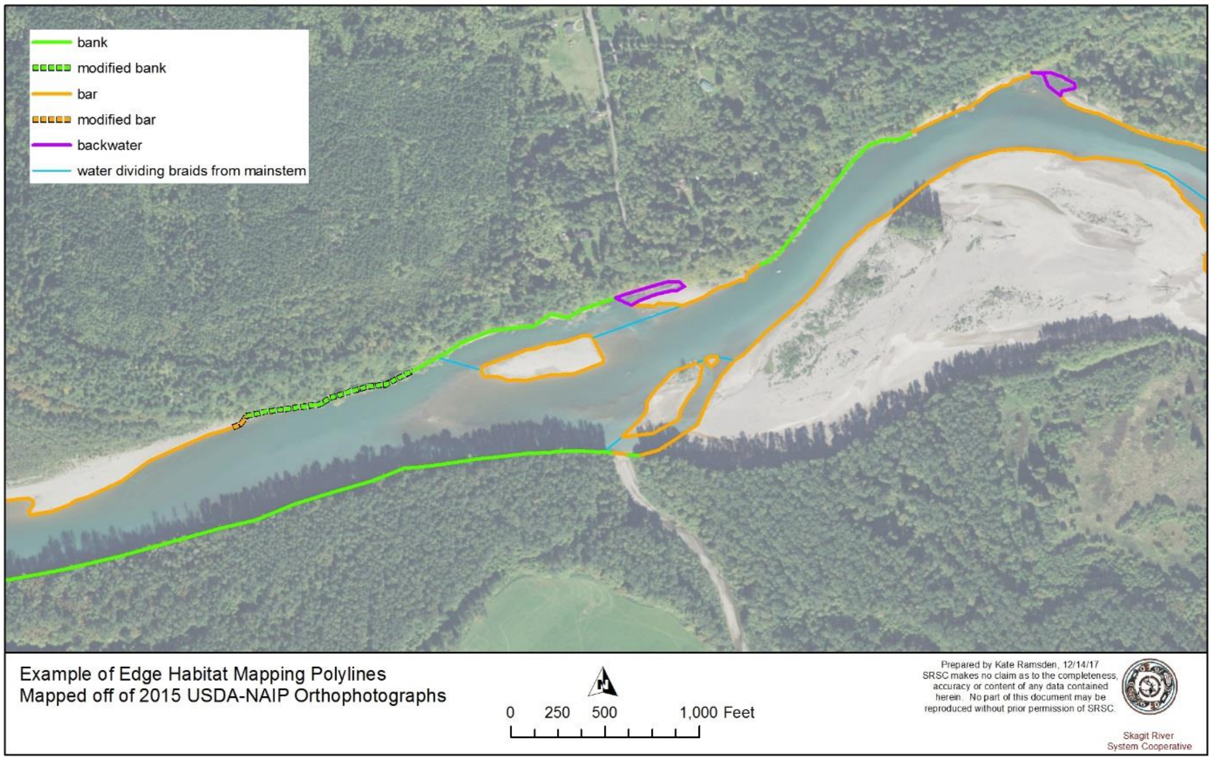

Figure 12. Example of 2015 edge habitat mapping.

Table 20. Summary of edge habitat conditions for each rearing range for 1998, 2006, 2015.

		Mainstem Channel Length (m)			Total Edge Habitat Length (m)		
Rearing Range	**Floodplain Reach**	**1998**	**2006**	**2015**	**1998**	**2006**	**2015**
All Stocks	Non-tidal Delta	22,779			57,390		
	SK060A - SK100	68,685	68,774	70,247	195,606	167,958	177,313
Upper (U) Skagit Summer and U Cascade Spring	SK100A - SK110 and CA010 - CA020	30,896	31,847	31,967	76,061	72,802	78,327
U Skagit Summer	SK120A - SK130B	16,292	16,314	16,297	39,244	36,360	37,016
U Cascade Spring	CA040A - CA040D	10,114	9,721	9,745	NA	21,543	23,976
All Sauk and Suiattle	SA010 - SA040	20,459	21,687	23,106	49,359	57,144	57,423
Lower (L) Sauk Summer and U Sauk Spring	SA050 - SA060D	30,312	30,337	29,657	78,541	69,188	77,526
U Sauk Spring	SA070	12,873	13,006	12,631	30,137	29,351	29,699

Suiattle Spring	SU010 - SU030	24,692	25,778	24,991	63,068	54,732	56,649
	SU040A - SU050	15,898	16,294	16,759	NA	33,873	35,674
Totals		**230,219**	**233,756**	**235,399**	**589,407**	**542,952**	**573,602**

Table 21. Summary of edge habitat condition for each rearing range, excluding mainstem braids.

		Total Edge Habitat Length (m)	
Rearing Range	**Floodplain Reach**	**2006**	**2015**
All Stocks	Non-tidal Delta		
	SK060A - SK100	150,494	153,572
Upper Skagit Summer and Upper Cascade Spring	SK100A - SK110 and CA010 - CA020	71,065	68,652
Upper Skagit Summer	SK120A - SK130B	33,785	33,863
Upper Cascade Spring	CA040A - CA040D	21,008	20,936
All Sauk and Suiattle	SA010 - SA040	45,391	48,473
Lower Sauk Summer and Upper Sauk Spring	SA050 - SA060D	64,130	62,784
Upper Sauk Spring	SA070	29,094	28,005
Suiattle Spring	SU010 - SU030	52,709	50,902
	SU040A - SU050	33,033	34,048
Totals		**500,709**	**501,235**

5.4 Large Mainstem Hydromodified Edge Length

Description of Indicator

Hydromodifications include rip rap bank armoring and dikes located along any mainstem edge type. Hydromodifications prevent channel migration and off channel habitat formation, and contain unnatural bank edges that are not preferred by juvenile Chinook (Beamer and Henderson 1998). It is a subset of the Large Mainstem Edge Length described in section 5.3

Methods

For the Skagit Chinook Recovery Plan, the mainstem edge habitat polylines described in section 5.3 were attributed with the presence or absence of hydromodifications along the edge. Hydromodifications (hydromods) were mapped during a 1998 field inventory, when hydromodified banks were drawn on aerial photographs while floating the river in a jetboat or raft and then digitized into a GIS.

Since publication of the Skagit Chinook Recovery Plan, the Upper Skagit Indian Tribe (USIT) has updated the survey by conducting a field-based inventory of hydromodifications in and immediately adjacent to the main river channel and major tributaries covering known Chinook distribution from 2010-2015 (Hartson and Shannahan 2015). This inventory does not include the non-tidal delta reach of the river. The surveyors used GPS to collect hydromod location in the field, then used those GPS files to digitize the structure as polylines in a GIS over 2011 or 2013 USDA-NAIP imagery. This updated inventory was used to attribute the edge habitat polylines for the 2006 and 2015 data sets. Because an inventory was not completed around the year 2006, care was taken to investigate whether hydromodifications appeared to be actually present in that year, based on hydromodification survey field notes, utilization of 2007 oblique aerial photographs, and local knowledge of the area.

The spatial extent of the two hydromod datasets varies slightly. The 1998 dataset includes delta and non-tidal delta reaches, whereas the 2010-2015 data do not. The latter data includes several major Chinook-bearing streams that the older data did not. The hydromod data did not always align perfectly with the edge mapping. For all year sets the beginning and end of the hydromod was sliced into the edge polyline that aligned best with the hydromod. Where several small hydromod segments were located adjacent to each other with very small gaps in between (primarily in the 2010-2015), those gaps were ignored, and a longer continuous segment was sliced into the edge.

Status and Trends

Table 22 summarizes the total hydromodified edge as delineated within the edge habitat polyline features. In 1998, the total modified edge within the freshwater rearing range (excluding the non-tidal delta) was 49,418 m. In 2006, it was estimated to be 41,375 m and in 2015, it was estimated to be 39,886 m.

Table 22. Summary of hydromodified edges for each rearing range as mapped within edge habitat mapping polyline shapefiles.

	Hydromodified Length (m)		
Floodplain Reach	**1998**	**2006**	**2015**
Non-tidal delta	29,021		
SK060A - SK100	30,260	25,618	23,609
SK100A - SK110 and CA010 - CA020	7,448	5,817	6,611
SK120A - SK130B	3,501	4,286	4,460
CA040A - CA040D	NA	30	32
SA010 - SA040	3,035	2,732	2,101
SA050 - SA060D	3,356	1,710	2,384
SA070	736	291	53
SU010 - SU030	1,081	891	636
SU040A - SU050	NA	0	0
Totals	**78,439**	**41,375**	**39,886**

Some of the difference is due to removal of hydromodifications via erosion or restoration, but some of the difference is due to mainstem channel migration. When the mainstem channel moved away from the hydromodification, it was not then captured in the edge habitat data, although it may still remain present on the floodplain and potentially adjacent to floodplain channels. The edge mapping for 1998 also captured quite a few more braided channels than did the mapping for 2006 and 2015, so it also captured more hydromodified edges than did those later years.

5.5 Large Mainstem Backwaters Perimeter

Description of Indicator

This indicator is the perimeter length of large mainstem backwaters. Backwaters are floodplain areas at the same elevation as the river and with little gradient where water has spread up or across stream flow direction. There is no emergent sill separating the out-of-channel water from the river. The backwater is held full by hydrologic pressure. It is accessible to fish. Backwater Perimeter is a subset of Mainstem Edge described in Section 5.3.

Methods

As described in the section on large mainstem edge length, backwater perimeters were also mapped from aerial photographs for 1998, 2006, and 2015.

Status and Trends

The Skagit Chinook Plan reports that backwater perimeter totals 63,239 m. This number is much higher than was mapped on the 2006 and 2015 aerial photographs. Again, much of this is due to the additional mainstem braids that were included in the first mapping effort that were not included in the 2006 and 2015 time-steps. From 2006 to 2015, there was a decrease in backwater perimeter by 3,614 m (Table 23).

Table 23. 2006 and 2015 backwater habitat perimeters as mapped within edge habitat mapping polyline shapefiles.

	Backwater Perimeter (m)	
Floodplain Reach	**2006**	**2015**
SK060A - SK100	8,875	10,179
SK100A - SK110 and CA010 - CA020	7,184	3,424
SK120A - SK130B	440	706
CA040A - CA040D	1,281	747
SA010 - SA040	1,062	1,732
SA050 - SA060D	3,042	2,387
SA070	875	315
SU010 - SU030	863	470
SU040A - SU050	55	105
Totals	**23,678**	**20,064**

5.6 Floodplain Channel Area

Description of Indicator

The floodplain channel area is described as the polygonal area of all wetted channel types in Skagit River floodplain reaches. Polygons were categorized as main channel, backwater, braid, and side/secondary channel. Main channel was the wetted mainstem channel. In places where the main channel was braided, the widest/deepest looking channel was identified as the main channel and the others as secondary channels (either braids or side/secondary channels). Braids attached to the mainstem on both ends and were separated from the mainstem by mostly unvegetated gravel bars. Braids function more as a mainstem than as a side channel. Side/secondary channels were separated from the mainstem by mostly vegetated bars or forested islands and may or may not attach to the mainstem on both ends. Backwater habitat was classified as described in section 5.5. Channel edge was often difficult to distinguish in forested areas where trees overhang and obscure the bank, so a best guess at bank edge had to be made when digitizing. Floodplain areas surrounded by channels were digitized and attributed with land cover types, including forested, cleared, or partially vegetated.

Methods

Floodplain channel habitat features (wetted channels?) were heads-up digitized as polygon features in a GIS from aerial photographs at a scale no closer than 1:3,000. Habitat types were mapped for the years 2006 and 2015 from USDA-NAIP orthophotography. The 2006 data was completed for the Skagit Yearling Study (Beamer et al 2010). The 2015 data was completed for the M&AM project using the same methods.

For the purposes of summarizing data, all channels that were not the main channel were grouped together and summarized as floodplain channels. Backwaters along the mainstem not touching a braid or secondary channel were summarized within the mainstem channel category, while backwaters that were located adjacent to braids and secondary features were grouped in with the floodplain channel area.

Status and Trends

The total area of floodplain channel types digitized over 2006 orthophotos was 560 ha. Mainstem habitat area totaled 1,855 ha (Figure 10). The 2015 mapping found that total mainstem area was 1,784 ha. The total floodplain channel area was 644 ha. Total habitat area (mainstem plus floodplain channels) for each dataset was nearly identical: 2,415 ha in 2006 and 2,428 ha in 2015. Upon further investigation, it was found that a few of the braids in 2006 had been assigned to the mainstem category.

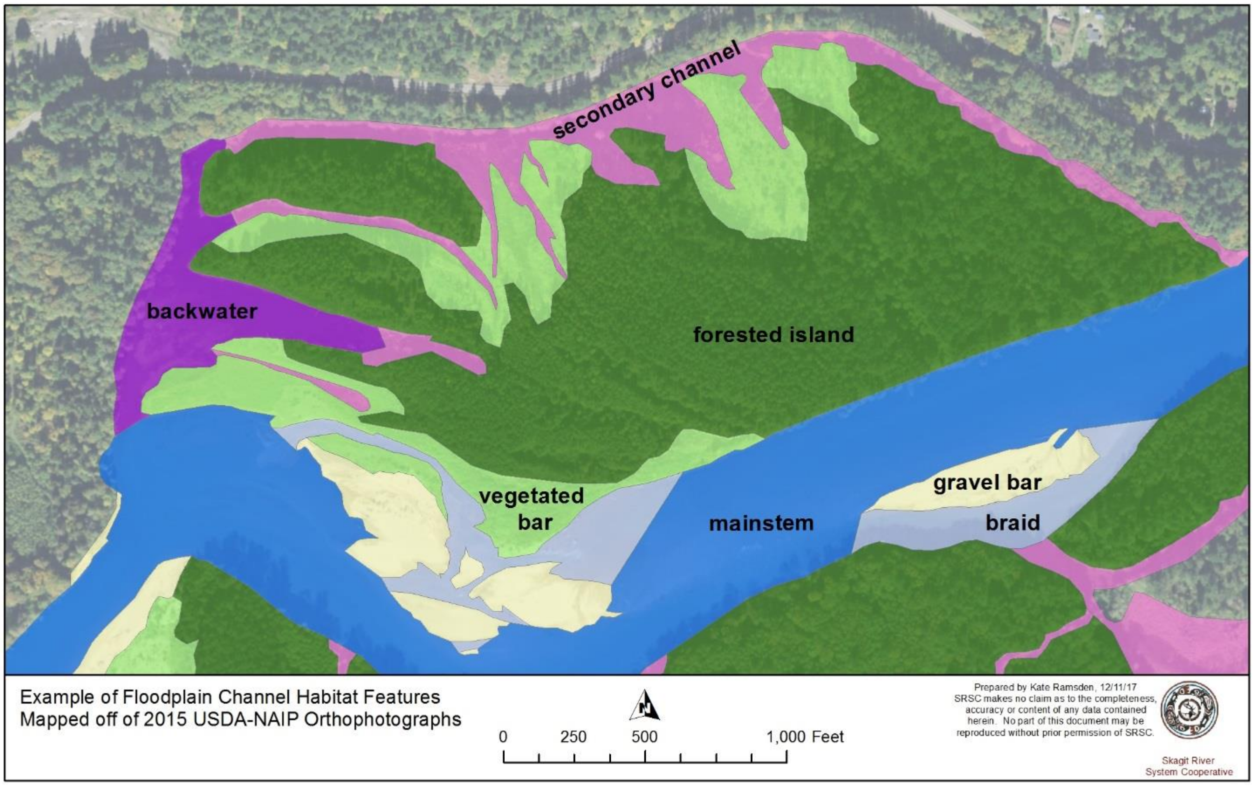

Figure 13. Example of floodplain habitat features layer.

5.7 Floodplain Channel Length

Description of Indicator

Floodplain channel length is the length of floodplain channels in unconfined reaches.

Methods

Within the Skagit Chinook Recovery Plan, floodplain channel length was determined by digitizing in a GIS visible floodplain channels as a polyline feature over the 1998 orthophotos and a United States Geological Survey 10-m DEM hillshade model.

Status and Trends

Results presented in the Skagit Chinook Recovery Plan quantify the length of floodplain channels totaling 371.1 km. This analysis has not been repeated since the Skagit Chinook Recovery Plan.

5.8 Connectivity of Large River Floodplain (Gaps in Rearing Habitat)

Description of Indicator

Connectivity of the large river floodplain is defined as the count of and distance between backwaters and floodplain channels. Evidence supports that connectivity of rearing habitat (backwaters and side channels) is limiting for juvenile Chinook salmon, so reaches of the river that have gaps in the availability of these habitats should be considered priority areas for restoration.

Methods

The spatial distribution of accessible off-channel habitat along mainstem channels was determined by measuring the linear distance between each backwater and floodplain channel outlet, as mapped by the floodplain and habitat polygon and polylines representing floodplain channels (see Section 5.2). The quantity of habitat was measured as perimeter length for backwaters and centerline length for floodplain channels (Sections 5.5 and 5.6). Gaps in off-channel habitat opportunity were identified where more than 1 km of main channel length provided access to less than 1,000 meters of either backwater perimeter or floodplain channel length. Mainstem channels with more than 5 km of continuous length with less than 1,000 m of backwater perimeter or floodplain channel length per kilometer of mainstem length were identified as the highest priority. Some areas were eliminated because they were in areas with narrow floodplains that likely naturally limited the availability of off-channel habitat.

Status and Trends

The results of the Skagit Chinook Plan show that the available habitat is fragmented and identifies 20 mainstem reaches with gaps in habitat availability that may be priority areas for restoration. This analysis has not been repeated since the Skagit Chinook Recovery Plan. If it is repeated for monitoring the status and trends of rearing habitat connectivity it may be better to simply measure the spacing of all rearing habitat opportunities (and their length or perimeter) along mainstems.

5.9 Tributary Connectivity and Structure

Description of Indicator

Small tributaries to the Skagit, Sauk, Suiattle, and Cascade rivers offer important spawning and rearing opportunities for anadromous salmonids. Within these tributaries, stream gradient is linked to channel morphology (Buffington et al. 2003), which in turn has been shown to influence spawning strategy and fish abundance (Montgomery et al. 1999). Chinook and coho show relatively high abundance in pool-riffle and forced pool riffle channels (0-4% slope) (Montgomery et al. 1999) while steelhead often can utilize slightly higher gradient channels in addition to low-gradient reaches (Cramer and Ackerman 2008). Low-gradient streams are also assumed to offer greater rearing habitat potential for juvenile salmonids (Skagit Watershed Council 2015). High gradient reaches can present natural barriers to fish passage, though fish can often move through moderately high gradient reaches for short distances (WDFW 2009). Sediment supply, hydromodifications, high water temperatures, and availability of freshwater rearing habitat have all been identified as limiting factors affecting productivity in tributary habitat for Skagit Chinook populations (SRSC and WDFW 2005). In the greater Skagit River watershed, tributary connectivity to the mainstem rivers has been reduced from historic levels due to road crossings and other structures that limit or restrict passage by anadromous salmonids.

Methods

As a first step towards mapping historically and currently available tributary habitat, we used a Skagit County hydrography GIS layer along with a LiDAR-derived digital elevation model to derive slopes for tributary streams within the Skagit, Sauk, Suiattle, and Cascade River watersheds. Following this, GIS databases of artificial and natural barriers to fish passage were coupled with this layer to assess whether habitat is currently accessible to fish, isolated by artificial barriers such as culverts, or is inaccessible due to natural barriers to fish passage. Finally, the layer was intersected with an alluvial plain/alluvial fan/upland layer to allow characterization of geomorphic position within the watershed.

Development of the slope, geomorphic position, and accessibility layer allows us to measure indicators for assessment of status and trends in tributary connectivity and availability of channel types. The indicators used to track the status and trends of tributary habitat in this study were identified by the Skagit Watershed Council Monitoring and Adaptive Management Subcommittee (Table 24). Similar indicators used elsewhere include "Percent historic miles available to adult Chinook" (Puget Sound Partnership Common Indicator).

Table 24. Relationship of habitat connectivity and stream structure area indicators and KEAs

Indicator	Related Phase I KEA(s)	Method/Data Type
Historic habitat length available to salmonids	Habitat Connectivity	GIS representation of accessible, isolated, and inaccessible tributary habitat by gradient class and geomorphic position within watershed (polyline data).

Status and Trends

Trend analysis has not yet been completed for the barrier indicator. A status report is underway and will be completed in early 2020.

5.10 Small Mainstem and Tributary Length

Description of Indicator

Small mainstem and tributary length is defined as the length of habitat, measured in meters of channel, within each tributary watershed by slope classes and geomorphic position within the watershed.

Methods

We used a variable interval spacing method for estimating tributary stream channel gradient to our hydrography layer (Nagel et al. 2010). Typically, slope is computed for segments between stream endpoints and intersections, which tends to over-average slopes in high-gradient reaches. A shorter interval spacing in such reaches better captures gradient variations, but conversely, a short sampling interval can increase error in lower gradient reaches. Therefore, the variable interval spacing method attempts to improve gradient estimates by sampling DEM elevations along channels at intervals based on average channel slope between tributary junctions (Nagel et al. 2010). Previous attempts to incorporate slope relied on fixed interval spacing as well as on hydrography data that were less accurate in low-gradient reaches.

To do this, we first sampled elevations from a DEM at the endpoints and intersections of our updated hydrography layer, and calculated slopes for each of the stream segments. We selected the National Elevation Dataset DEM as our base layer for elevation data because, though coarser than the 2006 Skagit County LiDAR data that are available, it still offers good resolution and covers the entire study area seamlessly. Following Nagel et al. (2010), the stream segments were placed into broad gradient classes using slope breaks corresponding to reach-level channel morphologies (Buffington et al. 2004). The gradient classes were then used to assign an interval spacing for slope estimation (Table 25). The interval widths approximate horizontal USGS Quad 40' contour interval spacings (Nagel et al. 2010).

Table 25. Reach-level channel morphology by gradient class (Buffington et al. 2004) and associated interval spacing for slope estimation (Nagel et al. 2010).

Reach Level Morphology	Gradient Class	Interval Width
Cascade	>7.5%	160 Meters
Step-Pool	3-7.5%	230 Meters
Plane-Bed	1.5-3%	540 Meters
Pool-Riffle	<1.5%	810 Meters

Following classification, the stream segments were split using their assigned interval widths, elevation was sampled again at all endpoints and intersections, and slopes were calculated for the new segments. Finally, the new segments were grouped by slope into classes that correspond to habitat use by adult and juvenile Chinook and were also sorted by location within the watershed using an alluvial plain/alluvial fan/upland GIS layer that was created separately (Table 26).

Table 26. Reach-level channel morphology (Buffington et al. 2004) by gradient class.

Reach Level Morphology	Gradient Range
Cascade	>16%
Cascade	8-16%
Step-Pool/Cascade	6-8%
Plane Bed/Step-Pool/Cascade	4-6%
Pool-Riffle/Plane Bed/Step-Pool	1-4%
Pool-Riffle/Plane Bed	0-1%

Status and Trends

Habitats are shown sorted first by gradient class and accessibility, and then by watershed position and accessibility. The 2015 data for Red Cabin Creek are presented here as an example (Table 27, Figure 14). An analysis of past conditions has not been completed, so no comparison data are available, but the table could be expanded to show similar information for each year of analysis. The estimates of gradient and accessibility rely on the accuracy of the underlying GIS layers. Improvements to these, particularly the barrier layers, would improve the quality of the final product.

Table 27. Habitat Length by Gradient Class and Geomorphic Position (Red Cabin Creek, Total Watershed Area: 1200 hectares)

	Habitat Length (Meters)			
Gradient Class	Accessible	Isolated	Inaccessible	**Total**
0-1%	589	160	0	**749**
1-4%	1,620	3,798	704	**6,122**
4-6%	9	1,223	1,189	**2,422**
6-8%	230	968	1,538	**2,736**
8-16%	160	1,269	8,521	**9,950**
> 16%	8	94	14,001	**14,103**
Total	**2,617**	**7,512**	**25,953**	**36,082**
Geomorphic Position				
Alluvial Plain	1,409	0	0	**1,409**
Alluvial Fan	810	810	0	**1,620**
Upland	398	6,702	25,953	**33,053**
Total	**2,617**	**7,512**	**25,953**	**36,082**

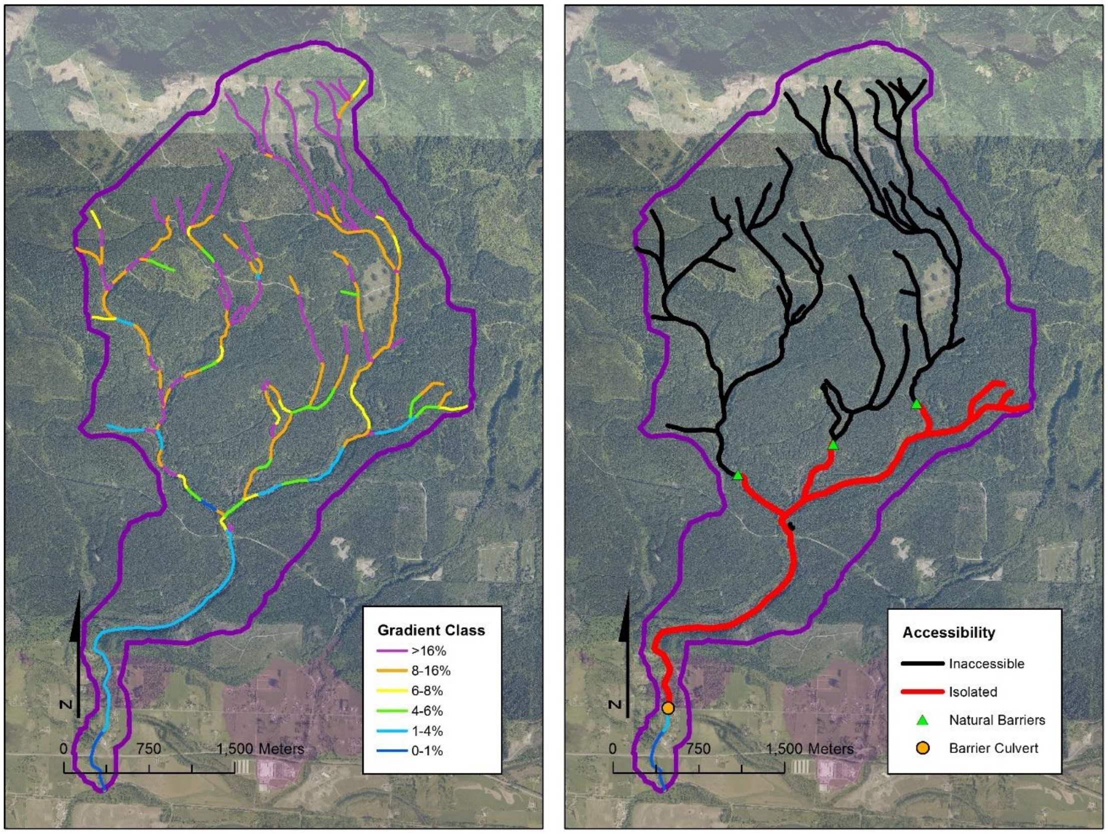

Figure 14.

5.12 Recommendations for Freshwater Habitats

Recommendations for Monitoring

Recommendation 18: For the sake of consistency, the SRSC floodplain extent used in the Skagit Chinook Plan will be used for future work.

Recommendation 19: For large river floodplain structure and connectivity repeat the GIS analysis in the future (2025) to determine if the area of shadowed and isolated habitats is trending. This will require an updated hydromodification survey and field mapping to determine if dikes and other bank hardening features are still present on the landscape. Effort will require agreement on protocol and database for tracking construction/removal of hydromodifications, roads, and levees.

Recommendation 20: For large mainstem edge length repeat habitat mapping in 5 years, primarily for the benefit of the next two indicators: hydromodified edges and backwaters.

Recommendation 21: Repeat the hydromodification survey in 5 years to determine if hydromodification length is actually decreasing. Develop a protocol and database for tracking construction/removal of hydromodifications, roads, and levees. Improve change analysis by creating two subcategories: Length of new (field survey and/or permit review), and Length removed (restoration projects or restoration + erosion).

Recommendation 22: Repeat the edge habitat mapping methods in 8 to10 years to determine if the decreasing trend for backwater edge indicator is continuing.

Recommendation 23: The 1998 data could be reorganized to remove the extra mainstem braided channels and make that data more comparable to latter two-year sets.

> *Considerations:* Mainstem habitat polygons were mapped for the Skagit Chinook Plan from 1998 aerial photographs, but included many more braids as mainstem habitat than did the 2006 and 2015 mapping efforts and therefore are not as easily compared. Floodplain channels were represented with polylines and lengths instead of polygon area. Additional work could be completed to better delineate the 1998 mainstem channel area into mainstem versus braids and digitize the floodplain channels using the polylines as a guide. Conversely, floodplain channel centerlines could be digitized using the 2006 and 2015 data.

Recommendation 24: Additional timesteps for GIS mapping of channels should be added as future photography becomes available to determine a clear trend in the area and length of floodplain channels.

Recommendation 25: Use Relative Elevation Modeling, using LiDAR (Light Detection and Ranging) topography to distinguish different levels of the floodplain and better define and locate floodplain channels, which are often obscured by shadow and vegetation in the orthophotos. This should benefit both M&AM and protection & restoration planning.

> *Considerations:* LiDAR data sets covering much (but not all) of the Skagit floodplain are available for the years 2003-2006 & 2015-2017 and could be used to map floodplain habitat features (either polygons or polylines) and potentially reduce some of the user error inherent in the interpretation of aerial photographs. It seems very likely that LiDAR topographical data will continue to become available for future time steps for a status and trends analysis. This work is underway.

Recommendation 26: Because floodplain channel lengths may be easier to compare from year to year than are areas we recommend measuring floodplain channel lengths for the 2006 and 2015 time steps.

> *Considerations:* Floodplain channel area in the form of habitat polygons has been measured instead of true length. However, it may be beneficial to map floodplain channel lengths for the 2006 and 2015 time steps using the mapped habitat channels and additional data (orthophotography, and 2006 and 2017 LiDAR topography) as guides. The rational being that precise boundaries of channels which can be somewhat difficult to map in heavily forested areas with overhanging vegetation, thereby creating bias and error with area calculations.

Recommendation 27: Vet and incorporate a new indicator for the number of functioning alluvial fans compared to the number of historic fans in Chinook bearing waters.

Recommendation 28: Field verify presence and location of artificial and natural barriers.

> *Considerations:* Available natural barrier data was created using a variety of sources, including field visits, map interpretation, and anecdotal information. Barriers observed in the field were recorded using rudimentary GPS technology, so positional accuracy was not high in many cases. Field verification using mapping-grade GPS units would greatly improve confidence in the natural barrier layer. Similar issues are present within the artificial barrier layer available from WDFW. However, efforts are currently ongoing to update and correct errors in the layer.

Recommendation 29: Incorporate channel width estimates into the hydrography layer.

> *Considerations:* (Channel width is a required parameter for the NOAA Fisheries Intrinsic Potential Model and would also allow estimation of habitat area).

Recommendation 30: Re-run the intrinsic potential model using the dataset updated with channel width estimates and reconvene expert panel to map out an updated fish distribution layer.

Recommendation 31: Combine gradient analysis with a riparian analysis to estimate supply of large woody debris.

> *Considerations:* Wood structure allows development of forced pool-riffle habitat, which is more beneficial to fish than the plane-bed channel morphology present in systems with low wood supply (Buffington et al. 2004).

Recommendation 32: Fill monitoring gaps from 2006 to provide for an initial baseline from which to compare future assessments.

> *Considerations:* We would like to analyze more 2006 tributaries to identify trends in watersheds outside of the Finney Creek - Skagit River Tributaries. This can be done using either heads-up digitizing or computer vision, since the methods have had similar results. While heads-up digitizing is more consistent with SRSC's previous methodology, computer vision is more repeatable (accuracy is independent from the digitizer's abilities) and potentially more efficient.

Recommendation 33: Create an implementation monitoring framework for freshwater mainstem and tributary restoration and protection projects to track the amount and location of progress to compare to our strategy. Connect this action-tracking framework to broader ambient habitat status and trends frameworks to understand the context of our actions within landscape scale changes.

Recommendation 34: Improve freshwater indicators by describing and quantifying them in terms of Chinook presence and benefit.

> *Considerations:* For example, the small mainstem and tributary length indicator quantifies habitat with either known, presumed, or absent Chinook habitat, which is not all the same value to Chinook salmon.

Acknowledgements

In 2015, Skagit River System Cooperative (SRSC) received a SRFB grant (#15-1449) to assist with the development of the freshwater portion of the Monitoring and Adaptive Management Plan (M&AM) for the Skagit basin by the Technical Work Group and Board of the Skagit Watershed Council.

5.13 References

Beamer E, Henderson R (1998) Juvenile Salmonid Use of Natural and Hydromodified Stream Bank Habitat in the Mainstem Skagit River, Northwest Washington. Skagit System Cooperative, La Conner, WA.

Beamer EM, Beechie T, Perkowski B, Klochak J (2000) Application of the Skagit Watershed Council's strategy -- river basin analysis of the Skagit and Samish Basins: tools for salmon habitat restoration and protection. Skagit Watershed Council, Mount Vernon, Washington. 80pp.

Beamer E, Shannahan J, Wolf K, Lowery E, and Pflug D (2010) Freshwater Habitat Rearing Preferences for Stream Type Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) and Steelhead (*O. mykiss*) in the Skagit River Basin: Phase 1 Study Report.

Beamer EM (2017) Skagit Monitoring Report June 30, 2017. Skagit Water Shed Council Monitoring and Adaptive Management Subcommittee, Mount Vernon, Washington. 18 pp.

Beechie TJ, Stefankiv O, Timpane-Padgham B, Hall J, Pess GR, Rowse M, Liermann M, Fresh K, Ford M (2015) Monitoring habitat status and trends in Puget Sound: development of sample designs, monitoring metrics, and sampling protocols for nearshore, delta, large river, and floodplain environments. National Oceanic and Atmospheric Administration, Seattle, Washington. 198 pp.
https://www.nwfsc.noaa.gov/news/events/program_reviews/2016/documents/supporting/B6_Beechie_et_al_2016.pdf accessed 12/13/2017.

Cassie D (2006) The thermal regime of rivers: A review. Freshwater Biology 51:1389–1406.

Collins BD (2000) Mid-19th century stream channels and wetlands interpreted from archival sources for three north Puget Sound estuaries. Report to Skagit System Cooperative, La Conner, Washington.

Collins BD, Sheikh AJ (2002) Methods used to map the historical riverine landscape and habitats of the Skagit River. Report to the Skagit System Cooperative, La Conner, Washington.

Elsner M, Cuo L, Voisin N, Deems J, Hamlet A, Vano J, Mickelson K, Lee S, Lettenmaier D (2010) Implications of 21st century climate change for the hydrology of Washington State. Climatic Change 102, 225-260.

Environmental Science Associates (2017) Skagit Watershed Council Riparian assessment & strategy update – TWG review draft, October 17, 2017. Prepared for the Skagit Watershed Council, Mount Vernon, Washington. 68 pp.

Federal Emergency Management Agency (1996) Q3 Flood Data, Skagit, WA, Snohomish, WA, and Whatcom, WA.

Hartson R, Shannahan J. 2015. Inventory and Assessment of Hydromodified Bank Structures in the Skagit River Basin: Chinook Bearing Streams. Upper Skagit Indian Tribe, Sedro Woolley, WA.

Heller NE, Zavaleta ES (2008) Biodiversity management in the face of climate change: A review of 22 years of recommendations. Biological conservation 142:14–32.

Konrad CP. 2015. Geospatial Assessment of Ecological Functions and Flood-Related Risks on Floodplains along Major Rivers in the Puget Sound Basin, Washington. U.S. Geological Survey Scientific Investigations Report 2015-5033.

Lee S, Hamlet AF (2011) Skagit River Basin Climate Science Report, a summary report prepared for Skagit County and the Envision Skagit Project by the Department of Civil and Environmental Engineering and The Climate Impacts Group at the University of Washington. https://www.Skagitcounty.net/ EnvisionSkagit/Documents/ClimateChange/ Complete.pdf accessed 11-16-17.

Naiman RJ, Decamps H (1997) The ecology of interfaces: Riparian zones. Annual Review of Ecology and systematics 28:621–658.

Seaber PR, Kapinos FP, Knapp GL (1987) Hydrologic Unit Maps: U.S. Geological Survey Water-Supply Paper 2294, 63 p. https://water.usgs.gov/GIS/huc.html accessed 11-15-17.

Seavy NE, Gardali T, Golet GH, Griggs FT, Howell CA, Kelsey R, Small SL, Viers JH, Weigand JF (2009) Why climate change makes riparian restoration more important than ever: recommendations for practice and research. Ecological Restoration 27: 330–338.

SRSC & WDFW (2005) Skagit Chinook Recovery Plan. Skagit River System Cooperative and Washington Department of Wildlife. La Conner, Washington. 304 pp.

Skagit County 2010. Mapping Riparian Land Use within Agricultural Zones – A Case Study in Skagit County. Skagit County GIS, Mount Vernon, Washington. 30 pp. https://www.skagitcounty.net/SalmonStrategy/Documents/White%20Paper%20v23% 20booklet-style.pdf accessed 11-15-17.

6.0 Riparian Habitats

6.1 Riparian Spatial Extent, Continuity, and Community Structure

Description of Indicators

Riparian and floodplain vegetation provide critical functions, structures, and conditions for salmon in Pacific Northwest ecosystems such as the Skagit and Samish Rivers. Following Puget Sound's common framework, the SWC M&AM Subcommittee has adopted key ecological attributes and indicators of riparian spatial extent & continuity and community structure to describe conditions in various freshwater ecosystem components of large channels, small channels, side channels, and non-channel lakes and wetlands in the floodplain (Table 28). Riparian spatial extent and continuity indicator measures the type, quantity and connectivity of aquatic-adjacent land cover in acres and percent of area. Two attributes are important: spatial scale and functional condition. Spatial scale has latitudinal (or perpendicular) and longitudinal (or parallel) attributes. Our intent is to track ambient status & trends (or cumulative effectiveness indicators) for these KEAs as well as pressure and implementation indicators, and to make recommendations for improvement.

Ideally there would be a discrete goal or DFC to measure each indicator against, but the ecological, societal, and technological complexities surrounding the riparian landscape have made agreement on a single, desired end state difficult. The Skagit Chinook Recovery Plan (2005) did not provide an explicit set of indicators or DFC for how much additional riparian area is enough. Instead, we have compiled herein relevant statements from a variety of foundational documents accumulating over decades that provide definitions and context for where we are with our current riparian policies and DFC, as well as preliminary DFCs in Table 28 as a starting point for future discussions.

- 1998 SWC Habitat Protection and Restoration Strategy – SWC's adopted goal in the Strategy is to "assist and encourage voluntary restoration and protection of natural landscape processes that formed and sustained the habitats to which salmon stocks are adapted." Based on literature values showing at least 80% of functions (e.g. LWD supply) are provided at 40m riparian widths from non-migrating channels, SWC recognized 40m forested widths as functional and an effective approach for reaching this goal. Functional riparian conditions in migrating channels and their floodplains were not fully addressed in the 1998 effort.
- 2005 Skagit Chinook Salmon Recovery Plan – The Swinomish Indian Tribal Community, Sauk-Suiattle Indian Tribe, Skagit River System Cooperative, Washington Department of Fish and Wildlife, and the National Marine Fisheries Service's adopted goals in the Skagit Chinook Recovery Plan are to protect current habitat conditions circa 2005 (via regulatory and voluntary approaches) while restoring productive rearing capacity (including riparian processes) for salmonids in estuarine and freshwater areas of the watershed. Explicit *aquatic* habitat capacity goals were proposed, though no explicit or quantitative *riparian* restoration goals (i.e. beyond protection) were proposed (i.e. how much more is enough?).

- 2015 SWC Strategic Approach – SWC further delineated priority objectives and strategies to voluntarily protect and restore riparian zones, including explicitly identifying up to 2 site potential tree heights (~91m) in Tier 2 floodplain areas.
- September 2017 SWC Resolution – SWC affirmed the Skagit Chinook Recovery Plan fish and habitat goals, though recognized the need for on-going community dialogue about the appropriate suite of strategies and actions necessary to meet those protection and restoration goals.
- December 2017 SWC Riparian Habitat Assessment – SWC adapted the Middle Skagit Reach Analysis (SRSC 2011) geomorphic conceptual model to a riparian conceptual model recognizing that riparian restoration and protection needs increase proportionally with increasing channel migration potential. As a result, riparian conditions were quantified across SWC-delineated geomorphic floodplains and their internal and external riparian areas. No additional goal or strategy development was undertaken by this assessment, though an informal set of recommendations for strategies were drafted for future consideration.

This accumulation of policy does not currently allow identification of a discrete answer for "how much of what quality forested riparian area, and where, is enough to meet the SWC mission and Skagit Chinook Recovery Plan goals." However, it is accurate to say that today the signatories to these documents are working to protect the Skagit River's current level of freshwater riparian function while continuing to restore degraded riparian functions within at least 40m of anadromous salmonid habitat (and greater alongside migrating channels) that, when taken together, will result in improved riparian habitat quantity and quality over time and compared to the 2005 status. Thus, this chapter of the 2018 Skagit M&AM Report presents, in that context, current information and conclusions for freshwater riparian habitat conditions and recommendations for future monitoring and adaptive management. The results from two assessments from different organizations using the same indicators, different methods, and similar results are presented. Finally, recommendations are presented for further consideration.

Table 28. Ecosystem components, KEAs, Indicators, Methods, and Preliminary Desired Future Conditions for Riparian Habitats in the Skagit Watershed.

Ecosystem Component	Key Ecological Attribute	Indicator	Methods	Preliminary Desired Future Conditions
Large Channels, Small Channels, Side Channels, and Non-channel Lakes & Wetlands	Riparian Spatial Extent & Continuity – Status & Trends	Acres and percent functional vegetation within 0-20, 20-40, 40-91m and floodplain	SRSC GIS census 2006-2015 SWC Image Classification 2013	No net loss; plus some amount (?) of gain over time
	Riparian Spatial Extent & Continuity – Pressures	Acres and percent altered vegetation within 0-20, 20-40, 40-91m and floodplain	SRSC GIS census 2006-2015 SWC Image Classification 2013	No gain; plus some amount (?) of loss over time

Ecosystem Component	Key Ecological Attribute	Indicator	Methods	Preliminary Desired Future Conditions
	Riparian Spatial Extent & Continuity – Implementation & Pressures yields Status & Trends	Acres and percent gained by planting and anthropogenic loss within 0-20, 20-40, 40-90m and floodplain	SWC Riparian Actions Geodatabase 2016 WDFW High Resolution Change Detection 2006-2013	No net loss; plus some amount (?) of gain over time
	Riparian Community Structure	Change in height bins 0-6.1, 6.1-18.3, >18.3m	SWC Canopy Height Model 2006 (2016 LiDAR TBD)	Net increase in tree heights of some amount (?)

Differences Between the Two Methods

SWC identified variable buffer widths perpendicular to aquatic habitats consistent with foundational documents listed above, including 4 width classes (0 to 20m, 20 to 40m, 40 to 91m, and the geomorphic floodplain extent). Longitudinally, measurements were taken that include the range of principal Chinook salmon spawning and rearing habitats, excluding for cost-control reasons important upstream habitats that have a less direct impact on those habitats. The two assessments presented have different focus areas, with SWC assessing the 4 width classes in all SWC Tier 1 and 2 and 2S Target Areas (mainstem floodplains and 14 primary chinook rearing tributaries, including upstream steelhead extent therein), and SRSC assessing primarily the 0 to 40m width along a larger set of tributaries, but no mainstem.

Functional vegetation condition includes all types of forest and shrub cover generally, whereas dysfunctional or altered vegetation condition includes all other types of land cover (i.e. impervious, built). SWC lumps impervious area with altered condition, and reports shrub cover separately. SRSC separates impervious or built cover to report those independently. Percent cover is the sum of that specific cover type divided by the specific study area: width, reach, HUC10, or WRIA. Acres of forest planted provide an indicator of riparian restoration implementation. SWC supported project implementers in compiling planting actions via a coordinated geodatabase, allowing quantification of gains in riparian function from 1998 to 2016. No effectiveness monitoring was completed to verify success of reported plantings.

Acres of functional forest loss provides an indicator of pressures (i.e. logging, development). SWC analyzed the WDFW High Resolution Change Detection database for years 2006 to 2013 in the same study width classes and areas to quantify loss of riparian function due to anthropogenic activity. Together they are an early indicator of trends in forest cover across important areas of the watershed.

Methods: Skagit Watershed Council Riparian Assessment - 2017

Methods for the 2017 SWC Riparian Assessment are provided in the final reports available at www.skagitwatershed.org/our-work/riparian.

Status and Trends: Skagit Watershed Council Riparian Assessment - 2017

Results for and discussion of the 2017 SWC Riparian Assessment are provided in the final reports, reach sheets, and mapping products available at www.skagitwatershed.org/our-work/riparian. More than 50,000 acres were classified in SWC target areas via spatially-referenced, high resolution and high accuracy analyses. The status of land cover type in 2013 at the broadest scale is presented in Table 29, with reach-level outputs (Figures 15-17).

Table 29. Watershed-Level Results of Total Riparian Cover Classification for the SWC Tier 1, Tier 2, and Tier 2S Target Areas in Acres

Riparian Cover Type		Acres	Percent
Forest	**Total Forest**	**33,203.90**	**65.92%**
Altered	Built (Structures, Roads, Impervious Surface)	1,955.70	3.88%
	Bare Earth, Dirt	1,198.70	2.38%
	Fine Vegetation (Grasslands, Pasture, Field)	10,236.50	20.32%
	Total Altered	**13,391.00**	**26.59%**
Other Natural	Shrub Herbaceous	2,468.30	4.90%
	Water (Lakes, Ponds)	346	0.69%
	Total Other Natural	**2,814.40**	**5.59%**
Unclassified		**957.4**	**1.90%**
Total		**50,366.70**	**100.00%**

**does not include active channel.*

Project sponsors planted more than 1,170 acres in priority floodplains (our widest buffer width representing geomorphic potential) of the Skagit Watershed, while about 280 acres of functional land cover was lost in the same geographic area, leaving about 880 acres of potential gain in forest cover. The majority of both anthropogenic (mostly due to forestry) and stream-caused loss (due to erosion) was upstream in WRIA 4, while most of the riparian planting was downstream in WRIA 3 (Tables 30 and 31). Summaries for various riparian extents at the reach scale are available in the final report. 38 of 44 reaches analyzed at one of the smallest buffer widths of 0-40m had either gains or no losses of riparian forest extent, while just 6 reaches showed losses, each with less than 0.3 acres of forest lost.

Overall, the 2017 SWC Riparian Assessment showed significant gains in riparian forest functions in the last two decades as a result of steady voluntary and regulatory protection coupled with voluntary riparian planting strategies.

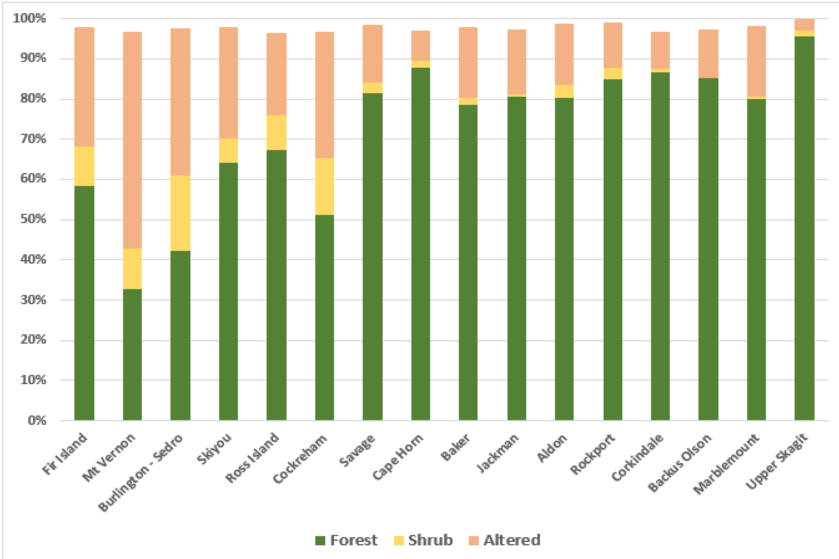

Figure 15. Riparian Cover within 40 m (131 ft) of Active Channel – Skagit Mainstem Reaches

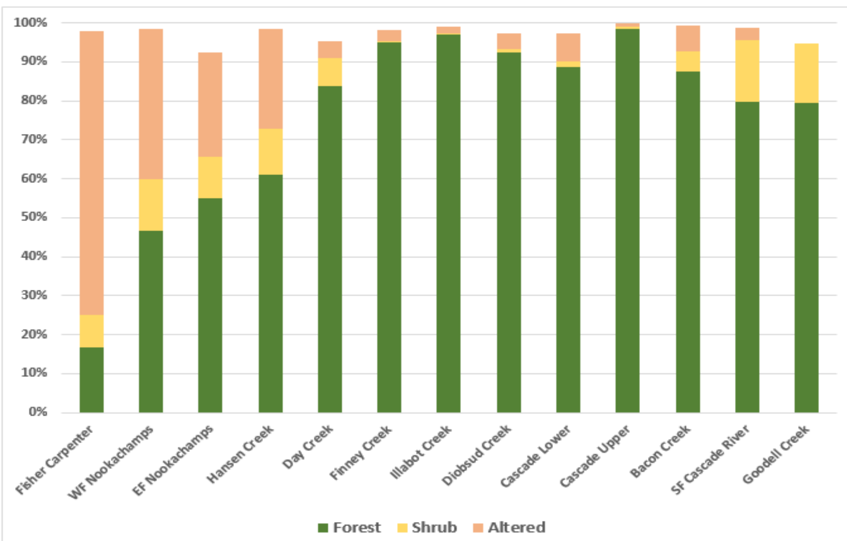

Figure 16. Riparian Cover within 40 m (131 ft) of Active Channel – Skagit Tributary Reaches

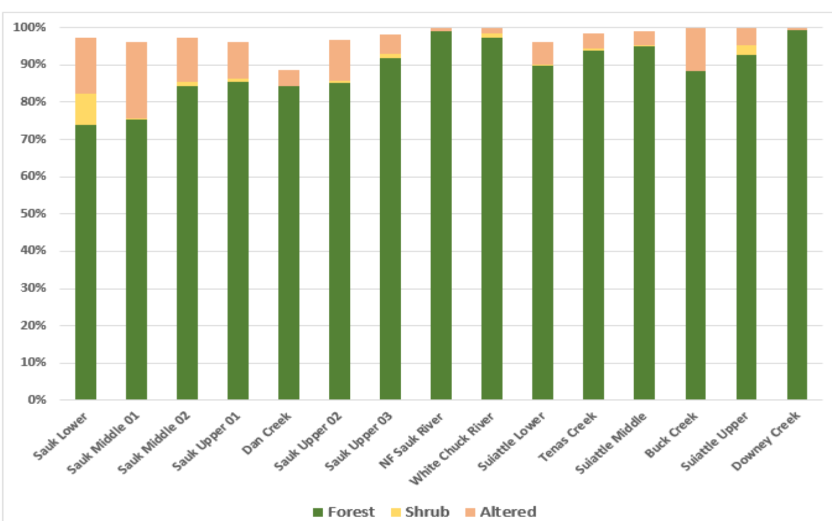

Figure 17. Riparian Cover within 40 m (131 ft) of Active Channel – Sauk & Suiattle Mainstem and Tributary Reaches

Table 30. Status and Trends of Floodplain and Riparian Cover Change by WDFW HRCD Change Agent, Time Period and including Riparian Plantings – WRIA 3

WRIA 3 - Lower Skagit - Samish		Time Period						Total Change (Acres)		Combined Total Change
		2006-2009		2009-2011		2011-2013				
Change Type	Land Cover/Change Agent	connected	isolated	connected	isolated	connected	isolated	connected	isolated	
	Forest, >90% Tree Cover	**86.1**	**4.6**	**17.7**	**0.8**	**28.3**	**4.6**	**132.2**	**10.0**	**142.2**
Loss (Anthropogenic)	Development	0.3		0.1				**0.4**	**0.0**	0.4
	Tree Removal	6.6	1.8	3.6	0.7	5.2	0.3	**15.5**	**2.9**	18.4
	Forestry	0.1	2.8	9.6				**9.8**	**2.8**	12.6
Loss (Natural)	Other, Natural			0.0	0.1	0.3	4.2	**0.3**	**4.3**	4.6
	Stream	79.1		4.4		22.8		**106.3**	**0.0**	106.3
	Herbs and Shrubs	**2.7**	**0.1**	**10.8**	**0.5**	**1.2**	**2.9**	**14.7**	**3.5**	**18.2**
Loss (Anthropogenic)	Development	2.3	0.1	8.5	0.5	0.4	2.5	**11.1**	**3.0**	14.2
	Tree Removal			0.0				**0.0**	**0.0**	0.0
	Other, Non-Natural	0.4		2.3	0.0	0.9	0.3	**3.6**	**0.3**	3.9
	Retention Pond						0.2	**0.0**	**0.2**	0.2
	Grand Total	**88.9**	**4.7**	**28.5**	**1.4**	**29.6**	**7.5**	**147.0**	**13.5**	**160.5**
Gain	SWC Riparian Plantings							**539.1**	**18.3**	557.4
	CREP Riparian Plantings							**147.1**		147.1
	Grand Total (Riparian Plantings)									704.5
	Total Change (Acres) **does not include stream*							**498.7**	**4.8**	**544.0**
	Percent Change *(Total Gains - Total Losses)/Total Riparian Area (*not including active channel))*									**(+) 3.1%**

Table 31. Status and Trends of Floodplain and Riparian Cover Change by WDFW HRCD Change Agent, Time Period and including Riparian Plantings – WRIA 4

WRIA 4 - Upper Skagit		Time Period						Total Change (Acres)		Combined Total Change
		2006-2009		2009-2011		2011-2013				
Change Type	Land Cover/Change Agent	connected	isolated	connected	isolated	connected	isolated	connected	isolated	
	Forest, >90% Tree Cover	**508.3**	**1.4**	**117.4**	**35.3**	**15.7**	**3.7**	**641.5**	**40.3**	**681.8**
Loss (Anthropogenic)	Development			0.0				**0.0**	**0.0**	**0.0**
	Tree Removal	3.9	1.4	3.1	0.2	3.7	0.2	**10.8**	**1.8**	**12.6**
	Forestry	0.2		65.5	33.3	0.4	3.5	**66.0**	**36.8**	**102.8**
Loss (Natural)	Other, Natural	0.6		11.6	1.8			**12.1**	**1.8**	**13.9**
	Stream	503.7	0.0	37.3		11.6		**552.6**	**0.0**	**552.6**
	Herbs and Shrubs	**1.8**		**0.1**		**0.1**		**2.0**	**0.0**	**2.0**
	Development			0.1				**0.1**	**0.0**	**0.1**
Loss (Anthropogenic)	Other, Non-Natural					0.1		**0.1**	**0.0**	**0.1**
Loss (Natural)	Stream	1.8						**1.8**	**0.0**	**1.8**
	Grand Total	**510.1**	**1.4**	**117.6**	**35.3**	**15.8**	**3.7**	**643.5**	**40.3**	**683.8**
Gain	SWC Riparian Plantings							**422.2**	**8.6**	430.8
	CREP Riparian Plantings							**36.3**		36.3
	Grand Total (Riparian Plantings)									467.1
	Total Change (Acres) **does not include stream*							**333.1**		**337.7**
	Percent Change *(Total Gains - Total Losses)/Total Riparian Area (*not including active channel))*									**(+) 1.1%**

Methods: Skagit River System Cooperative Riparian Assessment - 2015

The Skagit system consists of the mainstem Skagit and tributaries, plus the secondary rivers: Baker, Cascade, Sauk, Suiattle, and their tributaries. This study focuses on the spatial extent and continuity of riparian habitat in the mainstem tributaries' 40-m riparian corridors.

We sampled tributaries throughout the spawning grounds of five Skagit Basin Chinook populations. The 2006 analysis included a subset of salmon bearing Skagit River basin tributaries upstream of Mount Vernon, including a few Lower Sauk tributaries (Figure 18). The 2015 analysis sampled most of the salmon bearing Skagit River basin tributaries, including Cascade and Lower Sauk River tributaries, but excluding Suiattle and Upper Sauk River tributaries. Comparisons were made between tributaries sampled both years.

Polygons were mapped using heads-up digitizing and aerial photography taken in 2006 and 2015. 2006 cover was mapped using the USDA-FSA-APFO NAIP MrSID Mosaic orthophoto with 1-m pixel resolution, flown between July and August 2006. 2015 cover was mapped using the Skagit County pictometry orthophoto with 30-cm pixel resolution, flown between February and May 2015 and USDA-FSA-APFO NAIP MrSID Mosaic orthophoto with 0.5-m pixel resolution, flown between August and September 2015. All vegetation maps were drawn at a 3-m diameter patch resolution and a mapping scale of 1:1,000.

We analyzed 40-meters on either side of the tributaries, which extended from the edge of the active channel or the centerline, based on whether the tributary measured more than seven meters across. The study area extended from the tributary's mouth to the top of the alluvial fan.

We grouped the results by USDA Hydrologic Units (HUCs), delineated to the watershed (10-digit) level (Seaber et al. 1987). We also labeled each watershed as rainfall-dominated, snowpack-dominated, or mixed-rain-and-snow regimes, based on the proportion of October through March rainfall to April 1st snowpack (snow water equivalent), as defined by Elsner et al. (2010).

Functional Vegetation

Areas dominated by woody species were classified as functional vegetation (Figure 19). Common species included western red cedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*), Douglas fir (*Pseudotsuga menziesii),* black cottonwood (*Populus balsamifera* ssp. *trichocarpa*), red alder (*Alnus rubra)* and salmonberry (*Rubus spectabilis).* Percent functional vegetation was calculated as the sum of the functional vegetation polygons divided by the sum of the study area polygons.

Infrastructure

Areas containing structures, roads and parking lots were classified as Infrastructure. Percent infrastructure was calculated as the sum of the infrastructure polygons divided by the sum of the study area polygons.

Dysfunctional Vegetation

Areas containing agriculture, lawns and invasive species were classified as dysfunctional vegetation. Common invasive species included Himalayan blackberry (*Rubus armeniacus*) and reed canarygrass (*Phalaris arundinacea*). Percent dysfunctional vegetation was calculated as the sum of the dysfunctional vegetation polygons divided by the sum of the study area polygons.

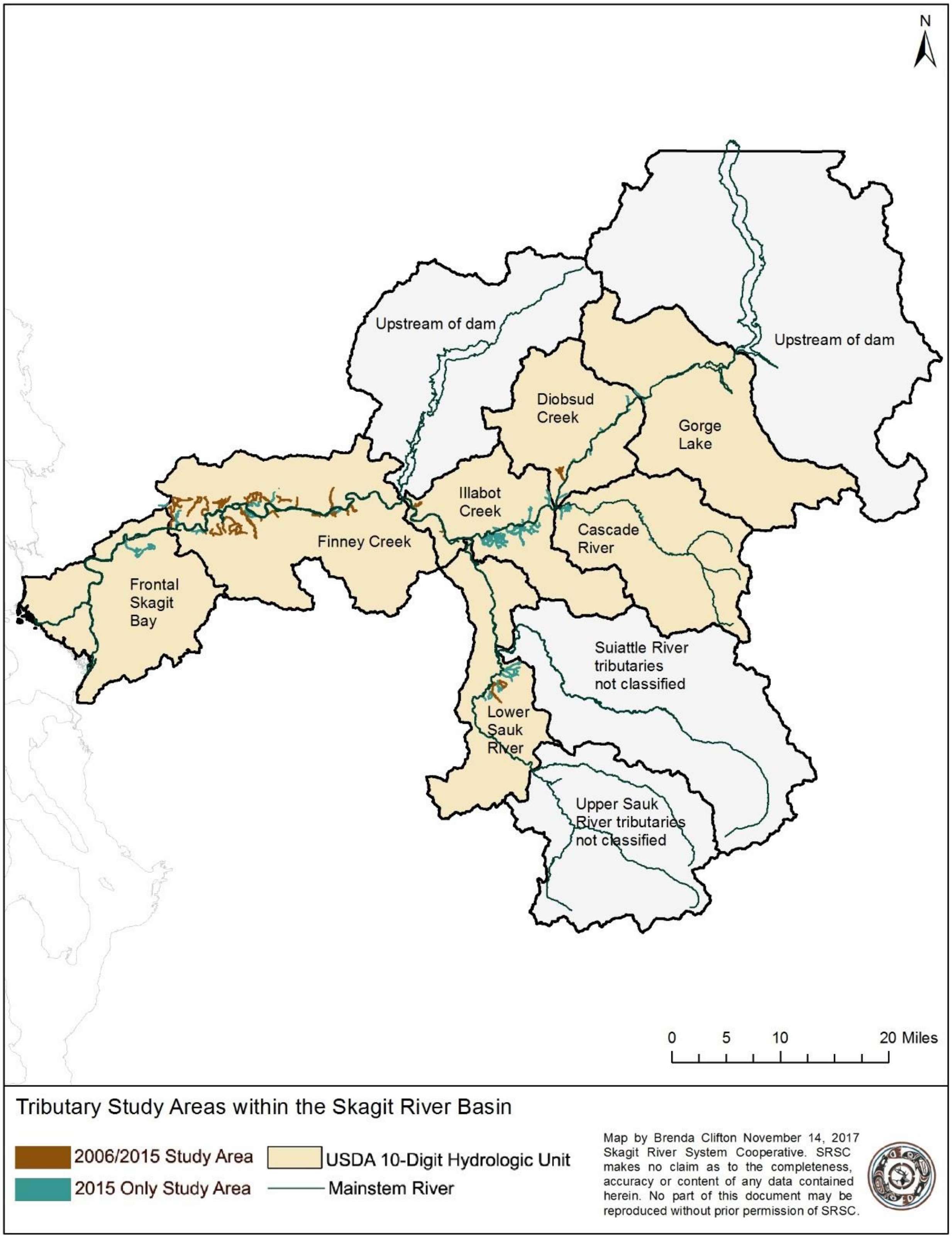

Figure 18. Map of the Skagit River basin tributaries included in the study.

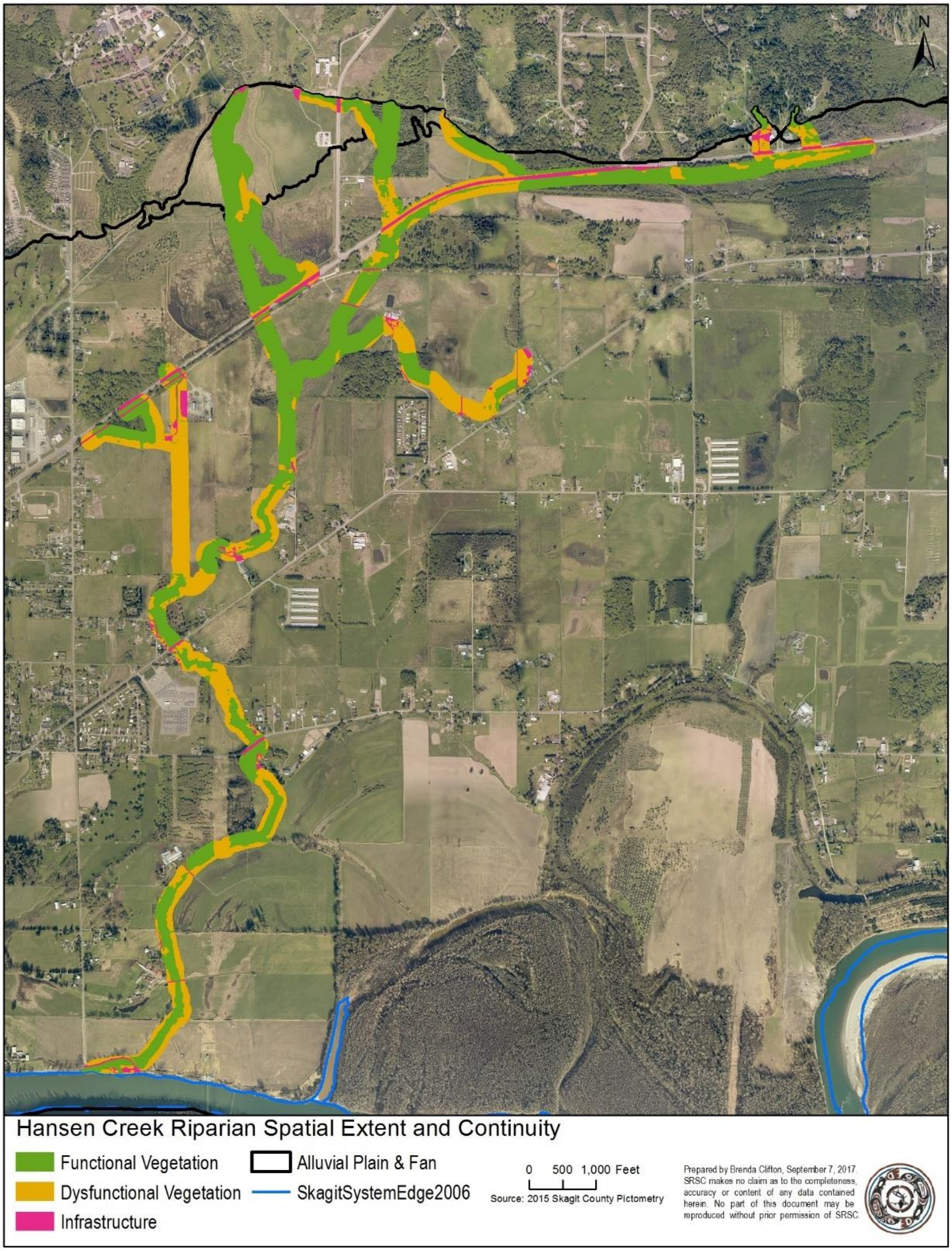

Figure 19. Example of polygon types and detail in Hansen Creek.

Status and Trends: Skagit River System Cooperative Riparian Assessment - 2015

Functional Vegetation

Percent functional vegetation increased from 2006 to 2015 (from 70.0% to 72.4%; Table 32). Percent functional vegetation increased in the Finney Creek - Skagit River Tributaries (from 66.1 to 69.3) but decreased in the Illabot Creek - Skagit River Tributaries, Diobsud Creek-Skagit River Tributaries and Lower Sauk Tributaries (from 90.5 to 87.6, 93.4 to 93.1 and 89.8 to 85.1, respectively). Combined percent functional vegetation was 74.9 for the larger 2015 study area (Table 33). The Frontal - Skagit Bay Tributaries and Diobsud Creek-Skagit River Tributaries had the lowest and highest percent functional vegetation (27.9 and 94.2).

Table 32. Comparison of 2006 and 2015 functional riparian vegetation in Skagit Basin tributaries (only tributaries analyzed both years included).

Watershed Type	Hydrologic Unit Name	2006 Cover	2015 Cover
Rain	Finney Creek - Skagit River Tributaries	66.1%	69.3%
Mixed Rain and Snow	Illabot Creek - Skagit River Tributaries	90.5%	87.6%
Mixed Rain and Snow	Diobsud Creek-Skagit River Tributaries	93.4%	93.1%
Mixed Rain and Snow	Lower Sauk Tributaries	89.8%	85.1%
	Combined	**70.0%**	**72.4%**

Table 33. 2015 functional riparian vegetation in Skagit Basin tributaries (all analyzed tributaries included).

Watershed Type	Hydrologic Unit Name	2015 Cover
Rain	Frontal - Skagit Bay Tributaries	27.9%
Rain	Finney Creek - Skagit River Tributaries	68.4%
Mixed Rain and Snow	Illabot Creek - Skagit River Tributaries	89.1%
Mixed Rain and Snow	Diobsud Creek-Skagit River Tributaries	94.2%
Mixed Rain and Snow	Lower Sauk Tributaries	74.1%
Snow	Gorge Lake -Skagit River Tributaries	90.2%
Snow	Cascade River Tributaries	88.1%
	Combined	**74.9%**

The functional vegetation cover within the study area falls short of the one hundred percent desired recovery condition. Watersheds near urban centers are the most degraded, for example the Frontal - Skagit Bay Tributary unit, which contains the city of Mount Vernon. In the Cascade foothills, the Diobsud Creek and Gorge Lake -Skagit River Tributaries watersheds remain relatively intact. Restoration efforts are improving riparian conditions–most of the gained functional vegetation polygons were planted areas–but work remains to be done.

Infrastructure

Percent infrastructure remained at 3.9 between 2006 and 2015 (Table 34). Percent infrastructure increased in Illabot Creek - Skagit River and Lower Sauk Tributaries (from 1.7 to 2.3 and from 1.1 to 2.0), but decreased in Diobsud Creek-Skagit River Tributaries (from 0.9 to 0.7). Infrastructure covered 3.0% of the larger 2015 study area (Table 35). Finney Creek - Skagit River and Cascade River Tributaries had the largest percentage of infrastructure (4.6 and 4.0); Cascade River Tributaries had the lowest percentage of infrastructure (1.4). The Cascade River Tributaries had the second highest percent infrastructure, despite their distance from metropolitan areas. The deep Cascade River basin minimized the study area between tributary mouths and alluvial fan tips, increasing the relative proportion of infrastructure.

Table 34. Comparison of 2006 and 2015 riparian infrastructure Skagit Basin tributaries (only tributaries analyzed both years included).

Watershed Type	Hydrologic Unit Name	2006 Cover	2015 Cover
Rain	Finney Creek - Skagit River Tributaries	4.4%	4.4%
Mixed Rain and Snow	Illabot Creek - Skagit River Tributaries	1.7%	2.3%
Mixed Rain and Snow	Diobsud Creek-Skagit River Tributaries	0.9%	0.7%
Mixed Rain and Snow	Lower Sauk Tributaries	1.1%	2.0%
	Combined	**3.9%**	**3.9%**

Table 35. 2015 riparian infrastructure in Skagit Basin tributaries (all analyzed tributaries included).

Watershed Type	Hydrologic Unit Name	2015 Cover
Rain	Frontal - Skagit Bay Tributaries	1.5%
Rain	Finney Creek - Skagit River Tributaries	4.6%
Mixed Rain and Snow	Illabot Creek - Skagit River Tributaries	1.5%
Mixed Rain and Snow	Diobsud Creek-Skagit River Tributaries	1.5%
Mixed Rain and Snow	Lower Sauk Tributaries	2.3%
Snow	Gorge Lake -Skagit River Tributaries	1.4%
Snow	Cascade River Tributaries	4.0%
	Combined	**3.0%**

Dysfunctional Vegetation

Percent dysfunctional vegetation decreased from 26.1 to 23.6 between 2006 and 2015 (Table 36). Percent dysfunctional vegetation decreased in Finney Creek - Skagit River Tributaries (from 29.4 to 26.3), but increased in Illabot Creek - Skagit River, Diobsud

Creek-Skagit River and Lower Sauk Tributaries (from 7.8 to 10.1, from 5.7 to 6.2 and from 9.1 to 12.9, respectively). Dysfunctional vegetation covered 22.0% of the larger 2015 study area (Table 37). Percent dysfunctional vegetation was highest in the Frontal - Skagit Bay Tributaries (70.6) and lowest in the Gorge Lake -Skagit River Tributaries (0.5).

Table 36. Comparison of 2006 and 2015 dysfunctional riparian vegetation in Skagit Basin tributaries (only tributaries analyzed both years included).

Watershed Type	Hydrologic Unit Name	2006 Cover	2015 Cover
Rain	Finney Creek - Skagit River Tributaries	29.4%	26.3%
Mixed Rain and Snow	Illabot Creek - Skagit River Tributaries	7.8%	10.1%
Mixed Rain and Snow	Diobsud Creek-Skagit River Tributaries	5.7%	6.2%
Mixed Rain and Snow	Lower Sauk Tributaries	9.1%	12.9%
	Combined	**26.1%**	**23.6%**

Table 37. 2015 dysfunctional riparian vegetation in Skagit Basin tributaries (all analyzed tributaries included).

Watershed Type	Hydrologic Unit Name	2015 Cover
Rain	Frontal - Skagit Bay Tributaries	70.6%
Rain	Finney Creek - Skagit River Tributaries	27.0%
Mixed Rain and Snow	Illabot Creek - Skagit River Tributaries	4.3%
Mixed Rain and Snow	Diobsud Creek-Skagit River Tributaries	4.3%
Mixed Rain and Snow	Lower Sauk Tributaries	23.6%
Snow	Gorge Lake -Skagit River Tributaries	0.5%
Snow	Cascade River Tributaries	8.0%
	Combined	**22.0%**

Comparison of Results to Similar Studies

The results in this study are not directly comparable to the Chinook Recovery Plan (SRSC & WDFW 2005). The Chinook recovery plan's study area included the entire extent of the anadromous zone, whereas this study focuses on the habitat below the top of the alluvial fan.

The 2006 results are comparable–within two percent–to a study done by Skagit County (2010), using 2007 Pictometry aerial photographs (Table 38). Skagit County assessed the cover of forests, wetlands, agricultural lands, grasses, developed lands and roads along tributaries in Agriculture (Ag-NRL) or Rural Resource (RRc-NRL) zones. Buffer widths followed County regulations, which varied from 50 to 200 feet.

Table 38. Comparison of Skagit River System Cooperative and Skagit County tributary riparian special extent and continuity results.

Skagit County			Skagit River System Cooperative	
Class	**Cover**	**Sum**	**Class**	**Cover**
Forest Wetland	61.1% 7.3%	**68.4%**	Functional Vegetation	**68.0%**
Agriculture Grass	22.0% 4.5%	**26.5%**	Dysfunctional Vegetation	**26.0%**
Developed Road	3.0% 1.8%	**4.8%**	Structures & Roads	**3.9%**
Other	0.3%	**0.3%**		

The 2015 results are similar–within four percent–to a study released by the Skagit Watershed Council (Table 39; Environmental Science Associates 2017), using 2013 NAIP aerial photographs. Environmental Science Associates used computer vision (automated digitizing) to derive land use data. We used ArcGIS shapefiles to assess areas common to both studies (1216.4 hectares) and compared the cover class results.

Table 39. Comparison of Skagit River System Cooperative and Skagit Watershed Council Skagit River tributary riparian special extent and continuity results.

Skagit Watershed Council			Skagit River System Cooperative	
Class	**Cover**	**Sum**	**Class**	**Cover**
Coniferous Deciduous Shrub Herbaceous Mixed Forest	10.6% 30.0% 7.0% 18.7%	**66.3%**	Functional Vegetation	**63.3%**
Grasslands, Pasture, Field Bare earth	11.4% 1.2%	**12.7%**	Dysfunctional Vegetation	**16.0%**
Structures, Road, Impervious	2.2%	**2.2%**	Structures & Roads	**1.7%**
Active Channel Water	9.9% 5.8%	**15.6%**	Active Channel	**19.0%**
Unclassified	3.2%	**3.2%**		

6.2 Recommendations for Riparian Habitats

Recommendations for Monitoring

Recommendation 35: Repeat land cover classification on a decadal timespan to continue to track status and trends at various scales. Continue updating SWC riparian action and

WDFW high resolution change detection databases to track gains and losses on a roughly 2-year timeframe.

Recommendation 36: Improve single-thread hydrography and river channel polygon GIS layers so that riparian assessment results more accurately characterize land cover.

Recommendation 37: Monitor effectiveness of planting methods at restoration sites to better estimate functional gain and facilitate adaptive management of riparian planting restoration methods.

Recommendation 38: Build a canopy height model with 2015/16/17 LiDAR and assess comparability to 2006 LiDAR for tracking trends in riparian community structure.

Recommendation 39: Utilize canopy height models and updated hydrography to develop additional riparian community structure and function indicators such as canopy cover, functional stream shading, wood loading, etc.

Recommendations for Hypotheses and Desired Future Conditions

Recommendation 40: Outline riparian habitat desired future conditions and goals in the watershed and reaches and track progress in relation to them.

Recommendations for Strategies

Recommendation 41: Clarify in the next iteration of the Strategic Approach the specific geographic extent of riparian target areas. The Strategic Approach should be able to qualify:

a. The geographic extent of riparian target areas in Tier 1 versus Tier 2 floodplains, and how the riparian width should be measured (e.g., from floodplains or rearing habitats?).

a. how planting in target areas within dynamic reaches should be considered relative to more stable reaches, with the aim of restoring processes that allow for channel migration and floodplain interaction, and assuming an inundation frequency of the 2-year recurrent flow.

Recommendation 42: Generate technical guidance outlining where riparian planting would provide the most benefit to adapt the watershed in preparation for future climate change impacts (e.g. solar inputs along juvenile rearing habitats).

Recommendation 43: Continue to bring practitioners together to share and document best practices and lessons learned.

6.3 References

Beamer EM, Beechie T, Perkowski B, Klochak J (2000) Application of the Skagit Watershed Council's strategy -- river basin analysis of the Skagit and Samish Basins: tools for

salmon habitat restoration and protection. Skagit Watershed Council, Mount Vernon, Washington. 80pp.
Beamer E, Shannahan J, Wolf K, Lowery E, and Pflug D (2010) Freshwater Habitat Rearing Preferences for Stream Type Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) and Steelhead (*O. mykiss*) in the Skagit River Basin: Phase 1 Study Report.
Beamer EM (2017) Skagit Monitoring Report June 30, 2017. Skagit Water Shed Council Monitoring and Adaptive Management Subcommittee, Mount Vernon, Washington. 18 pp.
Beechie TJ, Stefankiv O, Timpane-Padgham B, Hall J, Pess GR, Rowse M, Liermann M, Fresh K, Ford M (2015) Monitoring habitat status and trends in Puget Sound: development of sample designs, monitoring metrics, and sampling protocols for nearshore, delta, large river, and floodplain environments. National Oceanic and Atmospheric Administration, Seattle, Washington. 198 pp.
https://www.nwfsc.noaa.gov/news/events/program_reviews/2016/documents/supporting/B6_Beechie_et_al_2016.pdf accessed 12/13/2017.
Cassie D (2006) The thermal regime of rivers: A review. Freshwater Biology 51:1389–1406.
Collins BD (2000) Mid-19th century stream channels and wetlands interpreted from archival sources for three north Puget Sound estuaries. Report to Skagit System Cooperative, La Conner, Washington.
Collins BD, Sheikh AJ (2002) Methods used to map the historical riverine landscape and habitats of the Skagit River. Report to the Skagit System Cooperative, La Conner, Washington.
Elsner M, Cuo L, Voisin N, Deems J, Hamlet A, Vano J, Mickelson K, Lee S, Lettenmaier D (2010) Implications of 21st century climate change for the hydrology of Washington State. Climatic Change 102, 225-260.
Environmental Science Associates (2017) Skagit Watershed Council Riparian assessment & strategy update – TWG review draft, October 17, 2017. Prepared for the Skagit Watershed Council, Mount Vernon, Washington. 68 pp.
Federal Emergency Management Agency (1996) Q3 Flood Data, Skagit, WA, Snohomish, WA, and Whatcom, WA.
Hartson R, Shannahan J. 2015. Inventory and Assessment of Hydromodified Bank Structures in the Skagit River Basin: Chinook Bearing Streams. Upper Skagit Indian Tribe, Sedro Woolley, WA.
Heller NE, Zavaleta ES (2008) Biodiversity management in the face of climate change: A review of 22 years of recommendations. Biological conservation 142:14–32.
Konrad CP. 2015. Geospatial Assessment of Ecological Functions and Flood-Related Risks on Floodplains along Major Rivers in the Puget Sound Basin, Washington. U.S. Geological Survey Scientific Investigations Report 2015-5033.
Lee S, Hamlet AF (2011) Skagit River Basin Climate Science Report, a summary report prepared for Skagit County and the Envision Skagit Project by the Department of Civil and Environmental Engineering and The Climate Impacts Group at the University of Washington. https://www.Skagitcounty.net/ EnvisionSkagit/Documents/ClimateChange/ Complete.pdf accessed 11-16-17.
Naiman RJ, Decamps H (1997) The ecology of interfaces: Riparian zones. Annual Review of Ecology and systematics 28:621–658.

Seaber PR, Kapinos FP, Knapp GL (1987) Hydrologic Unit Maps: U.S. Geological Survey Water-Supply Paper 2294, 63 p. https://water.usgs.gov/GIS/huc.html accessed 11-15-17.
Seavy NE, Gardali T, Golet GH, Griggs FT, Howell CA, Kelsey R, Small SL, Viers JH, Weigand JF (2009) Why climate change makes riparian restoration more important than ever: recommendations for practice and research. Ecological Restoration 27: 330–338.
SRSC & WDFW (2005) Skagit Chinook Recovery Plan. Skagit River System Cooperative and Washington Department of Wildlife. La Conner, Washington. 304 pp.
Skagit County 2010. Mapping Riparian Land Use within Agricultural Zones – A Case Study in Skagit County. Skagit County GIS, Mount Vernon, Washington. 30 pp. https://www. skagitcounty.net/SalmonStrategy/Documents/White%20Paper%20v23% 20booklet-style.pdf accessed 11-15-17.

7.0 Future Monitoring

7.1 Large Woody Debris

Background

Throughout the Skagit River Basin, large woody debris forms key riverine habitat features that have a significant impact on hydraulic processes, geomorphology, and salmon habitat quality (Abbe and Montgomery 1996, Naiman et al. 2002, Opperman et al. 2006, Shields and Alonso 2012). Large Woody Debris (LWD), also known as log jams, promote the development of complex habitat features (Abbe et al. 2016, Montgomery et al. 1995), diversify water flow characteristics while decreasing flow velocity (Hafs et al. 2014, Linstead 2001, Shields and Gippel 1995), control sediment transport (Abbe and Montgomery 1996, Manga and Kirchner 2000, Montgomery et al. 2003, Nakamura and Swanson 1993), and improve habitat for fish and macroinvertebrates (Bisson et al. 1987, Lester and Boulton 2008, Roni and Quinn 2001, Shirvell 1990).

There were no overarching restoration activities targeting LWD in the 2005 Skagit Chinook Recovery Plan. Instead, the 2005 Plan focused on the protection of intact riparian zones and channel complexity features, such as LWD.

> *"Large woody debris placement can provide a short-term fix until the planted areas mature, but LWD projects should be limited to sites where pool-riffle habitat may once have existed and where the LWD won't be washed away. This plan does not specify any riparian planting or LWD placement projects. Instead, it addresses riparian degradation through protection actions and maintenance of buffers (Chapter 8)."*

Though a lack of large woody debris is not specifically mentioned in the 2005 Plan, LWD is directly connected to many of the listed factors. There are also several areas in the 2005 Plan where placement of LWD is identified as a specific part of recommended site-scale restoration action, especially in the context of floodplain restoration and reconnection.

Methods

In 2010, Beamer et al. published *Freshwater Habitat Rearing Preferences for Stream Type Juvenile Chinook Salmon(Oncorhynchus tshawytscha) and Steelhead (O. mykiss) in the Skagit River Basin: Phase 1 Study Report.* In this report, authors identified seasonal and habitat type preferences in freshwater habitat in the Skagit River basin by examining where habitat types are used by fish seasonally, where fish are located within the basin seasonally, and where habitats (by type) are within the basin.

The GIS layer *Logjams2007* was made in order to characterize log jams. See Beamer et al., (2010) for detail on the methods used to create the layer and geographic extent. The report identified 347 log jams within the photo area. Rare habitat for log jams was defined as those jams that were large enough to have a geomorphic influence on the channel. Log jams that touched at least 100 meters of water's edge were considered a good surrogate for geomorphic influence because most of the larger jams created islands or slowed lateral channel migration. Only 11%, or 53, of all log jams fit the definition of rare log jams (Figures 20).

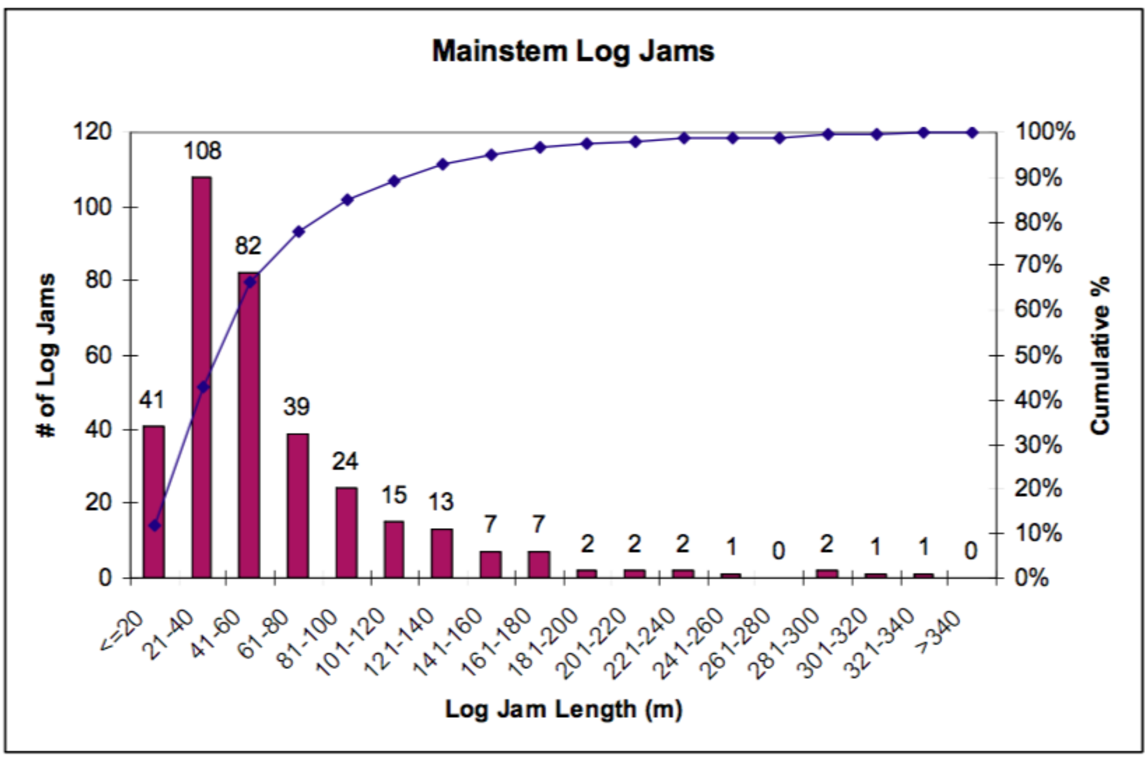

Figure 20. Frequency distribution of log jams by length of jam touching the water's edge in year 2007 by oblique Pictometry photos. (adopted from Beamer et al., 2010)

Future LWD Monitoring

In 2017, Skagit Watershed Council directed Natural Systems Design to produce *Skagit River Large Woody Debris Assessment: Connecting LWD to the 2005 Skagit Chinook Recovery Plan*. This report formalized a conceptual framework for how LWD fit within the existing Recovery Plan framework. It also investigated and presented potential metrics (Table 40) and methods for an assessment of large wood in Chinook habitat, in both mainstem rivers and tributaries.

Table 40. Summary of Recommended Metrics for Mainstem LWD Assessment

Summary of recommended metrics	
Number of jams	Number of jams >100ft in contact with landform (2006, 2017)
Jams/km	Number of key members
Jam type	Number of nodes (Beechie 2017)
Map of jams	River Complexity Index (Brown 2002)
Total number of pieces in reach	Volume of wood*
Number of functional jams in regulated vs. non-regulated systems/reaches	

*May not be able to be collected with a high level of accuracy.

The methods recommended for the assessment of large wood in the Skagit Watershed are a combination of LiDAR and aerial imagery (NAIP or equivalent) for larger rivers. Rationale included:

- High resolution LiDAR is an effective and cost-effective method for measurement of wood across large areas
- Green LiDAR has the potential to record data under the water surface if conditions are appropriate
- Imagery can be used to assess jam type and function and to validate LiDAR
- LiDAR for the basin was collected in 2017 and would be available for analysis
- Comparison with 2006 data layer could be made for change through time

7.2 Recommendations for Future Monitoring

Recommendation 62: The M&AM Subcommittee recommends that the initial priority for LWD monitoring be on large mainstems where remote sensing techniques have been proven. Information on tributaries and small streams is important, however the current methodologies with field crews completing inventories are costly. Implementation of the remote sensing approach should explore how far upstream into smaller tributaries the methodology can be successfully applied.

Recommendation 63: In the future, the Skagit partners may want to consider combining the LWD information with riparian zone succession modeling and updated sediment source data, as the processes are closely interlinked.

7.3 References

Abbe, T., Belby, B. and Shields Jr, F.D. (2016) National Large Wood Manual - Assessment, Planning, and Design of Large Wood in Fluvial Ecosystems: Restoring Process, Function, and Structure. p. 628, Bureau of Reclamation and U.S. Army Corps Research and Development Center.

Abbe, T.B. and Montgomery, D.R. (1996) Large woody debris jams, channel hydraulics and habitat formation in large rivers. Regulated Rivers: Research & Management 12, 201-221.

Beamer, E., Shannahan, JP, Wolf , K., Lowery, E., Pflug , D. Freshwater habitat rearing preferences for stream type juvenile Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*) in the Skagit River Basin: Phase 1 study report. Skagit River System Cooperative.

Bisson, P.A., Bilby, R.E., Bryant, M.D., Dolloff, C.A., Grette, G.B., House, R.A., Murphy, M.L., Koski, K.V. and Sedell, J.R. (1987) Large woody debris in forested streams in the Pacific Northwest: past, present, and future. In E. O. Salo and T. Cundy [ed.] Proceedings of an interdisciplinary symposium on streamside management: forestry and fisheries interactions. University of Washington Press, Seattle, WA.

Hafs, A.W., Harrison, L.R., Utz, R.M. and Dunne, T. (2014) Quantifying the role of woody debris in providing bioenergetically favorable habitat for juvenile salmon. Ecological Modelling 285, 30-38.

Lester, R.E. and Boulton, A.J. (2008) Rehabilitating agricultural streams in Australia with wood: a review. Environmental Management 42(2), 310-326.

Linstead, C. (2001) The effects of large woody debris accumulations on river hydraulics and implications for physical habitat. Hydro-ecology: Linking Hydrology and Aquatic Ecology (Proceedings of Workshop held in Birmingham, UK, July 1999), 91-99.

Manga, M. and Kirchner, J.W. (2000) Stress partitioning in streams by large woody debris. Water Resources Research 36(8), 2373-2379.

Montgomery, D.R. and Abbe, T.B. (2006) Influence of logjam-formed hard points on the formation of valley-bottom landforms in an old-growth forest valley, Queets River, Washington, USA. Quaternary Research 65(1), 147-155.

Montgomery, D.R. and Buffington, J.M. (1997) Channel-reach morphology in mountain drainage basins. Geological Society of America Bulletin 109, 596-611.

Naiman, R.J., Balian, E.V., Bartz, K.K., Bilby, R.E. and Latterell, J.J. (2002) Dead wood dynamics in stream ecosystems. USDA Forest Service General Technical Report PSW-GTR-181, 23-48.

Nakamura, F. and Swanson, F.J. (1993) Effects of coarse woody debris on morphology and sediment storage of a mountain stream system in western Oregon. Earth Surface Processes and Landforms 18(1), 43-61.

Opperman, J., Merenlender, A. and Lewis, D. (2006) Maintaining wood in streams: A vital action for fish conservation. University of California ANR Publications, 11p.

Roni, P. and Quinn, T. (2001) Density and size of juvenile salmonids in response to placement of large woody debris in western Oregon and Washington streams. Canadian Journal of Fisheries and Aquatic Sciences 58(2), 282-292.

Shields, F.D. and Alonso, C.V. (2012) Assessment of flow forces on large wood in rivers. Water Resources Research 48(4), n/a-n/a.

Shields, F.D. and Gippel, C.J. (1995) Prediction of Effects of Woody Debris Removal on Flow Resistance. Journal of Hydraulic Engineering 121(4), 341.

Appendix 1: Complete List of Key Ecological Attributes (KEAs) Identified in Phase 1

Shaded - Indicator Explicitly Identified in Phase 1 Translation

Component	Name	Explicit Skagit Indicator	Subcommittee Lead	Related NOAA indicator	PSP Common Indicator
Estuary	Fluvial sediment dynamics - condition				
Estuary	Tidal circulation - extent of dependent biological activity.				
Estuary	Freshwater hydrology - condition	Minimum instream flow	Eric Beamer/SRSC		
Estuary	Tidal channel formation and maintenance - extent of channels	Blind channels, distributary channels	Eric Beamer/SRSC	Tidal channel area #, Habitat Quantity Node density	Extent of functional tidal channels*
Estuary	Tidal channel formation and maintenance - connectivity of channels				
Estuary	Detritus recruitment and retention - extent				
Estuary	Habitat connectivity - condition	Blind channels landscape connectivity	Eric Beamer/SRSC	Length of tidal barriers/levees , Connectivity #	
Estuary	Estuarine habitats - extent	Tidal habitat; tidal delta footprint, all types	Eric Beamer/SRSC	Estuary surface area/drainage area	Functional estuary surface area*
Estuary	Estuarine habitats - distribution	Tidal delta habitat connectivity	Eric Beamer/SRSC	Land Use/Land Cover, Wetland area #, wetland type	
Estuary	Water quality				
Pocket estuary	Coastal sediment dynamics in drift cells - condition				

Component	Name	Explicit Skagit Indicator	Subcommittee Lead	Related NOAA indicator	PSP Common Indicator
Pocket estuary	Coastal sediment dynamics in drift cells - landscape context				
Pocket estuary	Fluvial sediment dynamics - condition				
Pocket Estuary	None specified	Length of mainstem natural edge, length of riparian edge consistent with BAS	Eric Beamer/SRSC		
Pocket Estuary	Tidal circulation - extent of dependent biological activity	Accessible pocket estuary area	Eric Beamer/SRSC		
Pocket estuary	Tidal circulation - dependent water condition				
Pocket estuary	Freshwater hydrology - dependent water condition				
Pocket Estuary	Freshwater hydrology - condition				
Pocket estuary	Tidal channel formation and maintenance - extent of channels				Extent of functional tidal channels*
Pocket estuary	Tidal channel formation and maintenance - connectivity of channels				
Pocket estuary	Habitat connectivity condition	Median distance between pocket estuaries	Eric Beamer/SRSC		
Pocket estuary	SAV beds - condition				
Pocket estuary	SAV beds - extent				
Pocket estuary	Estuarine habitats - extent	Number of pocket estuaries accessible to juvenile Chinook	Eric Beamer/SRSC		Pocket estuarine habitat area that is accessible*, Pocket estuary count
Pocket estuary	Estuarine habitats - distribution				

Component	Name	Explicit Skagit Indicator	Subcommittee Lead	Related NOAA indicator	PSP Common Indicator
Pocket estuary	Tidally influenced wetlands - extent				Extent of connected tidal wetlands*
Pocket estuary	Water quality				
Large channels	Sediment dynamics - sediment delivery	Sediment supply	?		
Large channels	Sediment dynamics - sediment transport and storage		?		
Large channels	Hydrology - high flow hydrological regime	Frequency, duration, and magnitude of peak flows, interday flow variability; high flow	?		
Large channels	Hydrology - low flow hydrological regime	Interday flow variability; low flow	?		
Large channels	Organic matter - inputs				
Large channels	Riparian - Spatial extent and continuity of riparian area	% and acres riparian cover at variable widths, % 500 year floodplain forested	Richard Brocksmith, Chis Vondrasek/SWC	Percent of mainstem riparian forested/disturbed/impervious #	% forest within 200 feet of anadromous streams*
Large channels	Riparian - Riparian community structure	Cover type and height at variable widths	Richard Brocksmith, Chis Vondrasek/SWC	Riparian buffer width and type	
Large channels	Riparian - function of riparian and wetland vegetation				
Large channels	Nutrient supply - nutrient cycling/flux	Nutrient loading, etc.	Steve Hinton/SRSC		
Large channels	Nutrient supply - water quality	Temp, turbidity, etc	Steve Hinton/SRSC		

Component	Name	Explicit Skagit Indicator	Subcommittee Lead	Related NOAA indicator	PSP Common Indicator
Large channels	Floodplain-channel interactions - floodplain connectivity	Area of all channel types in unconfined reaches, floodplain connectivity area, floodplain connectivity fragmentation, Duration and magnitude of habitat creating flows	Kate Ramsden, Tim Hyatt, Steve Hinton/SRSC	Edge habitat length by type, Area of connected floodplain #	Side channel length/mainstem length (ratio)*, connectivity
Large channels	Floodplain-channel interactions - floodplain structure and function	Duration and magnitude of habitat creating flows, large mainstem backwaters	Kate Ramsden, Tim Hyatt, Steve Hinton/SRSC	Sinuosity	Land use/land cover
Large channels	Habitat connectivity	Length of all edge types, length of connecected habitat, median landscape connectivity	Kate Ramsden, Tim Hyatt, Steve Hinton/SRSC	Percent of floodplain forested/bare/water	Extent of shoreline armoring*, % historic miles available to adult Chinook
Small channel	Sediment dynamics - sediment delivery				
Small channel	Sediment dynamics - sediment transport and storage				
Small channel	Hydrology - high flow hydrological regime				
Small channel	Hydrology - low flow hydrological regime				
Small channel	Organic matter - inputs				
Small channel	Organic matter - retention/processing				
Small channel	Riparian - spatial extent and continuity of riparian areas				% forest within 200 feet of anadromous streams*

Component	Name	Explicit Skagit Indicator	Subcommittee Lead	Related NOAA indicator	PSP Common Indicator
Small channel	Riparian - riparian community structure				
Small channel	Nutrient supply - nutrient cycling and flux				
Small channel	Nutrient supply - water quality	# of 303d listed parameters	Steve Hinton/SRSC		
Small channel	Floodplain channel interactions - floodplain connectivity	Length of all channel types, length of mainstem natural edge	SRSC		
Small channel	Floodplain-channel interactions - floodplain structure and function				
Small channel	Habitat connectivity	Interday flow variability; low flow and high flow	?		% historic miles available to adult Chinook
Side channels	Sediment dynamics - sediment delivery				
Side channels	Sediment dynamics - sediment transport and storage				
Side channels	Hydrology - high flow hydrological regime				
Side channels	Hydrology - low flow hydrological regime				
Side channels	Organic matter - inputs				
Side channels	Organic matter - retention and processing				
Side channels	Riparian - function of riparian vegetation				
Side channels	Nutrient supply - nutrient cycling/flux				
Side channels	Nutrient supply - water quality				

Component	Name	Explicit Skagit Indicator	Subcommittee Lead	Related NOAA indicator	PSP Common Indicator
Side channels	Floodplain-channel interactions - connectivity				
Side channels	Floodplain channel interactions - floodplain structure and function				
Side channels	Habitat connectivity	Length of all channel types in unconfined reaches, Interday flow variability; low flow and high flow	SRSC		% historic miles available to adult Chinook
Non-channel lakes & wetlands	Sediment dynamics - sediment transport and storage				
Non-channel lakes & wetlands	Hydrology - high flow hydrological regime				
Non-channel lakes & wetlands	Hydrology - low flow hydrological regime				
Non-channel lakes & wetlands	Organic matter - inputs				
Non-channel lakes & wetlands	Organic matter - retention/processing	Wood study?	Jen O'Neal, Natural Systems Design		
Non-channel lakes & wetlands	Nutrient supply - nutrient cycling/flux				
Non-channel lakes & wetlands	Nutrient supply - water quality				
Non-channel lakes & wetlands	Floodplain-channel interactions - floodplain connectivity	Unisolated floodplain area, floodplain connectivity area	Kate Ramsden, Tim Hyatt, Steve Hinton/SRSC		
Non-channel lakes & wetlands	Floodplain-channel interactions - structure and functions				

Component	Name	Explicit Skagit Indicator	Subcommittee Lead	Related NOAA indicator	PSP Common Indicator
Non-channel lakes & wetlands	Habitat connectivity	Floodplain connectivity fragmentation	Culverts? Blockages? Devin/SRSC, Rick/Upper Skagit (should also cover small channels?)		
Uplands	Sediment dynamics - sediment delivery	Sediment supply			
Uplands	none	Pervious area			

Nearshore - not covered in 2018 Monitoring Report					
Offshore marine systems	Freshwater hydrology - dependent water condition				
Offshore marine systems	Tidal circulation - dependent water condition				
Offshore marine systems	Water quality				
Bluff backed beaches	Coastal sediment dynamics in drift cells - condition				
Bluff backed beaches	Coastal sediment dynamics in drift cells - landscape context				
Bluff backed beaches	Coastal sediment deposition and accretion - extent				% sediment source intact by drift cell
Bluff backed beaches	Coastal sediment supply - extent				
Bluff backed beaches	Coastal sediment supply - distribution				
Bluff backed beaches	Coastal sediment dynamics - extent (size or volume) of wind and wave dependent features				

Component	Name	Explicit Skagit Indicator	Subcommittee Lead	Related NOAA indicator	PSP Common Indicator
Bluff backed beaches	Coastal sediment dynamics - condition of wind and wave dependent features				
Bluff backed beaches	Tidal circulation - extent of dependent biological activity				
Bluff backed beaches	TIdal circulation - dependent water condition				
Bluff backed beaches	Freshwater hydrology - dependent water condition				
Bluff backed beaches	SAV beds - condition				
Bluff backed beaches	SAV beds - extent				
Bluff backed beaches	Water quality				
Coastal landforms	Coastal sediment dynamics in drift cells - condition				
Coastal landforms	Coastal sediment deposition and accretion - extent				% sediment source intact by drift cell
Coastal landforms	Coastal sediment deposition and accretion - condition of impoundment				
Coastal landforms	Coastal sediment dynamics - distribution				
Coastal landforms	Coastal sediment dynamics - extent (size or volume) of wind and wave dependent features				
Coastal landforms	Tidal circulation - extent of dependent biological activity				
Coastal landforms	Tidal circulation - dependent water condition				
Coastal landforms	Freshwater hydrology - dependent water condition				
Coastal landforms	SAV beds - condition				

Component	Name	Explicit Skagit Indicator	Subcommittee Lead	Related NOAA indicator	PSP Common Indicator
Coastal landforms	SAV beds - extent				
Coastal landforms	Water quality				
Rocky beaches	Tidal circulation - extent of dependent biological activity				
Rocky beaches	Freshwater hydrology - dependent water condition				
Rocky beaches	SAV beds - condition				
Rocky beaches	SAV beds - extent				
Rocky beaches	Water quality				
					Proportion of current shoreline that is vegetated*
					Extent of shoreline armoring*

KEAs/common indicators not selected in the Skagit Phase 1 project					
Large channels	**Stream Structure**			What is the status of instream structure and complexity? (non-wadeable)	Sinuosity
Small channels	Freshwater Channel Formation (KEA 5.10)				Wood abundance
Small channels	**Stream Structure**			What is the status of instream structure and complexity? (wadeable)	LWD
	Freshwater Channel Formation (KEA 5.10)				Sinuosity
					Residual pool depth

Component	Name	Explicit Skagit Indicator	Subcommittee Lead	Related NOAA indicator	PSP Common Indicator
NOAA - indicators not identified by Skagit Phase 1					
Wood Jam Area #					
Pool frequency or spacing #					
Residual pool depth #					
Wood Abundance #					

Appendix 2: Phase 1 Viability Assessment

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHSP-C13	Skagit Chinook All Stocks	Fair	CHSP-K01.06	Diversity - life history diversity (Condition)												
CHSP-C13	Upper Sauk Spring Chinook		CHSP-K01.07	Diversity - genetic diversity (Condition)												
CHSP-C13	Upper Sauk Spring Chinook		CHSP-K01.05	Spatial distribution (Landscape Context)												
CHSP-C13	Upper Sauk Spring Chinook		CHSP-K01.06	Diversity - life history diversity (Condition)												
CHSP-C13	Upper Sauk Spring Chinook		CHSP-K01.01	Abundance goals		MSP Escapement Avg. Marine Survival	count	Good: 750								
CHSP-C13	Upper Sauk Spring Chinook		CHSP-K01.01	Abundance goals		MSP Recruitment Avg. Marine Survival	count	Good: 2270								

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHSP-C13	Upper Sauk Spring Chinook		CHSP-K01.01	Abundance goals		MSP Escapement High Marine Survival	count	Good: 1340								
CHSP-C13	Upper Sauk Spring Chinook		CHSP-K01.01	Abundance goals		MSP Recruitment High Marine Survival	count	Good: 5530								
CHSP-C13	Upper Sauk Spring Chinook		CHSP-K01.02	Productivity goals		MSP Recruits Per Spawner Avg. Marine Survival	count	Good: 3								
CHSP-C13	Upper Sauk Spring Chinook		CHSP-K01.02	Productivity goals		MSP Recruits Per Spawner High Marine Survival	count	Good: 4.1								
CHSP-C13	Lower Skagit Fall Chinook		CHSP-K01.07	Diversity - genetic diversity (Condition)												
CHSP-C13	Lower Skagit Fall Chinook		CHSP-K01.05	Spatial distribution (Landscape Context)												
CHSP-C13	Lower Skagit Fall Chinook		CHSP-K01.06	Diversity - life history diversity (Condition)												

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHSP-C13	Lower Skagit Fall Chinook		CHSP-K01.01	Abundance goals		MSP Escapement Avg. Marine Survival	count	Good: 3900								
CHSP-C13	Lower Skagit Fall Chinook		CHSP-K01.01	Abundance goals		MSP Recruitment Avg. Marine Survival	count	Good: 11900								
CHSP-C13	Lower Skagit Fall Chinook		CHSP-K01.01	Abundance goals		MSP Escapement High Marine Survival	count	Good: 7400								
CHSP-C13	Lower Skagit Fall Chinook		CHSP-K01.01	Abundance goals		MSP Recruitment High Marine Survival	count	Good: 39700								
CHSP-C13	Lower Skagit Fall Chinook		CHSP-K01.02	Productivity goals		MSP Recruits Per Spawner Avg. Marine Survival	count	Good: 3								
CHSP-C13	Lower Skagit Fall Chinook		CHSP-K01.02	Productivity goals		MSP Recruits Per Spawner High Marine Survival	count	Good: 5.4								
CHSP-C13	Lower Sauk Summer Chinook		CHSP-K01.07	Diversity - genetic diversity (Condition)												

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHSP-C13	Lower Sauk Summer Chinook		CHSP-K01.05	Spatial distribution (Landscape Context)												
CHSP-C13	Lower Sauk Summer Chinook		CHSP-K01.06	Diversity - life history diversity (Condition)												
CHSP-C13	Lower Sauk Summer Chinook		CHSP-K01.01	Abundance goals		MSP Escapement Avg. Marine Survival	count	Good: 1400								
CHSP-C13	Lower Sauk Summer Chinook		CHSP-K01.01	Abundance goals		MSP Recruitment Avg. Marine Survival	count	Good: 4200								
CHSP-C13	Lower Sauk Summer Chinook		CHSP-K01.01	Abundance goals		MSP Escapement High Marine Survival	count	Good: 2700								
CHSP-C13	Lower Sauk Summer Chinook		CHSP-K01.01	Abundance goals		MSP Recruitment High Marine Survival	count	Good: 12700								
CHSP-C13	Lower Sauk Summer Chinook		CHSP-K01.02	Productivity goals		MSP Recruits Per Spawner Avg. Marine Survival	count	Good: 3								

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHSP-C13	Lower Sauk Summer Chinook		CHSP-K01.02	Productivity goals		MSP Recruits Per Spawner High Marine Survival	count	Good: 4.8								
CHSP-C13	Upper Skagit Summer Chinook		CHSP-K01.07	Diversity - genetic diversity (Condition)												
CHSP-C13	Upper Skagit Summer Chinook		CHSP-K01.05	Spatial distribution (Landscape Context)												
CHSP-C13	Upper Skagit Summer Chinook		CHSP-K01.06	Diversity - life history diversity (Condition)												
CHSP-C13	Upper Skagit Summer Chinook		CHSP-K01.01	Abundance goals		MSP Escapement Avg. Marine Survival	count	Good: 5380								
CHSP-C13	Upper Skagit Summer Chinook		CHSP-K01.01	Abundance goals		MSP Recruitment Avg. Marine Survival	count	Good: 20600								
CHSP-C13	Upper Skagit Summer Chinook		CHSP-K01.01	Abundance goals		MSP Escapement High Marine Survival	count	Good: 9400								

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHSP-C13	Upper Skagit Summer Chinook		CHSP-K01.01	Abundance goals		MSP Recruitment High Marine Survival	count	Good: 61800								
CHSP-C13	Upper Skagit Summer Chinook		CHSP-K01.02	Productivity goals		MSP Recruits Per Spawner Avg. Marine Survival	count	Good: 3.8								
CHSP-C13	Upper Skagit Summer Chinook		CHSP-K01.02	Productivity goals		MSP Recruits Per Spawner High Marine Survival	count	Good: 6.6								
CHSP-C13	Upper Cascade Spring Chinook		CHSP-K01.07	Diversity - genetic diversity (Condition)												
CHSP-C13	Upper Cascade Spring Chinook		CHSP-K01.05	Spatial distribution (Landscape Context)												
CHSP-C13	Upper Cascade Spring Chinook		CHSP-K01.06	Diversity - life history diversity (Condition)												
CHSP-C13	Upper Cascade Spring Chinook		CHSP-K01.01	Abundance goals (Size)		MSP Escapement Avg. Marine Survival	count	Good: 290								

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHSP-C13	Upper Cascade Spring Chinook		CHSP-K01.01	Abundance goals (Size)		MSP Recruitment Avg. Marine Survival	count	Good: 870								
CHSP-C13	Upper Cascade Spring Chinook		CHSP-K01.01	Abundance goals (Size)		MSP Escapement High Marine Survival	count	Good: 510								
CHSP-C13	Upper Cascade Spring Chinook		CHSP-K01.01	Abundance goals (Size)		MSP Recruitment High Marine Survival	count	Good: 2340								
CHSP-C13	Upper Cascade Spring Chinook		CHSP-K01.02	Productivity goals (Size)		MSP Recruits Per Spawner Avg. Marine Survival	count	Good: 3.0								
CHSP-C13	Upper Cascade Spring Chinook		CHSP-K01.02	Productivity goals (Size)		MSP Recruits Per Spawner High Marine Survival	count	Good: 4.6								
CHEM-C10	Rocky pocket estuaries															
CHEM-C09	Pocket estuaries	Good	CHEM-K01.01	Coastal sediment dynamics in drift cells - condition												

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHEM-C09	Pocket estuaries	Good	CHEM-K02.01	Fluvial sediment dynamics - condition												
CHEM-C09	Pocket estuaries	Good	CHEM-K08.08	Tidally influenced wetlands - extent												
CHEM-C09	Pocket estuaries	Good	CHEM-K08.01	SAV beds - condition												
CHEM-C09	Pocket estuaries	Good	CHEM-K03.02	Tidal circulation - dependent water condition												
CHEM-C09	Pocket estuaries	Good	CHEM-K08.10	Water quality												
CHEM-C09	Pocket estuaries	Good	CHEM-K08.02	SAV beds - extent												
CHEM-C09	Pocket estuaries	Good	CHEM-K05.01	Tidal channel formation and maintenance - extent of channels												

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHEM-C09	Pocket estuaries	Good	CHEM-K07.01	Habitat connectivity - condition (Landscape Context)		Median landscape connectivity	Connectivity Index	Fair: 0.14 Good: 0.14	On-site Research	Good	0.014	10/24/2005	Intensive Assessment	Good	6/1/2055	0.014
CHEM-C09	Pocket estuaries	Good	CHEM-K01.02	Coastal sediment dynamics in drift cells - landscape context												
CHEM-C09	Pocket estuaries	Good	CHEM-K03.01	Tidal circulation - extent of dependent biological activity. (Size)		Accessible pocket estuary area	ha	Fair: 47.5 Good: 311.5Very Good: 340.7	On-site Research	Fair	47.5	10/24/2005	Intensive Assessment	Good	6/1/2055	311.5
CHEM-C09	Pocket estuaries	Good	CHEM-K08.05	Estuarine habitats - distribution		Median distance between pocket estuaries	km	Fair: 3.49Very Good: 1.26	On-site Research	Fair	3.49	10/24/2005	Intensive Assessment			
CHEM-C09	Pocket estuaries	Good	CHEM-K08.03	Estuarine habitats - extent		Number of pocket estuaries accessible to juvenile Chinook salmon	Count	Poor:8 Fair:12 Good: 22	On-site Research	Fair	8	10/24/2005	Intensive Assessment	Good	6/1/2055	12
CHEM-C09	Pocket estuaries	Good	CHEM-K05.02	Tidal channel formation and maintenance - connectivity of channels												
CHEM-C09	Pocket estuaries	Good	CHEM-K04.02	Freshwater hydrology - condition												

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHEM-C09	Pocket estuaries	Good	CHEM-K04.01	Freshwater hydrology - dependent water condition												
CHEM-C07	Coastal landforms		CHEM-K01.01	Coastal sediment dynamics in drift cells - condition												
CHEM-C07	Coastal landforms		CHEM-K01.07	Coastal sediment dynamics - distribution												
CHEM-C07	Coastal landforms		CHEM-K01.05	Coastal sediment deposition and accretion - condition of impoundment												
CHEM-C07	Coastal landforms		CHEM-K01.08	Coastal sediment dynamics - extent (size or volume) of wind and wave dependent features												
CHEM-C07	Coastal landforms		CHEM-K08.01	SAV beds - condition												
CHEM-C07	Coastal landforms		CHEM-K03.02	Tidal circulation - dependent water condition												

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHEM-C07	Coastal landforms		CHEM-K08.10	Water quality												
CHEM-C07	Coastal landforms		CHEM-K03.01	Tidal circulation - extent of dependent biological activity												
CHEM-C07	Coastal landforms		CHEM-K01.03	Coastal sediment deposition and accretion - extent												
CHEM-C07	Coastal landforms		CHEM-K08.02	SAV beds - extent		Extent of SAV beds	Area									
CHEM-C07	Coastal landforms		CHEM-K04.01	Freshwater hydrology - dependent water condition												
CHEM-C06	Natal Chinook estuaries	Fair	CHEM-K02.01	Fluvial sediment dynamics - condition												
CHEM-C06	Natal Chinook estuaries	Fair	CHEM-K04.02	Freshwater hydrology - condition												

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHEM-C06	Natal Chinook estuaries	Fair	CHEM-K06.01	Detritus recruitment and retention - extent												
CHEM-C06	Natal Chinook estuaries	Fair	CHEM-K05.01	Tidal channel formation and maintenance - extent of channels (Size)		Distributary channels	hectares of distributary channel area	Fair: 851.7Good: 895.8Very Good:	On-site Research	Fair	851.7	10/24/2005		Good	6/2/2055	895.8
CHEM-C06	Natal Chinook estuaries	Fair	CHEM-K05.01	Tidal channel formation and maintenance - extent of channels (Size)		Blind channels	hectares of blind channel area	Fair: 62.7Good: 110.8Very Good: 1158	On-site Research	Fair	62.7	10/20/2005	Intensive Assessment	Good	6/5/2055	110.8
CHEM-C06	Natal Chinook estuaries	Fair	CHEM-K08.10	Water quality												
CHEM-C06	Natal Chinook estuaries	Fair	CHEM-K07.01	Habitat connectivity condition (Size)		Blind channels landscape connectivity	connectivity index	Fair: .0190Good: .0246	Expert Knowledge	Fair	0.019	10/24/2005	Intensive Assessment	Good	6/1/2055	0.0246
CHEM-C06	Natal Chinook estuaries	Fair	CHEM-K08.03	Estuarine habitats - extent (Size)		Tidal habitat; tidal delta footprint, all types	hectares				3118	10/20/2005				
CHEM-C06	Natal Chinook estuaries	Fair	CHEM-K08.05	Estuarine habitats - distribution		Tidal delta habitat connectivity	Fragmentati on	Fair: Fragmented Good: Not fragmented	On-site Research	Fair	Fragmented	10/24/2005	Intensive Assessment	Very Good	6/1/2055	Not Fragmented

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHEM-C06	Natal Chinook estuaries	Fair	CHEM-K05.02	Tidal channel formation and maintenance - connectivity of channels (Landscape Context)												
CHEM-C06	Natal Chinook estuaries	Fair	CHEM-K03.02	Tidal circulation - dependent water condition												
CHEM-C12	Offshore marine systems		CHEM-K03.01	Tidal circulation - extent of dependent biological activity												
CHEM-C12	Offshore marine systems		CHEM-K08.10	Water quality												
CHEM-C12	Offshore marine systems		CHEM-K04.01	Freshwater hydrology - dependent water condition												
CHEM-C11	Rocky beaches		CHEM-K08.02	SAV beds - extent												
CHEM-C11	Rocky beaches		CHEM-K03.01	Tidal circulation - extent of dependent biological activity												

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHEM-C11	Rocky beaches		CHEM-K03.02	Tidal circulation - dependent water condition												
CHEM-C11	Rocky beaches		CHEM-K08.10	Water quality												
CHEM-C11	Rocky beaches		CHEM-K04.01	Freshwater hydrology - dependent water condition												
CHEM-C11	Rocky beaches		CHEM-K08.01	SAV beds - condition												
CHEM-C08	Bluff backed beaches		CHEM-K01.01	Coastal sediment dynamics in drift cells - condition												
CHEM-C08	Bluff backed beaches		CHEM-K01.02	Coastal sediment dynamics in drift cells - landscape context												
CHEM-C08	Bluff backed beaches		CHEM-K01.03	Coastal sediment deposition and accretion - extent												

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHEM-C08	Bluff backed beaches		CHEM-K08.01	SAV beds - condition												
CHEM-C08	Bluff backed beaches		CHEM-K08.10	Water quality												
CHEM-C08	Bluff backed beaches		CHEM-K01.06	Coastal sediment supply - extent												
CHEM-C08	Bluff backed beaches		CHEM-K04.01	Freshwater hydrology - dependent water condition												
CHEM-C08	Bluff backed beaches		CHEM-K08.02	SAV beds - extent												
CHEM-C08	Bluff backed beaches		CHEM-K01.07	Coastal sediment supply - distribution												
CHEM-C08	Bluff backed beaches		CHEM-K01.08	Coastal sediment dynamics - extent (size or volume) of wind and wave dependent features												

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHEM-C08	Bluff backed beaches		CHEM-K01.09	Coastal sediment dynamics - condition of wind and wave dependent features												
CHEM-C08	Bluff backed beaches		CHEM-K03.01	Tidal circulation - extent of dependent biological activity												
CHFW-C02	Large channels	Fair	CHFW-K02.01	Hydrology - high flow hydrological regime		Interday flow variability; high flow or low flow										
CHFW-C02	Large channels	Fair	CHFW-K02.01	Hydrology - high flow hydrological regime		Frequency, duration and magnitude of peak flows										
CHFW-C02	Large channels	Fair	CHFW-K03.01	Organic matter - inputs												
CHFW-C02	Large channels	Fair	CHFW-K04.01	Riparian - Spatial extent and continuity of riparian area												
CHFW-C02	Large channels	Fair	CHFW-K06.01	Nutrient supply - water quality												

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHFW-C02	Large channels	Fair	CHFW-K07.01	Floodplain channel interactions - floodplain connectivity (Size)		Length of mainstem natural edge, all types	km	Fair: 589.4Good: 623.5		Fair	589.4	6/1/2005	Intensive Assessment	Good	10/16/2055	623.5
CHFW-C02	Large channels	Fair	CHFW-K07.01	Floodplain channel interactions - floodplain connectivity (Size)		Length of all channel types in unconfined reaches	km	Fair: 371.1Good: 442.6	Expert Knowledge	Fair	371.1	6/4/2005	Intensive Assessment	Good	6/1/2055	442.6
CHFW-C02	Large channels	Fair	CHFW-K07.01	Floodplain channel interactions - floodplain connectivity (Size)		Area of all channel types in unconfined reaches	hectares	Fair: 560Good: 628	Expert Knowledge	Fair	560	12/1/2010	Rapid Assessment			
CHFW-C02	Large channels	Fair	CHFW-K07.01	Floodplain channel interactions - floodplain connectivity (Size)		Unisolated floodplain area	acres									
CHFW-C02	Large channels	Fair	CHFW-K07.01	Floodplain channel interactions - floodplain connectivity (Size)		Frequency, duration and magnitude of habitat connectivity flows										
CHFW-C02	Large channels	Fair	CHFW-K08.01	Habitat connectivity		Interday flow variability; high flow or low flow										
CHFW-C02	Large channels	Fair	CHFW-K01.01	Sediment dynamics - sediment delivery		Sediment supply									10/16/2055	1

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHFW-C02	Large channels	Fair	CHFW-K02.02	Hydrology - low flow hydrological regime		Frequency, duration and magnitude of peak flows										
CHFW-C02	Large channels	Fair	CHFW-K02.02	Hydrology - low flow hydrological regime		Interday flow variability; high flow or low flow										
CHFW-C02	Large channels	Fair	CHFW-K02.02	Hydrology - low flow hydrological regime		Number of hook ups added to service areas (with wells relinquished)	Count									
CHFW-C02	Large channels	Fair	CHFW-K04.02	Riparian - Riparian community structure												
CHFW-C02	Large channels	Fair	CHFW-K07.02	Floodplain channel interactions - floodplain structure and function (Size)		Large mainstem backwaters	km	Fair: 63.2Good: 97.3	On-site Research	Fair	63.2	12/1/2010	Intensive Assessment	Good	6/5/2055	97.3
CHFW-C02	Large channels	Fair	CHFW-K07.02	Floodplain channel interactions - floodplain structure and function (Size)		Frequency, duration and magnitude of habitat creation flows										
CHFW-C02	Large channels	Fair	CHFW-K07.02	Floodplain channel interactions - floodplain structure and function (Size)		Length of mainstem natural edge, all types	km				589.4	6/1/2005				

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHFW-C02	Large channels	Fair	CHFW-K01.02	Sediment dynamics - sediment transport and storage												
CHFW-C02	Large channels	Fair	CHFW-K04.03	Riparian - function of riparian vegetation												
CHFW-C02	Large channels	Fair	CHFW-K05.02	Nutrient supply - nutrient cycling and flux												
CHUP-C01	Uplands	Fair	CHFW-K01.01	Sediment dynamics - sediment delivery (Condition)		Sediment supply	sediment delivered to streams per square km /yr	Fair: 2269.9 Good: 4325.7 Very Good: 4325.7	External Research	Fair	2269.9	11/4/2005		Good	10/16/2055	4325.7
CHUP-C01	Uplands	Fair		Hydrologic processes		Total watershed pervious area (97%+)										
CHFW-C05	Non-channel lakes & wetlands	Fair	CHFW-K01.02	Sediment dynamics - sediment transport and storage												
CHFW-C05	Non-channel lakes & wetlands	Fair	CHFW-K02.02	Hydrology - low flow hydrological regime												

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHFW-C05	Non-channel lakes & wetlands	Fair	CHFW-K03.01	Organic matter - inputs												
CHFW-C05	Non-channel lakes & wetlands	Fair	CHFW-K03.02	Organic matter - retention and processing												
CHFW-C05	Non-channel lakes & wetlands	Fair	CHFW-K05.02	Nutrient supply - nutrient cycling/flux												
CHFW-C05	Non-channel lakes & wetlands	Fair	CHFW-K08.01	Habitat connectivity (Size)		Floodplain connectivity fragmentation	Fragmentation	Fair: Fragmented Good: Not fragmented Very Good: Not fragmented	Expert Knowledge	Fair	Fragmented	6/1/2005	Intensive Assessment	Good	6/5/2055	Not fragmented
CHFW-C05	Non-channel lakes & wetlands	Fair	CHFW-K06.01	Nutrient supply - water quality												
CHFW-C05	Non-channel lakes & wetlands	Fair	CHFW-K02.01	Hydrology - high flow hydrological regime												

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHFW-C05	Non-channel lakes & wetlands	Fair	CHFW-K07.01	Floodplain-channel interactions - connectivity		Floodplain connectivity area	hectares	Fair: 10510 Good: 12813 Very Good: 32648	Expert Knowledge	Fair	10510	6/1/2005	Intensive Assessment	Good	6/1/2055	12813
CHFW-C05	Non-channel lakes & wetlands	Fair	CHFW-K07.01	Floodplain-channel interactions - connectivity		Unisolated floodplain area										
CHFW-C05	Non-channel lakes & wetlands	Fair	CHFW-K07.02	Floodplain-channel interactions - structure and functions												
CHFW-C03	Small channels	Good	CHFW-K01.01	Sediment dynamics - sediment delivery		Length of roadway meeting RMAP provisions	Miles (or km?)									
CHFW-C03	Small channels	Good	CHFW-K02.01	Hydrology - high flow hydrological regime												
CHFW-C03	Small channels	Good	CHFW-K03.01	Organic matter - inputs												
CHFW-C03	Small channels	Good	CHFW-K06.01	Nutrient supply - water quality		# of 303d listed parameters										

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHFW-C03	Small channels	Good	CHFW-K07.01	Floodplain-channel interactions - floodplain connectivity (Size)		Length of all channel types	km	Fair: 125 Good: 125	On-site Research	Good	125	12/1/2010	Rapid Assessment	Good	6/1/2055	125
CHFW-C03	Small channels	Good	CHFW-K08.01	Habitat connectivity		length of connected habitat (per subbasin?)	Length miles or km									
CHFW-C03	Small channels	Good	CHFW-K04.01	Riparian - spatial extent and continuity of riparian areas		length of riparian edge consistent with BAS	Length Mile or km									
CHFW-C03	Small channels	Good	CHFW-K01.02	Sediment dynamics - sediment transport and storage												
CHFW-C03	Small channels	Good	CHFW-K02.02	Hydrology - low flow hydrological regime		Number of new wells	Count									
CHFW-C03	Small channels	Good	CHFW-K02.02	Hydrology - low flow hydrological regime		Relinquish Unused Water Rights	Volume of water									
CHFW-C03	Small channels	Good	CHFW-K02.02	Hydrology - low flow hydrological regime		Minimum instream flows										

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHFW-C03	Small channels	Good	CHFW-K03.02	Organic matter - retention/processing												
CHFW-C03	Small channels	Good	CHFW-K04.02	Riparian - riparian community structure												
CHFW-C03	Small channels	Good	CHFW-K05.02	Nutrient supply - nutrient cycling/flux		# of 303d listed parameters										
CHFW-C03	Small channels	Good	CHFW-K07.02	Floodplain-channel interactions - floodplain structure and function												
CHSP-C14b	Species & food webs		CHSP-K02.05	Prey population size (Size)												
CHSP-C14b	Species & food webs		CHSP-K02.06	Prey population condition (Condition)												
CHSP-C14b	Species & food webs		CHSP-K02.09	Food web community composition (Condition)												

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHFW-C04	Side channels		CHFW-K01.01	Sediment dynamics - sediment delivery (Condition)												
CHFW-C04	Side channels		CHFW-K02.02	Hydrology - low flow hydrological regime												
CHFW-C04	Side channels		CHFW-K03.01	Organic matter - inputs												
CHFW-C04	Side channels		CHFW-K04.03	Riparian - function of riparian and wetland vegetation												
CHFW-C04	Side channels		CHFW-K06.01	Nutrient supply - water quality												
CHFW-C04	Side channels		CHFW-K07.01	Floodplain-channel interactions - floodplain connectivity (Size)												
CHFW-C04	Side channels		CHFW-K08.01	Habitat connectivity		Length of connected habitat (per subbasin?)	length mile or km									

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHFW-C04	Side channels		CHFW-K01.02	Sediment dynamics - sediment transport and storage												
CHFW-C04	Side channels		CHFW-K07.02	Floodplain-channel interactions - floodplain structure and function												
CHFW-C04	Side channels		CHFW-K05.02	Nutrient supply - nutrient cycling/flux												
CHFW-C04	Side channels		CHFW-K03.02	Organic matter - retention/processing												
CHFW-C04	Side channels		CHFW-K02.01	Hydrology - high flow hydrological regime												
CHSP-C13	Suiattle Spring Chinook		CHSP-K01.07	Diversity - genetic diversity (Condition)												
CHSP-C13	Suiattle Spring Chinook		CHSP-K01.05	Spatial distribution (Landscape Context)												

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHSP-C13	Suiattle Spring Chinook		CHSP-K01.06	Diversity - life history diversity (Condition)												
CHSP-C13	Suiattle Spring Chinook		CHSP-K01.01	Abundance goals		MSP Escapement Avg. Marine Survival	count	Good: 160								
CHSP-C13	Suiattle Spring Chinook		CHSP-K01.01	Abundance goals		MSP Recruitment Avg. Marine Survival	count	Good: 450								
CHSP-C13	Suiattle Spring Chinook		CHSP-K01.01	Abundance goals		MSP Escapement High Marine Survival	count	Good: 270								
CHSP-C13	Suiattle Spring Chinook		CHSP-K01.01	Abundance goals		MSP Recruitment High Marine Survival	count	Good: 2340								
CHSP-C13	Suiattle Spring Chinook		CHSP-K01.02	Productivity goals		MSP Recruits Per Spawner Avg. Marine Survival	count	Good: 2.8								
CHSP-C13	Suiattle Spring Chinook		CHSP-K01.02	Productivity goals		MSP Recruits Per Spawner High Marine Survival	count	Good: 4.2								

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHSP-C13	Skagit Nearshore Chinook	Fair	CHSP-K01.01	Abundance (Size)		Suiattle spawner abundance		Fair: Good: >160 or >270								
CHSP-C13	Skagit Nearshore Chinook	Fair	CHSP-K01.01	Abundance (Size)		Emergent fry recruitment	count	Fair: 17900000 Good: 22800000	On-site Research	Fair	17900000	11/7/2005	Intensive Assessment	Good	6/1/2055	22,800,000
CHSP-C13	Skagit Nearshore Chinook	Fair	CHSP-K01.01	Abundance (Size)		Yearling smolt carrying capacity	count	Fair: 107000 Good: 140000		Fair	107000	11/7/2005	Intensive Assessment	Good	6/5/2055	1700000
CHSP-C13	Skagit Nearshore Chinook	Fair	CHSP-K01.01	Abundance (Size)		Parr migrant smolt carrying capacity	count	Fair: 1300000 Good: 1700000		Fair	1300000	11/11/2055	Intensive Assessment	Good	6/5/2055	1700000
CHSP-C13	Skagit Nearshore Chinook	Fair	CHSP-K01.01	Abundance (Size)		Natal estuary rearing smolt carrying capacity	count	Fair: 2250000 Good: 3600000	On-site Research	Fair	2250000	10/20/2005	Intensive Assessment	Good	6/1/2055	3600000
CHSP-C13	Skagit Nearshore Chinook	Fair	CHSP-K01.01	Abundance (Size)		Pocket estuary smolt carrying capacity	count	Fair: 70000 Good: 220000	On-site Research	Fair	70000	10/20/2005	Intensive Assessment	Good	6/5/2055	220000

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHSP-C13	Skagit Nearshore Chinook	Fair	CHSP-K01.04	Productivity - population growth (Size)		Natural origin adult to adult productivity		Fair: Good: >2.8 or >4.2	On-site Research		3.5				10/16/2055	2.8 - 4.2
CHSP-C13	Skagit Nearshore Chinook	Fair	CHSP-K01.04	Productivity - population growth (Size)		Migrants per spawner	count	Fair: 306-376 Good: 380-480 Very Good: 380-480	On-site Research	Fair	341	11/4/2005	Intensive Assessment	Good	6/1/2055	435
CHSP-C13	Skagit Nearshore Chinook	Fair	CHSP-K01.07	Diversity - genetic diversity (Condition)												
CHSP-C13	Skagit Nearshore Chinook	Fair	CHSP-K01.02	Productivity - survival rate (Size)												
CHSP-C13	Skagit Nearshore Chinook	Fair	CHSP-K01.05	Spatial distribution (Landscape Context)												
CHSP-C13	Skagit Nearshore Chinook	Fair	CHSP-K01.06	Diversity - life history diversity (Condition)												

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHSP-C13	Skagit Chinook All Stocks	Fair	CHSP-K01.01	Abundance (Size)		Emergent fry recruitment	count	Fair: 17900000 Good: 22800000	On-site Research	Fair	17900000	11/7/2005	Intensive Assessment	Good	6/1/2055	22,800,000
CHSP-C13	Skagit Chinook All Stocks	Fair	CHSP-K01.01	Abundance (Size)		Yearling smolt carrying capacity	count	Fair: 107000 Good: 140000		Fair	107000	11/7/2005	Intensive Assessment	Good	6/5/2055	1700000
CHSP-C13	Skagit Chinook All Stocks	Fair	CHSP-K01.01	Abundance (Size)		Parr migrant smolt carrying capacity	count	Fair: 1300000 Good: 1700000		Fair	1300000	11/11/2055	Intensive Assessment	Good	6/5/2055	1700000
CHSP-C13	Skagit Chinook All Stocks	Fair	CHSP-K01.01	Abundance (Size)		Natal estuary rearing smolt carrying capacity	count	Fair: 2250000 Good: 3600000	On-site Research	Fair	2250000	10/20/2005	Intensive Assessment	Good	6/1/2055	3600000
CHSP-C13	Skagit Chinook All Stocks	Fair	CHSP-K01.01	Abundance (Size)		Pocket estuary smolt carrying capacity	count	Fair: 70000 Good: 220000	On-site Research	Fair	70000	10/20/2005	Intensive Assessment	Good	6/5/2055	220000
CHSP-C13	Skagit Chinook All Stocks	Fair	CHSP-K01.04	Productivity - population growth (Size)		Natural origin adult to adult productivity		Fair: Good: >2.8 or >4.2	On-site Research		3.5				10/16/2055	2.8 - 4.2

Target Identifier	Target Name	Target Viability Status	Key Attribute Identifier	Key Attribute (Type)	Indicator Identifier	Indicator Name	Indicator Unit	Rating	Rating Source	Current Rating	Measurement Value	Measurement Date	Source	Future Rating	Future Date	Future Value
CHSP-C13	Skagit Chinook All Stocks	Fair	CHSP-K01.04	Productivity - population growth (Size)		Migrants per spawner	count	Fair: 306-376 Good: 380-480 Very Good: 380-480	On-site Research	Fair	341	11/4/2005	Intensive Assessment	Good	6/1/2055	435
CHSP-C13	Skagit Chinook All Stocks	Fair	CHSP-K01.07	Diversity - genetic diversity (Condition)												
CHSP-C13	Skagit Chinook All Stocks	Fair	CHSP-K01.02	Productivity - survival rate (Size)												
CHSP-C13	Skagit Chinook All Stocks	Fair	CHSP-K01.05	Spatial distribution (Landscape Context)												