SKAGIT WATERSHED COUNCIL

Riparian Assessment

Prepared for
Skagit Watershed Council

December 22, 2017

Photo Credit: Marc Duboiski

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Prepared by Environmental Science Associates

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Introduction

The Skagit Watershed Council (SWC) is dedicated to restoring and protecting landscape processes that will produce the long-term, sustainable recovery of habitat conditions that benefit multiple fish species, particularly Chinook salmon and steelhead in the Skagit River watershed. In the 2015 Strategic Approach, SWC identified the need to update the science and management recommendations for developing and implementing voluntary restoration, protection, and stewardship actions in critical estuarine, floodplain, tributary, and riparian habitats for Chinook salmon (SWC, 2015). SWC received grant funding from the Salmon Recovery Funding Board (SRFB) and the Recreation and Conservation Office (RCO) to update their inventory of riparian actions, assess the current riparian conditions, and provide updated management recommendations for developing and implementing voluntary riparian actions in priority floodplain and tributary habitats. Environmental Science Associates (ESA) was contracted to assist SWC with a scientific assessment of riparian conditions and to help answer the following key questions:

- How much riparian restoration work has been completed?
- What are the existing conditions in priority freshwater riparian areas?
- What are the status and trends of riparian habitat and function at the reach-scale by habitat type and ownership?
- Within the current target areas, what are the priority reaches and habitat types to focus future riparian restoration?
- What are collaborative strategies and management recommendations for future priority freshwater riparian restoration efforts in the Watershed?

This *Riparian Assessment* provides data and supporting information to help SWC answer these questions and will also build upon and implement riparian components of the new monitoring and adaptive management framework for the Skagit Chinook Salmon Recovery Plan. The document includes a brief overview of SWC's approach to salmon recovery in the Skagit River watershed, guiding principles for restoration and protection of salmon habitat, and their target areas for focusing restoration and protection efforts. A description of riparian analysis methods is provided followed by a summary of results of the riparian assessment. A summary of riparian restoration and protection strategies is provided which can be used in combination with the riparian assessment results to help identify and prioritize riparian actions in the watershed. Final decisions about identification and prioritizing reaches as well as appropriate strategies for each reach will be made by riparian implementers and Council participants. All maps and data sets used in this analysis will be provided to the SWC for this purpose.

A list of data sources is provided in Appendix A. A set of maps displaying key data layers used and developed as part of the assessment is provided in Appendix B. Additional reach-specific results from the riparian assessment are available online at: http://tabsoft.co/2y0ewzV.

Background & Context

This *Riparian Assessment* is specific to improving and maintaining riparian habitat conditions for salmonids and is an update to the riparian component of the 1998 Habitat Protection and Restoration Strategy (SWC, 1998) and the Application of the Strategy (SWC, 2000) documents. The 1998 Strategy adopted by the SWC provides a basis for screening and prioritizing projects in the watershed and a method for evaluating projects. The 2000 Application of the Strategy conducted a basin-wide estimate of riparian condition in GIS using 1993 LANDSAT land cover data supplemented by field-based riparian inventory data. The process estimated the amount of anadromous channel length (percent) characterized by impaired, moderately impaired, and functioning riparian conditions and developed an interim riparian conditions map (see Figure 2-11 of SWC, 2000). Notably, the GIS-based approach was reliable for only late- and mid-seral conifer dominated forest and non-forest areas, but not other types of forest (i.e., deciduous dominated or young forest). The 2000 Strategy Application recommended future work in field inventory of riparian forest conditions and research of reliable methods for analyzing satellite and aerial photograph data. This *Riparian Assessment* addresses that recommendation.

In 2005, the Skagit Chinook Recovery Plan was adopted by the Skagit River System Cooperative and Washington Department of Fish and Wildlife and endorsed a concerted focus on recovering Chinook salmon populations in the watershed (SRSC and WDFW, 2005). In response, SWC's 2010 and 2015 updates to their Strategic Approach (SWC, 2010; SWC, 2015) redirected efforts to better align with the Chinook Recovery Plan and areas identified as most important for Chinook habitat restoration and protection. In addition, the authors recast a set of previously–developed principles to guide restoration efforts based on their past experience and recent scientific contributions to the philosophy and conceptual basis for river restoration. The guiding principles are:

> Principle #1: Restore processes that form and sustain salmon habitats
>
> Principle #2: Protect functioning processes and habitats from degradation
>
> Principle #3: Focus protection and restoration on the most biologically important areas

SWC's approach is one in which restoration and protection measures are evaluated in the context of the entire watershed, rather than on a project by project basis. This allows SWC to develop a proactive, long-term plan in a collaborated and coordinated way throughout the Skagit River watershed.
At this watershed level, the priority objectives related to riparian conditions are to restore natural riparian structure and processes (including shade, large woody debris recruitment, and root reinforcement of banks and adjacent unstable slopes) by reforesting impaired riparian zones and LWD supplementation where necessary to recover pool-riffle habitat until trees mature (SWC, 2015).

Riparian Processes and Functions

In keeping with SWC principles, the goal of this *Riparian Assessment* is to assist and encourage the voluntary restoration and protection of natural landscape processes. Process-based restoration aims to reestablish the normal rates and magnitudes of physical, chemical, and biological processes that sustain river and floodplain ecosystems (Beechie et al. 2010), which create and maintain the habitat conditions in which native aquatic and riparian species have adapted (SWC, 1998). This approach to restoration is more effective than site-specific restoration (i.e., augmentation or repair of specific habitat characteristics) alone, which tend to favor engineered solutions that create artificial and unnaturally static habitats. Site-specific restoration may be prone to failure (Beechie et al., 2010; Roni et al., 2002), may not address the specific factors limiting fish production, and may overlook land use effects on processes that form and sustain habitats (Beechie and Bolton, 1999).

To the extent possible, riparian restoration and protection actions should be directed at the habitat-forming process instead of attempting to build specific conditions. Riparian processes and functions that affect stream ecosystems include root reinforcement of banks, wood supply to streams, sediment retention, leaf litter supply, and shading (Roni and Beechie, 2013). There is abundant literature documenting the importance of riparian forest functions for salmonid populations.

TWG Member Input and Meetings

The SWC Technical Working Group (TWG) helped to guide this riparian assessment. The working group is made up of 12 representatives from state and federal resources agencies that are actively involved in the management and recovery of salmon habitat in Skagit River watershed. The workgroup met four times over the course of the project to first obtain consensus on the project scope, then review and discuss methods of analysis, preliminary and draft assessment results, and refine the final products. A list of TWG members is provided in Table 1 below. Further, SWC convened two different riparian ad hoc working groups that first focused on developing the geodatabase of riparian actions recently implemented and second provided additional input on these assessments. Finally, the Skagit Fisheries Enhancement Group convened riparian implementers to discuss the latest developments in their work.

Table 1. Technical Working Group Members

Member	Affiliation
Alison Studley (Chair)	Skagit Fisheries Enhancement Group
Erik Anderson	Aspect Consulting
Doug Bruland	Puget Sound Energy
Ed Connor/Erin Lowery	Seattle City Light
Jeremy Gilman	US Forest Service
Rick Hartson	Upper Skagit Indian Tribe
Jeff McGowan	Skagit County Water Resources
Kari Odden	Skagit Land Trust
Tom Slocum	Skagit Conservation District
Devin Smith	Skagit River System Cooperative
Chris Vondrasek	Skagit Watershed Council
Bob Warinner	Washington Department of Fish & Wildlife

Assessment Methods

Study Area

The study area for the riparian assessment includes the SWC Tier 1, Tier 2 and Tier 2S (steelhead) target areas for habitat restoration and protection in the Skagit River Basin from the 2015 update to the Strategic Approach (SWC, 2015) and the 2016 Interim Steelhead Strategy (SWC, 2016). The three tiers are based on their importance to Chinook salmon and steelhead recovery, and on the number of populations that will benefit from habitat protection and restoration actions within each area (Figure 1).

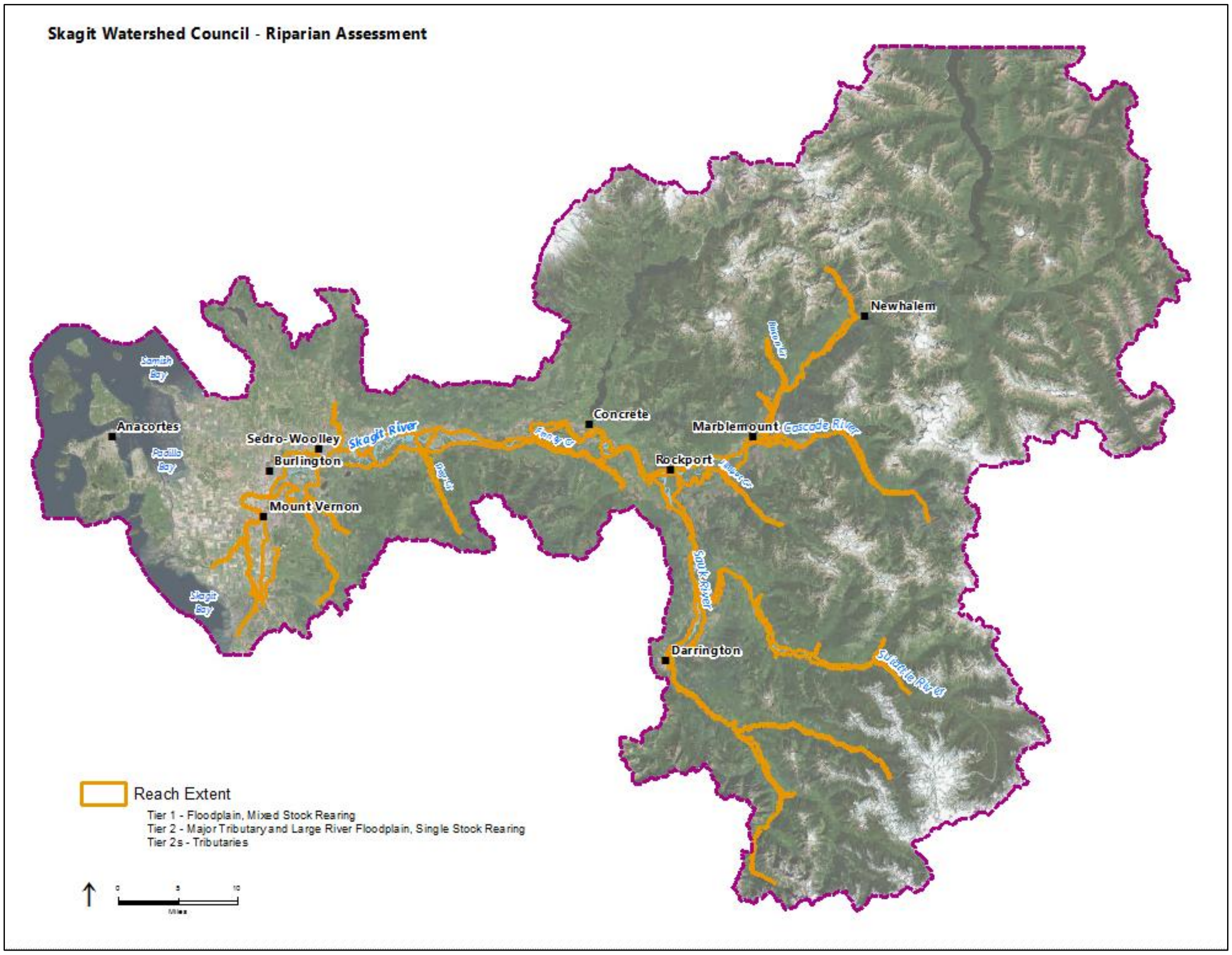


Figure 1. SWC Tier 1, Tier 2 and Tier 2S Target Areas and Extent of Riparian Assessment

While riparian projects in all tiers are consistent with the Chinook Recovery Plan, projects within the Tier 1 and 2 target areas are the primary focus as they are the habitats with the greatest potential to increase Chinook salmon populations. For the Tier 1 estuary, this includes the Skagit River to Skagit Bay delta along with Fisher and Carpenter Creeks. Tier 1 – Mixed Stock, Large River Floodplain includes the Skagit mainstem above the estuary to the Cascade River and Lower Sauk Rivers. Tier 2 Single Stock – Large River Floodplain includes the upper sections of the Skagit, Sauk and Suiattle Rivers. Tier 2 Single Stock – Major Tributaries include the East Fork Nookachamps, Hansen, Day, Finney, Illabot, Diobsud, Bacon, Goodell, Tenas, Dan, Buck, Downey Creeks and White Chuck and N Fork Sauk Rivers. Tier 2S includes areas of documented steelhead rearing immediately upstream of Tier 2 habitats.

Reaches

The reaches used for the riparian assessment were based on floodplain boundaries and reaches originally developed by Hayman et al. (1996) and subsequently evolved by SWC and the Skagit River System Cooperative (SRSC) and Washington Department of Fish and Wildlife (WDFW) for several restoration and protection planning efforts (Beamer et al. 2000; SRSC and WDFW, 2005; SRSC, 2011). For all other areas, ESA used the full extent of the regulatory 100-year floodplain or 300 feet (91 meters) from the outer edge of the active channel, whichever was greater. The reach boundary breaks were largely based on existing boundaries and breaks to align with other analyses and plans in the watershed. In places where there was not an existing reach break, natural hydrologic breaks at the confluence of a major river with a tributary or changes in channel type and degree of alteration were used to separate reaches. The final reaches used in this analysis are shown in Figure 2.

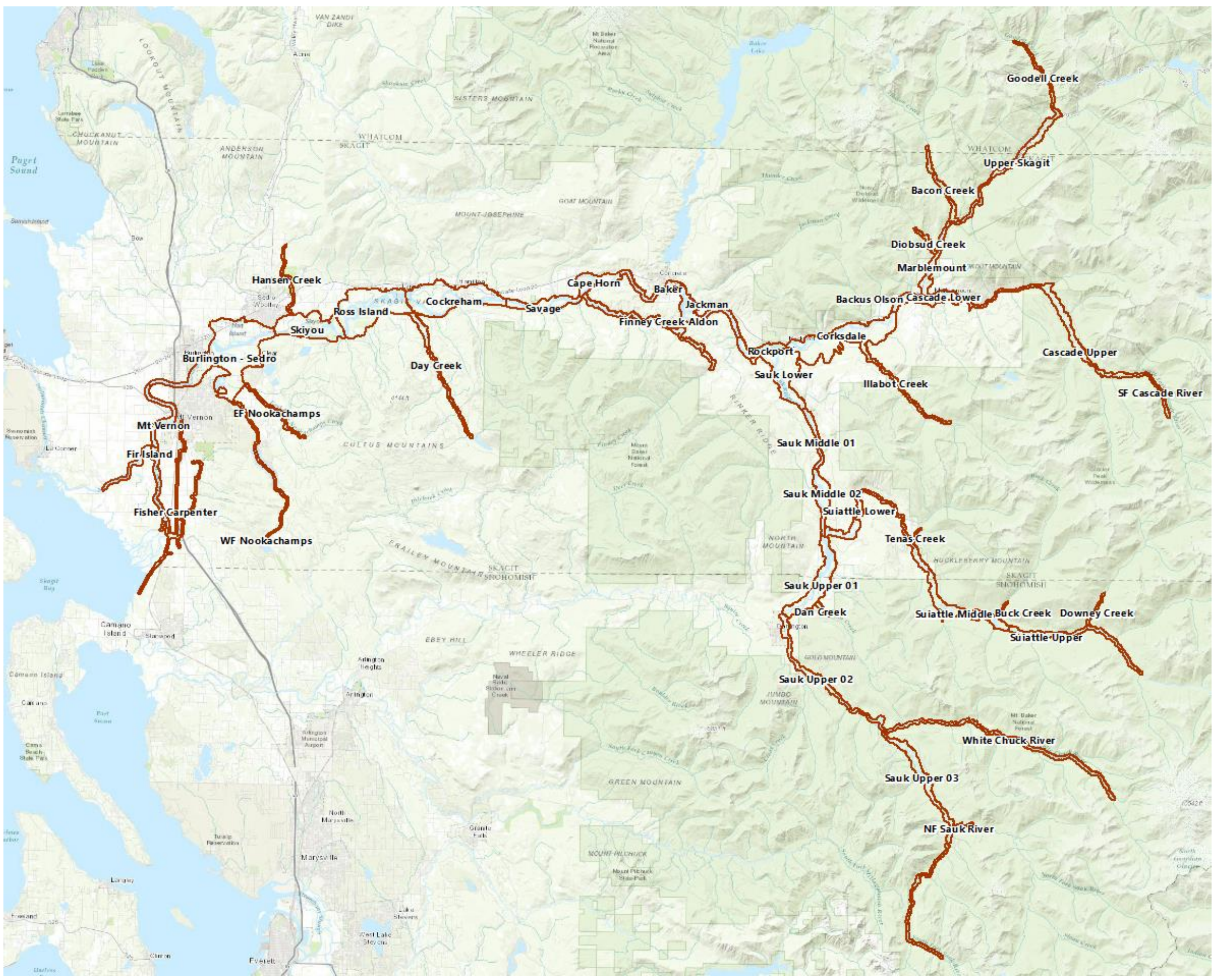


Figure 2. SWC Riparian Assessment Reaches

Classification Approach & Data Sources

To conduct the riparian cover classification, ESA used a hybrid approach that incorporated object-based image analysis and air-photo interpretation techniques to derive desired cover classes based on spectral and textural characteristics in combination with secondary datasets. The primary base imagery for classifying riparian cover was the USDA 1-m (3 & 4-band) ortho-rectified NAIP from 2013 in conjunction with the results from the Washington Department of Fish and Wildlife (WDFW) Puget Sound High Resolution Land Cover (HRLC) classification (WDFW, 2013). Secondary sources were used to support air-photo interpretation and refinement of the riparian classification. Primary and secondary data sources are included below in Table 2.

Table 2. Riparian Cover Classification - Data Sources

Role	Name	Source	Date
Primary	NAIP 4-band 1m Imagery	USDA	2013
Primary	NDVI - Derived Vegetation Index	USDA	2013
Primary	Land Cover Classification	WDFW	2013
Secondary	Hydrology	Skagit County	2015
Secondary	Pictometry 12" Imagery	Skagit County	Various
Secondary	LiDAR Canopy Height Model	USGS	2006
Secondary	Roads | Street Centerlines	Skagit County	2015
Secondary	Riparian Vegetation Classification Middle Skagit Assessment	SRSC	2011
Secondary	Riparian Cover Classification on Agricultural Lands	Skagit County	2009

Appendix A contains a comprehensive list of data sources from local organizations, tribes, county & state agencies to support the riparian assessment. The list includes all the sources of imagery and data relevant to the project, a description of their spatial extent and resolution, and their use in the assessment.

This assessment primarily uses the imperial system or US Standard Units (i.e., feet) with the exception of data and results for riparian width class, which uses metric system (i.e., meters) to be consistent with the terminology used for the three width class categories designated in SWC's 1998 Habitat Protection and Restoration Strategy (SWC 1998).

Figure 3 illustrates the approach and steps comprising the riparian cover classification approach and process used by ESA. Each step is described in detail below.

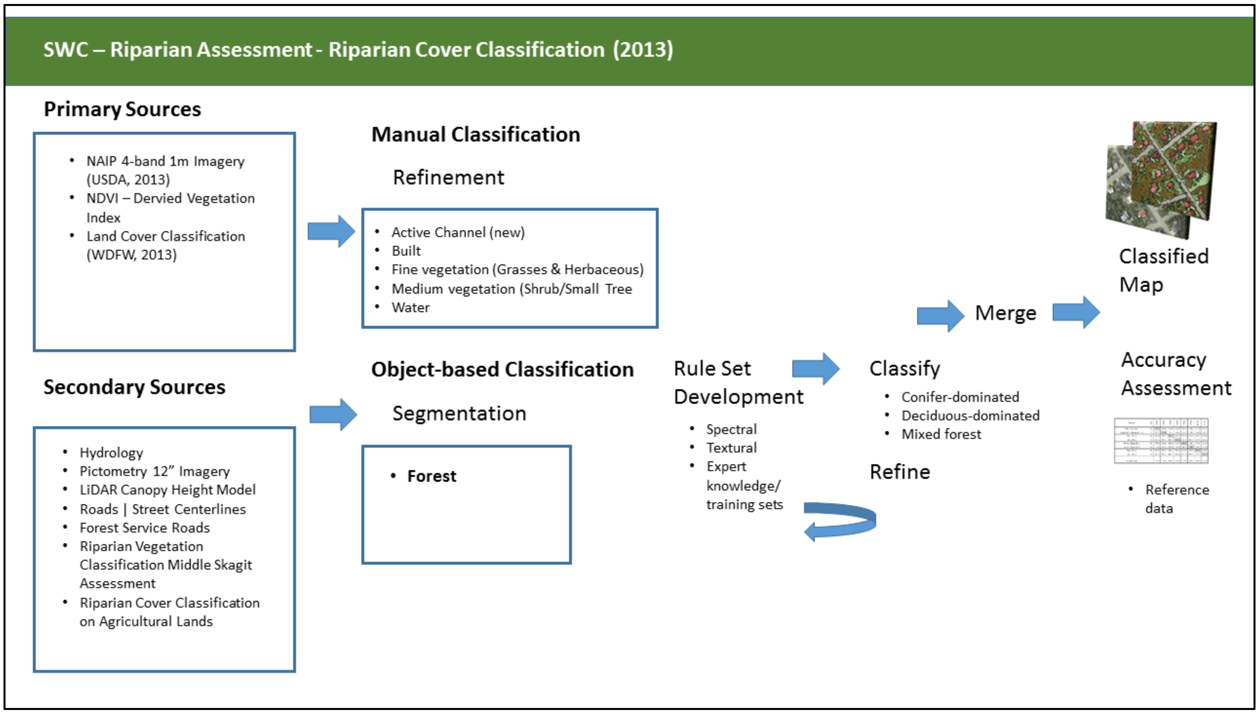


Figure 3. SWC Riparian Cover Classification Approach and Process

Data Preparation Pre-processing

First, ESA assembled the primary data sources and clipped them to the study area boundary (SWC Tier 1, Tier 2 and Tier 2S boundaries). ESA performed an initial manual review of the clipped boundary and the 2013 WDFW land cover classification.

The 2013 WDFW land cover classification included the following cover classes:

1. Built – structures, roads and impervious surfaces
2. Dirt – bare earth
3. Fine Vegetation – Grasses & Herbaceous
4. Medium Vegetation – Shrub/Small tree
5. Coarse Vegetation – Forest
6. Water
7. Potential Non-Vegetated Wetland
8. Potential Vegetated Wetland

An example screen shot of the land cover classes is shown below as Figure 4.

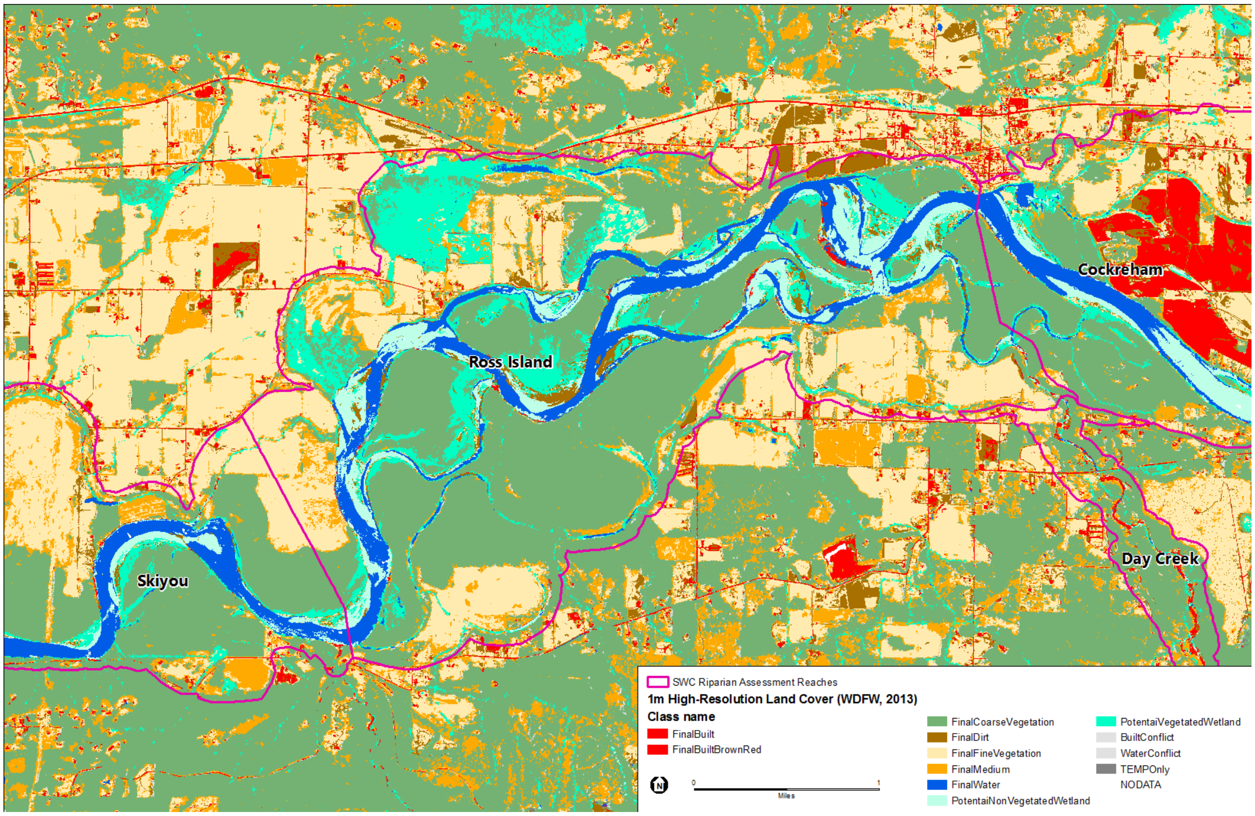


Figure 4. WDFW High Resolution Land Cover Classification (2013) output for the Ross Island Reach.

Cover Classes

For the riparian assessment, the following riparian cover classes were developed:

- Active Channel
- Built (roads, buildings and non-natural conditions)
- Vegetation Classes
  - Grass | Herbaceous
- Shrub-dominated
- Forest Cover
  - Conifer-dominated Forest
  - Deciduous-dominated Forest
  - Mixed Forest

As shown in Figure 3, ESA extracted several cover classes for manual refinement using air-photo interpretation techniques. The classes included: built, dirt, fine vegetation, medium vegetation, and water. Forest cover polygons were extracted for additional sub-classification using object-based classification techniques to develop finer classes of forest cover including: conifer-dominated, deciduous-dominated and mixed forest types. Each cover type is described in the following sections.

Active Channel

The active channel is defined as the portion of the channel commonly wetted during the winter base flows, identified by rooted vegetation or moss growth on rocks along stream margins. The ordinary high water mark is sometimes given as the elevation defining the active channel. To create this cover class, ESA used a combination of the active channel layer from the Middle Skagit Plan (SWC, 2011), the Middle Skagit Reach Level Analysis (SRSC, 2011) and the Washington Department of Natural Resources (WDNR) Hydro polygon layer as a starting point. Air photo interpretation techniques were then used to delineate the active channel regions for upper watershed areas where the active channel was not entirely mapped. Using air photo interpretation methods, we included unvegetated sand and gravel bar areas. Small channels obscured by trees that were not captured by the DNR Hydro polygon layer were not captured.

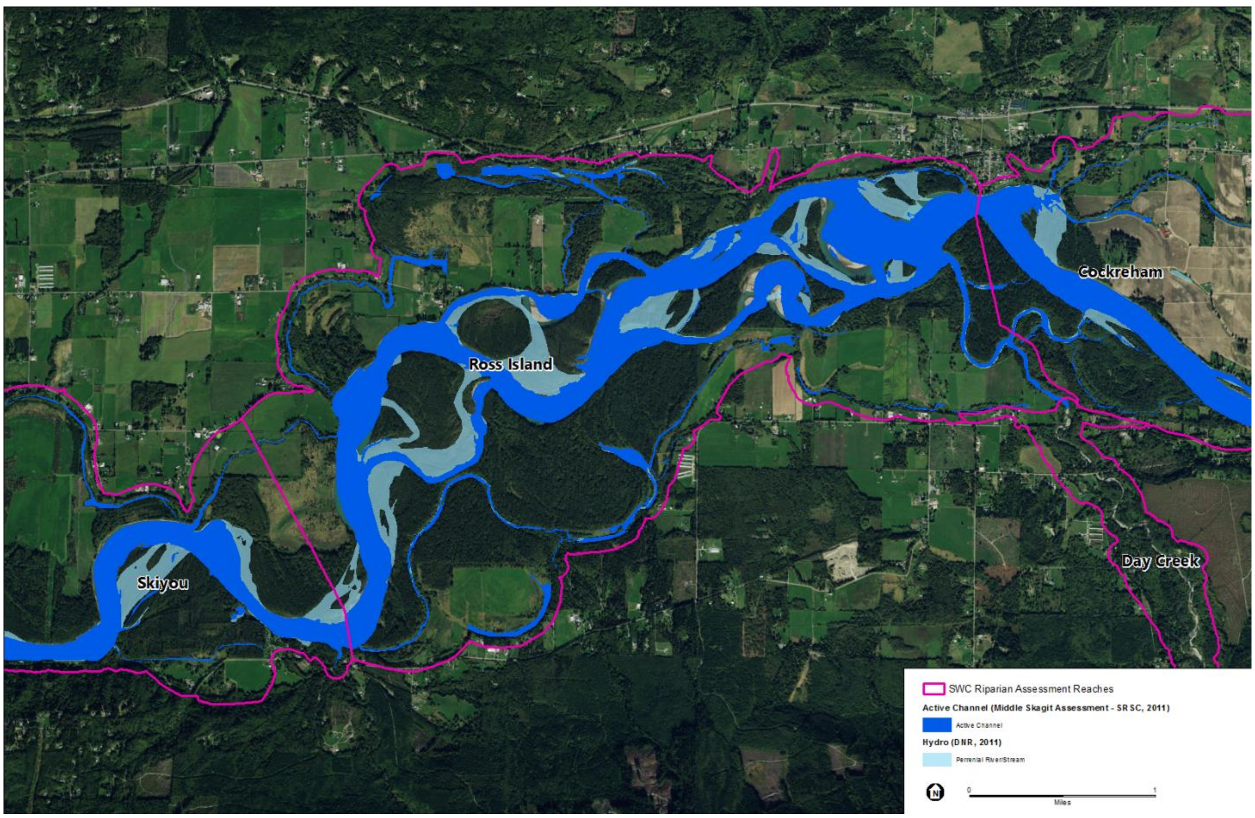


Figure 5. Active Channel Input Sources for the Ross Island Reach.

Built

Areas characterized by a landscape that is altered due to human activities. This includes roads, building & structures and other impervious surfaces. Sources include the FinalBuilt and FinalBuiltBrownRed cover classes from the WDFW 2013 land cover classes along with a 25' buffer of the street centerlines and USFS Roads geospatial data (USFS, 2017).

Dirt | Bare Earth

Areas characterized by bare rock, gravel, sand, silt, clay, or other earthen material, with little or no "green" vegetation present regardless of its inherent ability to support life. This includes the FinalDirt cover class from the WDFW 2013 land cover classification.

Grass | Herbaceous

Areas characterized by upland grasses and forbs as a majority. These areas are not subject to intensive management, but they are often utilized for grazing. This includes the Fine Vegetation cover class from the WDFW 2013 land cover classification.

Shrub-dominated

Areas dominated by shrubs; shrub canopy accounts for 25-100 percent of the cover. Shrub cover is generally greater than 25 percent when tree cover is less than 25 percent. Shrub cover may be less than 25 percent in cases when the cover of other life forms (e.g. herbaceous or tree) is less than 25 percent and shrubs cover exceeds the cover of the other life forms.

Forest Classes

ESA used the Coarse Vegetation cover type from the WDFW 2013 land cover classification as the initial forest class, and then subdivided this cover type into three forest classes:

- Conifer-dominated
- Deciduous-dominated
- Mixed

An example screen shot of the forest polygons is shown below as Figure 6.

Figure 6. WDFW High Resolution Land Cover Classification (2013) outputs displaying forest polygons for the Skiyou Reach.

The WDFW land cover classification did not extend to all area in the upper watershed of WRIA 4 within the project boundary. In these cases, ESA manually delineated forest polygons using traditional air-photo interpretation techniques using the 2013 1m NAIP imagery.

Unclassified

Areas unable to classify based on remote sensing techniques due to shadows, shading or other. Unclassified areas represent a small percentage (<5% of the total study area).

Forest Classification

Image Segmentation

To subdivide the Forest Cover polygons into three forest classes, an image segmentation was run within the forested regions using the 4-band NAIP imagery as the primary input to generate polygons based on similar spectral and textural characteristics. ESA used the Orfeo Toolbox in QGIS for the image segmentation. An example screen shot of the segmentation polygons is shown below as Figure 7.

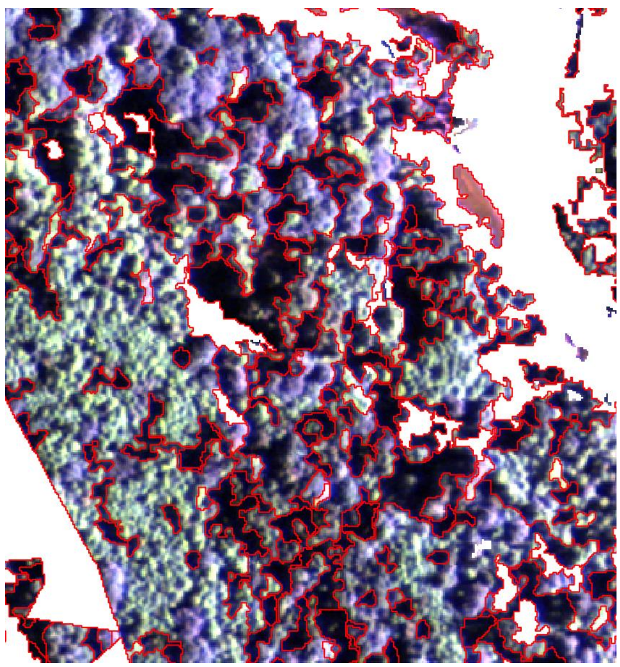


Figure 7. Example output segmentation (range 30) of forest cover polygons using the Extract Large-scale Mean-Shift segmentation algorithm from the Orfeo Toolbox in QGIS.

Object-based Classification

For each of the proposed forest cover classes (conifer-dominated, deciduous-dominated and mixed forest), ESA developed a set of rules that uniquely define the characteristics for a given forest cover type. Ancillary data was also used to support the rule sets for given cover types. Once rule sets were defined, the support vector machine (SVM) classifier was used to compute statistics for each polygon. As part of this classification assessment, ESA selected training polygons for each representative cover type to generate a signature file based on spectral and textural thresholds to be used for the classification.

The train image classifier and Image Classification algorithms were then used to perform the classification run. A shade class was also used to remove shadow areas from the classification so it did not confuse shaded areas with conifer-dominated forest areas. An example screen shot of the forest cover polygons is shown below as Figure 8.

Very-high resolution drone imagery   2013 NAIP NIR Band   Draft Classification Output

Figure 8. Example output of forest cover types (Conifer, Deciduous)

Each evaluated forest cover polygon with the minimum polygon size roughly 0.01 acre (400 sq ft) included a representative percentage of the polygon as either deciduous-dominated, conifer-dominated, mixed forest or shadow (unclassified). Polygons with greater than 75% conifers were assigned the conifer-dominant class. In sequence, polygons with greater than 50% deciduous were assigned the deciduous-dominant class. Polygons that had greater than 75% shadow were assigned the shadow class. All remaining polygons that did not have a majority or exhibit canopy dominance were assigned to the mixed forest class. These thresholds were established through an iterative review process by comparing output percentages to aerial imagery.

Preliminary Accuracy Assessment & Error Matrix

Using the reference dataset, ESA performed an initial accuracy assessment on the entire draft riparian cover classification output to yield an individual class and overall classification accuracy. Our target was 80% or higher. Based on the results of the accuracy assessment, the rule set for forest cover classes was then refined to improve the overall classification and increase its accuracy. Final accuracy assessment results are included below.

Manual Editing | Final Revisions

Based on classification outputs for each cover type, some additional manual editing was performed to improve overall accuracy.

Additional Data Preparation for Tree Canopy Height

To characterize riparian condition by canopy height, ESA evaluated three canopy height model (CHM) layers to derive elevation values for each forest cover polygon in the project extent. This included:

2006 LiDAR-Derived Canopy Height Model – This data product was derived by SWC staff from 2006 USGS LiDAR depicting tree height as a continuous surface. The original LiDAR product includes a first return point cloud that subtracts the bare earth to yield the canopy height values for each pixel.

2015-LiDAR-Derived Canopy Height Model - This data product was also derived by SWC staff from 2015 Glacier Peak USGS LiDAR depicting tree height as a continuous surface. The original LiDAR product includes a first return point cloud that subtracts the bare earth to yield the canopy height values for each pixel.

2015 Photogrammetric Detection and Ranging (PhoDAR)-Derived Canopy Height Model – This data product developed by Washington Department of Natural Resources (WDNR) is an alternative technology to conventional photogrammetry used to generate point clouds. For this product, the point clouds were derived from stereoscopic 2015 1m NAIP imagery. This product is coarser resolution than its LiDAR counterpart, but represented the best available data at the time of this work that was also similar in time period to the 2013 cover classification.

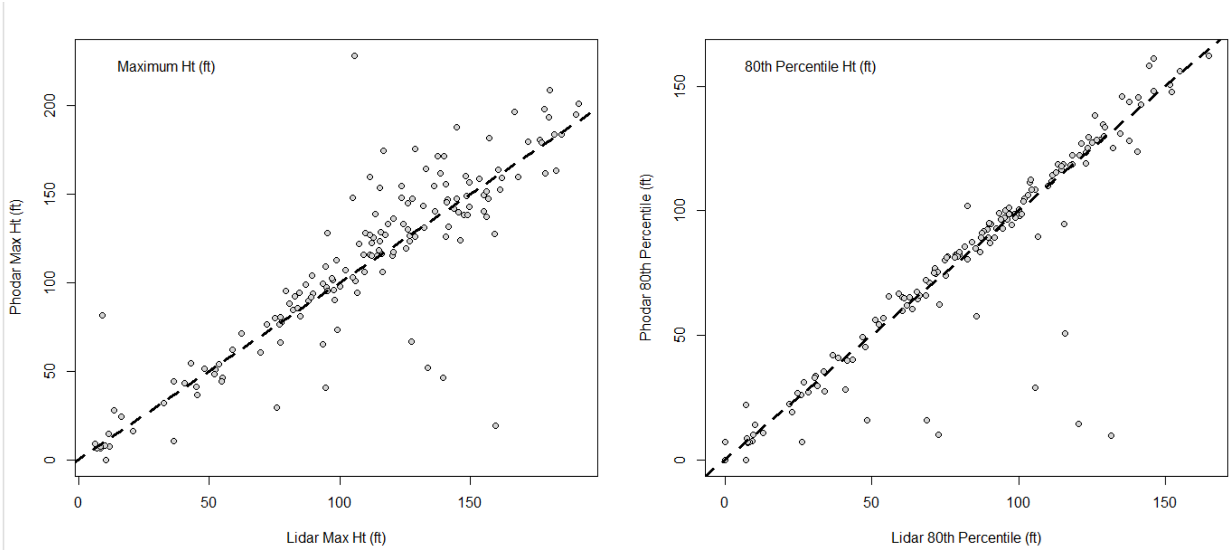
For this analysis, we included the elevation values from all three sources in the final GIS data layer for comparative purposes, though no further comparative analyses were completed given the difference in methodologies.

CHM Accuracy

LiDAR derived canopy height models are from two products of the LiDAR point cloud: a digital surface model (DSM) raster produced from the heights of the first measurable returns of the LiDAR point cloud minus the bare earth elevation or digital terrain model (DTM) raster produced from the last returns of LiDAR point cloud. The USGS bases its standards for new LiDAR acquisitions on a combination of LiDAR point cloud spacing and density, swath overlap, and repeatability. The accuracy of a LiDAR project (the Fundamental Vertical Accuracy) is judged by the accuracy of many hundreds of ground control points. However, due to the variation in tree top density and how far down each tree the many thousands of LiDAR pulses may hit, it is rare to quantify absolutely the height of the first return data. For example, the 2015 Glacier Peak USGS LiDAR is a USGS acceptable dataset although the height of the first return data can vary from the aggregate accuracy. First return LiDAR data is processed by the vendor from the same LiDAR point cloud and with the same protocols for accuracy as the last returns or digital elevation models. For this analysis, the first return data has been processed similarly to achieve the aggregate accuracy used to create a digital surface model (DSM) product as the processing to an aggregate accuracy used to produce the DTM. This DSM height minus the DTM elevation produced the LiDAR canopy height models in this assessment.

WDNR conducted a recent analysis between LiDAR-based and PhoDAR-based canopy height models by examining 157 1/10th acre plots on the west side of the Cascade Range where both PhoDAR from NAIP and LiDAR from 2014 or 2015 were present. These locations represent sample plots where forest metrics are measured to create regression models. They looked at the highest point in each cell (max ht) and the 80th percentile height (height where 80% of points are below and 20% are above) as shown in the table below. The dotted line is a 1:1 relationship, representing a perfect match.

Table 3. Comparison of LiDAR to PhoDAR Canopy Height Comparison



Results from this comparative analysis indicate strong correlation between LiDAR and PhoDAR at the maximum and 80th percentile heights for recent acquisitions. It is difficult to say anything conclusive about the older 2006 LiDAR CHM but there is general consensus with local practitioners that canopy heights are useful for delineation of fields, shrub and forests categories.

For each dataset, ESA used a majority filter in ArcGIS to extract a single elevation value from each CHM layer to each polygon in the riparian cover classified layer as stored in the attribute table of the final classification layer. For the purposes of the assessment, forest cover types were then grouped into three size classes as shown in Table 3.

Table 4. Tree Canopy Height Size Classes

Size Class	Height
Small	0-20 feet
Medium	20-60 feet
Large	>60 feet

The minimum and maximum heights for each of the three size classes were selected to distinguish shrub vegetation from young trees and distinguish young trees from taller trees, which provide greater riparian function such as LWD supply and long-term recruitment. Tree canopy height size classes are presented in Appendix B - Map 2. The individual elevation values are included in the final GIS layer to support further differentiation of height classes above 60' elevation. Additionally, it would be worth repeating a canopy height analysis of forest polygons using the 2017 LiDAR-Derived Canopy Height Model when this information is available.

Riparian Cover Classification Accuracy

The accuracy assessment analyzed the individual and overall accuracy of the riparian cover classification output. For all of the cover types, including the three subclasses of forest (conifer, deciduous, and mixed forest), the classification had an overall accuracy of 81.5% (Table 4). When the forest subclasses were aggregated into a single forest cover class, the overall accuracy improved to 90.3% (Table 5). The accuracy percentages for individual cover types are also presented in Tables 4 and 5. Specifically, with the forest classes, conifer forest yielded individual accuracies of 86.4% (Producer's accuracy) and 70.4% (User's Accuracy). In an accuracy assessment, producer's accuracy represents how well reference polygons of the ground are classified. User's accuracy represents the probability that a polygon classified into a given category actually represents that category on the ground. Deciduous forest category had a producer's accuracy of 67.1% and user's accuracy of 89.9%. Mixed forest had a producer's accuracy of 72.1% and user's accuracy of 66.0%. Although none of these categories achieved a combined individual accuracy greater than 80%, user's accuracy for conifer and deciduous forest types were above 70% meaning the probability of a polygon classified as either conifer or deciduous would have a >70% chance of it actually representing that category on the ground.

With regards to the aggregated forest cover category, the producer's accuracy was 91% and user's accuracy was 98.5%. The probabilities of differentiating water, built and forest cover types is high using this aggregated dataset. The lowest user's accuracy was represented by the shrub type with a 57.1% accuracy. Confusion between forest and shrub categories is attributed to this lower classification accuracy. Maps 1, 1a, 1b and 1c in Appendix B show the riparian cover results for each reach.

Table 5. Accuracy Assessment for Riparian Cover Classification

	Active Channel	Built	Conifer-dominated	Deciduous-dominated	Bare Earth	Grasslands, Pasture, Field	Mixed Forest	Shrub-dominated	Water	Unclassified	Total	Percent
Active Channel	**27**			1						1	29	93.1%
Built		**25**				1					26	96.2%
Conifer-dominated			**19**	1		1	6				27	70.4%
Deciduous-dominated			1	**53**			4	1			59	89.8%
Bare Earth		3			**27**	4		2			36	75.0%
Grasslands, Pasture, Field						**33**					33	100.0%
Mixed Forest			1	15			**31**				47	66.0%
Shrub-dominated			1	9		3	2	**20**			35	57.1%
Water (lakes, ponds, etc)									**25**	2	27	92.6%
	27	28	22	79	27	42	43	23	25	3	**319**	
	100.0%	89.3%	86.4%	67.1%	100.0%	78.6%	72.1%	87.0%	100.0%			
											260	
Overall Accuracy	**81.50%**		21	69			41					

Table 6. Accuracy Assessment for Aggregated Riparian Cover Classification

	Active Channel	Built	Bare Earth	Grasslands, Pasture, Field	Forest	Shrub-dominated	Water (lakes, ponds, etc.)	Unclassified	Total	Percent
Active Channel	**27**				1			1	29	93.1%
Built		**25**		1					26	96.2%
Bare Earth		3	**27**	4		2			36	75.0%
Grasslands, Pasture, Field				**33**					33	100.0%
Forest				1	**131**	1			133	98.5%
Shrub-dominated				3	12	**20**			35	57.1%
Water (lakes, ponds, etc.)							**25**	2	27	92.6%
	27	28	27	42	144	23	25	3	**319**	
	100.0%	89.3%	100.0%	78.6%	91.0%	87.0%	100.0%		288	
Overall Accuracy	**90.3%**									

Trend Analysis

To characterize trends in the quantity of forest cover and other cover types over time, ESA evaluated and summarized multiple data sources as described in the following sections.

WDFW High Resolution Change Detection Dataset

To assess recent trends in habitat loss and conversion in the study area, the WDFW High-Resolution Change Detection (HRCD) dataset was examined. The data summarize changes in land cover between the following time stamps: (1) 2006–2009, (2) 2009–2011, and (3) 2011–2013. The changes in land cover are associated with attributes or "change agents" such as urbanization, forest clearing, or natural disturbance events. The following is a list of the potential change agents associated each polygon identified in the dataset:

- Development
- Forestry
- Tree Removal
- Stream/hydrologic change
- Redevelopment
- Retention Pond
- Other Natural
- Other Non-natural

Furthermore, each polygon can be compared across the three time periods in terms of its total change percentage, changes in tree cover, and impervious and semi-pervious surfaces. WDFW is in the process of finalizing an additional time period (2013-2015) based on updated imagery. For more information on this dataset, see the final report available online at: http://wdfw.wa.gov/publications/01454/.

This project evaluates areas that started as forest (>90% cover) or shrub types and were anthropogenically altered/modified to help understand areas that have "lost" function due to human activities. To do this, only the polygons that were coded as forest or shrub at the start and then changed to a human altered category (i.e., development, tree removal, forestry, other non-natural) were selected and presented.

The analysis also quantified forest loss within both isolated and connected areas of the Skagit floodplain and riparian areas (see Isolated Areas Overlay below).

Riparian areas lost over time due to stream erosion, though mostly a natural process, were also documented and presented. However, since it isn't a predominantly human action, lost areas were not tallied together with anthropogenic changes. Results for the Ross Island reach are presented on Map 9 in Appendix B.

SWC Riparian Plantings Database

ESA used the SWC riparian plantings database to quantify the amount of area and percent forest gained through planting efforts in the basin. SWC staff and seven primary implementers of riparian restoration planting and invasive species treatment restoration projects (Skagit Land Trust, Skagit Fisheries Enhancement Group, Skagit River System Cooperative, Skagit County Public Works, the US Forest Service, the Nature Conservancy, and the Upper Skagit Indian Tribe) collaborated to design and complete a comprehensive database and GIS map polygons of past riparian restoration projects (including invasive species treatments, erosion control, livestock exclusion, and planting work, as well as documenting funding and expected future maintenance needs) in the watershed. This project used this discrete database and GIS layer to quantify and present only the planting area improved by the riparian implementers (and does not include non-planting activities such as invasive species control).

Conservation Reserve Enhancement Program (CREP) Plantings Database

Since it is not included in the SWC riparian plantings database, ESA used the US Farm Service Agency's Conservation Reserve Enhancement Program's (CREP) riparian plantings extent calculations provided by the Washington Conservation Commission at the reach-level and by variable riparian widths to assess the amount for riparian cover representing "gained" riparian function. The CREP program is a joint federal and state funded program that targets high priority conservation areas for incentivizing conservation practices such as restoring riparian habitat by planting native trees and shrubs and installing fencing.

Isolated Areas Overlay

SWC and partners are targeting those places that are functionally connected hydrologically and hydraulically to the system for restoration and riparian planting efforts. Isolated areas represent areas physically isolated from the system due to physical barriers such as roads, dikes or levees. Building on SRSC's floodplain delineations (SRSC and WDFW, 2005; SRSC, 2011), SWC followed the same methodology to expand coverage for this overlay throughout the study area. ESA incorporated this layer into the trend analysis to differentiate geomorphically-connected areas from isolated areas.

Project Web-based Collaboration & Mapping Tool

ESA created a project web-based tool in ArcGIS Online to publish results of the riparian cover classification and other data layers to an interactive map format accessible from any web browser. During the draft phases of the project, the tool used a login & password authentication for access. The tool also facilitated review and feedback from SWC staff, key riparian implementers, and its technical group. In addition to the riparian assessment results, the tool displays several other attributes including: SWC's Tier 1, Tier 2, and Tier 2S target areas, existing riparian restoration sites, areas identified by the Department of Ecology with water quality impairments, habitat types, and protected/public lands. An example screen shot of the web-based tool is shown below as Figure 9.

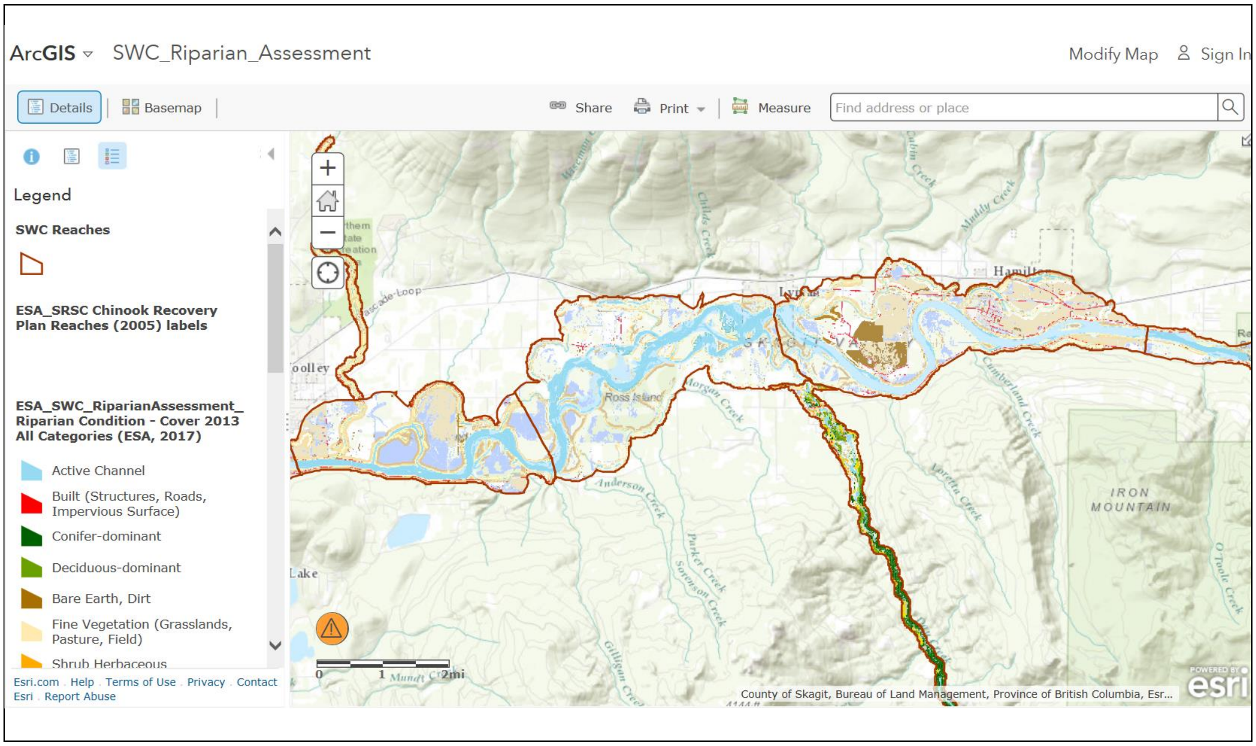


Figure 9. Example of web-based tool used to facilitate review and feedback during project.

Targeted Field Assessment

Both ESA staff and members of the SWC's technical working group collected field data and classified point locations as reference data to support the accuracy assessment. For the field campaign, ESA created a simple field data collection form for the ESA team and SWC staff to use as reference in the field. This data form was used to create an ESRI ArcGIS Online editable feature services accessible in the field using the ESRI Collector App. A total of 160 points were collected in the field to support the classification representing all of the cover types in the study area. Data and geotagged photos were stored in a file geodatabase. An example screen shot of the field data collection service is shown below as Figure 10.

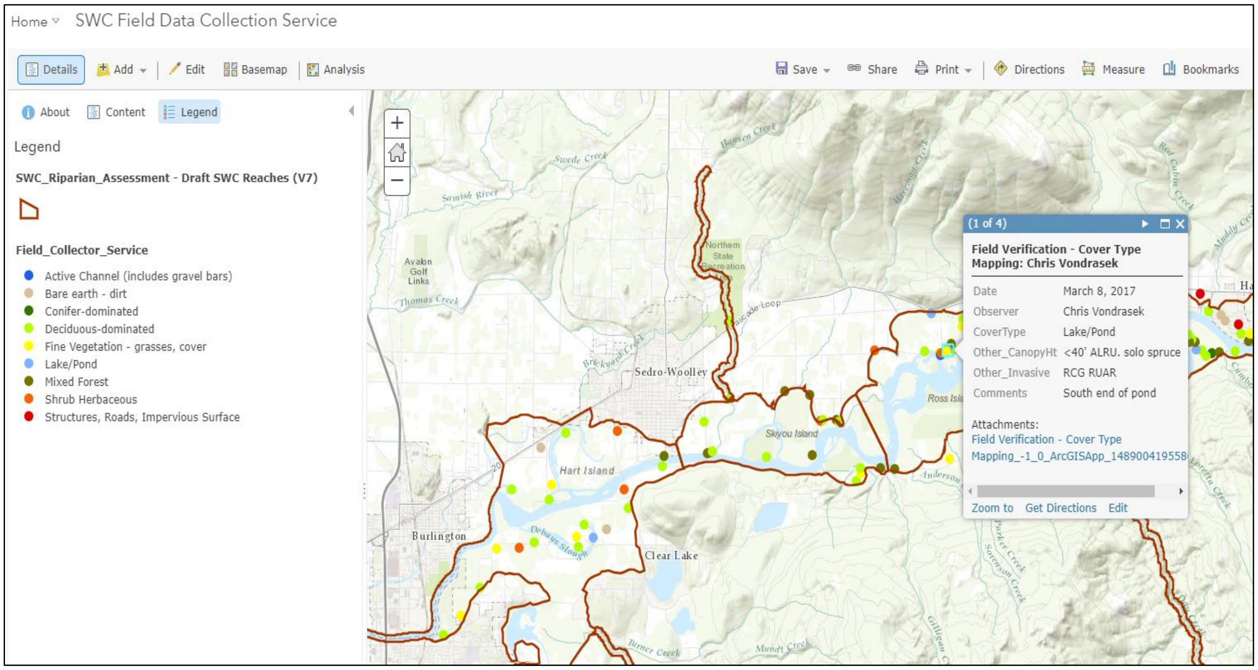


Figure 10. Example of mobile data collection feature service used to obtain training and reference data point supporting the riparian cover classification.

ESA also supplemented the field data by conducting manual air-photo interpretation of high resolution imagery. The field data and the additional manual review created a reference dataset with a total of 319 points.

Riparian Assessment Metrics

ESA assembled the riparian cover classes into metrics to characterize current riparian condition of SWC's Tier 1, Tier 2, and Tier 2S Target Areas. The riparian assessment metrics are based on a literature review of relevant work and include metrics and indicators from the SWC Habitat Protection and Restoration Strategy (1998), the draft list of freshwater indicators for the new Monitoring & Adaptive Management (M&AM) framework for the Skagit Chinook Salmon Recovery Plan (list dated 11-6-15), the Middle Skagit Reach Level Analysis (SRSC, 2011) and several other sources listed in the References section of this document. The metrics include riparian function, migration potential, and impairment, as shown in Figure 11 and described in the sections below. Additional datasets were also assembled to support the riparian assessment. Appendix B contains a set of maps displaying the metrics and other key data layers.

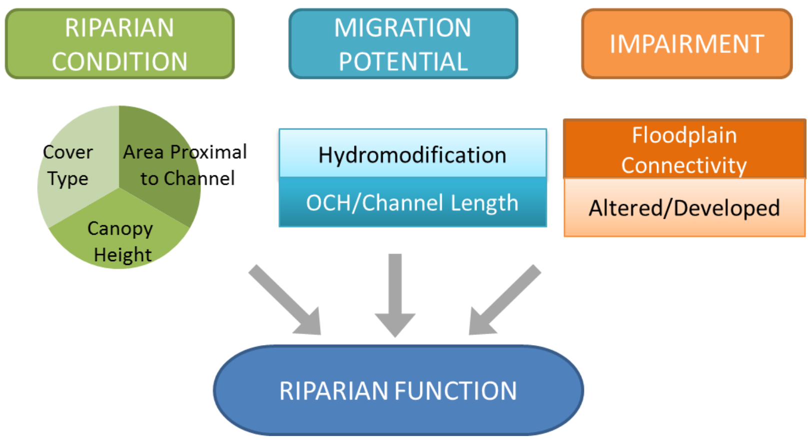


Figure 11. Framework for Integrating Riparian Cover Classification Results

Riparian Condition

Riparian function is partly driven by the type of vegetation (e.g. coniferous or deciduous or shrub), structure and complexity, and extent of contiguous riparian area (Macfarlane et al. 2016). These features dictate the condition of a given riparian area and its potential for the recruitment of large woody debris to the stream system (WNDR, 2011). Three metrics provide an indication of riparian condition: 1) vegetation type, 2) vegetation height, and 3) the amount of riparian area that is proximal to active stream channels. For the amount of riparian area proximal to active stream channel, the assessment tabulated riparian area into three width classes plus the floodplain extent. The width class categories come from SWC's 1998 Habitat Protection and Restoration Strategy (SWC, 1998) and 2015 Strategic Approach (SWC, 2015).

Migration Potential

To assess the migration potential of each reach, ESA assembled data on hydromodifications and off-channel habitats per reach length. For hydromodifications, the presence or absence of hydromodified banks within each reach was assessed using the inventories completed by the Upper Skagit Indian Tribe

(USIT, 2010 and 2013). The USIT hydromodification inventories collected data in 2009 and 2010 (Skagit River and floodplain) and in 2012 and 2013 (Upper Skagit River and tributaries).

For habitat type, ESA incorporated SWC's analysis of off-channel habitat to channel length ratio for mainstem reaches following the methods in the Middle Skagit Reach Level Analysis (SRSC, 2011) which used the ratio of off-channel habitat (OCH) (sq. ft.) by channel length (ft.) as a simple metric to evaluate the geomorphic potential for channel migration in floodplain reaches. This metric assumes that dynamic reaches will be most likely to form OCHs and that even if they currently are impaired that reaches with high geomorphic potential will have more floodplain channels currently than reaches with lower geomorphic potential. For this current assessment, SWC staff used shapefiles from Skagit River System Cooperative based on 2015 aerial imagery and limited field information. The OCHs were quantified in GIS using polygons of Skagit River habitat types, and excluded artificial OCHs such as the spawning channels near Illabot. The channel lengths were quantified using polylines of channel centerlines. Both shapefiles were clipped to Skagit Chinook Recovery Plan reach polygons to derive the habitat areas and channel lengths within each reach. The areas and lengths were exported into a spreadsheet where the ratio calculations were completed. The calculations were then resorted to correspond to riparian assessment reaches. It is noted that the SRSC habitat type dataset is not informed by site-scale studies and actual bank armoring conditions and should therefore be considered with this in mind.

For Tributary reaches, SWC calculated the 2-year flood event from LiDAR-derived topography and hydrologic and hydraulic modeling. For six of the Chinook tributaries, this '2-year inundated channel area' to 'channel length' ratio acts as a comparable but not equivalent measure for the OCH/length ratio used in the larger mainstem rivers to describe geomorphic potential. The data for the OCH/length ratio came from polygons derived from image interpretation. The data for the tributary '2-year inundated channel area' to 'channel length' ratio comes from LiDAR derived modeling.

Hydraulic models to describe the '2-year inundated channel area' were completed on six, Tier 2 Chinook tributaries situated upriver of Sedro Woolley and downstream of the steeper mountain valleys in the upper watershed. These six include: Day, Finney, Dan, Illabot, Diobsud, and Bacon Creeks. The modeled lengths of these creeks varied in the modeled length flowing through a floodplain and the length more confined in a valley, but focused on the lower rivers. Three of the six (Illabot, Diobsud, and Bacon) were more accurately described by breaking the creek into two reaches, a wider, lower reach and more confined, upper reach. Three were described as a single reach (Day, Finney, and Dan).

Impairment

The extent of altered or developed land cover was derived from the riparian cover classification results as a measure of impairment. Classes combined for this measure include the built environment, bare earth, pasture and grasses. ESA also used the Floodplain Impairment data developed by SRSC to quantify area and percent of isolated or shadowed habitat areas by roads and hydromodifications in the floodplain.

Table 6 summarizes the individual metrics, their classes, and the origin and/or connection with the M&AM framework for the Skagit Chinook Salmon Recovery Plan.

Table 7. Riparian Assessment Metrics - Classes and Origin

Metric		Classes	Origin and/or Connection
Riparian Condition	Cover Type	Dirt/bare earth	*High-Resolution Land Cover Classification (WDFW 2013)* *Riparian Cover Classification (ESA, 2017)* *Forest Practices Watershed Analysis Manual Appendix D – Riparian Function Module (WDNR 2011)* M&AM Common Indicator: Riparian – Spatial extent and continuity
		Grassland/landscaped (cleared, lawn, landscaped areas)	
		Shrub-dominated	
		Forest cover classes (Conifer-dominant, Deciduous-dominant and Mixed based on riparian cover classification)	
	Canopy Height	0-20 feet	*LiDAR Canopy Height Model (USGS, 2006)* *PhoDAR Canopy Height Model (WDNR, 2015)* *Simple tools to estimate impacts of development on water quantity, water quality, and riparian processes (Roberts 2003)*
		20-60 feet	
		>60 feet	
	Area Proximal to Active Stream Channel	0-20m (0-66 ft)	*SWC Habitat Protection and Restoration Strategy (SWC 1998) and SWC Strategic Approach (SWC 2015)* M&AM Common Indicator: Riparian – Spatial extent and continuity
		20-40m (66-131ft)	
		40m-91m (131-300 ft)	
		>91m (300 ft) (Within Floodplain)	
Migration Potential	Hydromodification	Hydromodification presence	*Assessment and Inventory of Hydromodified Bank Structures in the Skagit River and Floodplain (USIT, 2010) and Tributaries (USIT, 2013)*
		Hydromodification absence	
	OCH/Channel Length	Ratio	Ratio of off-channel habitat (OCH) (sq. ft.) by channel length (ft) as metric to evaluate the geomorphic potential for channel migration in floodplain reaches (SRSC, 2011; SWC, 2017)
Impairment	Floodplain Connectivity	Isolated and Shadowed Habitat Areas	*Floodplain Impairment* (SRSC, 2015) dataset represents floodplain areas that are isolated or shadowed by roads or hydromodifications.
	Altered/Developed	Developed or human-altered environment (roads, buildings, structures, bare earth, pasture, grasslands)	*High-Resolution Land Cover Classification (WDFW 2013)* M&AM Common Indicator: Riparian – Spatial extent and continuity

Additional Data Overlays

ESA acquired and assembled several datasets to overlay the riparian cover classification results and support the riparian assessment. In addition to the metrics described previously, these overlays can inform the identification of strategies and priorities for riparian restoration. Data overlays for protected lands (Map 6), habitat types (Map 7) and 303d water quality listings (Map 8) are presented in Appendix B.

Protected Lands and Ownership

SWC developed an interim, 2017 parcel-based protected and conservation lands layer for Skagit and Snohomish Counties for use on several on-going projects. This layer combines salmon habitat parcels acquired with Salmon Recovery Funding Board (SRFB) grants by the Skagit Land Trust, Seattle City Light and the Nature Conservancy with conservation lands publicly-owned by the US Forest Service, the US National Park Service, WA State Department of Natural Resources, WA Department of Fish and Wildlife, WA State Parks, and Skagit County. This protected and conservation lands layer focuses on cataloging sites with permanent habitat protections, usually for salmon habitat purposes, and excludes other publicly-owned lands for other purposes such as those with easements to protect agricultural lands from development. An updated data layer will be finalized in 2018.

Habitat Conditions

Habitat Type & Edge Habitat Type

The habitat type and edge habitat type categories are derived from the Middle Skagit Reach-Level Analysis (SRSC, 2011) and are based on the Skagit Chinook Recovery Plan (SRSC and WDFW, 2005) and 1995 Skagit River Chinook Restoration Research (Hayman et al. 1996). For the Middle Skagit project, the surface area was measured for mainstem, backwater, off-channel, and tributary habitats and the length was measured for mainstem banks and bars, and perimeter was measured for backwaters. This information is available as polygon and line files for use in this assessment, but is not available for all of the reaches considered in this riparian assessment, particularly the tributary reaches (applicable for major rivers above Sedro-Woolley).

Water quality impairments

The Department of Ecology's assessment of water quality generates a list of 303(d) waters every two years. Information on 303(d) waters is available from 2012 as polygon files for use in this assessment. The 303(d) listing includes waterbodies that are in the polluted water category, for which beneficial uses – such as drinking, recreation, aquatic habitat, and industrial use – are impaired by pollution.

Presence of invasive species

The Skagit Fisheries Enhancement Group (SFEG) maintains a database of invasive species locations in the watershed. This information is available as point files.

Presence of log jams

A 2007 logjams dataset developed by SRSC was included to provide a listing of log jams in the project extent. This line file includes 347 records and also includes information on length, reach, type and stock type.

Riparian Assessment Results

This chapter presents summary results of the riparian assessment conducted for the Tier 1, Tier 2, and Tier 2S target areas. The 44 reaches evaluated vary in size, complexity, and degree of disturbance or intactness. This section highlights some key watershed and reach-level assessment results that characterize riparian condition, migration potential, impairment, and other factors. In addition, all of the riparian assessment results are available for viewing and analysis via a web-based dashboard at: http://tabsoft.co/2y0ewzV.

Watershed-level Results

Riparian cover was classified for 62,683 acres of riparian and floodplain areas of the Skagit River watershed. Overall, more than 65% of the landward study area is comprised of forest and approximately 26% representing altered cover types. Table 7 provides a watershed-level summary of the riparian cover classification.

Table 8. 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.*

Riparian cover types vary depending on the location in watershed (e.g. lower and upper) as shown below in Figure 12. Of the 62,683 acres of riparian areas, approximately 42% of the area is within WRIA 3 and 58% of the area is in WRIA 4. In the lower watershed, fine vegetation (i.e., grasslands, pastures and fields) is the dominant cover type (35%) followed by forest (26%). As would be expected, the extent of fine vegetation decreases (to 5%) and forest cover is substantially more prevalent in the upper watershed (increasing to 69%). In particular, there is nearly three times the amount of combined forest cover types in the upper watershed compared to the lower watershed target areas, and nearly three times the amount of built land cover in the lower watershed than the upper watershed. Bare earth and shrub cover types are also vastly more prevalent downstream than upstream.

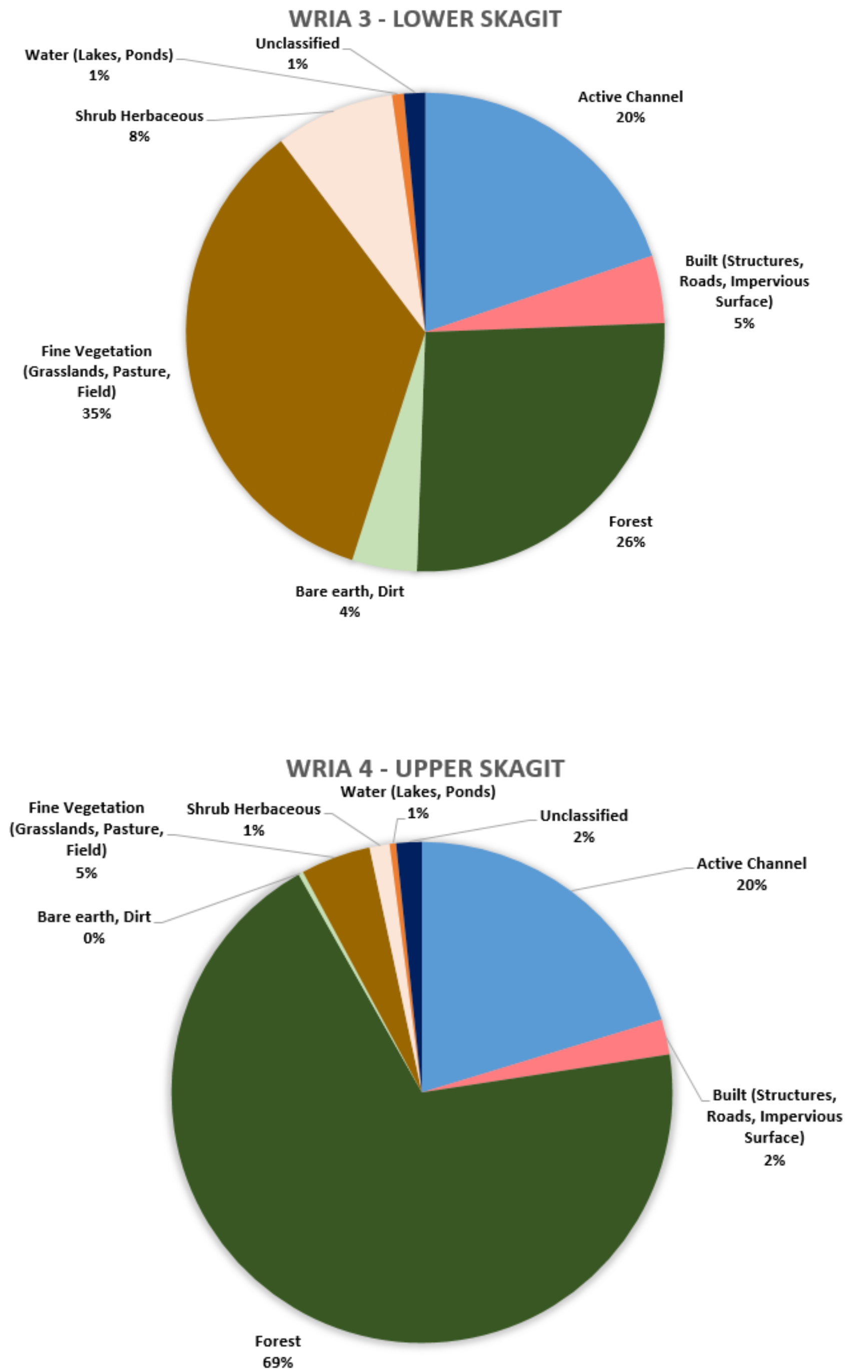


Figure 12. Distribution of Riparian Cover Types in WRIA 3 and WRIA 4.

Riparian Condition

The riparian assessment included an analysis of the extent of riparian forest cover adjacent to the active channel (including the mainstem, side/off channels, and tributaries) as an indication of riparian condition. Table 8 provides the extent of forest cover within the three width class categories and floodplain extent designated in SWC's 1998 Habitat Protection and Restoration Strategy (SWC 1998). Due to the substantial differences in the dominant cover type between WRIA 3 and WRIA 4 (as described above), the results for each WRIA are shown separately.

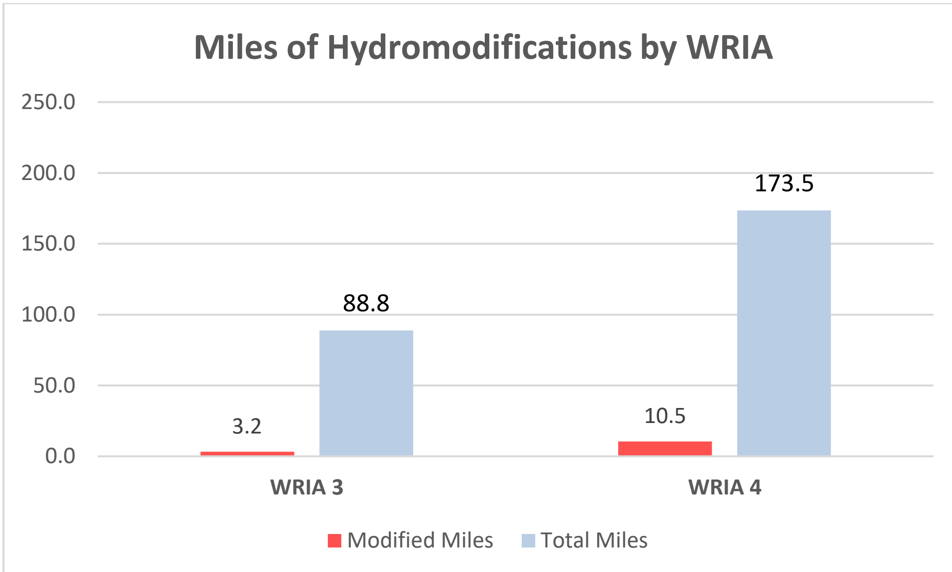
Table 9. Riparian Forest by Riparian Width Classes – WRIA 3 & WRIA 4

Riparian Width	Acres	Percent of Total
WRIA 3 – LOWER SKAGIT		
0-20m (0-66 ft) Forest Cover	1,366.20	53.65%
20-40m (66-131 ft) Forest Cover	1,203.20	49.50%
40-91m (131-300 ft) Forest Cover	2,432.50	42.35%
Floodplain Outside of Riparian Buffer Widths Forest Cover	2,902.20	28.10%
Total	**7,904.10**	**37.55%**
WRIA 4 – UPPER SKAGIT		
0-20m (0-66 ft) Forest Cover	3,441.20	88.46%
20-40m (66-131 ft) Forest Cover	3,386.90	90.25%
40-91m (131-300 ft) Forest Cover	8,147.70	89.44%
Floodplain Outside of Riparian Buffer Widths Forest Cover	9,195.30	84.98%
Total	**24,171.10**	**87.66%**

Interestingly there are differing conditions between Lower and Upper Skagit WRIAs with respect to their function as measured by forest cover at variable widths from stream habitat. In the Lower Skagit where agricultural, residential, and commercial land uses are dominant there is a pattern of decreasing forest cover as distance from the active channel increases, ranging from 54% (within 20m) down to 42% (within 40-91m) forest cover. In the Upper Skagit where forestlands and more natural resource land uses prevail, with only interspersed residential uses, forest cover generally shows no decreasing pattern as distance from the active channel increases, ranging from 88% to 90%. Further insights can be found below on a reach by reach scale.

Migration Potential

We used the USIT hydromodification inventory data layer to help assess channel migration potential at the watershed and reach-levels. This dataset is based on an analysis of mainstem and secondary river channels of the Skagit River and Chinook salmon bearing tributaries within the Skagit floodplain from the confluence of the Sauk River downstream to the Highway 9 Bridge in Sedro-Woolley. The inventory surveyed areas adjacent and water ward of active mainstem and secondary channels in their current configuration for structures visually identifiable that were currently impacting edge habitat. This reach level assessment collected preliminary screening data to be incorporated into additional modeling to determine the areas of greatest habitat potential. Figure 13 displays the amount of hydromodification within WRIA 3 and WRIA 4 as derived from the USIT hydromodification data.



**No Hydromodification data for Fir Island, Fisher Carpenter, Mt Vernon and WF Nookachamps Reaches in WRIA 3.*

Figure 13. Miles of Hydromodifications by WRIA.

Impairment

The riparian assessment included an analysis of the extent of altered or developed land cover along with the extent of altered/developed land that is connected to the active channel as an indication of impairment or degradation of riparian condition. Altered riparian cover is an aggregate of the built (structures, roads, impervious surface), bare earth/dirt and fine vegetation (grasslands, pasture, field) cover types. Figure 14 displays the amount of altered or developed land cover for WRIA 3 and WRIA 4 as derived from the riparian cover classification results within the entire study area.

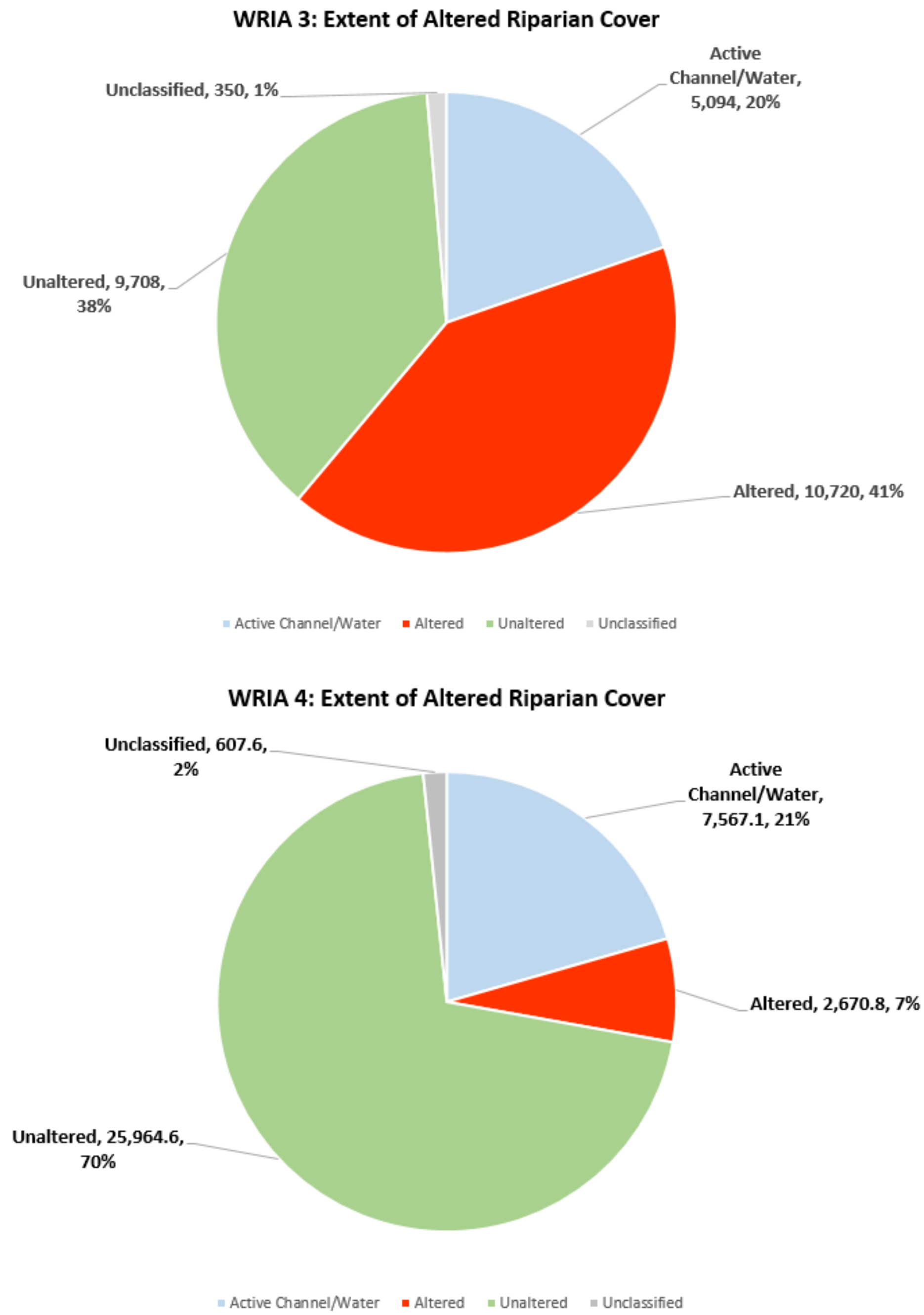


Figure 14. Extent of Altered/Developed Land Cover - WRIA 3 and WRIA 4.

Reach-level Results

Riparian Cover

For the reach-level, Table 9 presents the riparian cover (forest, shrub, and altered) by reach within 40 meters (0-131 feet) of the active channel based on the ESA 2013 riparian cover classification.

Table 10. Riparian Cover (Forest, Shrub, Altered) by Reach within 0-40m (0-131ft) of Active Channel

Reach	% Forest	% Shrub	% Altered
Downey Creek	99%	0%	1%
NF Sauk River	99%	0%	1%
Cascade Upper	98%	1%	1%
White Chuck River	97%	1%	2%
Illabot Creek	97%	0%	2%
Upper Skagit	96%	2%	3%
Suiattle Middle	95%	0%	4%
Finney Creek	95%	0%	3%
Tenas Creek	94%	0%	4%
Suiattle Upper	93%	3%	4%
Diobsud Creek	93%	1%	4%
Sauk Upper 03	92%	1%	5%
Suiattle Lower	90%	0%	6%
Cascade Lower	89%	1%	7%
Buck Creek	88%	0%	12%
Cape Horn	88%	2%	8%
Bacon Creek	87%	5%	7%
Corkindale	87%	1%	9%
Sauk Upper 01	85%	1%	10%
Backus Olson	85%	0%	12%
Sauk Upper 02	85%	1%	11%
Rockport	85%	3%	11%

Reach	% Forest	% Shrub	% Altered
Sauk Middle 02	84%	1%	12%
Dan Creek	84%	0%	4%
Day Creek	84%	7%	4%
Savage	82%	3%	14%
Jackman	80%	1%	16%
Aldon	80%	3%	15%
Marblemount	80%	1%	17%
SF Cascade River	80%	16%	3%
Goodell Creek	79%	15%	0%
Baker	78%	2%	18%
Sauk Middle 01	75%	0%	21%
Sauk Lower	74%	9%	15%
Ross Island	67%	9%	21%
Skiyou	64%	6%	28%
Hansen Creek	61%	12%	26%
Fir Island	58%	10%	30%
EF Nookachamps	55%	11%	27%
Cockreham	51%	14%	31%
WF Nookachamps	47%	13%	39%
Burlington - Sedro	42%	19%	37%
Mt Vernon	33%	10%	54%
Fisher Carpenter	17%	8%	73%

Several upper watershed reaches including Downey, NF Sauk, Cascade Upper, White Chuck, Illabot, Upper Skagit Suiattle Middle and Finney Creeks are almost exclusively forested (95% or greater). There were a few reaches that had some anomalies, primarily in the upper watershed where expected cover is predominantly forest. Buck Creek, for example has 88% forest with 12% mapped as altered due to the presence of forest service roads and campground through the reach. Goodell Creek has no altered cover, but includes 15% shrub located primarily at the bottom of a recent, major landslide deposit near the middle of the reach. Sauk Middle 01 reach had 21% altered mainly due to residential uses and roads on the east bank of the Sauk River.

The results were geographically grouped into the following super-reaches for display purposes:

- Skagit Mainstem Reaches
- Skagit Tributaries
- Sauk & Suiattle Mainstem and Tributary Reaches

Within each super-reach, results were summarized for forest, shrub, and altered cover area and percentages by reach within 40 meters (131 feet) of the active channel (Figures 15, 16, and 17). Altered riparian cover is an aggregate of the built (structures, roads, impervious surface), bare earth/dirt and fine vegetation (grasslands, pasture, field) cover types. In the Skagit Mainstem reaches, Cape Horn, Rockport, Corkindale, Backus Olson, and Upper Skagit reaches all had 85% or greater percentage of forest cover within this zone. Conversely, Mount Vernon and Burlington-Sedro reaches both had less than 45% forest cover within 40 meters (131 feet) of the active channel. Percentage of shrub cover class is noticeably higher in reaches below and including the Cockreham reach.

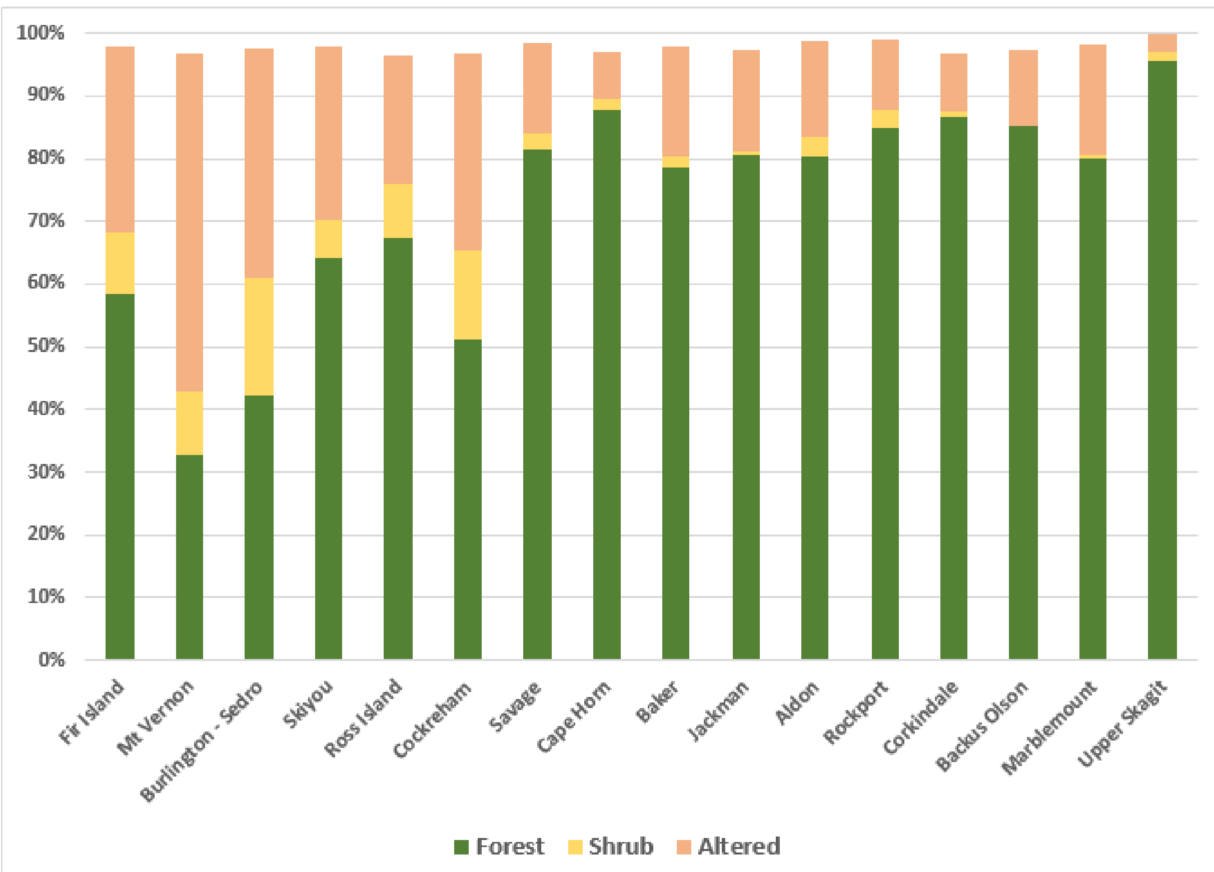


Figure 15. Riparian Cover within 40 m (131 ft) of Active Channel – Skagit Mainstem Reaches

In the Skagit Tributary reaches, Cascade Upper, Illabot Creek, Finney Creek and Diobsud Creek had 90% or greater forest cover within the 0-40m (0-131 ft) zone. Hansen Creek, EF Nookachamps, WF

Nookachamps and Fisher Carpenter (the lowest four tributaries analyzed in this study) had less than 61% forest cover types in the 0-40m (0-131 ft) zone. Again, shrub cover percentages are higher in downstream tributaries due mainly to past anthropogenic activities. But interestingly shrub cover percentages increase again in the upper portions of the highest elevation tributaries mainly due to natural disturbances such as landslide impacts and persistent snow cover impacting tree growth.

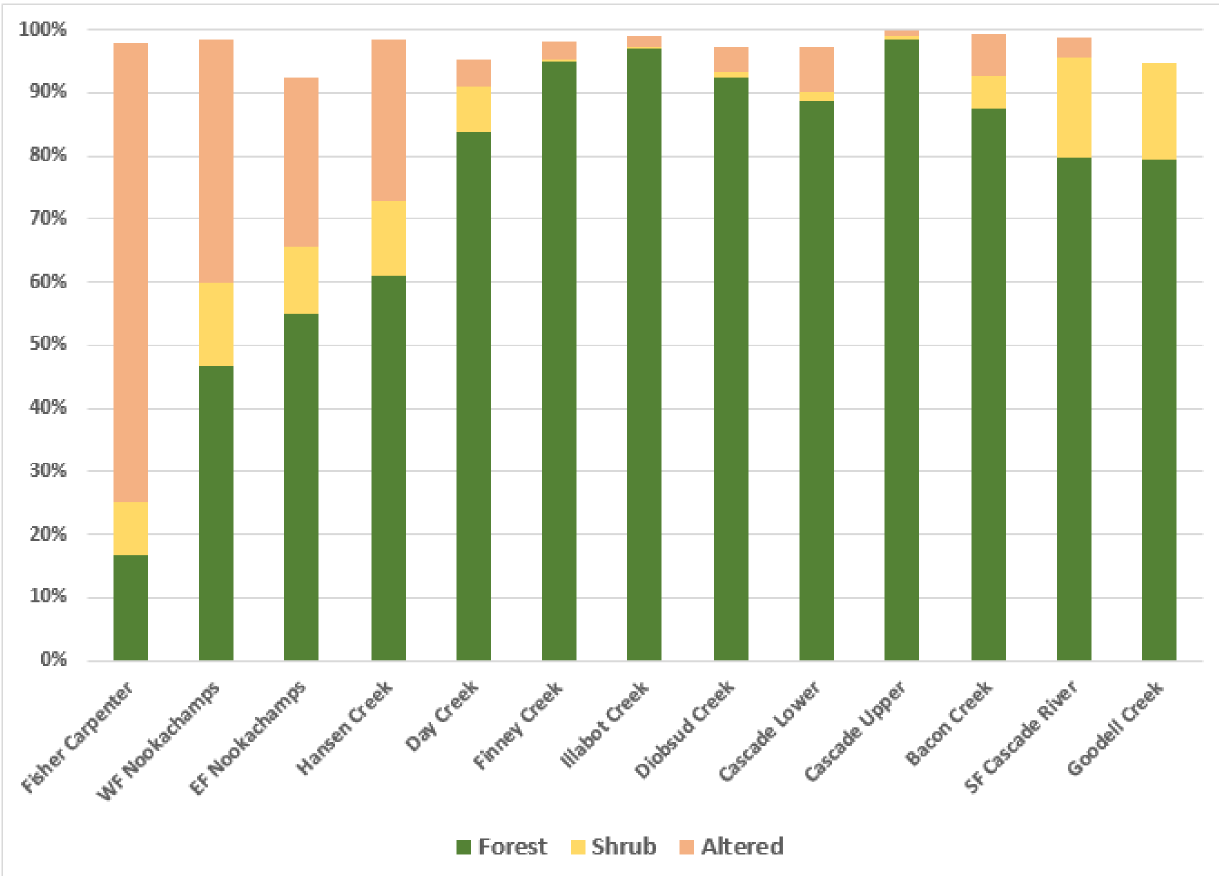


Figure 16. Riparian Cover within 40 m (131 ft) of Active Channel – Skagit Tributary Reaches

In the Sauk & Suiattle mainstem and tributary reaches, all reaches had 74% or greater forest cover within the 0-40m (0-131ft) zone. Only Sauk Middle 01 had altered riparian cover greater than 20% within 40 meters (0-131ft). The relatively few places with shrub cover (e.g. Sauk Lower and Suiattle Upper) were associated with natural vegetation succession following river erosional processes.

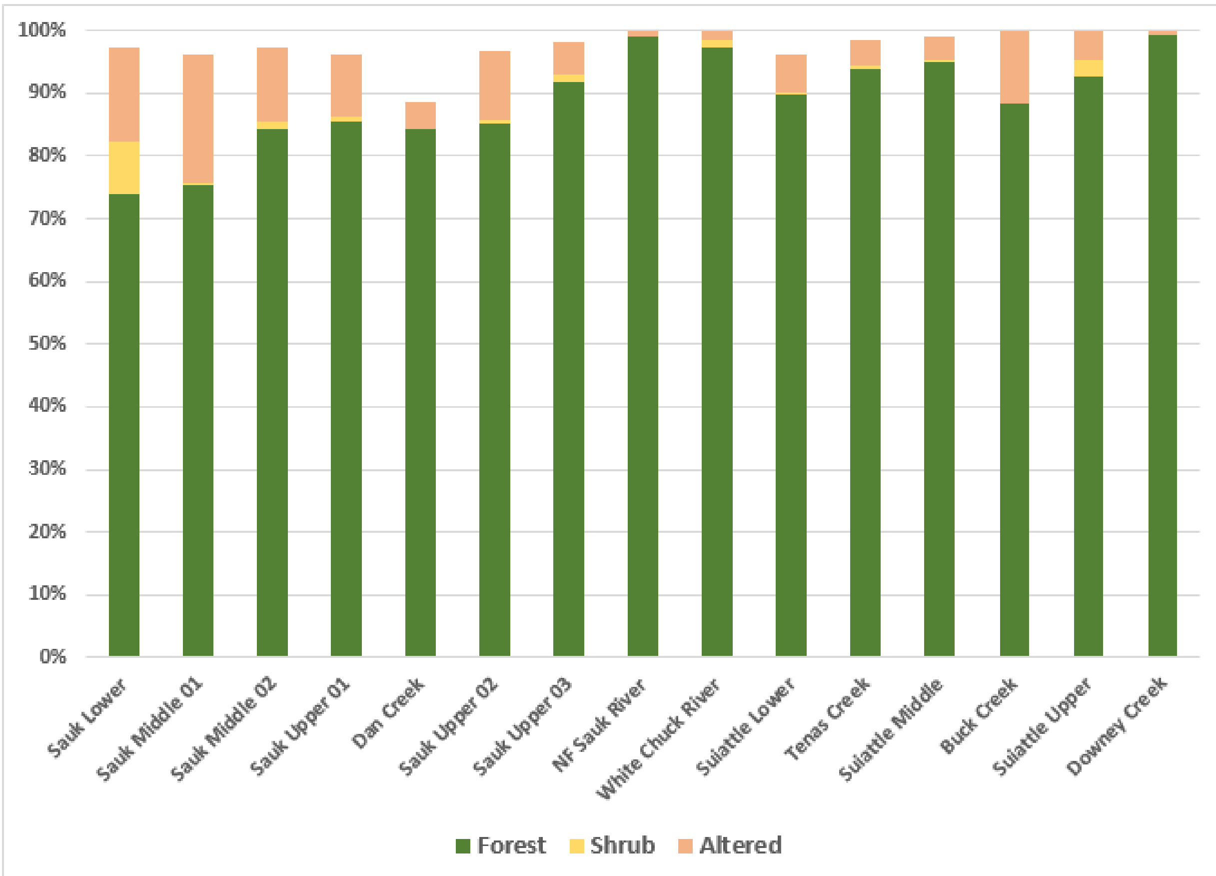


Figure 17. Riparian Cover within 40 m (131 ft) of Active Channel – Sauk & Suiattle Mainstem and Tributary Reaches

In general, reaches with high forest percentages (>90%) within 40m of the active channel represent reaches that are important for protection. Reaches that include higher percentages of shrub cover in lower elevations and outside of actively migrating channels can represent opportunities to improve the level of forest cover in the near future. In subsequent sections, we include a screening layer showing shrub, grass, and bare earth cover types on protected lands as early opportunities for riparian plantings, particularly in the lower Skagit Mainstem and tributary reaches where they have significant altered or shrub cover types combined with the need for and value of improved rearing habitat in the lower sections of the system (Maps 12a, b, and c in Appendix B).

Riparian Width

Figures 18, 19, and 20 show forest cover by riparian width for the riparian widths 0-20m (0-66ft), 20-40m (66-131ft) and 40-91m (131-300ft). In the Skagit Mainstem reaches, there is a general trend of declining forest cover laterally (from 20m to 40m to 91m) from the active channel in the more heavily developed lower river, whereas in the upper reaches with wider forested buffers this pattern does not hold. All reaches above and including Savage have greater than 80% forest cover within the 0-20m (0-66ft) zone. Skiyou and Ross Island reaches have relatively high forest cover within 0-20m, however functional riparian conditions rapidly decline in leveed reaches including Cockreham, Burlington-Sedro, Mt Vernon, and Fir Island. The latter reach benefits from a robust freshwater riparian area at Cottownwood Slough by the forks, suggesting it is a relatively important area for riparian function.

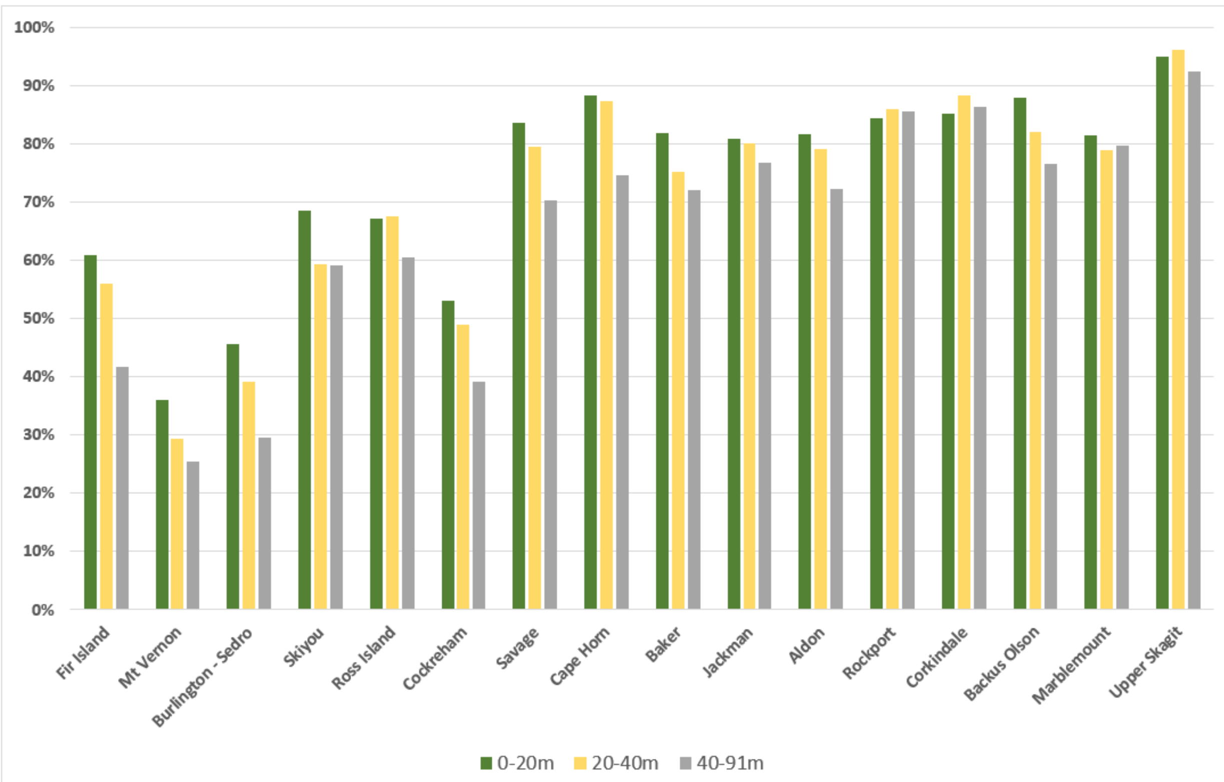


Figure 18. Forest Cover by Riparian Width Class – Skagit Mainstem Reaches

In the Skagit Mainstem Tributaries, there is significant variability between them. Similar to the Skagit Mainstem reaches, forested watersheds (e.g. Finney Creek, Diobsud Creek, Cascade Upper, and Illabot) all maintain high percentages of forest cover across all riparian widths, while more developed tributary watersheds in the lower watershed (e.g. EF Nookachamps, WF Nookachamps, Fisher Carpenter and Hansen Creek) show significantly lower percentages of forest cover as distance from the channel increases, particularly outside of the 0-40m (0-131ft) zone. Goodell Creek, South Fork Cascade River, and to some degree Bacon Creek exhibit lower percentages of riparian cover along the active channel in this super-reach, which can be partially attributed to large swaths of adjacent shrubs in these high elevation and gradient systems.

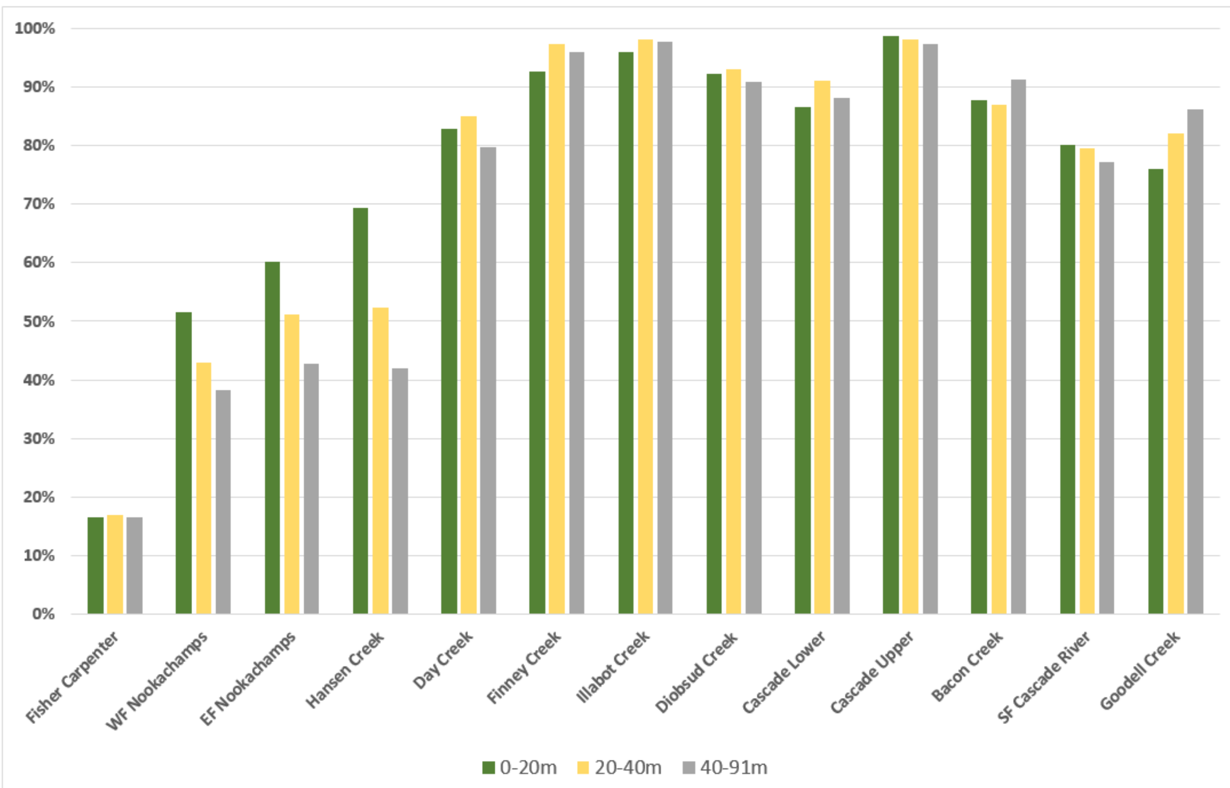


Figure 19. Forest Cover by Riparian Width Class from 0-91m – Skagit Tributary Reaches

In the Sauk Suiattle watershed, many of the reaches maintain high percentages of forest cover across all of the riparian widths and include greater than 70% forest cover overall. The Sauk and Suiattle mainstem reaches exhibit a unique pattern compared to all other reaches in the study area of increasing forest cover percentages as distance from the channel increases. This is likely attributable to the wide and dynamic alluvial nature of these systems resulting in active channels and gravel bars contributing to land cover in the 0-20m width class, as opposed to anthropogenic clearing adjacent to these mainstems.

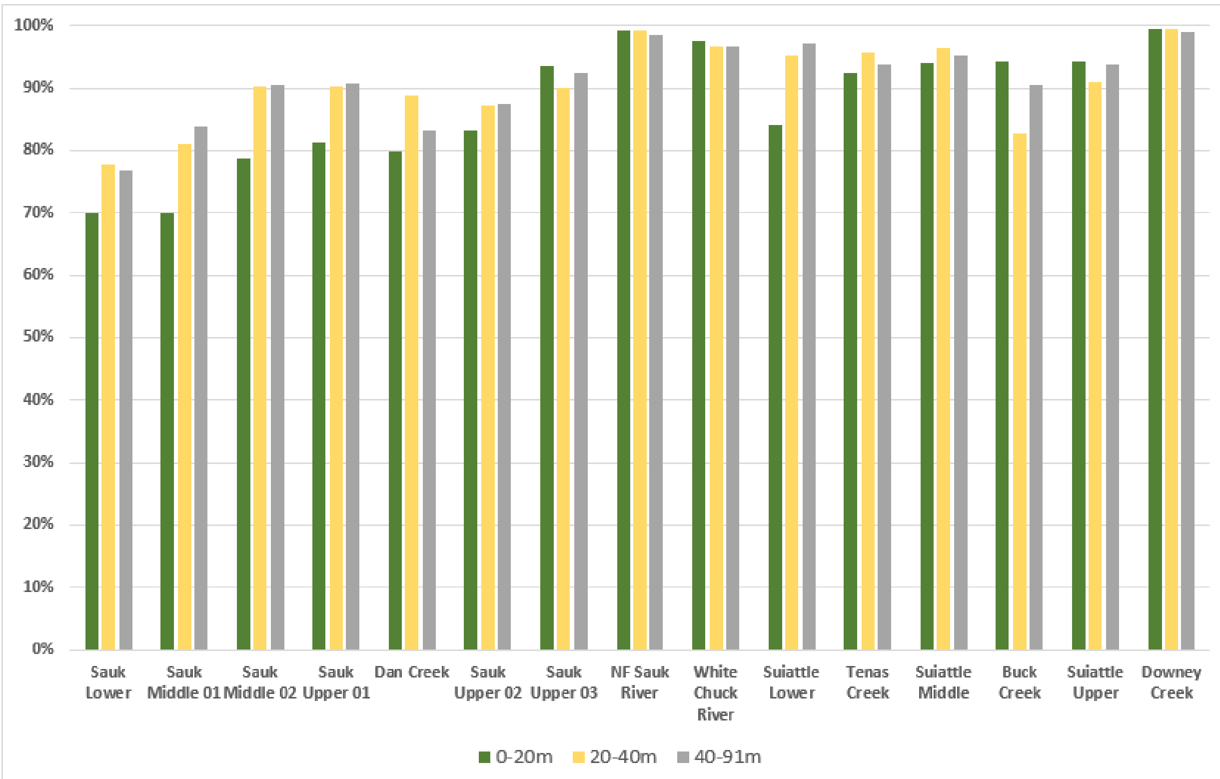


Figure 20. Forest Cover by Riparian Width Class –Sauk & Suiattle Mainstem and Tributary Reaches

Canopy Height

We incorporated the 2006 LiDAR-derived canopy height model (CHM) to assess reach-level percentages of canopy height for 0-20 feet, 20-60 feet and > 60 foot bins. In the GIS riparian cover layer, each polygon was assigned a height value using a majority filter and then assigned one of the three bins. Additionally, we also incorporated the 2015 PhoDAR-derived canopy height model into the GIS riparian cover layer. However, we decided to only include the 2006 LiDAR-derived data in this results section for two reasons:

1. The 2006 LiDAR-derived CHM data is higher resolution and higher level of accuracy associated with it than the 2015 PhoDAR-derived data product.
2. The 2006 LiDAR-derived CHM data will provide a better CHM data point when comparing against future LiDAR-derived CHMs for evaluating changes over time. In the recommendations for further study section of this report, we recommend a comparative analysis between the 2006 and 2017 LiDAR-derived CHM data for observing changes in canopy height and structure over time.

In the Skagit Mainstem reaches, Upper Skagit, Rockport, Backus Olson and Corkindale had canopy heights greater than 60 feet in more than 70% of the reach (Figure 21). Cockreham, Jackman and Savage reaches had demonstrably lower percentages of tall canopy heights.

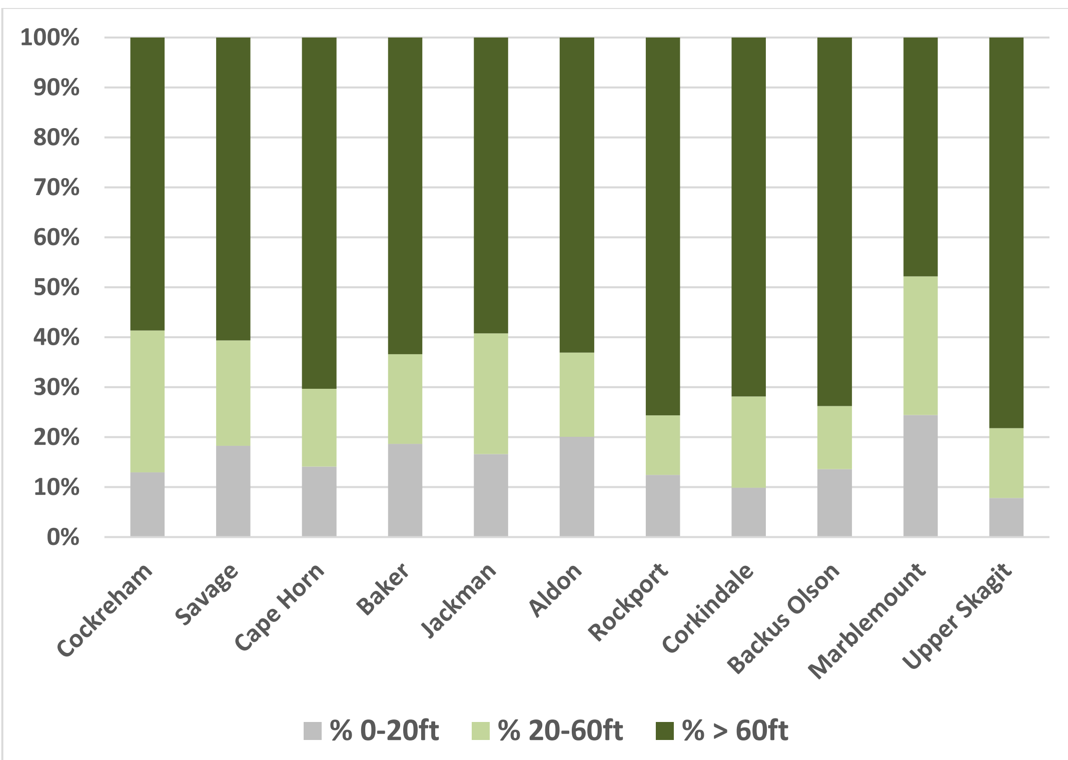


Figure 21. 2006-LiDAR Derived Canopy Height Model in the Skagit Mainstem Floodplain and Riparian Forested Areas (excluding areas with >50% no data or poor data quality)

For the Skagit Mainstem Tributaries, Illabot Creek and Bacon Creek were the only reaches with greater than 70% of the reach area with the largest canopy height bin (>60 feet) (Figure 22). Day Creek, Finney Creek and Cascade Lower all had greater than 50% cover of the largest canopy height bin, but lower than 65%.

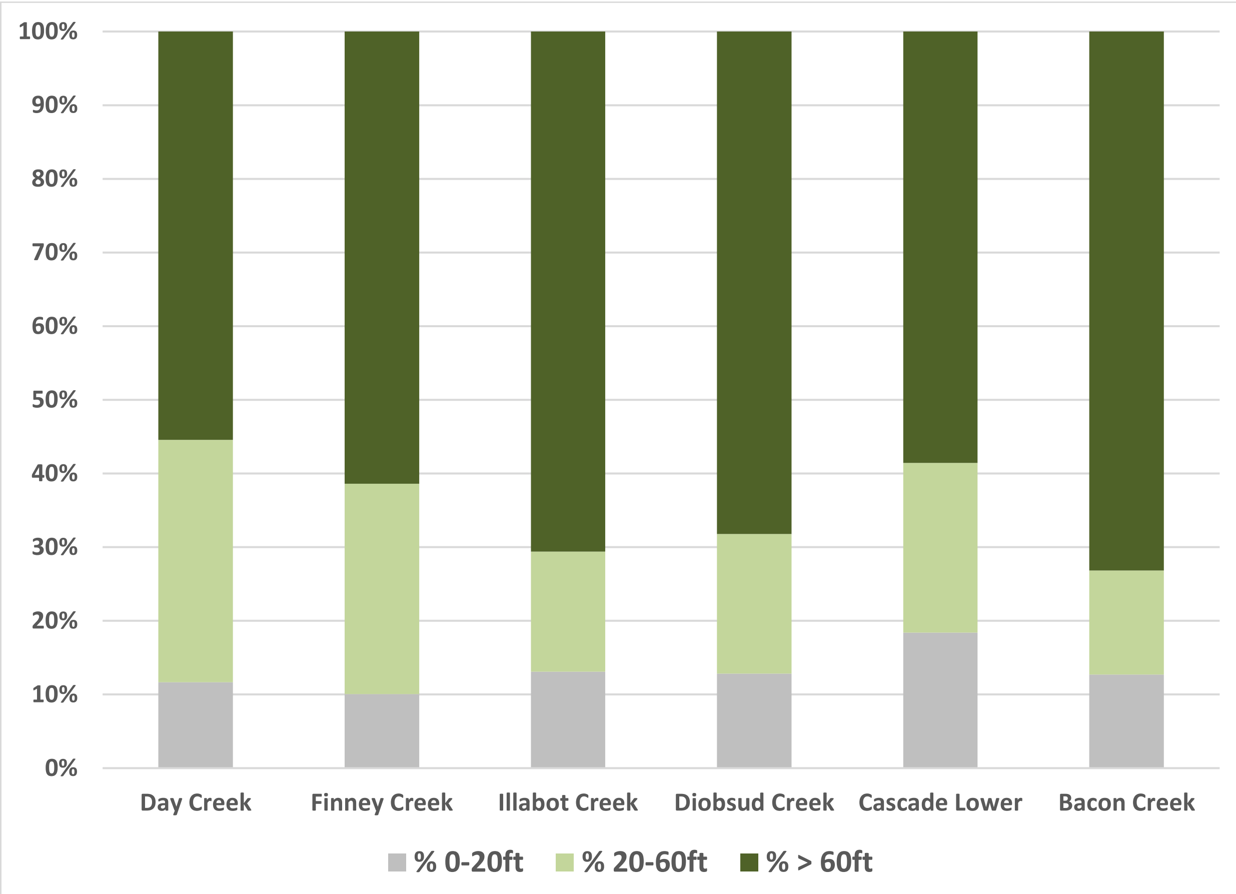


Figure 22. 2006-LiDAR Derived Canopy Height Model in the Skagit Tributaries Floodplains and Riparian Forested Areas (excluding areas with >50% no data or poor data quality)

For the Sauk and Suiattle Watershed reaches, only Sauk Middle 01, Sauk Upper 02 and Sauk Lower had greater than 50% of the reach area with the largest canopy height bin (>60 feet) (Figure 23).

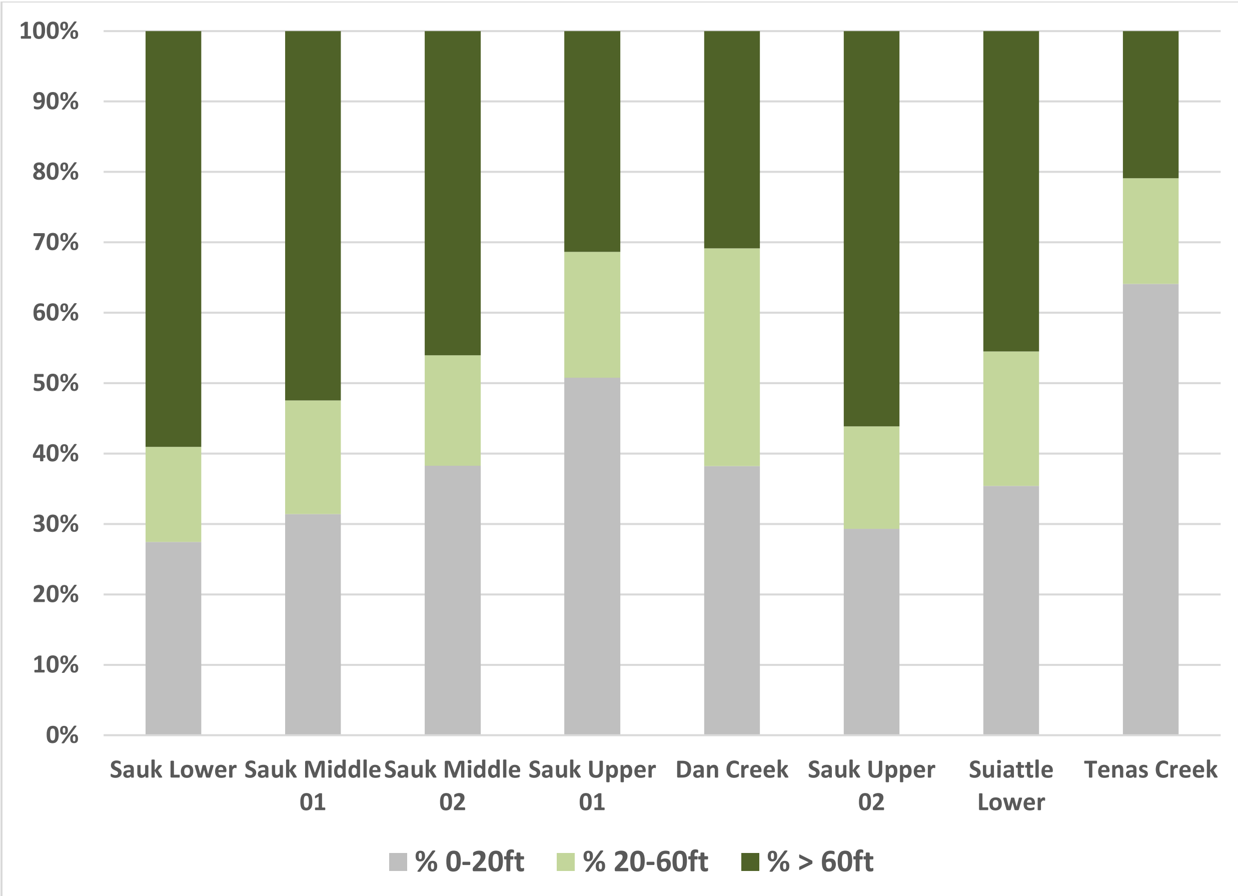


Figure 23. 2006-LiDAR Derived Canopy Height Model in the Sauk & Suiattle Mainstem and Tributary Floodplains and Riparian Forested Areas (excluding areas with >50% no data or poor data quality)

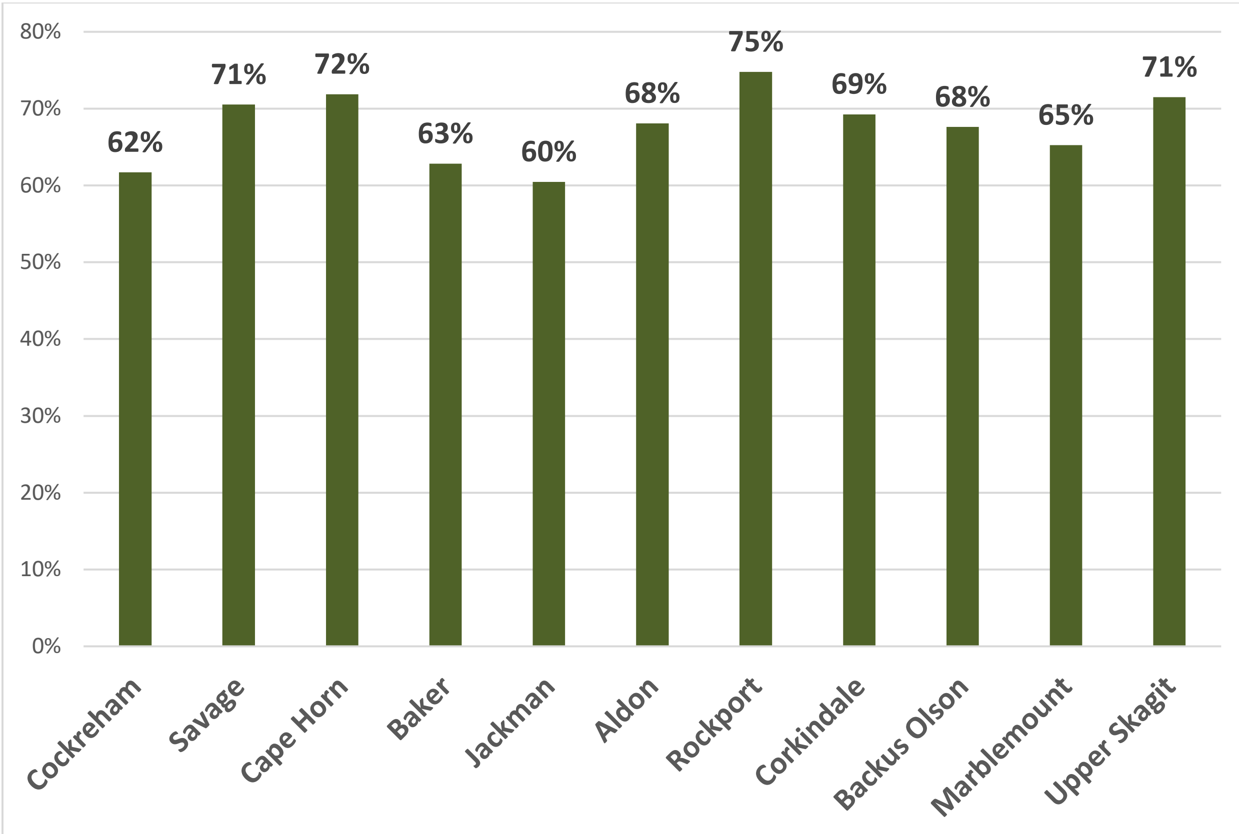


Figure 24. Percent of Reach with Tree Canopy (based on 2006-LiDAR Derived Canopy Height Model) Greater than 60 Feet Height within 0-40m in the Skagit Mainstem Reaches

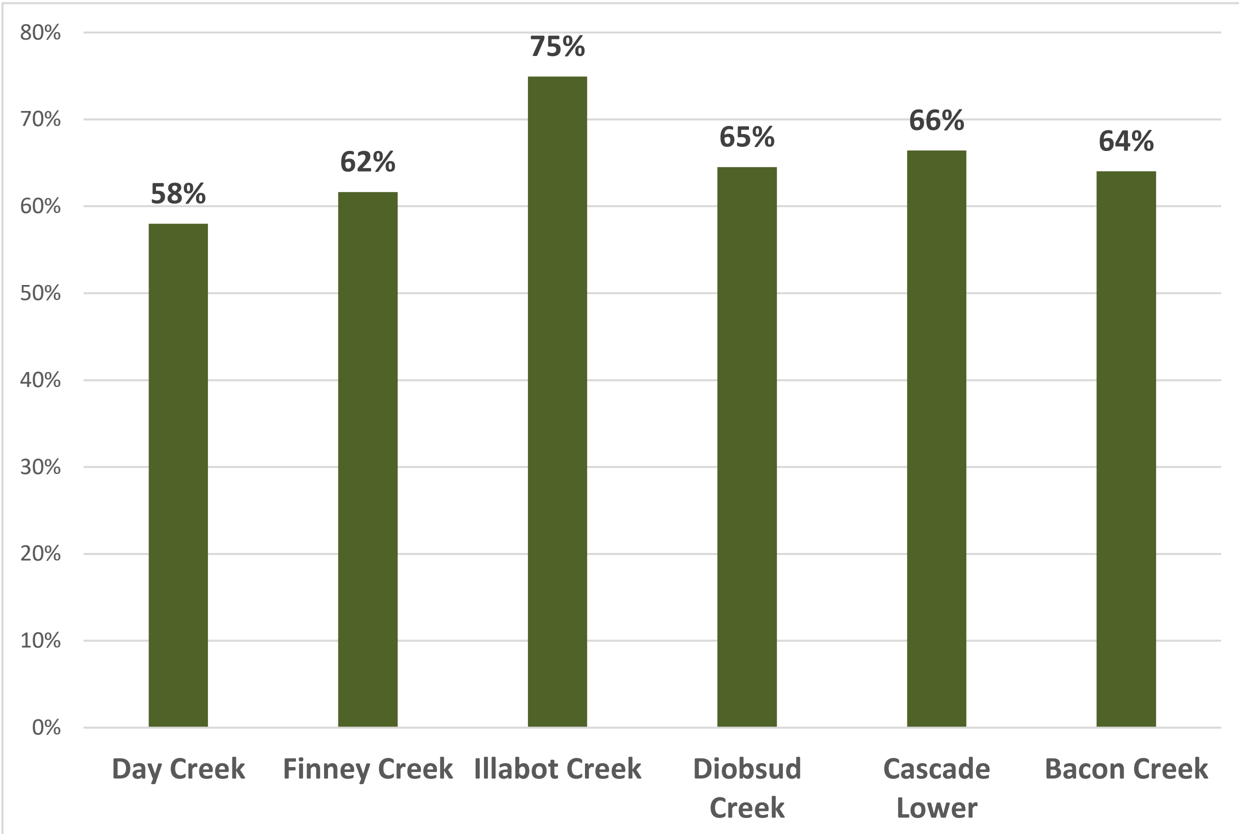


Figure 25. Percent of Reach with Tree Canopy (based on 2006-LiDAR Derived Canopy Height Model) Greater than 60 Feet Height within 0-40m in the Skagit Tributaries

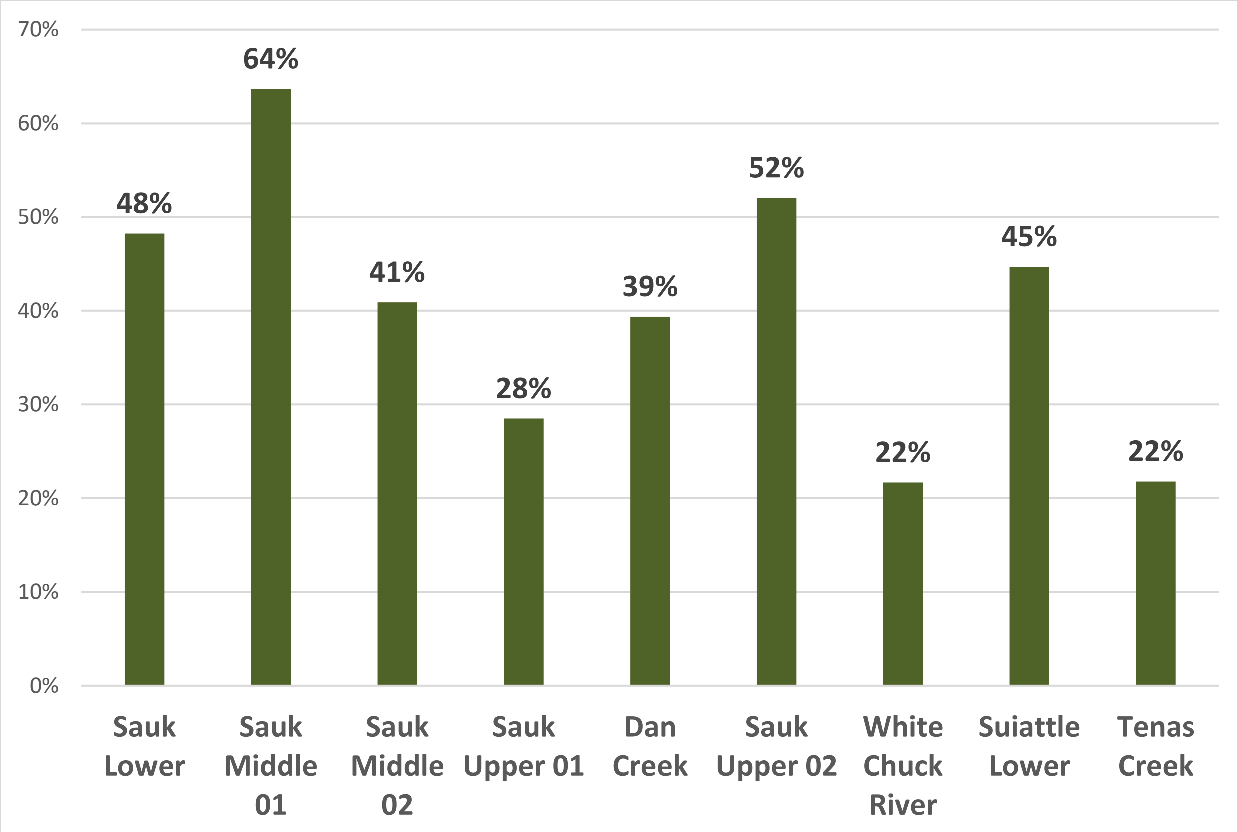


Figure 26. Percent of Reach with Tree Canopy (based on 2006-LiDAR Derived Canopy Height Model) Greater than 60 Feet Height within 0-40m in the Sauk & Suiattle Mainstem and Tributary Reaches

Large Woody Debris Recruitment Potential

Important factors for wood recruitment potential include tree height (as a proxy for size) and proximity to the active channel. ESA looked at this relationship using 2006-LiDAR derived canopy height within 40m of the active channel (Figures 24 to 26) and 91m of the active channel and within the floodplain (Maps 11a-11c). Large percentages of trees >60 feet present opportunities for protection while areas without tree cover or with trees between 20 and 60 feet present opportunities to restore recruitment.

In the Skagit Mainstem, there are no reaches with greater than 70% tree canopy > 60 feet in height within 0-40m. Reaches with the highest percentages for all areas include Finney Creek (81%), Dan Creek (73%) and Upper Skagit (74%). In the Skagit Mainstem, Ross Island and Corkindale reaches show higher amounts of riparian habitat with large tree stands within 91m of the active channel. Similarly, Day Creek, Finney Creek and Bacon Creek also show sections of the respective reaches with these characteristics. In the Sauk & Suiattle watershed reaches, Sauk Middle 02, Suiattle Lower and Sauk Upper 01 reaches also all have high percentages of taller trees within close proximity to the active channel and in connected floodplain habitat areas. In these reaches, there are also numerous mapped logjams within this extent.

Migration Potential

The riparian assessment included analysis of the ratio of off-channel habitat (OCH) by channel length to provide an indication of the geomorphic potential for channel migration by reach. Table 10 provides the ratios of the off-channel habitat to channel length for the Skagit, Sauk, and Suiattle Mainstem Reaches included in this analysis.

Additionally, SWC calculated the ratio of the area of 2-year flood events per channel length of modeled Tier 2 tributaries as an indicator of geomorphic potential (Table 11). This data was not assembled for remaining tributaries.

Table 11. Geomorphic Potential for Channel Migration Skagit Mainstem Reaches

Reach	Off Channel Habitat (Sq Ft)	Channel Length	Ratio: Off-Channel/Channel Length
Corkindale	14,857,534	41,134	361.2
Cockreham	20,702,114	100,095	206.8
Sauk Upper 01	5,609,593	34,578	162.2
Sauk Middle 02	3,970,659	38,023	104.4
Savage	2,515,326	24,702	101.8
Jackman	1,887,307	19,536	96.6
Sauk Lower	2,462,121	28,048	87.8
Rockport	1,380,623	19,595	70.5
Aldon	854,645	16,713	51.1
NF Sauk River	2,008,128	48,364	41.5
Cape Horn	992,807	25,397	39.1
Suiattle Middle	2,052,776	52,838	38.9
Suaittle Lower	1,831,328	55,182	33.2
Sauk Upper 02	1,698,785	58,959	28.8
Backus Olson	475,430	17,399	27.3
Upper Skagit	1,276,667	53,468	23.9
Suiattle Upper	1,144,946	54,979	20.8
Sauk Middle 01	406,055	20,891	19.4
Marblemount	341,924	24,237	14.1
Baker	263,937	25,686	10.3

Table 12. Geomorphic Potential for Channel Migration in Select Skagit Tributary Reaches

Name	Reach	Length (ft)	2-Year OCHs Area	Ratio: Off-Channel/Channel Length
Illabot Creek Lower Reach	Lower	15,221	10,193,470	669.7
Bacon Creek Lower Reach	Lower	9,116	3,689,908	404.8
Bacon Creek Upper Reach	Upper	18,294	7,388,730	403.9
Dan Creek	All	13,506	4,032,093	298.6
Diobsud Creek Lower Reach	Lower	8,562	2,277,402	266.0
Finney Creek	All	68,466	14,515,127	212.0
Day Creek	All	22,667	4,475,400	197.4
Illabot Creek Upper Reach	Upper	16,074	1,531,093	95.3
Diobsud Creek Upper Reach	Upper	4,326	369,507	85.4

As shown in Table 11, reach-level results for geomorphic potential in the Skagit Mainstem reaches, Corkindale, Cockreham, Sauk Upper 01 and Sauk Middle 02 showed the highest off channel to channel length ratios. Conversely, Suiattle Upper, Sauk Middle 01, Marblemount and Baker reaches show lower off channel to channel length ratios. In the Skagit Tributary reaches, Illabot Creek Lower Reach and Bacon Creek reaches represented higher off-channel to channel length ratios based on their 2-year OCH area. This information can be used as a coarse-scale tool in the absence of hydrodynamic modeling to show areas with higher potential for channel migration. In general, these areas with higher channel migration potential paired with high percentages of riparian condition can indicate higher potential for large wood contribution, and vice versa.

Table 13. Hydromodifications by Reach

Reach	Total Miles (both banks)	Modified (Miles)	Modified (Percent)		Reach	Modified (Miles)	Modified (Percent)
Fir Island	26.6	No Data	No Data		Corksdale	1.7	4%
Fisher Carpenter	15.5	No Data	No Data		Bacon Creek	0.4	4%
Mt Vernon	11.2	No Data	No Data		Rockport	0.4	3%
WF Nookachamps	8.8	No Data	No Data		Illabot Creek	0.5	3%
Skiyou	17.4	3.9	22%		Cape Horn	0.3	3%
Hansen Creek	2.7	0.5	19%		Sauk Upper 01	0.7	2%
EF Nookachamps	8.0	1.0	12%		Buck Creek	0.0	2%
Cockreham	29.1	3.6	12%		Burlington - Sedro	1.4	2%
Jackman	10.6	1.3	12%		Finney Creek	0.5	2%
Sauk Middle 01	8.2	1.0	12%		Sauk Lower	0.2	1%
Backus Olson	7.3	0.8	10%		Suiattle Lower	0.3	1%
Upper Skagit	26.8	2.1	8%		Suiattle Upper	0.2	1%
Tenas Creek	2.3	0.2	8%		Day Creek	0.2	1%
Baker	11.0	0.8	7%		Sauk Upper 03	0.3	1%
Sauk Middle 02	13.3	0.9	7%		Suiattle Middle	0.1	0%
Ross Island	40.6	2.6	6%		NF Sauk River	0.0	0%
Aldon	6.8	0.4	5%		Cascade Upper	0.1	0%
Marblemount	12.3	0.6	5%		Goodell Creek	0.0	0%
Savage	14.2	0.7	5%		Downey Creek	0.0	0%
Sauk Upper 02	23.1	1.1	5%		Dan Creek	0.0	0%
Cascade Lower	18.2	0.7	4%		SF Cascade River	0.0	0%
Diobsud Creek	4.8	0.2	4%		White Chuck River	0.0	0%

Impairment

ESA quantified floodplain impairment at the reach level based on isolated and shadowed habitat areas (SRSC, 2015) (Table 13 and Maps 11 and 12 in Appendix B). The data used for this tabulation is specific to mainstem reaches above Burlington-Sedro and does not include tributary reaches in the lower or upper watershed. Burlington-Sedro and Cockreham in the lower watershed had high percentages of isolated habitat. Corkindale and Backus Olson had higher percentages of shadowed (by road or levee) habitat areas relative to other reaches.

Table 14. Floodplain Impairment (Isolated & Shadowed Habitat Areas) by Reach for the Full Extent of the Reach

Reach	Floodplain Impairment					
	Isolated (acres)	Isolated (%)	Shadowed (acres)	Shadowed (%)	Non-impaired (acres)	Non-impaired (%)
Burlington - Sedro	2,977.9	40%		0%	4,531.3	60%
Skiyou	286.3	10%	599.3	21%	1,958.5	69%
Ross Island	316.8	7%	886.3	19%	3,367.5	74%
Cockreham	1,913.1	43%	774.0	17%	1,742.4	39%
Savage	59.1	5%	230.9	18%	1,022.0	78%
Cape Horn	177.2	16%	142.3	13%	788.3	71%
Baker	16.8	2%	39.2	5%	697.5	93%
Jackman	2.3	0%	105.3	11%	819.5	88%
Aldon	2.4	0%	27.1	5%	465.0	94%
Rockport	10.6	1%	52.5	7%	686.1	92%
Corkindale	780.8	18%	1,373.1	31%	2,210.2	51%
Backus Olson	0.3	0%	148.6	24%	473.5	76%
Marblemount	136.3	16%	157.3	18%	575.2	66%
Upper Skagit	146.0	10%	113.2	8%	1,213.7	82%
Sauk Lower	393.9	15%	462.4	17%	1,811.2	68%
Sauk Middle 01	106.4	18%	32.0	5%	451.6	77%
Sauk Middle 02		0%	31.1	3%	1,115.0	97%
Sauk Upper 01	2.6	0%	369.2	16%	1,986.8	84%
Sauk Upper 02	78.5	5%	48.6	3%	1,354.8	91%
Sauk Upper 03	12.1	0%	54.0	2%	2,362.7	97%
Cascade Lower	146.3	13%	124.3	11%	859.2	76%
Cascade Upper		0%	36.0	2%	1,571.3	98%
Suiattle Lower	12.7	1%	27.1	2%	1,312.2	97%
Suiattle Middle	9.1	0%	142.7	7%	1,962.3	93%

Similarly, altered riparian cover in these reaches was generally higher than most of the upper watershed reaches (Table 14). Fisher Carpenter represents the highest altered reach at 74% overall.

Table 15. Altered Riparian Cover by Reach within 0-40m (0-131ft)

Reach	% Forest	%Shrub	% Altered
Fisher Carpenter	17%	9%	74%
Mt Vernon	34%	10%	56%
WF Nookachamps	48%	13%	39%
Burlington - Sedro	43%	19%	38%
Cockreham	53%	15%	32%
Fir Island	60%	10%	30%
EF Nookachamps	59%	11%	29%
Skiyou	66%	6%	28%
Hansen Creek	62%	12%	26%
Sauk Middle 01	78%	0%	21%
Ross Island	70%	9%	21%
Baker	80%	2%	18%
Marblemount	82%	1%	18%
Jackman	83%	1%	17%
Aldon	81%	3%	16%
Sauk Lower	76%	9%	15%
Savage	83%	3%	14%
Backus Olson	87%	0%	12%
Sauk Middle 02	87%	1%	12%
Buck Creek	88%	0%	12%
Sauk Upper 02	88%	1%	11%
Rockport	86%	3%	11%

Reach	% Forest	%Shrub	% Altered
Sauk Upper 01	89%	1%	10%
Corkindale	90%	1%	10%
Cape Horn	90%	2%	8%
Cascade Lower	91%	1%	8%
Bacon Creek	88%	5%	7%
Suiattle Lower	93%	0%	6%
Sauk Upper 03	93%	1%	5%
Dan Creek	95%	0%	5%
Day Creek	88%	7%	5%
Suiattle Upper	93%	3%	4%
Tenas Creek	95%	0%	4%
Diobsud Creek	95%	1%	4%
Suiattle Middle	96%	0%	4%
SF Cascade River	81%	16%	3%
Finney Creek	97%	0%	3%
Upper Skagit	96%	2%	3%
Illabot Creek	98%	0%	2%
White Chuck River	97%	1%	2%
Cascade Upper	98%	1%	1%
NF Sauk River	99%	0%	1%
Downey Creek	99%	0%	1%
Goodell Creek	84%	16%	0%

Status and Trends of Forest and Shrub Cover Change

The riparian assessment conducted an analysis of recent trends in riparian habitat loss and conversion in the Tier 1, Tier 2, and Tier 2S target areas according to the WDFW High-Resolution Change Detection (HRCD) dataset. The WDFW analysis included a comprehensive evaluation of the change in all of the land cover types by change agent and by time period and by variable width from the active channel.

For the entire project extent, the results show a loss of 165.1 acres of forest from anthropogenic activities between 2006-2013, of which 117.4 acres are in the connected floodplain extent. There was twice the loss of forest cover from anthropogenic activities upstream in WRIA 4 (115.5 acres) than downstream in WRIA 3 (49.6 acres). Specifically, in WRIA 4, 31.4 acres in Corkindale and 69.9 acres in Sauk Lower reaches were due to forestry activities located outside of riparian widths (>91m) but within the floodplain extent.

Natural loss of forest cover was much higher than anthropogenic loss of forest cover, with the results showing a loss of 679.2 acres of forest, mostly from stream erosion and mostly in the connected floodplain extent. Again there was a significantly larger loss of forest cover upstream in WRIA 4 (568.3 acres) than downstream in WRIA 3 (110.9 acres).

While forest cover loss at the larger floodplain extent is relevant to long-term habitat evolution via channel migration and avulsion, ESA also analyzed forest cover loss within 40m of the active channel to quantify near-term riparian functional loss.

To quantify the addition or gain of forest cover in the Tier 1, Tier 2, and Tier 2S target areas, the total amount of voluntary riparian plantings was assembled from the SWC Riparian Plantings database and the CREP Plantings database. Tables 16 and 17 show the differences in forest cover change due to specific change agent for WRIA 3 and WRIA 4 and the gains from riparian plantings. It is important to note that planting effectiveness has not been monitored and thus likely represents less gain than indicated solely via reporting of area planted. It is also important to note that quantified plantings include a longer time period from circa 2000 to 2015 compared to the HRCD-measured time period of loss from 2006 to 2013. Future assessments should allocate planting years and conduct planting effectiveness monitoring.

For the entire project extent, the results show a gain of 1,171.6 acres of riparian plantings and gained riparian function. About 60% of this revegetation work occurred downstream in WRIA 3.

Combining loss of forest cover from anthropogenic activities and gain of function from riparian planting work, there is a grand total gain across both WRIAs of 881.7 acres, which equates to a gain in vegetation cover of about 3.1% in WRIA 3 and 1.1% in WRIA 4. These results are also illustrated at the reach-level below in Figures 27-29 for the floodplain extent and in Figures 30-32 for 0-40m extent.

Table 16. Status and Trends of Floodplain and Riparian Cover Change by WDFW HRLC 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 17. Status and Trends of Floodplain and Riparian Cover Change by WDFW HRLC 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%**

The following definitions are included for reference from the WDFW HRCD analysis: **Tree Removal** - >10%. Removal of large and small trees. Minimum removal is 10%. Does not include obvious Forestry. **Forestry** - Removal of trees for commercial use. **Development** - Must include at least 10% new impervious surface (buildings, permanent road, etc.). Also includes conversion to well-defined, compacted parking areas (dirt/gravel), and driveways (dirt/gravel) leading to a permanent structure.

Figures 27 through 29 show total anthropogenic losses and gains by reach within the floodplain extent along with the total anthropogenic change in acres for each super-reach.

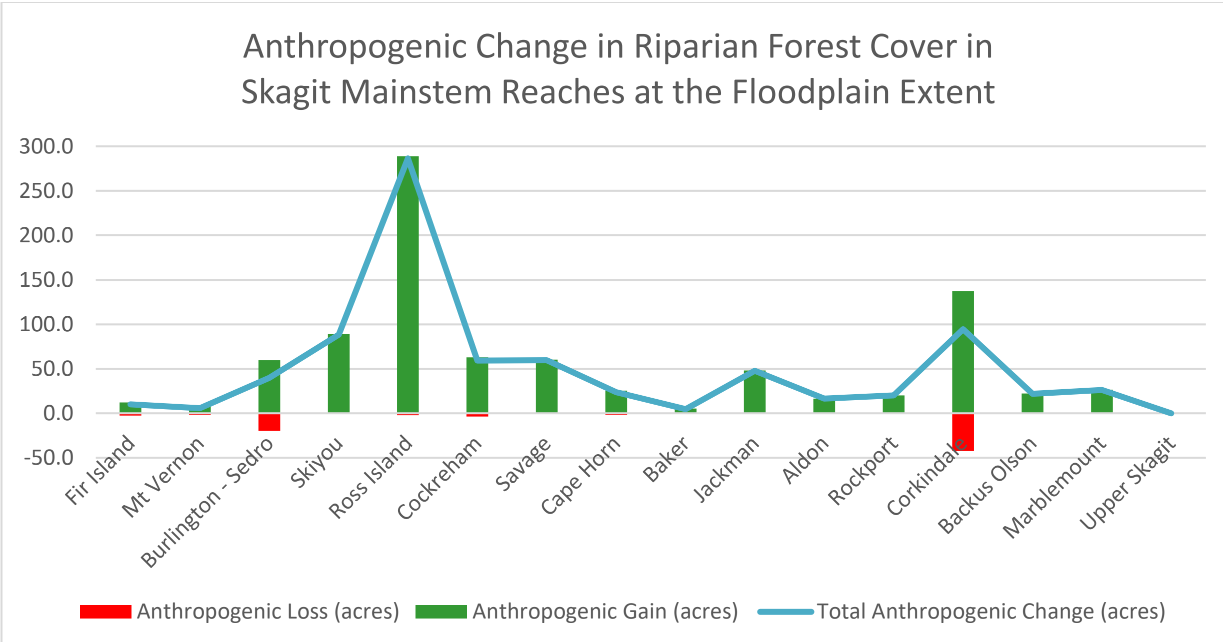


Figure 27. Anthropogenic Change in Riparian Forest Cover in the Skagit Mainstem Reaches

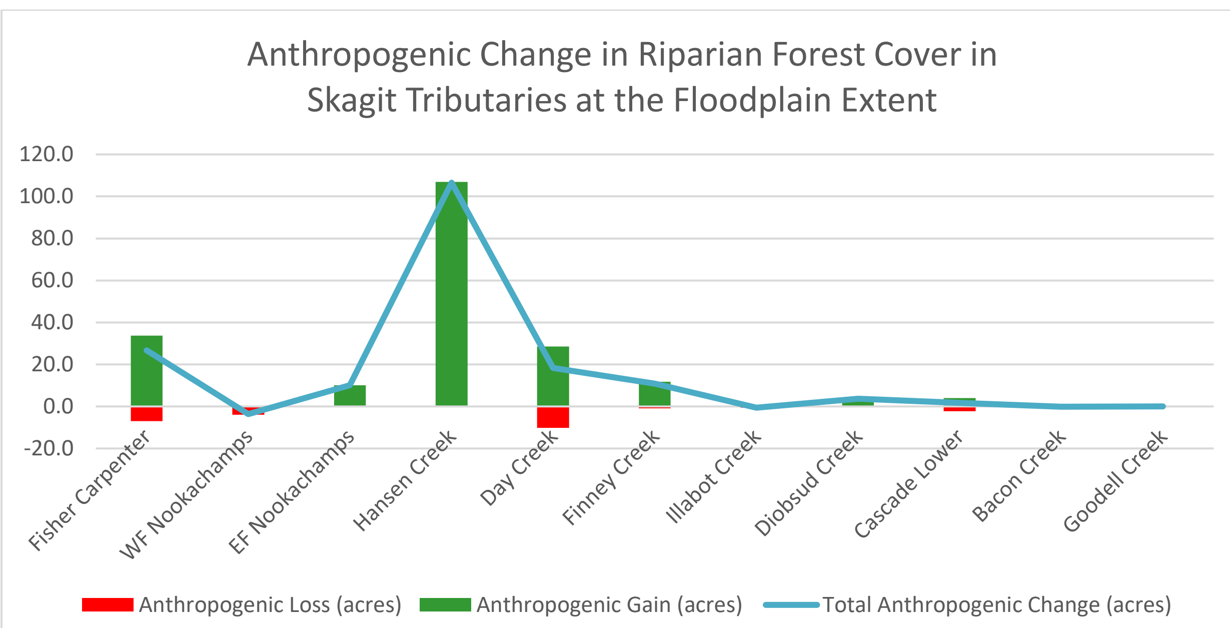


Figure 28. Anthropogenic Change in Riparian Forest Cover in the Skagit Tributaries

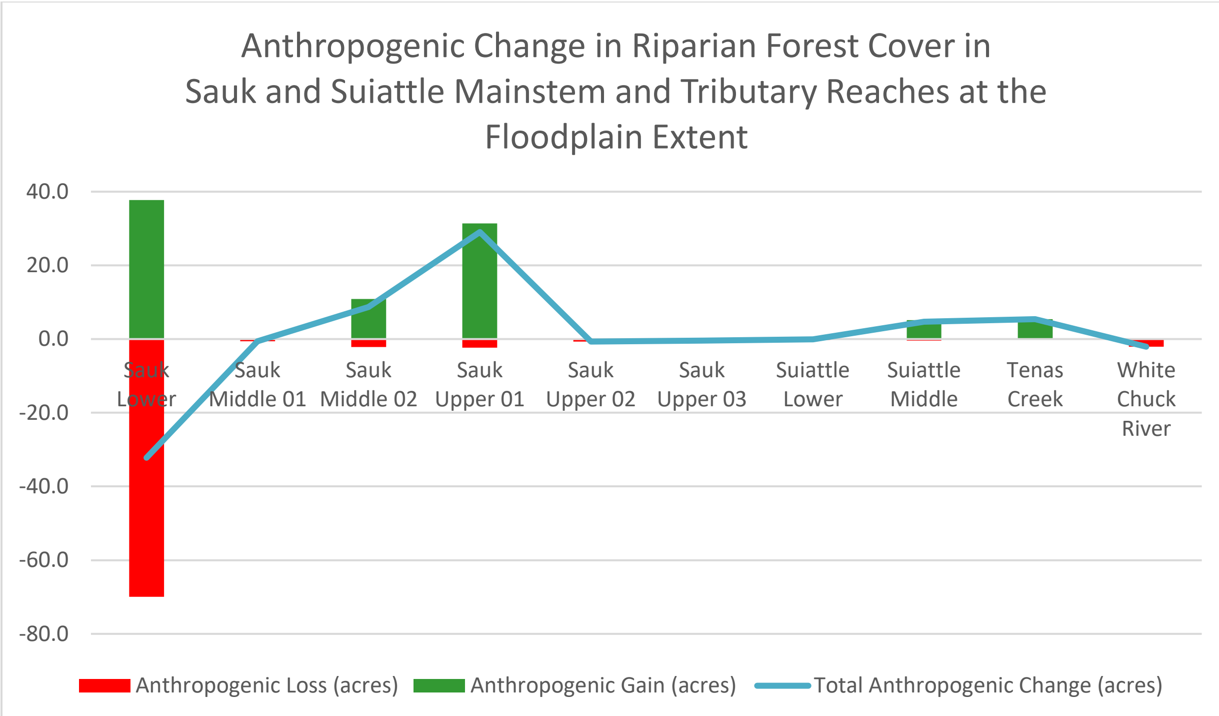


Figure 29. Anthropogenic Change in Riparian Forest Cover in the Sauk and Suiattle Mainstem and Tributary Reaches

Three of the reaches with the most dramatic forest cover loss were the result of forestry activities that occurred more than 91 m (300ft) beyond the active channel, though still within the SWC geomorphic floodplain boundaries. While these areas are important over longer timeframes for channel migration and salmon rearing area purposes, they don't represent an immediate loss of rearing habitat function. These reaches include the Sauk Lower reach (69.9acres), Corkindale reach (31.4acres), and Day Creek (9.8acres).

Figures 30 through 32 show total anthropogenic losses and gains by reach within the 0-40 m extent along with the total anthropogenic change in acres for each super-reach.

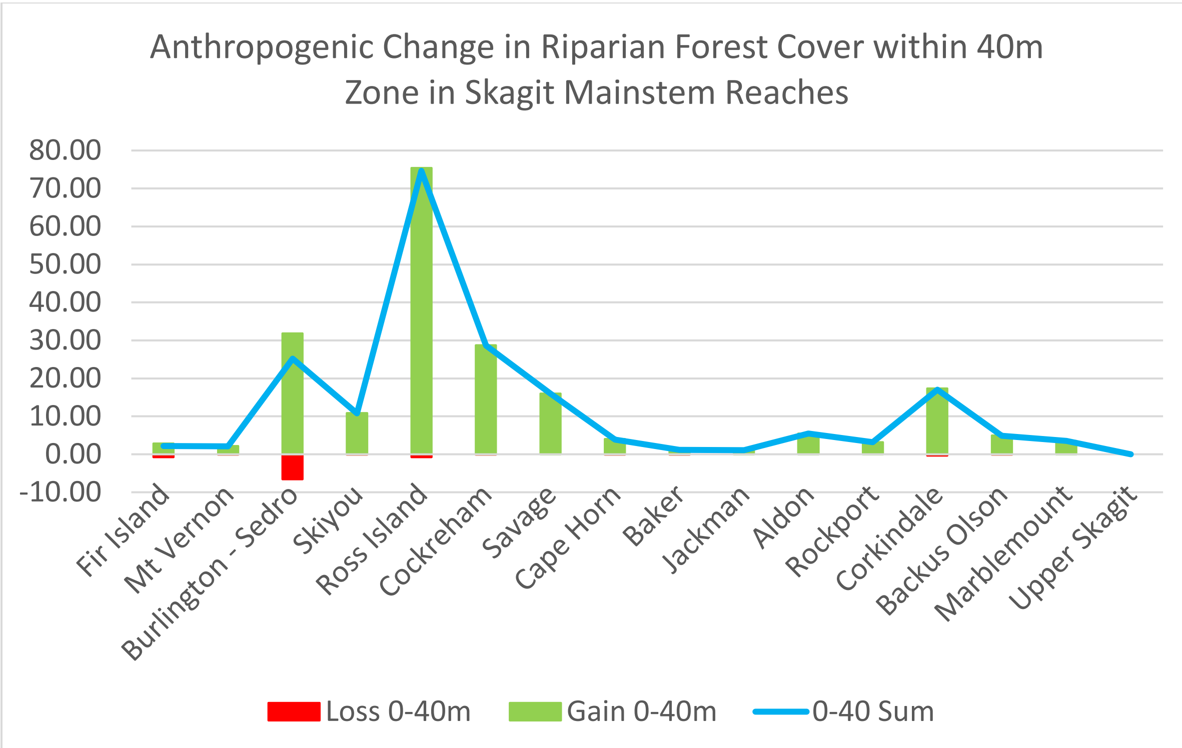


Figure 30. Anthropogenic Change in Riparian Forest Cover in 0-40m in the Skagit Mainstem Reaches

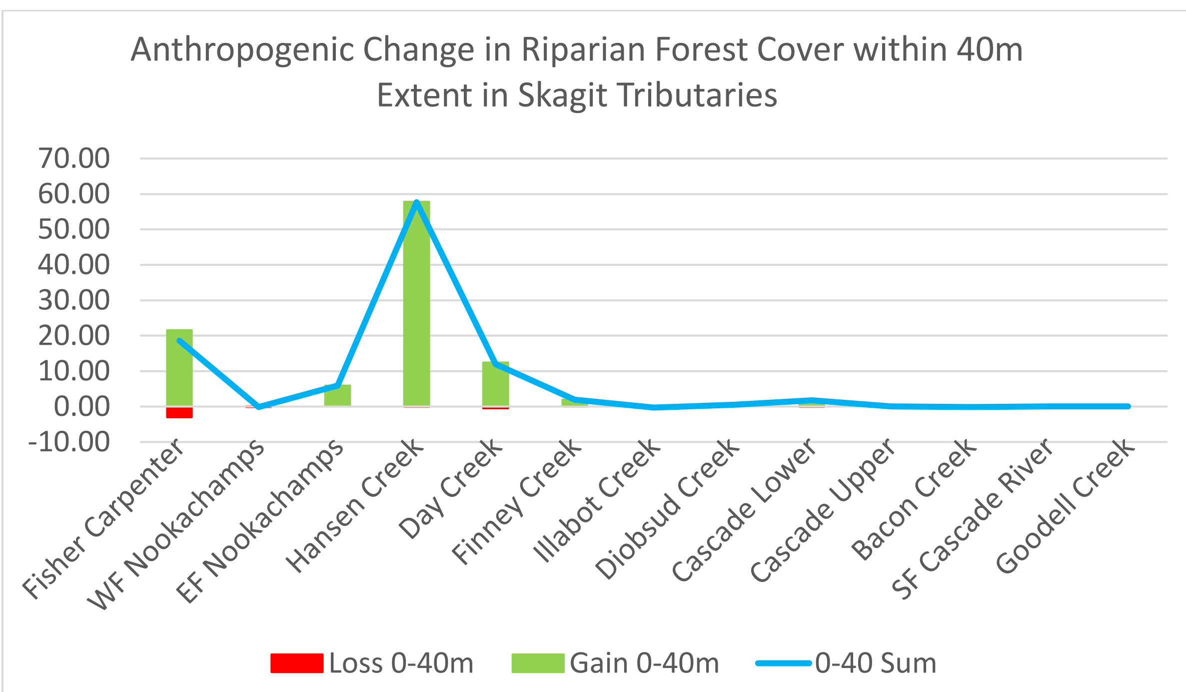


Figure 31. Anthropogenic Change in Riparian Forest Cover in 0-40m in the Skagit Tributaries

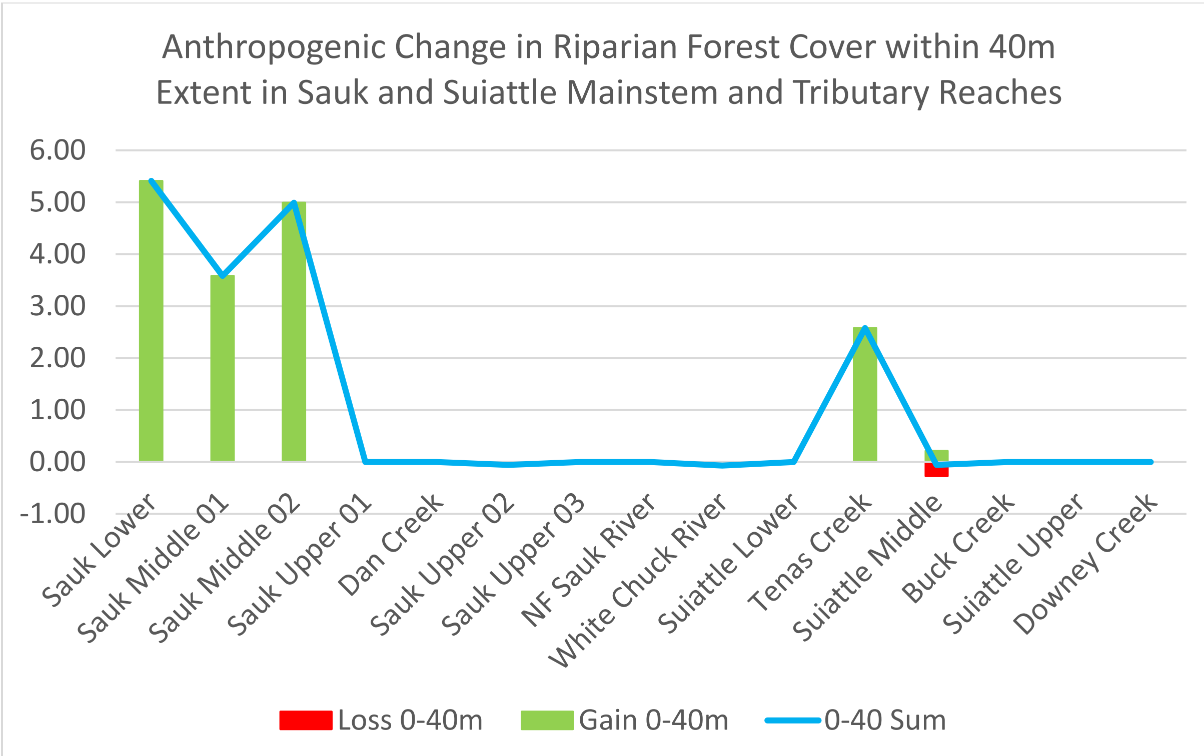


Figure 32. Anthropogenic Change in Riparian Forest Cover in 0-40m in the Sauk and Suiattle Mainstem and Tributary Reaches

Analyzing the riparian zone immediately adjacent (within 40m) of active channels removes much of the commercial forestry impact to forest cover classification in these critical areas and reduces area planted. In the Skagit mainstem reaches, total anthropogenic change ranges from 74.6 acres gained (Ross Island) to 0 acres gained or lost (Upper Skagit), with no reaches displaying cumulative loss. In the Skagit mainstem tributary reaches, total anthropogenic change ranges from 57.7 acres gained (Hansen Creek) to 0.3 acres lost (Illabot Creek due to a levee removal restoration project). In this super-reach, there were three reaches with no gain or loss in this time period (Upper Cascade, South Fork Cascade, and Goodell Creek) and three reaches with minor amounts of cumulative loss (West Fork Nookachamps (0.2 acres), Illabot Creek (0.3 acres), and Bacon Creek (0.1 acre)). In the Sauk and Suiattle watershed reaches, total anthropogenic change ranges from 5.4 acres gained (Lower Sauk) to 0.1 acres lost. Eight reaches had no gain or loss in this time period and three reaches had minor amounts of cumulative loss under 0.1 acres (Upper Sauk 02, White Chuck, and Suiattle Middle). Cumulative gains in this last super-reach were an order of magnitude lower than the other two super-reaches. Overall, significant gains in riparian forest functions have been gained in the last two decades as a result of steady voluntary and regulatory protection coupled with voluntary riparian planting strategies.

ESA plotted the acres of gain and loss for each reach to identify possible outliers in the study area (Figure 33). Based on the data, Sauk Lower reach had the greatest amount of loss in acreage when compared to all other reaches. Conversely, Ross Island reach had the greatest amount of gains due to plantings when compared to all other reaches. Table 18 below shows the results for all the reaches along with the primary change agent. Table 19 shows the change in riparian cover by change agent.

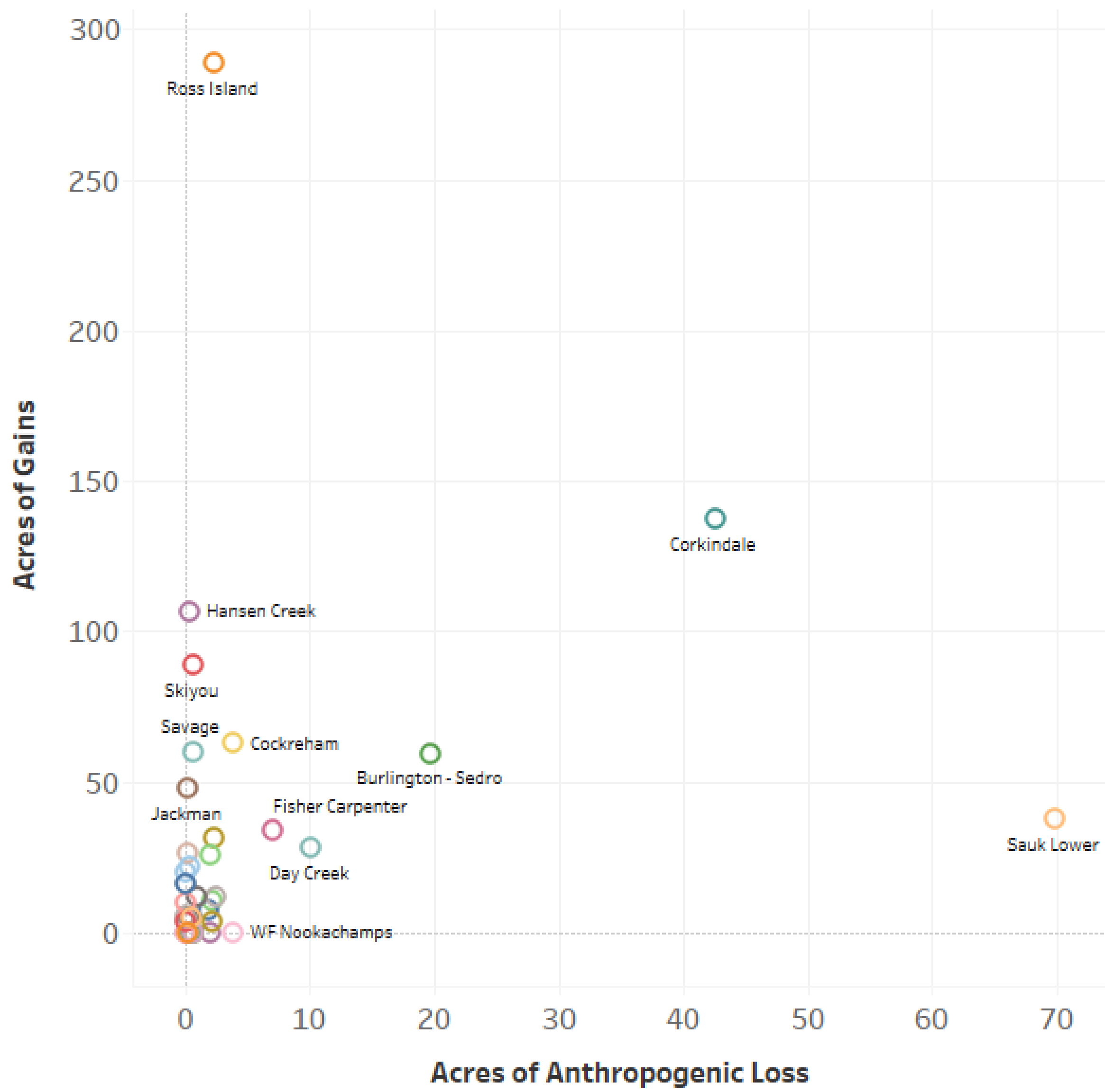


Figure 33. Status and Trends of Forest Cover for All Reaches

Table 18. Status and Trends of Forest Cover and Primary Change Agent for All Reaches within the Floodplain Extent.

Reach	Loss		Gains		Total Gains	Total
Reach Name	**Acres of Anthropogenic Loss**	**Primary Change Agent of Natural Loss**	**Acres of Gains** *(Riparian Plantings -*	**Acres of Gains** *(CREP Database)*	**Acres of Gains** *(SWC Database + CREP*	**Total Change**
Ross Island	2.3	Tree Removal	254.6	34.2	288.8	286.5
Hansen Creek	0.3	Tree Removal	87.9	18.9	106.8	106.6
Corkindale	42.6	Forestry	115.3	21.9	137.2	94.6
Skiyou	0.6	Tree Removal	89.0	0.0	89.0	88.4
Savage	0.6	Development	60.2	0.0	60.2	59.6
Cockreham	3.8	Tree Removal	40.0	22.9	62.9	59.1
Jackman	0.2	Tree Removal	48.0	0.0	48.0	47.8
Burlington - Sedro	19.7	Development	21.3	38.3	59.6	39.9
Sauk Upper 01	2.3	Tree Removal	31.4	0.0	31.4	29.1
Fisher Carpenter	7.0	Development	12.9	20.8	33.8	26.8
Marblemount	0.2	Tree Removal	26.5	0.0	26.5	26.3
Cape Horn	2.0	Tree Removal	25.6	0.0	25.6	23.6
Backus Olson	0.3	Tree Removal	22.3	0.0	22.3	22.0
Rockport	0.0	None	20.2	0.0	20.2	20.2
Day Creek	10.1	Forestry	28.5	0.0	28.5	18.4
Aldon	0.0	Tree Removal	14.4	2.0	16.5	16.5
Finney Creek	0.9	Forestry	11.8	0.0	11.8	10.9
EF Nookachamps	0.0	Tree Removal	0.0	10.1	10.1	10.1
Fir Island	2.4	Development	6.2	6.1	12.3	9.9
Sauk Middle 02	2.2	Other, Natural	10.9	0.0	10.9	8.7
Mt Vernon	1.8	Development	5.7	1.8	7.6	5.7
Tenas Creek	0.0	None	5.4	0.0	5.4	5.4
Baker	0.5	Tree Removal	5.3	0.0	5.3	4.7
Suiattle Middle	0.4	Tree Removal	5.1	0.0	5.1	4.7
Diobsud Creek	0.1	Other, Natural	3.8	0.0	3.8	3.7
Cascade Lower	2.2	Tree Removal	3.9	0.0	3.9	1.7
Goodell Creek	0.0	Other, Natural	0.0	0.0	0.0	0.0
Suiattle Lower	0.2	Forestry	0.2	0.0	0.2	-0.1
Upper Skagit	0.1	Other, Natural	0.0	0.0	0.0	-0.1
Bacon Creek	0.1	Tree Removal	0.0	0.0	0.0	-0.1
Sauk Upper 03	0.4	Other, Natural	0.0	0.0	0.0	-0.4
Illabot Creek	0.6	Tree Removal	0.0	0.0	0.0	-0.6
Sauk Middle 01	0.6	Tree Removal	0.0	0.0	0.0	-0.6
Sauk Upper 02	0.6	Tree Removal	0.0	0.0	0.0	-0.6
White Chuck River	2.0	Tree Removal	0.0	0.0	0.0	-2.0
WF Nookachamps	3.9	Tree Removal	0.3	0.0	0.3	-3.6
Sauk Lower	69.9	Forestry	31.4	6.3	37.7	-32.2

Ross Island reach had the highest amount of total change within the floodplain extent with 286.5 acres, given the large amount of riparian plantings (254.6 acres) and modest amount of anthropogenic loss (2.3 acres). Sauk Lower and Corkindale reaches had the highest acreages of loss, both due to forestry activities outside of the narrower riparian widths but within the floodplain. Ross Island, Corkindale and Skiyou reaches all had greater than 75 acres of riparian plantings.

Table 19. Riparian Cover (Forest or Shrub) Change by WDFW HRLC Change Agent (2006-2013) and by Reach

	Change Agent (Acres)					
Reach	Development	Forestry	Other, Natural	Other, Non-Natural	Retention Pond	Tree Removal
WF Nookachamps						3.88
Burlington - Sedro	7.16	2.80	4.13	2.37	0.16	3.54
Cockreham	0.49			0.10		3.21
Sauk Upper 01		0.03				2.31
Ross Island	0.06		0.14			2.25
Cascade Lower	0.01		0.20			2.00
Fisher Carpenter	4.01		0.27	0.83		1.96
Cape Horn		0.11				1.87
White Chuck River			0.28			1.78
Fir Island	1.44			0.05		1.43
Corkindale		31.40	10.21			1.06
Day Creek		9.79				0.97
Sauk Middle 02			1.77			0.55
Baker		0.04				0.50
Sauk Upper 02			0.15			0.49
Skiyou	0.10		0.09			0.48
Sauk Middle 01		0.18				0.44
Illabot Creek			0.14	0.06		0.39
Hansen Creek						0.30
Backus Olson						0.29
Suiattle Middle			0.10			0.29
Savage	0.24		0.13			0.22
Marblemount						0.19
Jackman						0.19
Mt Vernon	1.17			0.52		0.15
Bacon Creek						0.12
Sauk Upper 03			0.60			0.07
EF Nookachamps						0.02
Aldon						0.01
Sauk Lower		69.90				0.01
Diobsud Creek			0.07			
Finney Creek		0.88				
Goodell Creek			0.16			
Suiattle Lower		0.24				
Upper Skagit			0.06			

To analyze gains in forest cover, ESA combined the SWC riparian plantings database and the CREP Plantings database to show total plantings. Figures 34-36 show the total amount of plantings by reach and by riparian width class within each of the three super-reaches. Based on the data, the Ross Island reach had the greatest amount of gain in acreage when compared to all other reaches. The Ross Island reach also has the most planting outside 91 meters (300 feet) and within the floodplain, followed closely by Corkindale. Of note is that only the Upper Skagit of all Skagit mainstem reaches showed no plantings undertaken.

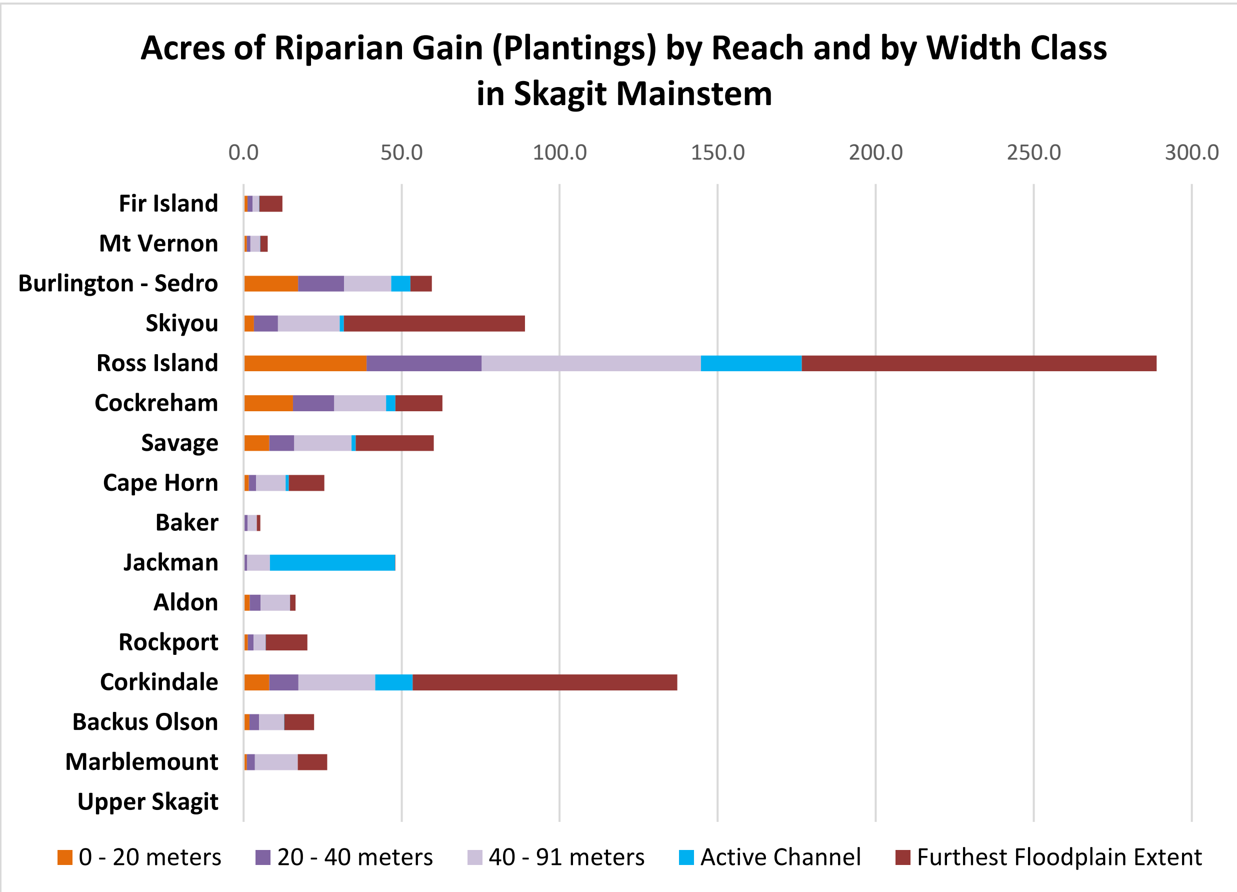


Figure 34. Riparian Plantings by Width in the Skagit Mainstem Reaches

For the Skagit mainstem tributaries, Hansen Creek had the greatest amount of gain in acreage when compared to all other reaches, with over half of the amount planted outside 91 meters (300 feet). Conversely, the West Fork Nookachamps had the least amount of gains due to plantings when compared to all other reaches where plantings occurred. Of further note is that no plantings have occurred in five of the Skagit mainstem tributaries.

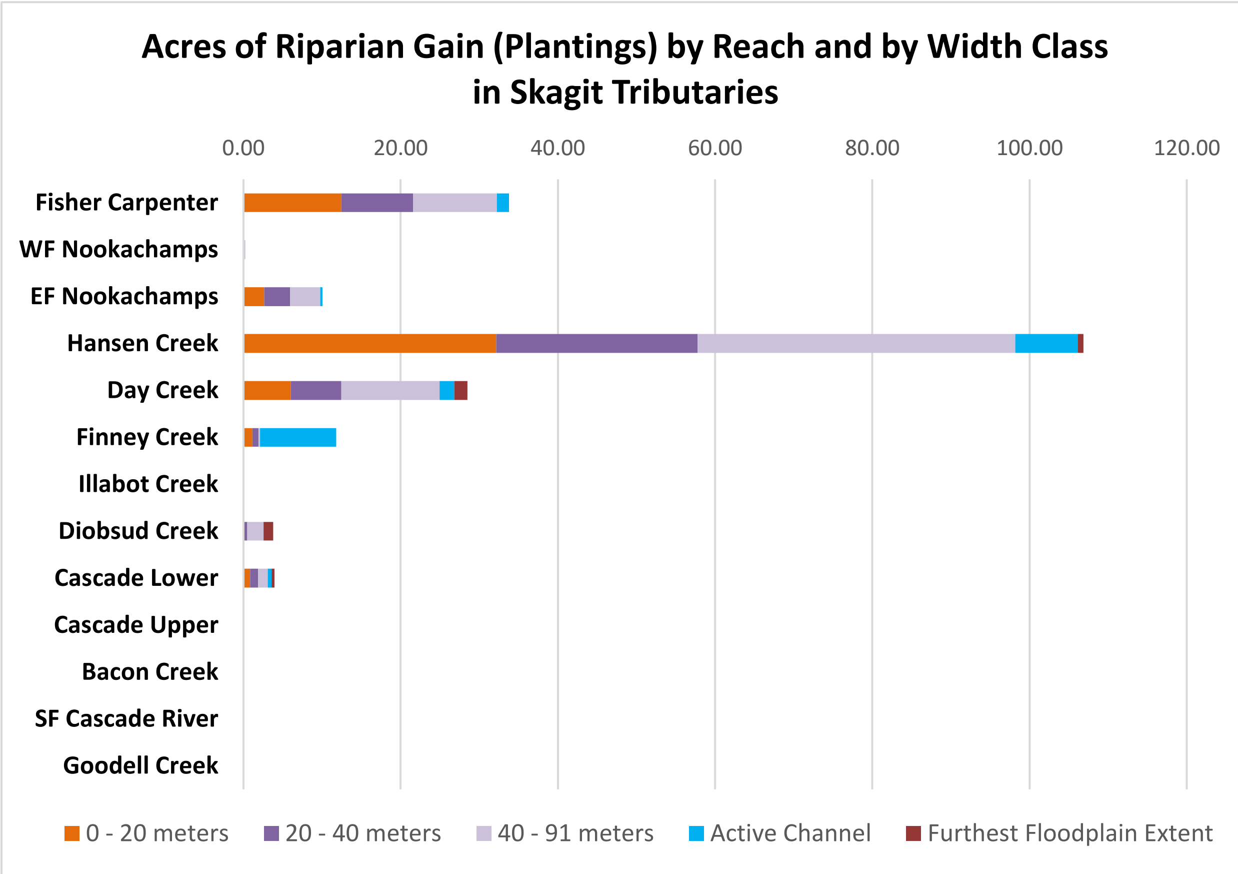


Figure 35. Riparian Plantings by Width in the Skagit Tributary Reaches

For the Sauk and Suiattle watersheds, both Sauk Lower and Sauk Middle 02 reaches had over 30 acres of plantings with the majority beyond 91m (300 ft) of the active channel. Suiattle Lower reach had the least amount of gains due to plantings, where plantings occurred. Of further note is that no plantings have occurred in nine of the Sauk and Suiattle mainstem and tributary reaches.

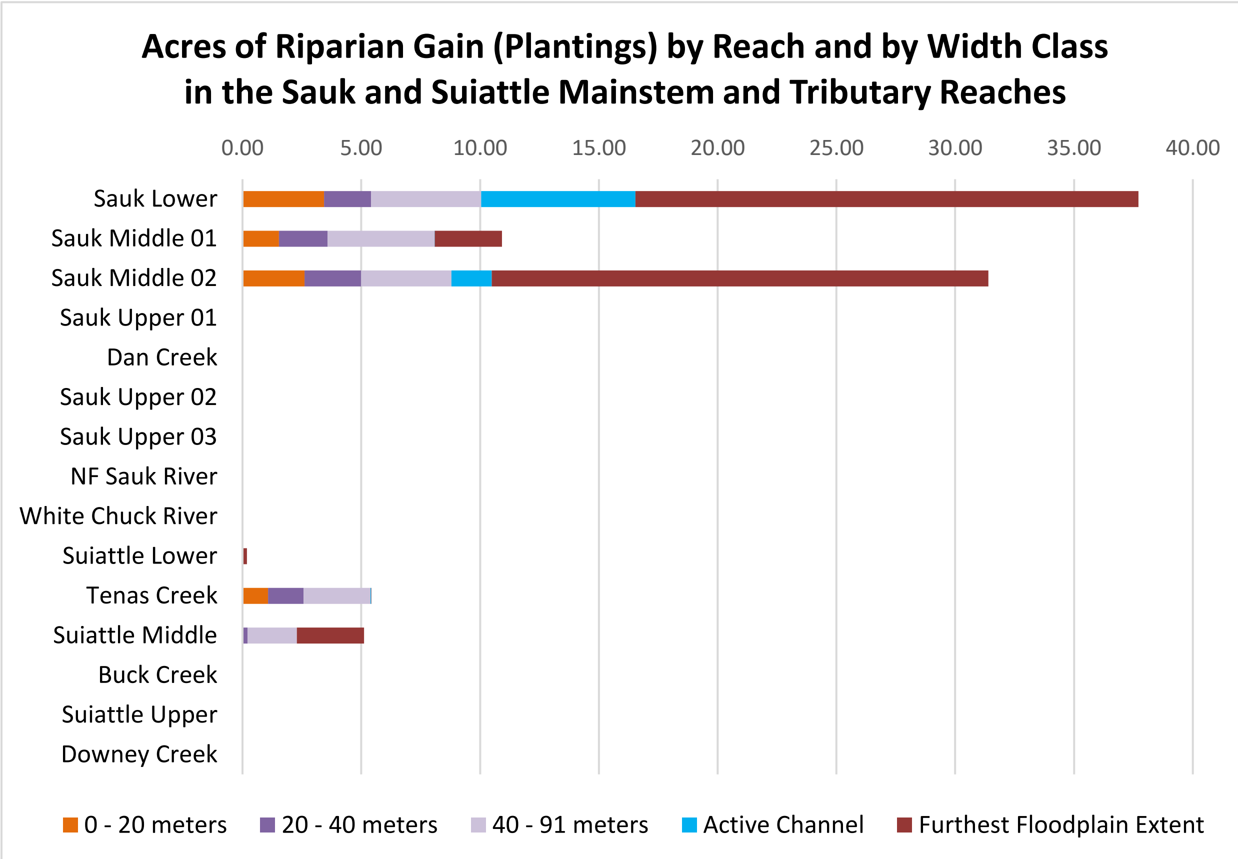


Figure 36. Riparian Plantings by Width in the Sauk & Suiattle Mainstem and Tributary Reaches

Additional Data Overlays

Reaches vary in their ownership type and protected status as shown in Figures 37, 38, and 39. Reaches that are currently in protected status for their full extent (i.e., 100%) include Downey Creek, Buck Creek, White Chuck River, South Fork Cascade River, and North Fork Sauk River. All of these reaches are located in the upper watershed and flow from the Mt. Baker Snoqualmie National Forest. An additional seven reaches have greater than 75% of their extent in protected status. Maps 10a-10c in Appendix B show areas that have unaltered forest on protected land connected to the floodplain and within 40m of the active channel for each reach. This information can be used as a possible screening layer for protection (functional riparian habitat on protected lands).

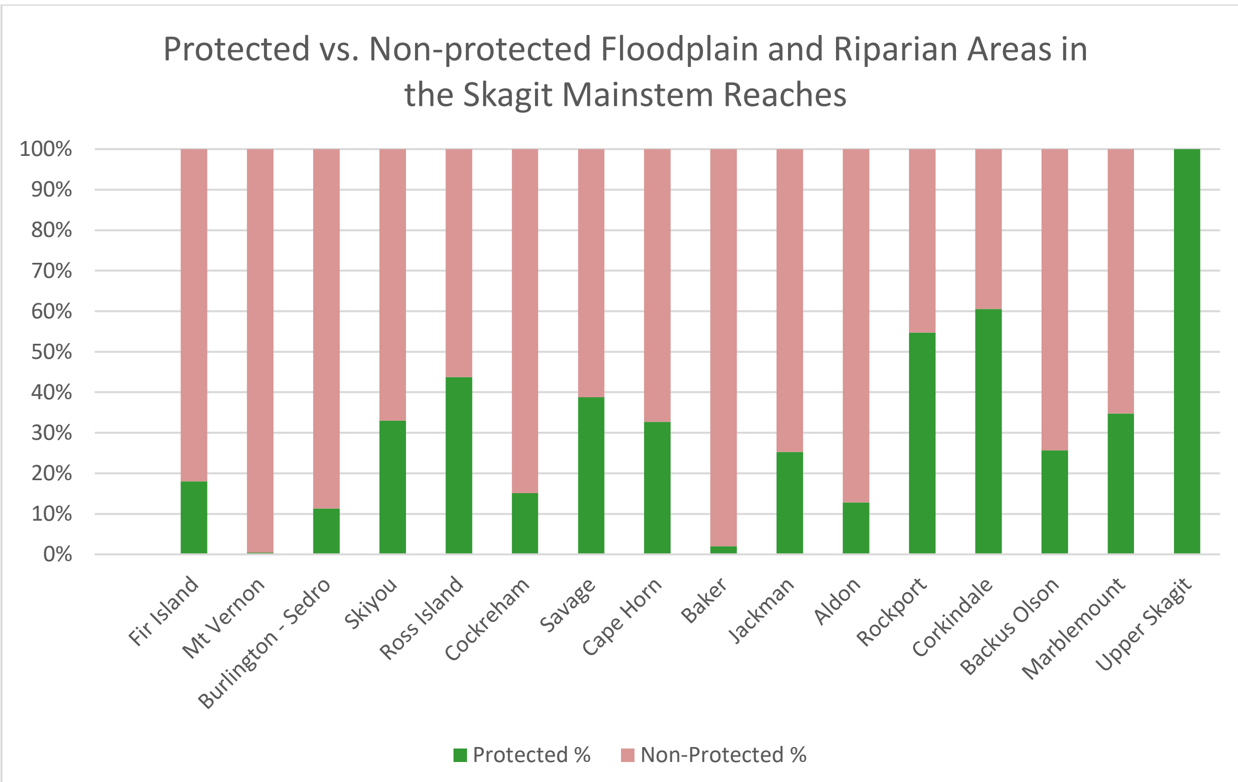


Figure 37. Protected vs Non-Protected Floodplain and Riparian Areas in the Skagit Mainstem Reaches

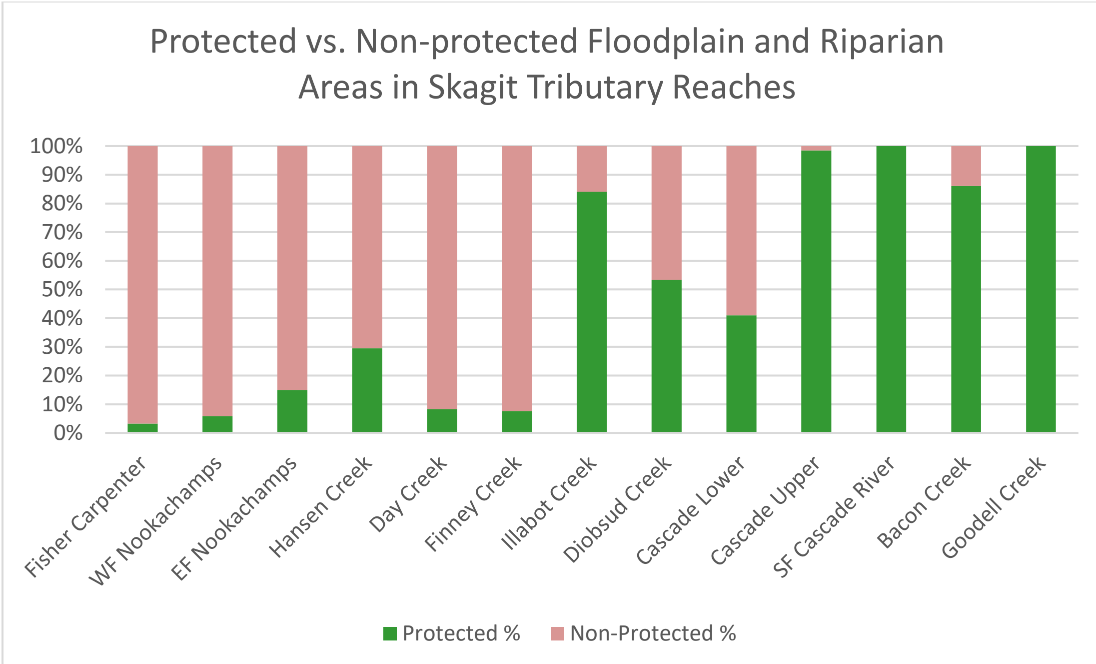


Figure 38. Protected vs Non-Protected Floodplain and Riparian Areas in the Skagit Tributary Reaches

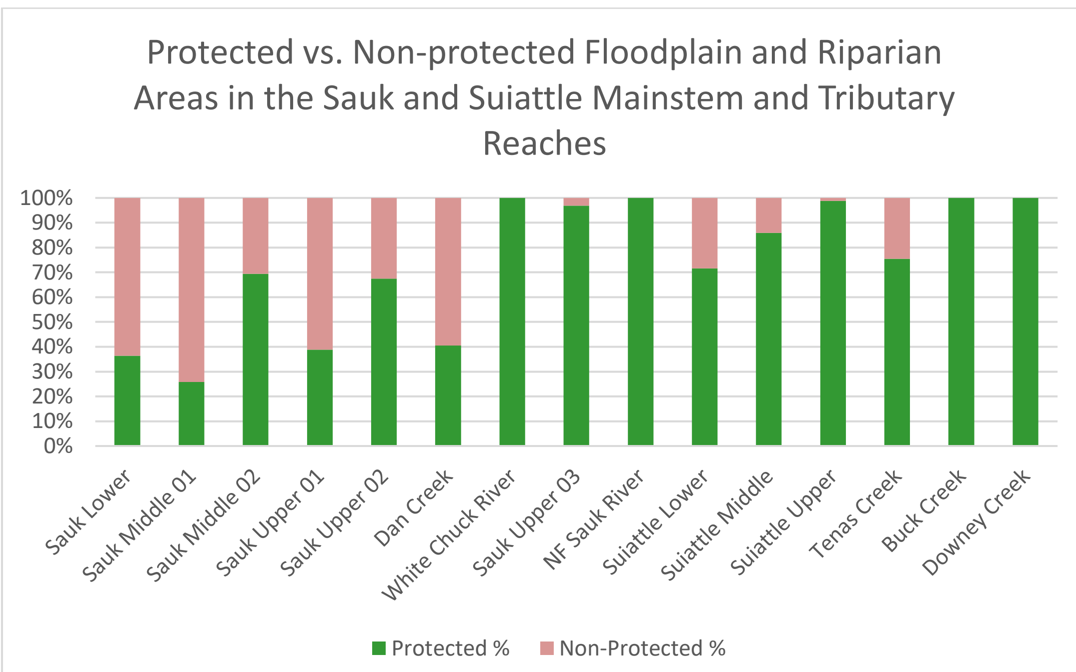


Figure 39. Protected vs Non-Protected Floodplain and Riparian Areas in the Sauk and Suiattle Mainstem and Tributary Reaches

In WRIA 3, 20% of Tier 1, Tier 2 and Tier 2S target areas contain lands in protected status, while 57% of WRIA 4 in those target areas is in protected status. Figure 40 below shows the overall distribution of protected lands at nearly 42%.

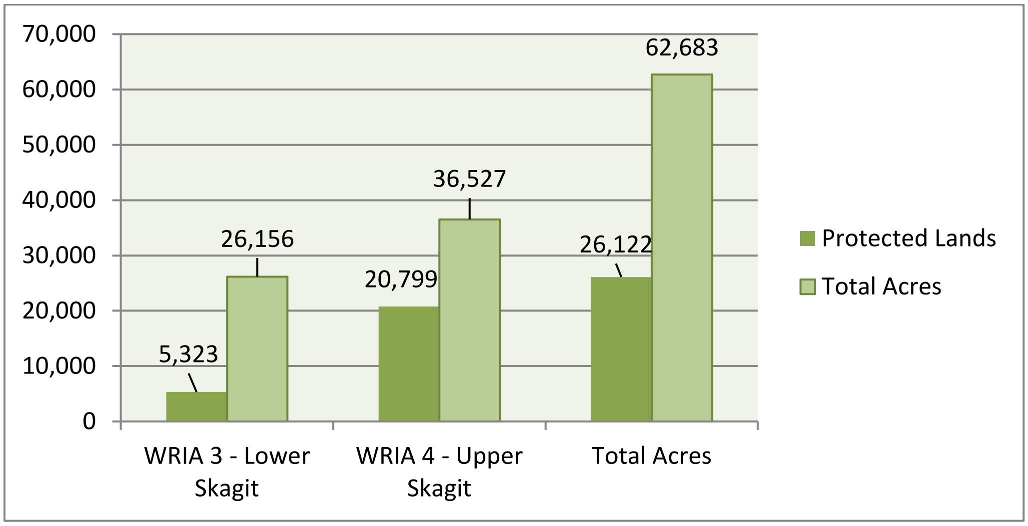


Figure 40. Distribution of Land in Protected Status in SWC Target Areas in Acres

There are several reaches in the lower watershed that are listed as impaired waterbodies, including Burlington-Sedro, Cockreham, Day Creek, EF Nookachamps, Fir Island, Fisher Carpenter, Hansen Creek, Mt Vernon, Ross Island, Sauk Upper 01, Sauk Upper 02, Skiyou and WF Nookachamps (Table 20). Most of these waterbodies are listed due to dissolved oxygen, pH and temperature. WF Nookachamps has additional listings for Dioxin, Hexachlorobenzene and PCBs. These are important factors when identifying areas for riparian restoration and protection.

Table 20. Reaches with Water Quality Impairments (Ecology 303d List in 2012)

Reach	Listed Waterbody	Parameter Name
Burlington - Sedro	Brickyard Creek	Dissolved Oxygen
		pH
	College Way Creek	Dissolved Oxygen
		Temperature
	Nookachamps Creek	Dissolved Oxygen
	Nookachamps Creek, E.F.	Dissolved Oxygen
	Skagit River	pH
		Polychlorinated Biphenyls (PCBs)
	Unnamed Creek (Trib To Skagit River)	Dissolved Oxygen
Cockreham	Mannser Creek	Bacteria
		Dissolved Oxygen
		pH
Day Creek	Day Creek	Temperature
EF Nookachamps	Nookachamps Creek, E.F.	Dissolved Oxygen
Fir Island	Unnamed Creek (Trib To Skagit River, N.F.)	Dissolved Oxygen
Fisher Carpenter	Big Ditch / Maddox Slough	Dissolved Oxygen
		pH
		Temperature
	Fisher Creek	Dissolved Oxygen
	Hill Ditch	Dissolved Oxygen
	Unnamed Creek (Trib To Carpenter Creek)	Dissolved Oxygen
Hansen Creek	Hansen Creek	Dissolved Oxygen
Mt Vernon	Skagit River	pH
Ross Island	Wiseman Creek	Bacteria
Sauk Upper 01	Prairie Creek	Bacteria
Sauk Upper 02	Sauk River	Temperature
Skiyou	Coal Creek	Bacteria
		Dissolved Oxygen
	Hansen Creek	Dissolved Oxygen
WF Nookachamps	Big Lake	2,3,7,8-TCDD (Dioxin)
		Hexachlorobenzene
		Polychlorinated Biphenyls (PCBs)
	Nookachamps Creek	Dissolved Oxygen

Application of Riparian Assessment

The purpose of this riparian assessment is to provide data and supporting information for SWC partners to understand the current condition of riparian areas, trends in habitat loss and conversion, and the extent and location of previous riparian planting work in order to identify and prioritize areas for future riparian restoration. To provide a framework for using the previously described riparian assessment metrics and data overlays to characterize riparian functions, ESA developed the diagram below (Figure 41). The framework is meant to support the characterization of conditions at the reach scale and, when paired with additional data, inform riparian restoration. The framework represents a qualitative approach based on the cause-effect relationships researched in the literature and the cumulative knowledge, experience, and input of TWG members.

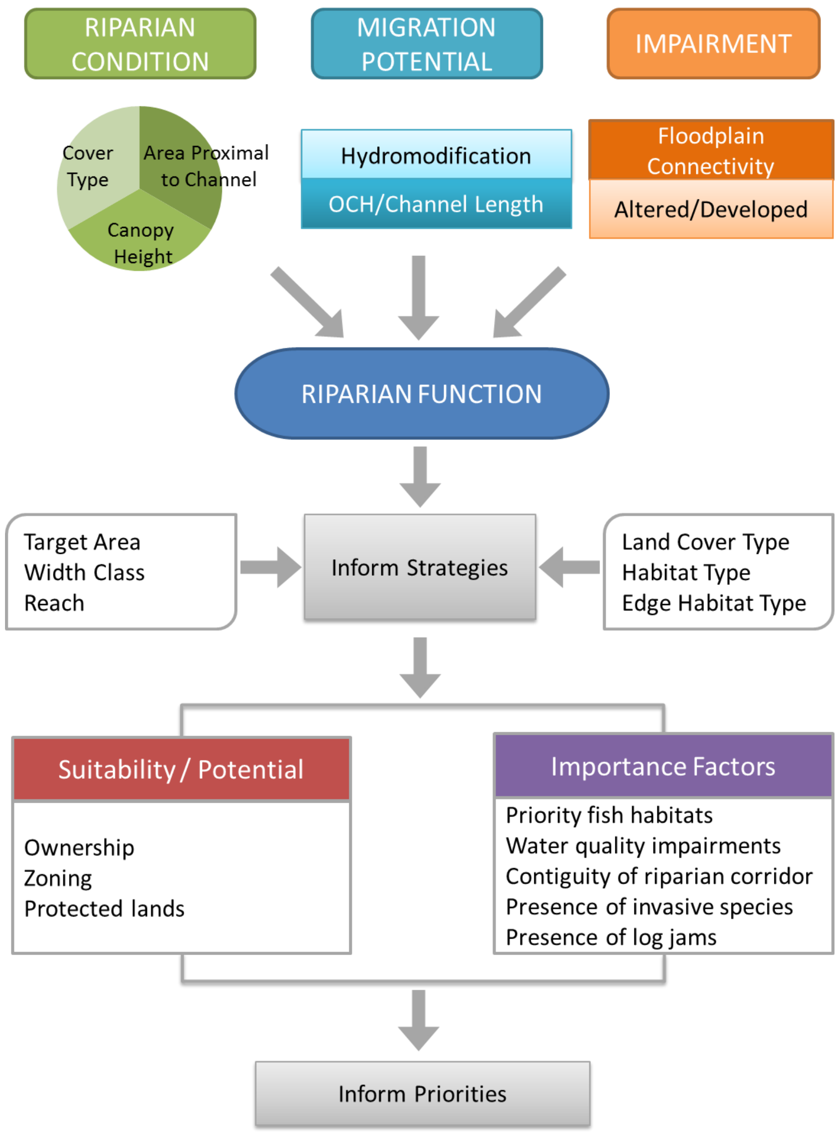


Figure 41. Framework for Using Riparian Assessment Results to Inform Riparian Strategies and Priorities

At the reach-scale, the final riparian cover classification and riparian assessment results can be used to support a reach characterization, which can then point to specific strategies for that reach (i.e., reach conditions lead to appropriate strategies). Using the conceptual model below (Figure 42), reaches can be evaluated to determine their potential to protect or restore Tier 1, Tier 2, or Tier 2S target habitats. The axes of the model refer back to the metrics described previously and shown in the framework above: riparian condition, migration potential, and impairment.

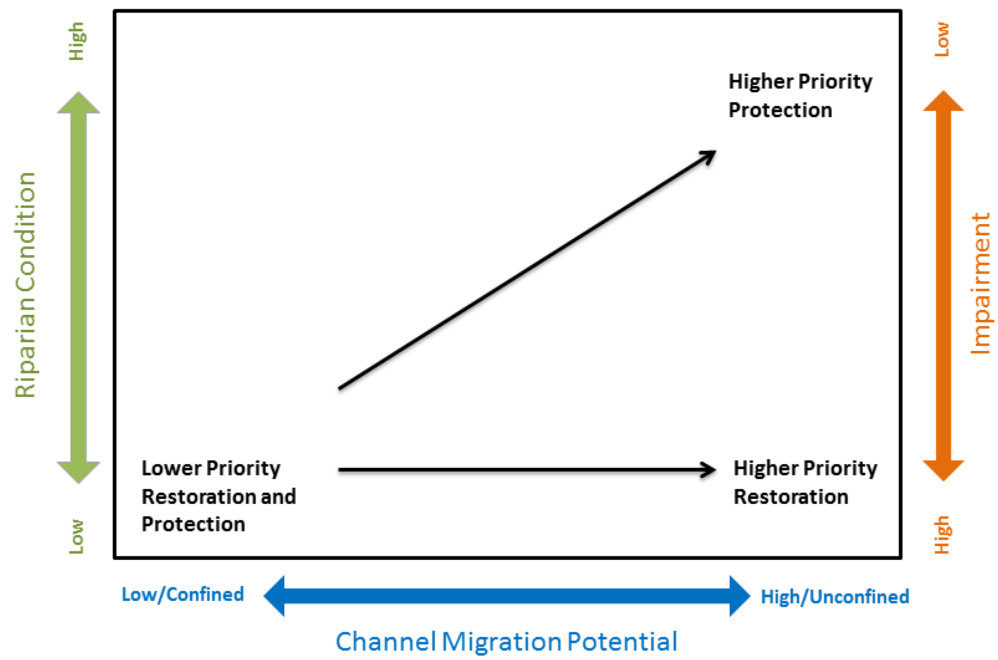


Figure 42. Conceptual Model for Reach-Level Characterization

The model is offered as a guide for identifying potential strategies based on reach characteristics. In some cases, the appropriate strategy for a given reach, and more commonly for any given parcel in that reach, may not be consistent with the model. For example, an area with low channel migration potential may warrant a higher priority for riparian restoration because it is unimpaired, in protected status, and adjacent to a known spawning area for salmonids.

Definitions

303(d) list - the federal Clean Water Act (CWA) requires states to maintain a list of stream segments that do not meet water quality standards. The list is called the 303(d) list because of the section of the CWA that makes the requirement.

Ecosystem – a unit comprising interacting organisms considered together with their environment.

Geomorphic potential - the potential of the channel within a reach to migrate across its floodplain and reconnect or create new side channel, off-channel, and form complex mainstem edge habitats.

Isolated habitat - habitat characterized as being a migration barrier to juvenile or adult anadromous salmonids. Habitat is isolated through anthropogenic disturbances such as tide gates, impassable road crossings, dikes or other floodplain fills.

Mainstem - the highest order portion of a river into which lower order tributaries flow.

Natural landscape processes / functions – natural landscape processes / functions are those that existing prior to Euroamerican settlement. Processes and functions are typically measured as rates and characterize what ecosystems or components of ecosystems do. The processes and functions in forested mountain river basin of the temperate zone primarily center around vegetation, water, and sediment.

Object-based image analysis – a technique used to analyze digital imagery that involves pixels being grouped into objects based on either spectral similarity or an external variable such as ownership, soil or geological unit and then using those groups to classify objects.

Process-based restoration – restoration efforts that aim to reestablish the normal rates and magnitudes of physical, chemical, and biological processes that sustain river and floodplain ecosystems

Protection – preserving ecosystems with relatively natural aquatic habitat conditions by preventing future impacts from unnatural disturbance and maintaining natural landscape processes and functions.

Restoration – the return of an ecosystem, or selected components of an ecosystem to its original form through actions by man or allowing recovery to occur naturally.

Stream reach - a section of a body of water that is defined either by the morphology of the stream, the geology of the stream, the hydrology of the stream, a predefined length, or a legal boundary.

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Appendix A

Data Sources List

Appendix B

Maps