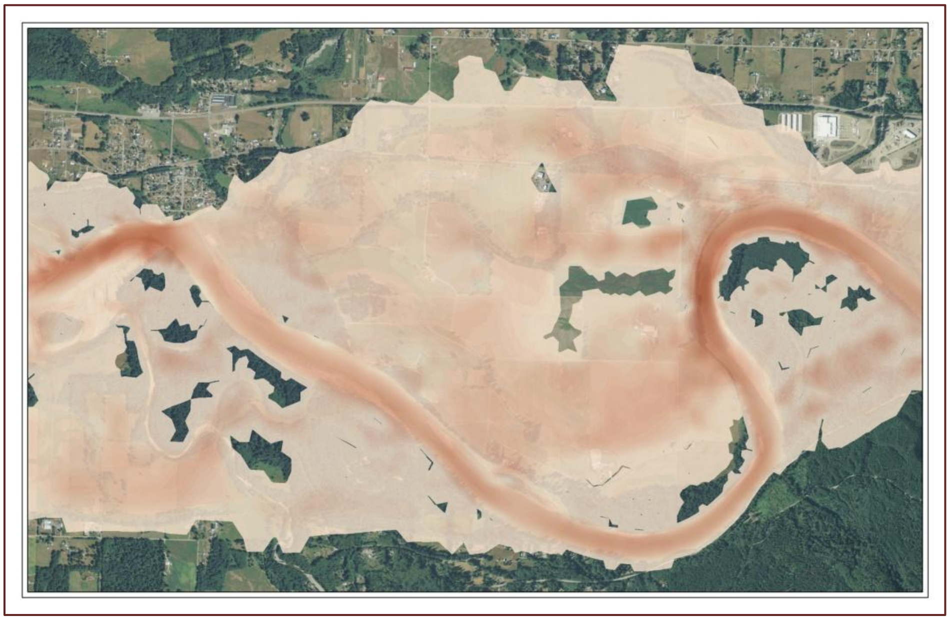
# Reach Level Analysis

# For the Middle Skagit River Assessment



**Report Prepared for**

**The Skagit Watershed Council**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**Skagit River System Cooperative**


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## Introduction

The middle reach of the Skagit River extends approximately 43 miles from the town of Sedro-Woolley upstream to the confluence of the Sauk River (Map 1). The Skagit Watershed Council targeted the Middle Skagit River in a grant to the Salmon Recovery Funding Board intended to identify high value habitat protection and restoration opportunities that would benefit Chinook salmon. To accomplish this goal, the Skagit Watershed Council convened three workgroups composed of relevant stakeholders to guide the assessment and hired contractors to complete several analyses that will be compiled into a restoration planning document.

The purpose of this analysis was to identify priority reaches within the Middle Skagit River to target habitat restoration and protection actions. A combination of existing data and new data were used to define reaches within the floodplain of the Middle Skagit River, to characterize habitat, geomorphic, and land use conditions within each of these reaches, and to compare reaches for restoration and protection potential. These data are also intended to be used in the next step of the Middle Skagit Assessment that will identify and prioritize specific restoration and protection projects at a site level.

This report outlines the analysis framework that was used for evaluating reaches, describes each of the data sets that were compiled and collected, provides maps and summary statistics for each of the data sets, and makes recommendations for how they can be used for evaluating floodplain reaches. Lastly, the report includes recommendations for additional data that could be collected for more detailed site level analysis and provides some examples of how the data contained in this report can be used for that analysis.

Final decisions about prioritizing reaches and appropriate restoration strategies for each reach will be made by the workgroups and described in the larger planning document. All maps and data sets used in this analysis will be provided to the Skagit Watershed Council for this purpose.

## Analysis Framework

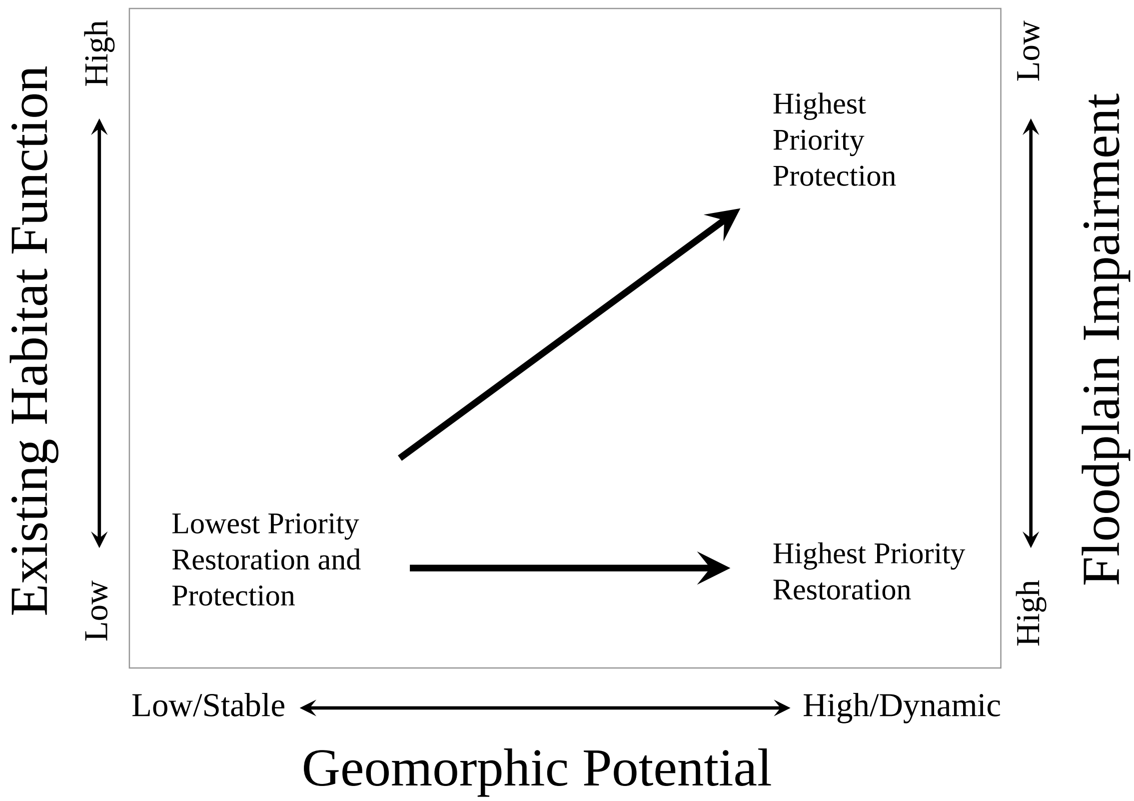
The Skagit Chinook Recovery Plan (SRSC and WDFW 2005) established freshwater juvenile rearing habitat as a limiting factor for Chinook salmon due to density-dependent use of freshwater habitats by juveniles. The plan also specifically identified floodplain and mainstem edge rearing habitats as high priorities for restoration and recommended the following types of actions:

1) Remove or upgrade hydromodifications
    a. Reconnect historic off-channel habitat in the floodplain
    b. Restore floodplain processes that create and maintain off-channel habitat and complex mainstem edge habitat
    c. Restore mainstem edge habitat complexity
2) Protect and restore riparian habitat in floodplain reaches
3) Protect existing floodplain and complex mainstem edge habitat

The Middle Skagit Criteria work group supported an approach to evaluating reaches that was based on the strategies identified in the Chinook Plan.  Therefore the goal of this reach analysis was to evaluate reaches based on the potential to protect or restore floodplain and complex mainstem edge rearing habitats.

To accomplish this goal, reaches were evaluated using a conceptual model (Figure 1) that includes geomorphic potential, existing habitat function, and floodplain impairment as the primary factors.  Geomorphic potential refers to the potential of the channel within a reach to migrate across its floodplain and reconnect or create new side channel, off-channel, and complex mainstem edge habitats.  This factor was considered the most important for identifying high priority reaches because dynamic channels and large floodplain areas are essential for creating and maintaining the floodplain and mainstem rearing habitats that are the focus of this analysis.  The other two factors, existing habitat function and level of floodplain impairment were primarily used to distinguish between protection and restoration actions.

**Figure 1.  Conceptual model for rating reaches**




## Data Sources and Reach Summaries

This analysis used a combination of existing data, data collected for the Middle Skagit Assessment by other organizations, and new data collected from aerial photographs to define and evaluate reaches. Data sets were selected for the analysis that could be used to accomplish the goal of reach evaluation and that would also be useful for the next step of site level project identification. All data were compiled into a consistent Geographic Information System (GIS) format using English units and are organized by the floodplain reaches used for this analysis. This was done to facilitate using multiple data sets from different sources for reach level comparisons, and also so the information is readily available for future analyses to be completed as part of the Middle Skagit Assessment.

Specific GIS data layers were developed to characterize floodplain reaches, flow and velocity conditions from hydrodynamic modeling, floodplain dynamics and vegetation, current habitat conditions, floodplain impairment from hydromodifications and roads, and currently protected lands. The data sources, methods and summary statistics for each of these data sets are described below, and recommendations for using these data to evaluate reaches are described in the following section. All GIS maps referred to in the analysis are provided in 11” X 17” page format included as Appendix A and more detailed methods and descriptions of the attributes contained in each data set are provided as Appendix B.

Floodplain Reaches

The reaches used for this analysis were based on floodplain reaches that were originally developed by SRSC and have been used in several restoration planning efforts (Beamer et al. 2000, SRSC and WDFW 2005). The outer boundaries were based on the regulatory 100-yr floodplain (FEMA 1989) as a starting point, but in relatively flat areas they were extended outward to the first terrace break to capture the geomorphic floodplain. For this analysis, the floodplain boundaries were extended in a few cases to capture recent channel erosion that occurred beyond the original boundary. This delineation of the geomorphic floodplain was intended to be used for analysis of river and floodplain interactions and for restoration planning, and generally represents the area where channel migration and habitat formation might be expected to occur over time in the absence of roads, development, and erosion protection structures. It does not represent the area likely to be flooded at a specific flow and does not define the floodplain or channel migration zone for any regulatory purpose.

The reach breaks were originally based on channel type and amount of hydromodification in the reach as described in Hayman et al. (1996) and SRSC and WDFW (2005). The breaks between reaches were changed at the request of the Skagit Watershed Council to better integrate with other analyses completed as part of the Middle Skagit Assessment and each reach was provided a unique name. The changes to floodplain reach breaks are shown on Map 2 and the final reaches used in this analysis are shown on Map 3.

The changes to the reach breaks were intended to maintain the original intent of developing reaches with similar channel type and hydromodification. The previous reach SK060A was divided into two smaller reaches (Skiyou and Ross Island) where the channel changes from a multi-thread channel (Ross Island) to a single-thread channel (Skiyou) with both reaches having similar hydromodification. The reach break for the previous reach SK060B (Cockreham) was moved slightly downstream to include the large influence from the Cockreham Levee on the floodplain and Etach Slough in one reach. The previous reaches SK070A and SK070B are two relatively short reaches with similar channel characteristics that were combined into one.

Floodplain reaches were characterized with several descriptive statistics that were calculated in GIS using 2009 aerial photography and 2006 USGS LiDAR (Table 1 and Table 2). Channel length was measured along the center of the mainstem wetted channel, and floodplain length was measured along the center of each floodplain reach. Average channel width was calculated by dividing the active channel area (which includes both wetted channel and gravel bar areas) by channel length, and average floodplain width was calculated by dividing the floodplain area by floodplain length. To calculate gradient, four elevation points were sampled from LiDAR along the channel at each reach break and averaged to estimate the channel elevation. For each reach, the channel elevation at the downstream end was subtracted from the elevation at the upstream end and divided by channel length to calculate channel gradient and by floodplain length to calculate floodplain gradient. Confinement was calculated by dividing average floodplain width by average channel width, and sinuosity was calculated by dividing channel length by floodplain length. Finally, a ratio was calculated by dividing floodplain area by channel length. More detailed information about the methods used to develop these statistics can be found in Appendix B. Reaches with the least confinement, largest floodplain areas, and widest floodplain widths occur in the downstream end of the study area and include Skiyou, Ross Island, and Cockreham.

**Table 1. Floodplain reach characteristics**

| Reach | Mainstem Channel Length (mi) | Average Channel Width (ft) | Channel Gradient | Floodplain Length (mi) | Floodplain Area (ac) | Average Floodplain Width (ft) | Floodplain Gradient |
|---|---|---|---|---|---|---|---|
| 1 - Skiyou | 4.7 | 602 | 0.0004 | 3.8 | 2733 | 5975 | 0.0005 |
| 2 - Ross Island | 6.2 | 1023 | 0.0008 | 4.1 | 4388 | 8840 | 0.0012 |
| 3 - Cockreham | 7.7 | 669 | 0.0007 | 5.6 | 4220 | 6179 | 0.0010 |
| 4 - Savage | 4.7 | 655 | 0.0009 | 4.3 | 1183 | 2247 | 0.0010 |
| 5 - Cape Horn | 4.8 | 523 | 0.0009 | 2.8 | 989 | 2939 | 0.0016 |
| 6 - Baker | 4.8 | 474 | 0.0009 | 4.6 | 557 | 992 | 0.0009 |
| 7 - Jackman | 3.7 | 735 | 0.0011 | 2.5 | 825 | 2724 | 0.0017 |
| 8 - Aldon | 3.2 | 544 | 0.0006 | 3.1 | 374 | 988 | 0.0006 |
| 9 - Rockport | 3.4 | 660 | 0.0011 | 3.3 | 662 | 1658 | 0.0011 |

**Table 2. Floodplain reach characteristics (continued)**

| Reach | Confinement | Sinuosity | Ratio: Floodplain Area (ac)/ Channel Length (mi) |
|---|---|---|---|
| 1 - Skiyou | 9.9 | 1.3 | 577.4 |
| 2 - Ross Island | 8.6 | 1.5 | 712.0 |
| 3 - Cockreham | 9.2 | 1.4 | 550.4 |
| 4 - Savage | 3.4 | 1.1 | 253.5 |
| 5 - Cape Horn | 5.6 | 1.7 | 205.4 |
| 6 - Baker | 2.1 | 1.0 | 115.0 |
| 7 - Jackman | 3.7 | 1.5 | 225.1 |
| 8 - Aldon | 1.8 | 1.0 | 118.2 |
| 9 - Rockport | 2.5 | 1.0 | 192.4 |

Hydrodynamic Modeling

The Skagit Watershed Council contracted with Pacific Northwest National Laboratory (PNNL) to develop a three-dimensional hydrodynamic model covering all of the Middle Skagit study area with the exception of the Rockport reach. The model was developed with the Finite Volume-Coastal Ocean Model (FV-COM) software and can be used to estimate water depth, velocity, and shear stress across the channel and floodplain for a range of flow conditions. Floodplain elevations were taken from 2006 USGS LiDAR and channel bathymetry was based on existing cross section data from the US Army Corps of Engineers (ACOE). The LiDAR elevation data does not always accurately represent ground elevation in areas of dense vegetative cover (can be incorrect by five feet or more) and the ACOE cross sections are based on data originally collected in the 1970s so the model results are most useful for reach-level evaluation. More current and detailed elevation and bathymetry information would likely be needed for site-level analysis. Validation was conducted using known surface water elevations at river gages during the October 2003 flood and velocity information collected by R2 Resource Consultants for Puget Sound Energy between 2002-2003. Additional information about the model can be found in the report provided by PNNL (ICOM 2010). More detailed information about how the model outputs were used for this analysis is provided in Appendix B.

PNNL provided model outputs under existing conditions for three flow scenarios (Table 3). Peak flow conditions were selected so results from the model could be used to evaluate geomorphic potential for floodplain reaches, with the assumption that floodplain reaches with larger inundation areas during peak flows would have the greatest potential for channel movement and habitat formation. Specific peak flows were selected based on an initial model simulation completed by PNNL for the Middle Skagit Data Workgroup to evaluate which flows would show the greatest differences between model runs. Once flows were selected, the approximate recurrence intervals were calculated by running a standard USGS Log-Pearson Type III flood frequency analysis (Interagency Advisory Committee on Water Data 1982) at the Skagit River near Concrete, WA gage using data from 1956-2009, which includes only dam-regulated flow conditions. These recurrence intervals are not appropriate for use in regulatory or flood management purposes and should not be compared with other flood frequency analyses that have been completed for the Skagit River. They were only developed to characterize the different flow conditions that were modeled for this analysis. The model was created using flow conditions throughout the entire hydrograph, so it would be relatively inexpensive to obtain model outputs for additional flow conditions.

**Table 3. Flow conditions used in hydrodynamic model**

| Flow at Concrete gage (cfs) | Approximate Recurrence Interval |
|---|---|
| 72,500 | 2-year |
| 104,500 | 5-year |
| 154,000 | 25-year |

The total area of floodplain inundated by each of the three modeled flows is summarized in Table 4 and the area of floodplain inundated by each of the flow conditions is shown on Map 4. Although reach lengths differ, reaches with the greatest inundation area under all flow scenarios are Skiyou, Ross Island, and Cockreham, which is consistent with the much wider floodplain widths in these reaches compared to other reaches.

The percent increase in inundation area between flows for each reach is presented in Table 6, and shows some differences between the reaches. Some reaches, such as Savage and Baker, included a larger portion of higher elevation areas of the floodplain that did not get wet until the 25-yr flow condition which may indicate less frequent interaction with the river and suggesting a smaller likelihood of habitat formation in these areas. Other reaches, such as Skiyou, Cockreham, and Ross Island have relatively large floodplains and much of them are relatively low elevation so were wet even under the 2-yr or 5-yr flow condition, without much additional increase in area at the 25-yr flow condition. This suggests that large portions of these floodplains interact with the river relatively frequently and may have a higher likelihood of habitat formation.

In some areas, the modeled 25-yr flow inundation area was slightly larger than the mapped floodplain area used for delineating reaches. The most likely explanations are the differences in methods used and the resolution of the input data. The mapped floodplain boundaries were delineated from FEMA maps, topography and a visual interpretation of slope breaks with minor modifications based on recent channel changes, while the flow inundation maps were developed from a hydraulic model based on LiDAR data and older ACOE bathymetry, which both have limitations as described above. Considering these differences the boundaries between flow inundation and the floodplain boundary line up fairly well, and are definitely sufficient for the purpose of reach level evaluation. For this analysis, the two data sets were kept separate, but if additional topography and bathymetry data are collected to improve the flow model in the future, it could be used to revise and improve the floodplain boundary.

**Table 4. Inundation areas from hydrodynamic model for existing conditions**

| Reach | Mainstem Length (mi) | Floodplain Area (ac) | 2-Yr Flow (ac) | 5-Yr Flow (ac) | 25-Yr Flow (ac) |
|---|---|---|---|---|---|
| **1 - Skiyou** | 4.7 | 2,733 | 2,093 | 2,541 | 2,684 |
| **2 - Ross Island** | 6.2 | 4,388 | 2,692 | 3,922 | 4,322 |
| **3 - Cockreham** | 7.7 | 4,220 | 2,176 | 3,891 | 4,198 |
| **4 - Savage** | 4.7 | 1,183 | 584 | 802 | 1,228 |
| **5 - Cape Horn** | 4.8 | 989 | 790 | 963 | 1,083 |
| **6 - Baker** | 4.8 | 557 | 478 | 568 | 737 |
| **7 - Jackman** | 3.7 | 825 | 502 | 666 | 770 |
| **8 - Aldon** | 3.2 | 374 | 313 | 340 | 393 |
| **9 - Rockport** | -- | -- | -- | -- | -- |
| **Total** | **39.7** | **15,269** | **9,628** | **13,692** | **15,415** |

Velocity conditions predicted for the 2-yr flow are shown on Map 5, and velocity conditions predicted for the 25-yr flow are shown on Map 6. Velocity conditions were not used explicitly in this analysis to compare reaches, but could be useful for future site level planning if combined with information about floodplain substrate size to identify areas that may be prone to erosion and channel formation.

In addition to modeling existing conditions, PNNL provided model outputs for the same three flow scenarios under an alternative condition with a number of hydromodifications removed from the model grid by modifying the elevations of the levee structures to match the surrounding floodplain elevation. The hydromodifications that were removed were selected from a recent field inventory (USIT 2010) by the Skagit Watershed Council because they had elevations higher than the floodplain, were potentially isolating floodplain channel habitat, or were likely to result in significant changes to the model results if removed. No hydromodifications were removed from the Savage reach or any reaches upstream. The total area of floodplain inundated by each of the three modeled flows under the alternative condition is summarized in Table 5 and the percent increase in inundation area between each flow under the existing and alternative condition is summarized in Table 6. The location of hydromodifications that were removed and the area inundated by each of the three modeled flows under the alternative condition are shown in Map 7.

The change in inundation area from existing to alternative conditions with a 5-yr flow is shown on Map 8, and the change in velocity from existing to alternative conditions with a 5-yr flow is shown on Map 9. The actual inundation area did not change significantly between the two conditions, and surprisingly showed a net reduction in inundation area at the 5-yr flow. However, in some areas velocity conditions in the floodplain changed substantially. More detailed site level work will be needed for project planning, but in particular the Cockreham Levee and the levee near Gilligan Creek both showed relatively large increases in velocity across the floodplain in the alternative condition, which suggests the potential for channel and habitat formation if these structures were to be removed through restoration. Several other sites in the Skiyou and Ross Island reaches also showed potential for velocity changes with restoration.

**Table 5. Inundation areas for alternative condition (selected hydromods removed)**

| Reach | Mainstem Length (mi) | Floodplain Area (ac) | 2-Yr Flow (ac) | 5-Yr Flow (ac) | 25-Yr Flow (ac) |
|---|---|---|---|---|---|
| 1 - Skiyou | 4.7 | 2,733 | 2,017 | 2,420 | 2,669 |
| 2 - Ross Island | 6.2 | 4,388 | 2,643 | 3,769 | 4,288 |
| 3 - Cockreham | 7.7 | 4,220 | 2,228 | 3,850 | 4,235 |
| 4 - Savage | 4.7 | 1,183 | 585 | 802 | 1,231 |
| 5 - Cape Horn | 4.8 | 989 | 791 | 964 | 1,082 |
| 6 - Baker | 4.8 | 557 | 478 | 567 | 736 |
| 7 - Jackman | 3.7 | 825 | 502 | 666 | 770 |
| 8 - Aldon | 3.2 | 374 | 313 | 340 | 393 |
| 9 - Rockport | -- | -- | -- | -- | -- |
| **Total** | **39.7** | **15,269** | **9,557** | **13,378** | **15,405** |

**Table 6. Percentage increase in area of inundation between flow conditions**

| Reach | Existing Conditions | | Alternative Conditions | |
|---|---|---|---|---|
| | 2-Yr to 5-Yr flow | 5-Yr to 25-Yr flow | 2-Yr to 5-Yr flow | 5-Yr to 25-Yr flow |
| 1 - Skiyou | 17.6% | 5.3% | 16.7% | 9.3% |
| 2 - Ross Island | 31.4% | 9.3% | 29.9% | 12.1% |
| 3 - Cockreham | 44.1% | 7.3% | 42.1% | 9.1% |
| 4 - Savage | 27.2% | 34.7% | 27.0% | 34.9% |
| 5 - Cape Horn | 17.9% | 11.1% | 17.9% | 10.9% |
| 6 - Baker | 15.9% | 22.9% | 15.7% | 23.0% |
| 7 - Jackman | 24.7% | 13.5% | 24.6% | 13.5% |
| 8 - Aldon | 7.8% | 13.5% | 7.8% | 13.6% |
| 9 - Rockport | -- | -- | -- | -- |
| **Total** | **29.7%** | **11.2%** | **28.6%** | **13.2%** |

Floodplain Dynamics and Vegetation Mapping

To quantify river-floodplain dynamics in the Middle Skagit River, the age of forest vegetation on floodplain surfaces for each reach was estimated from aerial photographs and related to channel pattern using similar methods as described in Beechie et al. (2006). The average age and diversity of floodplain forests were used as indicators to determine how frequently floodplain surfaces were disturbed by lateral channel erosion. In that study, channel types were classified into straight, meandering, island-braided, and braided based on the channel pattern observed from aerial photographs. Straight channels have the least disturbance from lateral channel erosion and have floodplains dominated by older forest stands. Braided channels have the most disturbance from lateral channel erosion and have floodplains dominated by young forested stands and gravel bars. Meandering and island-braided channels have intermediate rates of disturbance and a high diversity in the age of floodplain surfaces and forest stands.

Meandering and island-braided channels were expected to support the highest biological diversity because they support a range of floodplain forest ages and habitat types, with island-braided channels expected to have the most diverse aquatic habitat because they include multiple side channels (Beechie et al. 2006).

The Middle Skagit reaches have some differences from the channels included in Beechie et al. (2006) because they are more heavily modified by human activities, and in some cases have greater topographic confinement, however it was expected that these methods could generate useful information about geomorphic potential of the reaches. So for this analysis, 2009 aerial photography was used to classify the channel pattern for each reach and to delineate the floodplain into channels and the four size classes of forest stands used in Beechie et al. (2006). In addition, floodplain surfaces were classified into developed areas, roads, and forests that had been modified by human activities so may not represent time since channel disturbance (Table 7). These areas cannot be used for quantifying river-floodplain dynamics based on the methods in Beechie et al. (2006), but documenting them was expected to be useful for determining the amount of floodplain impairment and for identifying restoration opportunities. More detailed information about the methods used for mapping floodplain vegetation can be found in Appendix B.

**Table 7. Floodplain vegetation types adapted from Beechie et al. (2006)**

| Floodplain Vegetation Type | Description | Age range (yrs) |
|---|---|---|
| CH | Channel with no vegetation | 0 |
| V1 | Newly established vegetation | <5 |
| V2 | Forests with crown diameter < 16 feet | 5-25 |
| V3 | Forests with crown diameter 16 – 33 feet | 25-75 |
| V4 | Forests with crown diameter > 33 feet | 75-250 |
| D | No forest vegetation, typically cleared for agricultural or residential purposes | Unknown |
| R | Public roads | Unknown |
| HM – V1,V2, or V3 | Human modified forests within the V1-V3 size categories | Same as size categories above |

Table 8 shows the observed channel pattern for each reach and also summarizes the amount of floodplain covered by unmodified vegetation classes compared to cover classes that have been modified by human activity. Skiyou was classified as a straight channel and Cockreham a meandering channel because they currently have single-thread channels and lack abundant side channels separated by forested islands. However, both reaches show evidence of historic floodplain channels that have been isolated or altered as a result of hydromodifications, so current channel patterns are likely different than they were historically. The results for different categories of forest vegetation classes not modified by human activity are provided in

Table 9, and the different cover categories that have been clearly modified by human activity are provided in Table 10. All vegetation and human disturbance categories are included on Map 10.

The floodplain vegetation results can be used to evaluate how much floodplain disturbance from human activities is present in each reach (as described in the Reach Evaluation section later in this document) and to identify specific habitat restoration projects. For identifying habitat projects, the primary emphasis would be on areas that have been developed or entirely cleared of native forest vegetation, as presented on Map 11.

**Table 8. Summary of channel patterns, reach totals for unmodified vegetation, and reach totals for human modified cover classes**

| Reach | Observed Channel Pattern | Floodplain Area (ac) | Channel Area (ac) | Total Unmodified Veg V1-V4 (ac) | Total Unmodified Veg V1-V4 (%)* | Total Human Modified Cover (ac) | Total Human Modified Cover (%)* |
|---|---|---|---|---|---|---|---|
| 1 - Skiyou | Straight | 2,733 | 402 | 855 | 37% | 1,476 | 63% |
| 2 - Ross Island | Island-Braided | 4,388 | 941 | 2,228 | 65% | 1,218 | 35% |
| 3 - Cockreham | Meandering | 4,220 | 742 | 1,077 | 31% | 2,401 | 69% |
| 4 - Savage | Straight | 1,183 | 411 | 408 | 53% | 363 | 47% |
| 5 - Cape Horn | Meandering | 989 | 313 | 434 | 64% | 242 | 36% |
| 6 - Baker | Straight | 557 | 283 | 164 | 60% | 110 | 40% |
| 7 - Jackman | Island-Braided | 825 | 331 | 325 | 66% | 169 | 34% |
| 8 - Aldon | Straight | 374 | 213 | 123 | 76% | 38 | 24% |
| 9 - Rockport | Straight | 662 | 293 | 307 | 83% | 62 | 17% |

* Percentages calculated without channel area included

**Table 9. Unmodified vegetation cover categories**

| Reach | Veg Cover V1 (ac) | Veg Cover V1 (%) | Veg Cover V2 (ac) | Veg Cover V2 (%) | Veg Cover V3 (ac) | Veg Cover V3 (%) | Veg Cover V4 (ac) | Veg Cover V4 (%) |
|---|---|---|---|---|---|---|---|---|
| 1 - Skiyou | 34 | 4% | 153 | 18% | 471 | 55% | 197 | 23% |
| 2 - Ross Island | 148 | 7% | 718 | 32% | 1,113 | 50% | 249 | 11% |
| 3 - Cockreham | 56 | 5% | 145 | 13% | 777 | 72% | 99 | 9% |
| 4 - Savage | 9 | 2% | 52 | 13% | 235 | 58% | 111 | 27% |
| 5 - Cape Horn | 12 | 3% | 119 | 27% | 259 | 60% | 45 | 10% |
| 6 - Baker | 12 | 7% | 34 | 21% | 81 | 49% | 37 | 23% |
| 7 - Jackman | 36 | 11% | 59 | 18% | 186 | 57% | 45 | 14% |
| 8 - Aldon | 9 | 7% | 0 | 0% | 62 | 50% | 52 | 42% |
| 9 - Rockport | 18 | 6% | 82 | 27% | 183 | 60% | 24 | 8% |

**Table 10. Floodplain cover as modified by human activities**

| Reach | Roads/ Developed (ac) | (%) | Veg Cover HM-V1 (ac) | (%) | Veg Cover HM-V2 (ac) | (%) | Veg Cover HM-V3 (ac) | (%) |
|---|---|---|---|---|---|---|---|---|
| 1 - Skiyou | 1,219 | 83% | 81 | 5% | 113 | 8% | 64 | 4% |
| 2 - Ross Island | 1,126 | 92% | 76 | 6% | 9 | 1% | 7 | 1% |
| 3 - Cockreham | 2,244 | 93% | 23 | 1% | 97 | 4% | 37 | 2% |
| 4 - Savage | 363 | 100% | 0 | 0% | 0 | 0% | 0 | 0% |
| 5 - Cape Horn | 236 | 97% | 6 | 3% | 0 | 0% | 0 | 0% |
| 6 - Baker | 100 | 91% | 10 | 9% | 0 | 0% | 0 | 0% |
| 7 - Jackman | 141 | 83% | 15 | 9% | 14 | 8% | 0 | 0% |
| 8 - Aldon | 34 | 88% | 4 | 12% | 0 | 0% | 0 | 0% |
| 9 - Rockport | 44 | 71% | 18 | 29% | 0 | 0% | 0 | 0% |

Beechie et al. (2006) provided several measures of floodplain disturbance frequency calculated from the vegetation classifications for each channel type (Table 11). To apply these methods to the Middle Skagit reaches, the vegetation classes that were not modified by human activity (
Table **9**) were used to calculate a similar set of measures for each reach and were also averaged for each channel type and the results are presented in Table 12. Even though Beechie et al. (2006) only used unconfined reaches (confinement < 4), these measures were calculated for all the Middle Skagit reaches so that floodplain dynamics could be compared for the entire study area. The Rockport reach was presented separately in the table because the vegetation and floodplain metrics for that reach do not include the floodplain area associated with the confluence of the Sauk River, so it may not be appropriate to compare it with other straight channel types. Braided channel types are not represented in the Middle Skagit study area.

Regardless of the variability in channel confinement, the straight channel types in the Middle Skagit study area had the highest percent of floodplain greater than 75 years and the highest average floodplain age, indicating less disturbance from lateral channel erosion than other channel types, and likely less habitat diversity. It is interesting to note that the Skiyou reach followed a similar pattern as other straight reaches even though it was likely more dynamic historically before human modification. The meandering and island-braided channel types together had a lower percent of floodplain greater than 75 years and lower mean floodplain ages, indicating higher rates of disturbance, but likely still less than would be expected for braided channel types. This suggests a more intermediate rate of channel disturbance and higher habitat diversity for these channel types. These results are generally consistent with Beechie et al. (2006) for comparing straight channels with other channel types, however the meandering and island-braided reach types were poorly distinguished from one another within the Middle Skagit study area. It is likely that the cause of this discrepancy is that so much of the floodplain and channel area in the Middle Skagit has been modified by human activities that the resulting vegetation ages provide a less accurate measure of natural floodplain disturbances. For this reason the results were not used for rating or classifying reaches in this analysis.

**Table 11. Measures of floodplain vegetation age by channel type from Beechie et al. (2006)**

| Channel Type | Mean % Channel | Mean % of Flood-plain < 5 yrs old | Mean % of Flood-plain > 75 yrs old | Mean Age of Floodplain | Median Age of Floodplain |
|---|---|---|---|---|---|
| Straight | 22% | 3% | 42% | 85 | 65 |
| Meandering | 12% | 2% | 24% | 63 | 48 |
| Island-braided | 30% | 18% | 12% | 41 | 23 |
| Braided | 72% | 48% | <1% | 12 | 6 |

**Table 12. Measures of floodplain vegetation age calculated for Middle Skagit reaches**

| Reach | Observed Channel Patern | Confine-ment Ratio | % Channel | % of Floodplain < 5 yrs old | % of Floodplain > 75 yrs old | Area Weighted Age of Floodplain (yrs) |
|---|---|---|---|---|---|---|
| **1 - Skiyou*** | Straight | 9.9 | 14.7% | 4.0% | 23.0% | 64.9 |
| **4 - Savage** | Straight | 3.4 | 34.8% | 2.2% | 27.3% | 71.8 |
| **6 - Baker** | Straight | 2.1 | 50.7% | 7.1% | 22.7% | 62.1 |
| **8 - Aldon** | Straight | 1.8 | 57.0% | 7.1% | 42.4% | 89.1 |
| **Mean** | | | **39.3%** | **5.1%** | **28.9%** | **71.9** |
| **3 - Cockreham*** | Meandering | 8.6 | 17.6% | 5.2% | 9.2% | 52.0 |
| **5 - Cape Horn** | Meandering | 3.7 | 31.6% | 2.8% | 10.3% | 49.4 |
| **Mean** | | | **24.6%** | **4.0%** | **9.7%** | **50.7** |
| **2 - Ross Island*** | Island-Braided | 9.2 | 21.5% | 6.7% | 11.2% | 46.8 |
| **7 - Jackman** | Island-Braided | 5.6 | 40.1% | 11.0% | 13.8% | 52.3 |
| **Mean** | | | **30.8%** | **8.8%** | **12.5%** | **49.6** |
| **9 - Rockport**** | Straight | 2.5 | 44.3% | 5.7% | 7.7% | 45.6 |

* Reaches with confinement ratios consistent with Beechie et al. (2006)

** Anamolous straight reach due to confluence with Sauk River

## Current Habitat Conditions

To characterize current habitat conditions in the Middle Skagit River, habitats were delineated from 2009 aerial photographs based on the habitat types used in Hayman et al. (1996) and SRSC and WDFW (2005). Hayman et al. (1996) characterized mainstem habitat and sampled juvenile Chinook use throughout the 1995 smolt migration period to estimate Chinook distribution among the mainstem habitat types. SRSC and WDFW (2005) used this information along with more recently collected habitat data to estimate

Chinook capacity throughout the Skagit River basin. These methods were used in this analysis to estimate juvenile Chinook capacity for each reach in the Middle Skagit River so that reaches could be compared based on their current capacity to produce Chinook. If detailed information was developed on habitat changes that would result from specific restoration projects, then these methods could also be used to quantify and compare benefits from different restoration projects.

The primary channel types that were measured for this analysis are described in Table 13 and mainstem channels were further delineated into edge habitats as described in Table 14. Map 12 shows examples of each of the habitat types. As indicated in the table, habitat area was collected for smaller tributaries in the floodplain, but this information was not used to estimate Chinook capacity because tributaries were not included in either Hayman et al. (1996) or SRSC and WDFW (2005).

**Table 13. Primary habitat types**

| **Channel Type** | **Description** |
|---|---|
| Mainstem channel | Higher velocity main channel areas including major side channels |
| Off-channel | Low gradient side channels, wetlands and sloughs in floodplain separate from main channel |
| Tributary | Tributary stream channels within the floodplain |

**Table 14. Edge habitat types for further delineating mainstem channels**

| **Mainstem Edge Habitat Type** | **Description** |
|---|---|
| Banks | Vertical or nearly vertical shore |
| Bars | Shallow, low-gradient connection to the shore |
| Backwaters | Enclosed low-velocity areas |
| Hydromodified | Each edge habitat type classified as hydromodified or not based on USIT (2010). |

Surface area was measured for mainstem, backwater, off-channel, and tributary habitats and the results are presented in Table 15. In addition, length was measured for mainstem banks and bars, and perimeter was measured for backwaters (Table 15). Map 13 shows the location and extent of all habitats that were measured. More detailed information about methods for measuring habitat types can be found in Appendix B.

**Table 15. Habitat area by reach**

| Reach | Mainstem (sq ft) | Backwater (sq ft) | Off-channel (sq ft) | Tributary (sq ft) |
|---|---|---|---|---|
| 1 - Skiyou | 12,919,472 | 378,799 | 1,944,316 | 131,899 |
| 2 - Ross Island | 20,206,920 | 1,086,118 | 6,318,082 | 352,975 |
| 3 - Cockreham | 20,595,054 | 461,908 | 4,386,435 | 394,417 |
| 4 - Savage | 11,314,966 | 355,913 | 1,275,778 | 161,386 |
| 5 - Cape Horn | 10,247,569 | 72,093 | 229,505 | 31,161 |
| 6 - Baker | 11,016,677 | 0 | 30,957 | 159,979 |
| 7 - Jackman | 10,046,814 | 10,110 | 176,372 | 235,995 |
| 8 - Aldon | 7,450,326 | 140,515 | 66,094 | 0 |
| 9 - Rockport | 8,458,164 | 45,683 | 730,446 | 0 |
| **Total** | **112,255,962** | **2,551,139** | **15,157,985** | **1,467,811** |

**Table 16. Edge habitat length by reach**

| Reach | Mainstem Length (ft) | Backwater perim (ft) | % hydro-modified | Bar length (ft) | % hydro-modified | Bank length (ft) | % hydro-modified |
|---|---|---|---|---|---|---|---|
| 1 - Skiyou | 24,994 | 10,028 | 15.8% | 17,851 | 1.2% | 38,094 | 48.2% |
| 2 - Ross Island | 32,539 | 32,010 | 4.6% | 91,166 | 0.6% | 66,137 | 14.8% |
| 3 - Cockreham | 40,481 | 11,445 | 16.7% | 46,261 | 0.9% | 52,578 | 30.0% |
| 4 - Savage | 24,633 | 10,733 | 0.0% | 33,915 | 0.0% | 29,364 | 11.7% |
| 5 - Cape Horn | 25,410 | 1,612 | 0.0% | 33,236 | 1.0% | 22,024 | 5.1% |
| 6 - Baker | 25,577 | 0 | 0.0% | 17,784 | 0.0% | 40,175 | 10.4% |
| 7 - Jackman | 19,351 | 798 | 0.0% | 32,331 | 1.9% | 32,163 | 17.5% |
| 8 - Aldon | 16,713 | 5,670 | 0.0% | 13,538 | 0.0% | 27,184 | 5.7% |
| 9 - Rockport | 18,166 | 2,875 | 0.0% | 28,814 | 0.5% | 25,779 | 6.9% |
| **Total** | **227,864** | **75,170** | **6.6%** | **314,896** | **0.7%** | **333,497** | **18.5%** |

In order to estimate juvenile Chinook capacity for each reach, the first step was to estimate surface area for banks and bars, which can only be measured by length from aerial photographs. The measured length of these habitat features was multiplied by an average width from Hayman et al. (1996) which was based on field measurements taken during the fish sampling effort (Table 17). The area of the remaining habitat types was measured in GIS. Then the assumed fish capacity was calculated for each habitat type using the densities provided in Table 18, and the results were totaled by habitat type (Table 19) and for each reach (Table 20).

**Table 17. Average width values used for edge habitats**

| Habitat Type | Average width (ft) |
|---|---|
| Bank edge habitat | 8.5 |
| Bar edge habitat | 51.2 |
| Backwaters, mainstem, off-channel | Area measured in GIS |

**Table 18. Juvenile Chinook density by habitat type from Hayman et al. (1996) and SRSC and WDFW (2005)**

| Habitat Type | Fish/ft$^2$ |
|---|---|
| Natural backwater | 0.165 |
| Hydromodified backwater | 0.059 |
| Natural bar | 0.041 |
| Hydromodified bar | 0.015 |
| Natural bank | 0.090 |
| Hydromodified bank | 0.032 |
| Mid-channel areas | 0.0001 |
| Off-channel habitat | 0.0045 |

**Table 19. Juvenile Chinook capacity by habitat type**

| Reach | Natural Backwater | Hydro-modified Backwater | Natural Bar | Hydro-modified Bar | Natural Bank | Hydro-modified Bank | Mid-Channel Areas | Off-Channel Habitat |
|---|---|---|---|---|---|---|---|---|
| 1 - Skiyou | 52,644 | 3,525 | 37,002 | 167 | 15,140 | 5,015 | 1,086 | 8,749 |
| 2 - Ross Island | 170,969 | 2,947 | 190,159 | 418 | 43,278 | 2,665 | 1,393 | 28,431 |
| 3 - Cockreham | 63,478 | 4,555 | 96,197 | 321 | 28,248 | 4,308 | 1,653 | 19,739 |
| 4 - Savage | 58,726 | 0 | 71,166 | 0 | 19,912 | 935 | 868 | 5,741 |
| 5 - Cape Horn | 11,895 | 0 | 69,022 | 263 | 16,053 | 304 | 777 | 1,033 |
| 6 - Baker | 0 | 0 | 37,318 | 0 | 27,648 | 1,136 | 908 | 139 |
| 7 - Jackman | 1,668 | 0 | 66,563 | 468 | 20,374 | 1,535 | 755 | 794 |
| 8 - Aldon | 23,185 | 0 | 28,408 | 0 | 19,679 | 423 | 607 | 297 |
| 9 - Rockport | 7,538 | 0 | 60,188 | 101 | 18,426 | 485 | 629 | 3,287 |
| **Total** | **390,102** | **11,026** | **656,022** | **1,737** | **208,758** | **16,806** | **8,676** | **68,211** |

**Table 20. Juvenile Chinook capacity totals for Middle Skagit reaches**

| Reach | Mainstem Length (ft) | Total Fish |
|---|---|---|
| 1 - Skiyou | 24,994 | 123,328 |
| 2 - Ross Island | 32,539 | 440,259 |
| 3 - Cockreham | 40,481 | 218,498 |
| 4 - Savage | 24,633 | 157,347 |
| 5 - Cape Horn | 25,410 | 99,347 |
| 6 - Baker | 25,577 | 67,149 |
| 7 - Jackman | 19,351 | 92,158 |
| 8 - Aldon | 16,713 | 72,599 |
| 9 - Rockport | 18,166 | 90,653 |
| **Total** | **227,864** | **1,361,340** |

## Floodplain Impairment from Hydromodifications

Hydromodifications include roads, rip-rap bank armoring structures, dikes, levees and other structural modifications that change flow and erosion patterns in the channel and floodplain. Hydromodifications can degrade habitat conditions by reducing mainstem edge habitat complexity (Beamer and Henderson 1996) and by reducing floodplain connectivity, limiting channel migration, and preventing habitat formation (SRSC and WDFW 2005). As part of the Middle Skagit assessment, the Upper Skagit Indian Tribe completed a field survey of hydromodifications in and immediately adjacent to the Middle Skagit River channel (USIT 2010). This survey provided a much needed update for data collected on hydromodifications in 1994-95 (Beamer and Henderson 1996) and used similar methods. The survey also included useful information on smaller scale features such as recreational boat ramps that may be degrading edge habitat conditions.

In order to evaluate the potential impacts to floodplain processes from hydromodifications in the Middle Skagit River, the recent field survey (USIT 2010) was used to identify hydromodifications influencing the channel, and data from the Chinook Plan (SRSC and WDFW 2005) were used to identify roads in the floodplain. Data collected on smaller scale features such as boat ramps in the USIT (2010) survey were not included. Methods from the Chinook Plan were used to estimate floodplain impairment from hydromodifications and roads for each reach, and are described in detail in Appendix B. These methods delineated areas in the floodplain that were “isolated” or “shadowed” by hydromodifications. Isolated areas were surrounded on all sides by roads or hydromodifications. Shadowed areas were located behind roads or hydromodifications but were not completely disconnected from river processes. Shadowed areas were delineated for each hydromodification using a line perpendicular to the floodplain on the upstream side and a line perpendicular to channel flow on the downstream side. Shadowed areas were extended along these lines to the floodplain boundary or at most for one meander length downstream. These methods are somewhat simplistic, so the shadowed area likely does not accurately reflect the effect of individual hydromodifications on existing habitat conditions or on the potential for habitat development, but is useful for characterizing floodplain impairment at a reach level from numerous hydromodifications.

The results of the evaluation of floodplain impairment from hydromodifications are provided in Map 14 and Table 21.

**Table 21. Hydromodification length and floodplain impairment area by reach**

| Reach | Mainstem Length (ft) | Hydromod Length (ft) | Floodplain Area (ac) | Isolated (ac) | Shadowed (ac) | Road (ac) |
|---|---|---|---|---|---|---|
| **1 - Skiyou** | 24,994 | 20,438 | 2,733 | 284 | 601 | 38 |
| **2 - Ross Island** | 32,539 | 13,805 | 4,388 | 316 | 930 | 22 |
| **3 - Cockreham** | 40,481 | 18,231 | 4,220 | 1,912 | 734 | 143 |
| **4 - Savage** | 24,633 | 3,474 | 1,183 | 59 | 135 | 17 |
| **5 - Cape Horn** | 25,410 | 1,479 | 989 | 177 | 137 | 15 |
| **6 - Baker** | 25,577 | 4,151 | 557 | 17 | 37 | 13 |
| **7 - Jackman** | 19,351 | 6,357 | 825 | 2 | 102 | 11 |
| **8 - Aldon** | 16,713 | 1,947 | 374 | 2 | 18 | 2 |
| **9 - Rockport** | 18,166 | 1,952 | 662 | 11 | 50 | 6 |
| **Total** | **227,864** | **71,834** | **15,931** | **2,780** | **2,745** | **266** |

Protected Lands

This analysis identified the location and area of properties protected for habitat purposes in each reach. This included properties that were acquired or have permanent easements specifically to protect habitat and also publicly owned lands that were expected to be managed to protect and maintain habitat in the future. To identify these properties, information was taken from the following sources:

1) Skagit County Database Consortium (SCDC) conservation lands database, which was updated in 2010 for use in the Middle Skagit project
2) A previous project completed by SRSC that identified protected properties (Ramsden 2008)
3) 2010 parcel data from Skagit County GIS/Mapping Services and the Assessor's Office.

The specific rules for determining which parcels should be considered protected were provided by the Skagit Watershed Council and are described in more detail in Appendix B.

To develop a GIS data layer for this analysis and to determine the area and location of protected lands, property boundaries for parcels identified as protected in this analysis were taken from the 2010 Skagit County parcel layer but only the portions of the parcels within the floodplain boundary were included. The parcel layer provides a good representation of property boundaries for tax purposes but does not include formal land surveys so does not reflect precise legal property boundaries. The resulting errors in calculating the area of protected land are likely insignificant at a reach scale, but there are two other difficulties with existing parcel data that had a larger effect on the analysis, as described below:

Parcels coded as "water." The parcel layer contains parcels coded as "water" by Skagit County to indicate the location of river channels. Unfortunately, these parcel locations and the neighboring property boundaries are not regularly updated as channels migrate across the floodplain over time. In places where recent channel migration has occurred, parcels identified as "water" were in different locations than channels mapped for this analysis and the resulting changes in property ownership were not known. For this analysis, "water" parcels were reported separately on maps and tables, and the adjacent protected properties were reported based on the existing parcel data even where the channel has changed locations.

Parcels with unknown ownership. The parcel layer contains parcels that have no information about ownership from the Skagit County Assessor's office. Many of these are likely historic river channel locations and may be in public ownership or belong to adjacent property owners. For this analysis it was assumed that actual ownership of these parcels has not been resolved so parcels with unknown ownership were not considered protected, and are reported separately on maps and tables.

Map 15 shows the currently protected lands and Map 16 shows the currently protected lands compared to the 25-yr inundation area predicted by the hydrodynamic model. Summary information about currently protected lands in each reach is provided in Table 22. In this table, "water" parcels were subtracted from the total floodplain area before calculating the percentages of available floodplain land that is protected or unprotected.

**Table 22. Protected lands in Middle Skagit River**

| Reach | Total Floodplain Area (ac) | "Water" Parcels (ac) | Unknown Parcels (ac) | Protected Parcels (ac) | % Protected | % Unprotected/ Unknown |
|---|---|---|---|---|---|---|
| 1 - Skiyou | 2,733.4 | 452.4 | 212.1 | 758.1 | 33.2% | 66.8% |
| 2 - Ross Island | 4,388.1 | 573.1 | 356.0 | 1,651.4 | 43.3% | 56.7% |
| 3 - Cockreham | 4,219.8 | 555.0 | 140.1 | 613.9 | 16.8% | 83.2% |
| 4 - Savage | 1,182.5 | 316.5 | 23.6 | 469.7 | 54.2% | 45.8% |
| 5 - Cape Horn | 988.5 | 235.7 | 8.8 | 300.1 | 39.9% | 60.1% |
| 6 - Baker | 557.1 | 262.9 | 8.4 | 6.8 | 2.3% | 97.7% |
| 7 - Jackman | 825.1 | 297.2 | 18.4 | 283.7 | 53.7% | 46.3% |
| 8 - Aldon | 374.1 | 183.1 | 8.8 | 39.3 | 20.6% | 79.4% |
| 9 - Rockport | 662.1 | 239.0 | 60.9 | 320.6 | 75.8% | 24.2% |
| **Total** | **15,931** | **3,115** | **837** | **4,443** | **34.7%** | **65.3%** |

## Reach Evaluation

In addition to providing useful information for restoration planning, the data sets described in the previous section were used to rate floodplain reaches to identify the most important reaches to focus restoration and protection efforts. Reaches were rated based on the conceptual model described in Figure 1, which includes geomorphic potential, existing habitat function, and floodplain impairment as the primary factors. Geomorphic potential was considered the most important factor for identifying high priority reaches because dynamic channels and large floodplain areas are essential for creating and maintaining the floodplain and mainstem rearing habitats that are the focus of this analysis. The other two factors, existing habitat function and level of floodplain impairment were primarily used to distinguish between protection and restoration actions.

In order to rate reaches based on the conceptual model, one or more metrics were used for each factor and reaches were ranked in order based on the results. Reaches were compared on a relative scale, with the top reaches rated as "High" for each factor and the bottom reaches rated as "Low." Each factor in the model is described below along with the metric or metrics that were used to rate the reaches, followed by an evaluation matrix that compiles the rankings for each factor to make a recommendation for restoration and protection priorities.

<u>Geomorphic Potential</u>

Geomorphic potential refers to the potential of the channel within the reach to migrate across its floodplain and create or maintain abundant side channel, off-channel, and complex mainstem edge habitats. These rearing habitats were identified as high priorities in the Skagit Chinook Recovery Plan (SRSC and WDFW 2005) so these dynamic reaches should be targeted for both habitat protection and restoration efforts. Reaches with high geomorphic potential may contain abundant habitat currently that should be protected and are also the most likely to respond to projects that restore floodplain processes by removing or modifying hydromodifications.

The first metric that was used to evaluate geomorphic potential was based on the amount of floodplain area inundated during the 25-yr flow as predicted by the hydrodynamic model developed by PNNL. Inundation areas were normalized by mainstem channel length so that reaches with different channel lengths could be compared. The assumption is that reaches that have wide floodplains and larger inundation areas are likely to have the greatest potential for habitat formation. While all inundated areas may not be used by fish as habitat during flood flows, this metric assumes they provide a good indicator of where channel changes or habitat formation may occur in the future and then persist during lower flow conditions. The 25-yr flow was the highest modeled flow and was selected for this metric because the highest modeled flow captures the largest potential differences in floodplain inundation and therefore river-floodplain interaction between reaches. Flood inundation areas are presented in Map 4, and the results are provided in Table 23. Ross Island, Skiyou, and Cockreham are by far the top reaches based on this metric, with inundation area per channel length for each of these reaches more than double the next rated reach. Baker and Aldon were the two lowest rated reaches, and Rockport was not included in the modeled area.

**Table 23. 25-Yr flow inundation area averaged over mainstem channel length**

| Reach | Main Channel Length (mi) | Inundation Area (ac) | Inundation Area/Channel Length (ac/mi) |
|---|---|---|---|
| **2 - Ross Island** | 6.2 | 4,322 | 701.3 |
| **1 - Skiyou** | 4.7 | 2,684 | 566.9 |
| **3 - Cockreham** | 7.7 | 4,198 | 547.5 |
| **4 - Savage** | 4.7 | 1,228 | 263.3 |
| **5 - Cape Horn** | 4.8 | 1,083 | 225.1 |
| **7 - Jackman** | 3.7 | 770 | 210.0 |
| **6 - Baker** | 4.8 | 737 | 152.0 |
| **8 - Aldon** | 3.2 | 393 | 124.3 |
| **9 - Rockport** | -- | -- | -- |
| **Total** | **39.7** | **15,415** | **388.1** |

The original intention was to use floodplain dynamics based on Beechie et al. (2006) to provide an additional metric to evaluate geomorphic potential. Unfortunately, the results from that part of the analysis did not effectively distinguish straight and island-braided reaches in the Middle Skagit floodplain. Instead, a simpler metric was used, based on the amount of existing off-channel habitat in the floodplain normalized by mainstem channel length. This assumes that dynamic reaches are most likely to form off-channel habitat and that even if they are impaired, reaches with high geomorphic potential will have more floodplain channels currently than reaches with lower geomorphic potential. Data on off-channel habitats are presented in Map 17 and the results are provided in Table 24. The results are very similar to those from the flow inundation area metric, with Ross Island, Cockreham, and Skiyou rated the highest, and Aldon and Baker rated lower. Cape Horn was rated somewhat lower with this metric.

**Table 24. Off-channel area compared to channel length**

| Reach | Main Channel Length (ft) | Off-channel Habitat (sq ft) | Off-channel Area/Channel Length (sq ft/ft) |
|---|---|---|---|
| **2 - Ross Island** | 32,539 | 6,318,082 | 194.2 |
| **3 - Cockreham** | 40,481 | 4,386,435 | 108.4 |
| **1 - Skiyou** | 24,994 | 1,944,316 | 77.8 |
| **4 - Savage** | 24,633 | 1,275,778 | 51.8 |
| **9 - Rockport** | 18,166 | 730,446 | 40.2 |
| **7 - Jackman** | 19,351 | 176,372 | 9.1 |
| **5 - Cape Horn** | 25,410 | 229,505 | 9.0 |
| **8 - Aldon** | 16,713 | 66,094 | 4.0 |
| **6 - Baker** | 25,577 | 30,957 | 1.2 |
| **Total** | **227,864** | **15,157,985** | **66.5** |

Current Habitat Function

Current habitat function refers to the amount of habitat currently functioning in the reach, and is used as a factor in the conceptual model to distinguish between restoration and protection actions. Reaches that have high current habitat function should be targeted for protection, although restoration may still be important if geomorphic potential is high and there are specific impairments that can be addressed. The metric used for evaluating current habitat function was juvenile Chinook capacity of existing habitat normalized by mainstem channel length. Current habitat conditions are presented on Map 13 and results are presented in Table 25.

The Ross Island reach was rated by far the highest for existing habitat, with more than twice as much juvenile Chinook capacity estimated per unit of mainstem channel length than the next rated reach. Savage and Cockreham were the other highest rated reaches, with Aldon, Cape Horn, and Baker rated lowest. The Skiyou reach rated in the middle for existing habitat even though it was rated relatively high for geomorphic potential, suggesting that habitat restoration may increase habitat in this reach.

**Table 25. Reach-level capacity for juvenile Chinook**

| Reach | Mainstem Length (ft) | Total Fish | Fish/Channel Length (#/mi) |
|---|---|---|---|
| 2 - Ross Island | 32,539 | 440,259 | 71,440 |
| 4 - Savage | 24,633 | 157,347 | 33,726 |
| 3 - Cockreham | 40,481 | 218,498 | 28,499 |
| 9 - Rockport | 18,166 | 90,653 | 26,348 |
| 1 - Skiyou | 24,994 | 123,328 | 26,053 |
| 7 - Jackman | 19,351 | 92,158 | 25,146 |
| 8 - Aldon | 16,713 | 72,599 | 22,936 |
| 5 - Cape Horn | 25,410 | 99,347 | 20,643 |
| 6 - Baker | 25,577 | 67,149 | 13,862 |
| **Total** | **227,864** | **1,361,340** | **31,545** |

Floodplain Impairment

Floodplain impairment refers to degradation of existing floodplain function that may be reducing available habitat, or preventing new habitat from forming through natural floodplain processes. It is used as a factor in the conceptual model primarily to distinguish between restoration and protection actions. Reaches with high floodplain impairment should be targeted for restoration, although protection projects may still be important if geomorphic potential is high and there are areas in the reach that have abundant habitat currently or if protection projects are needed to support restoration actions.

The primary metric used to determine floodplain impairment was the percentage of floodplain that has been impaired by hydromodifications. The areas isolated or shadowed by hydromodifications and roads and the surface area of roads were added together to calculate a percent impairment compared to total floodplain area for each reach. Floodplain impairment conditions are presented on Map 14 and the results are provided in Table 26.

The Cockreham reach rated by far the highest for floodplain impairment from hydromodifications and roads, with almost double the percent floodplain impairment as the next rated reach. Skiyou and Cape Horn were the next highest reaches with Ross Island rated fourth. Aldon and Rockport were the lowest rated reaches.

**Table 26. Floodplain impairment from hydromodifications and roads**

| Reach | Floodplain Area (ac) | % Isolated | % Shadowed | % Road | % Floodplain Impairment |
|---|---|---|---|---|---|
| 3 - Cockreham | 4,220 | 45.3% | 17.4% | 3.4% | 66.1% |
| 1 - Skiyou | 2,733 | 10.4% | 22.0% | 1.4% | 33.8% |
| 5 - Cape Horn | 989 | 17.9% | 13.9% | 1.5% | 33.3% |
| 2 - Ross Island | 4,388 | 7.2% | 21.2% | 0.5% | 28.9% |
| 4 - Savage | 1,183 | 5.0% | 11.4% | 1.4% | 17.8% |
| 7 - Jackman | 825 | 0.3% | 12.4% | 1.3% | 14.0% |
| 6 - Baker | 557 | 3.0% | 6.7% | 2.3% | 12.0% |
| 9 - Rockport | 662 | 1.6% | 7.5% | 0.9% | 10.0% |
| 8 - Aldon | 374 | 0.6% | 4.7% | 0.5% | 5.8% |
| **Total** | **15,931** | **17.4%** | **17.2%** | **1.7%** | **36.4%** |

An additional metric used for evaluating floodplain impairment was percent of floodplain that has been cleared of native forests due to human modification. The assumption was that currently forested areas are either functioning now or are likely on a trajectory to providing habitat functions in the future as forested stands mature. But floodplain areas where native forests have been cleared for development, agriculture, or other purposes are impaired and are likely to continue to have poor floodplain function unless they are restored. Current forest conditions are presented on Map 11 and percent of floodplain that is non-forested in each reach are provided in Table 27.

Once again the Cockreham reach has the highest floodplain impairment based on forest conditions, followed by Skiyou and Savage. Ross Island is again rated fourth, with Aldon and Rockport rated the lowest. Savage and Cape Horn switched places with this metric compared to the percent impairment from hydromodifications and roads.

**Table 27. Riparian and floodplain vegetation impairment**

| Reach | Floodplain Area (ac) | Non-forest (ac) | % Non-forest |
|---|---|---|---|
| 3 - Cockreham | 4,220 | 2,244 | 53.2% |
| 1 - Skiyou | 2,733 | 1,219 | 44.6% |
| 4 - Savage | 1,183 | 363 | 30.7% |
| 2 - Ross Island | 4,388 | 1,126 | 25.7% |
| 5 - Cape Horn | 989 | 236 | 23.8% |
| 6 - Baker | 557 | 100 | 18.0% |
| 7 - Jackman | 825 | 141 | 17.1% |
| 8 - Aldon | 374 | 34 | 9.0% |
| 9 - Rockport | 662 | 44 | 6.6% |
| **Total** | **15,931** | **5,506** | **34.6%** |

<u>Reach Evaluation Matrix</u>

The final determination about ranking reaches for further site level project identification and developing restoration and protection strategies for each of the reaches in the Middle Skagit River will be made by the Middle Skagit Criteria Workgroup. In order to provide a recommendation to that group based on this analysis, a simple relative ranking system was used to apply the conceptual model described in Figure 1. For each factor, reaches were ordered based on each of the evaluation metrics and the top three reaches were rated "High," the lowest three were rated "Low," and the remaining three were rated as "Medium." These factors were combined into a reach evaluation matrix that rates priority reaches for protection and restoration (Table 28). The percentage of protected lands in each reach was also used to provide a similar rating for current habitat protection and is included on the matrix for reference although it was not used to rate the reaches for protection or restoration.

**Table 28. Reach evaluation matrix**

| Reach | Geomorphic Potential | Habitat Function | Flooplain Impairment | Protected lands | Protect | Restore |
|---|---|---|---|---|---|---|
| **1 - Skiyou** | High | Med | High | Med | Med/High | High |
| **2 - Ross Island** | High | High | Med | High | High | Med/High |
| **3 - Cockreham** | High | High | High | Low | High | High |
| **4 - Savage** | Med | High | Med | Med | Med/High | Med |
| **5 - Cape Horn** | Low | Low | High | Med | Low | Low |
| **6 - Baker** | Low | Low | Low | Low | Low | Low |
| **7 - Jackman** | Med | Med | Med | High | Med | Med |
| **8 - Aldon** | Low | Low | Low | Low | Low | Low |
| **9 - Rockport** | Med | Med | Low | High | Med | Med |

The top three reaches for geomorphic potential, Skiyou, Ross Island, and Cockreham were rated as high for both restoration and protection actions. As it turns out these dynamic reaches were also rated relatively high for the other factors, so habitat function and floodplain impairment were used to modify the recommendation for protection versus restoration. Skiyou was rated "Med/High" for protection because current habitat function was rated as medium, and Ross Island was rated "Med/High" for restoration because floodplain impairment was rated as medium. Savage was also rated "Med/High" for protection because even though it was rated medium for geomorphic function it was rated high for current habitat function.

This simple rating system has shortcomings because it does not rely on absolute thresholds to determine current or potential function for any of the factors, so some reaches with similar ratings may actually have large differences for some of the factors, and other reaches may be fairly close for some factors but receive different ratings. For example, Ross Island rated by far the highest for current habitat function and geomorphic potential but has the same rating as Skiyou and Cockreham. It might make more sense to give this one reach the highest overall rating for targeting restoration and protection efforts. Cockreham rated by far the highest for current floodplain impairment but is rated similar for impairment as Cape Horn and Skiyou. Cockreham received a high rating for protection, but given the substantial floodplain impairments, it is likely that significant restoration will need to be combined with protection actions. Lastly, some reaches that were rated lower in the matrix may still provide important functions, for example providing a small amount of an essential habitat type may be important for fish migrating between more productive areas. So habitat protection and restoration actions should still be considered in these reaches.

## Recommendations for Additional Site Level Analysis

Once the highest priority reaches are identified, the intention of the Middle Skagit Assessment is to identify and prioritize specific restoration and protection projects at a site level within those reaches. It was beyond the scope of this analysis to complete that work, however many of the data layers developed for this analysis can provide useful information for site level evaluation. This section provides a discussion and some examples of how existing data might be used for project identification and makes recommendations for additional data that could be collected to support site level project evaluation.

Use of existing data

Some of the data sets used in this analysis were primarily intended for reach level evaluation and may not have sufficient resolution to identify or evaluate all site level restoration and protection projects. However, some appropriate uses for these data sets are described below.

*Hydrodynamic model*. The FV-COM hydrodynamic model provides information about velocity and flow inundation areas for each of the floodplain reaches. The model was developed using existing information on topography and bathymetry from 2006 USGS LiDAR and ACOE bathymetry cross sections, which do not accurately represent existing conditions, so more detailed topography and bathymetry information would be needed to model precise site level responses to individual projects. However, the current model could be useful for guiding specific project development and to identify potential project sites that may warrant more detailed data collection and model runs. In addition, at a reach level the model likely has enough accuracy to prioritize areas within the floodplain with the assumption that lower elevation areas inundated at lower flow conditions are more likely to develop complex mainstem edge and off-channel habitat relative to areas that are only inundated at higher flow conditions. For example, it could make sense to target restoration and protection to areas modeled to be inundated during the 2-yr flow and place less emphasis on areas that are only inundated at higher flows.

*Riparian and floodplain vegetation data*. While detailed vegetation characteristics can be difficult to distinguish with aerial photographs, the information collected is accurate enough to distinguish between areas that are cleared or devoid of vegetation from areas that are forested. This information can be used along with habitat and parcel data to identify specific projects. For example, existing cleared or developed areas that contain mainstem or off-channel habitat could be targeted for restoration and information on forest and habitat conditions on private properties could be used to prioritize protection projects.

*Habitat data*. The location of existing habitat features can be useful for identifying both restoration and protection projects. The habitat information collected for this analysis were based on 2009 aerial photographs, which is useful for identifying the amount of habitat at a reach level, but have some limitations in identifying habitat features at a site level. Some smaller habitat features obscured by forest canopy cover were not captured in the data, and flow conditions are difficult to accurately capture from photographs, so some larger habitat features that were identified may actually have relatively low wetted areas or may not have connectivity with mainstem habitats at the times of year when fish would use them. Additional field surveys could refine this information, but the existing data layers provide a good start for identifying the location of habitats and for targeting field surveys.

*Floodplain impairment data*. The field-surveyed information provides a complete inventory of existing hydromodifications that could be targeted for restoration actions. However, comparing the relative merits of project sites may prove difficult without more detailed evaluation. The floodplain impairment metrics that quantify isolated and shadowed areas provide a useful index of impairment at a reach level, but are not sufficient to evaluate the amount of habitat that could be restored at a site level from individual hydromodifications. It could provide a useful start for identifying potential projects for additional analysis and when combined with other data, such as floodplain development, roads or parcel information, may be used as a first step in identifying which projects are more likely to feasible. Then more detailed evaluation could be completed just for those projects.

Map 18 provides an example of how data sets may be combined in GIS to identify protection projects in the Ross Island reach. The map shows areas modeled to be inundated in the 2-yr flow condition and shows existing protected parcels. With the assumption that more frequently flooded areas have greater habitat potential, then protection projects could be targeted for areas that are not currently protected within the modeled flow area. Further refinements (not shown on the map) could be used, such as targeting areas with existing habitats and intact riparian vegetation condition. Areas that are influenced by existing hydromodifications may have a lower priority, or would need to be combined with projects that restore floodplain function.

Map 19 provides an example of how data sets may be combined in GIS to identify riparian restoration projects in the Ross Island reach. This map show all cleared or developed areas within the reach and also shows 2-yr flow inundation and existing habitats. Riparian projects could be identified for cleared areas within 150 feet of existing habitat and also within the flood inundation area for other areas of the floodplain. Specific habitat features may need additional field verification, but these existing data can provide a good start on project identification.

<u>Additional data collection</u>

This section provides recommendations for additional data collection that may be useful for additional site level analysis.

*Project feasibility*. Rating individual projects may require additional information about project feasibility and costs. Projects that would likely affect numerous properties, homes and extensive infrastructure may be very expensive or politically challenging to accomplish. If these projects have substantial habitat benefits then they should likely be pursued, but information about costs and social factors affecting project success or appropriate indicators of those factors should be incorporated into the project ranking process.

*Field check for existing habitat features*. The habitat information mapped from aerial photographs for this analysis has some limitations as described above. More accurate habitat information could be obtained for one or two priority reaches by field checking mapped habitats to ensure they have connectivity with the mainstem river and to identify smaller habitat features that may have been missed in the photograph analysis.

*Hydrodynamic modeling for individual hydromodifications.* Additional FV-COM model runs can be completed to evaluate changes in habitat or floodplain conditions that would be expected from removing or modifying individual hydromodifications. This could be done to determine which structures would result in the greatest gains in floodplain habitat and to identify property and infrastructure that could be affected by a project. It could also identify hydromodifications that provide relatively limited flood or erosion protection and could be restored to provide mainstem edge habitat benefits with limited or no effect on surrounding property or infrastructure. These model runs need to be done individually for each hydromodification considered, and will likely need additional data on topography, bathymetry, floodplain sediment conditions, and locations of relic channels to refine the model grid for use at a site level.

*Photo survey to identify historic channels and migration patterns*. Mapping historic channel locations from aerial photographs and other historic records could be useful for several purposes. Channel migration rates can help identify areas that are highly dynamic and therefore more responsive to restoration projects, locations of historic channels provide information about where specific habitats could be restored or created, and migration patterns can be useful for evaluating channel response to restoration projects.

*Fish modeling of potential new habitat*. If hydrodynamic modeling or other analyses are conducted to identify habitat conditions that would be expected to develop from individual projects, additional fish modeling could be completed so that projects can be compared based on likely benefits to fish.

## References

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

Beamer, E.M., T. Beechie, B. Perkowski, and J. Klochak. 2000. Application of the Skagit Watershed Council's Strategy -- River Basin Analysis of the Skagit and Samish Basins: Tools for Salmon Habitat Restoration and Protection. Skagit Watershed Council, Mount Vernon, WA.

Beechie, T.J., M. Liermann, M.M. Pollock, S. Baker, and J. Davies. 2006. Channel Pattern and River-Floodplain Dynamics in Forested Mountain Systems. Geomorphology 78: 124-141.

Federal Emergency Management Agency. 1989. Flood Insurance Rate Map for Skagit County, WA (numerous panels). FEMA, Washington D.C.

Hayman, R.A., E.M. Beamer, and R.E. McClure. 1996. FY 1995 Skagit River Chinook Restoration Research. Report Prepared for NWIFC. Skagit System Cooperative, LaConner, WA.

Integrated Coastal Ocean Modeling Group (ICOM). 2010. Hydrodynamic Modeling for Assessment of Floodplain Restoration Potential on the Middle Skagit River, WA. Report to Skagit Watershed Council. Pacific Northwest National Laboratory, Seattle, WA.

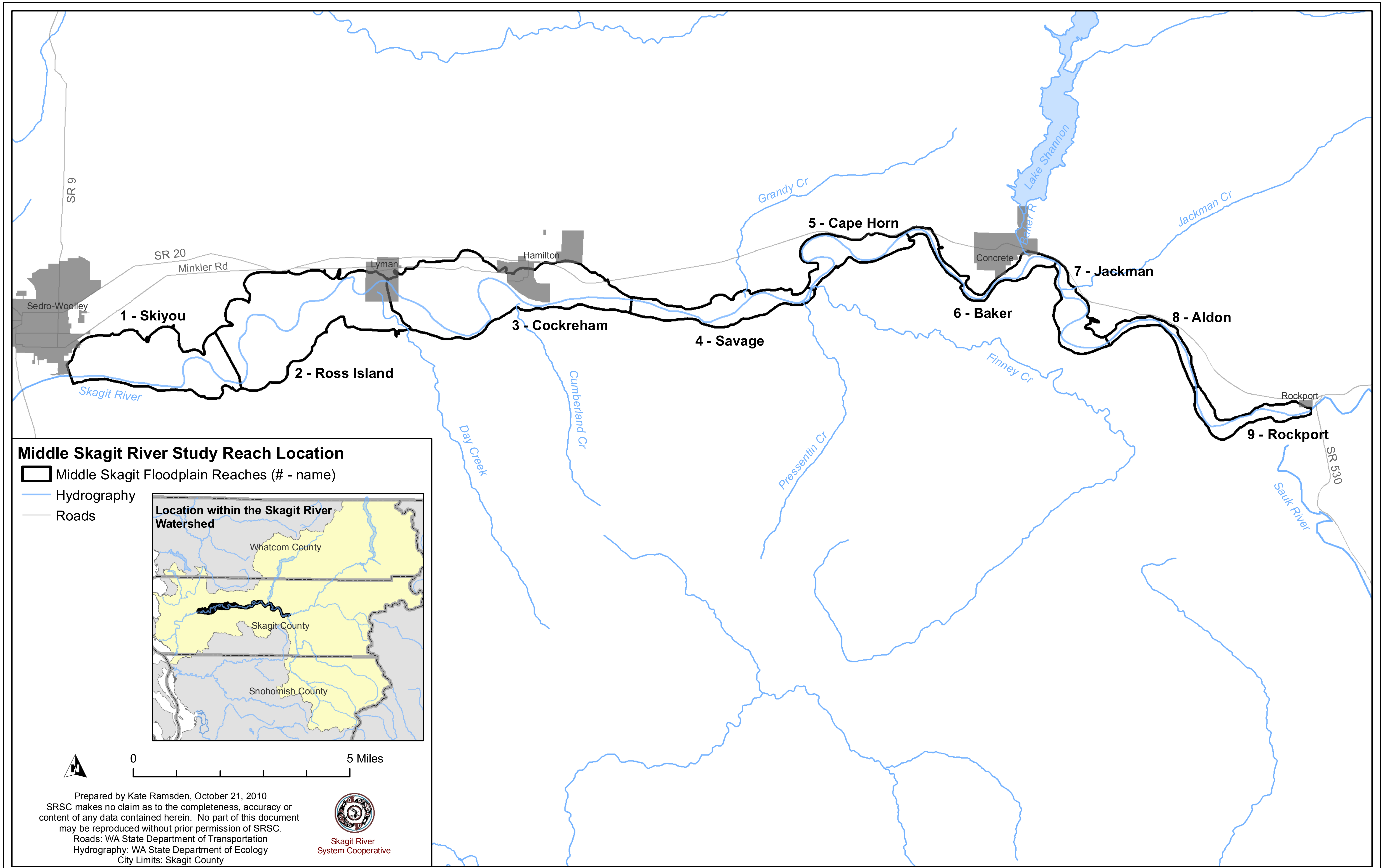
Interagency Advisory Committee on Water Data. 1982. Guidelines for Determining Flood Flow Frequency, Bulleten # 17B of the Hydrology Subcommittee. USGS, Reston, Virginia.

Ramsden, K. 2008. Unpublished GIS data compiled for wildlife management purposes. Skagit River System Cooperative, LaConner, WA.

The Upper Skagit Indian Tribe (USIT). 2010. Assessment and Inventory of Hydromodified Bank Structures in the Skagit River and Floodplain. Report to the Skagit Watershed Council. The Upper Skagit Indian Tribe, Natural Resources Division, Sedro-Woolley, WA.

SRSC and WDFW. 2005. Skagit Chinook Recovery Plan. Skagit River System Cooperative, LaConner, WA.

## Appendix A. Middle Skagit Reach Level Analysis Maps



Middle Skagit River Study Reach Location
Middle Skagit Floodplain Reaches (# - name)
Hydrography
Roads
Location within the Skagit River Watershed
Whatcom County
Skagit County
Snohomish County
0
5 Miles
Prepared by Kate Ramsden, October 21, 2010
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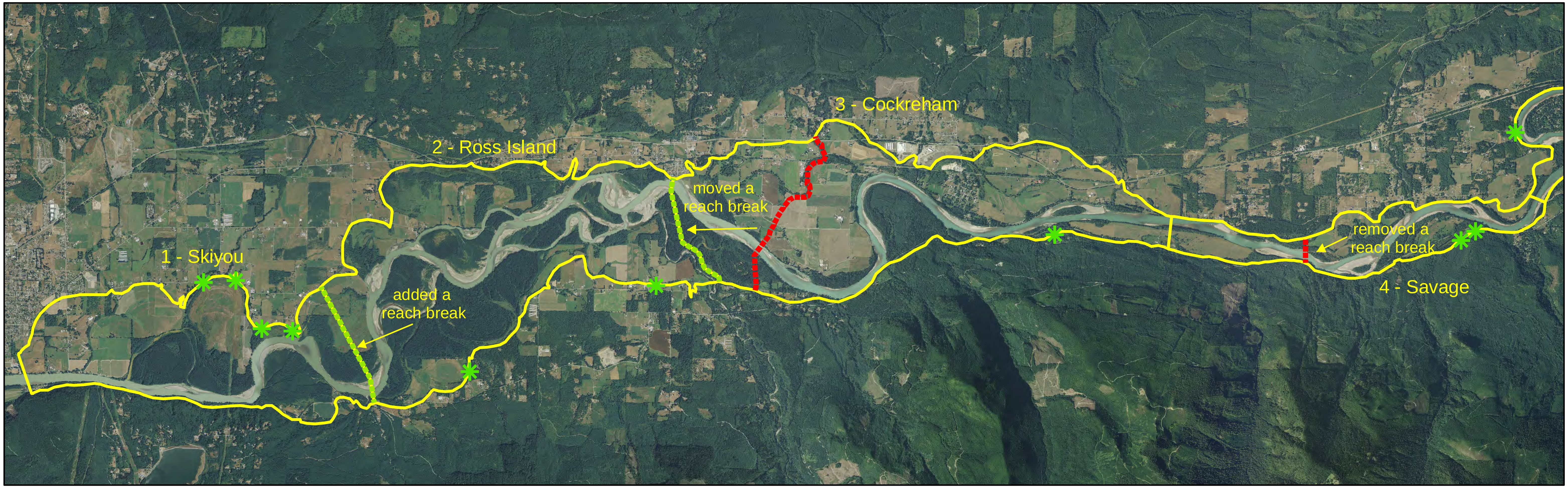
Roads: WA State Department of Transportation
Hydrography: WA State Department of Ecology
City Limits: Skagit County
Skagit River System Cooperative
1 - Skiyou
2 - Ross Island
3 - Cockreham
4 - Savage
5 - Cape Horn
6 - Baker
7 - Jackman
8 - Aldon
9 - Rockport
Sedro-Woolley
Lyman
Hamilton
Concrete
Rockport
SR 9
SR 20
SR 530
Minkler Rd
Skagit River
Day Creek
Cumberland Cr
Grandy Cr
Pressentin Cr
Finney Cr
Lake Shannon
Baker R
Jackman Cr
Sauk River




## Middle Skagit Floodplain Reach Modifications

- Floodplain reaches
- Reach break added
- Reach break removed
- Floodplain boundary modified

0 1 2 Miles

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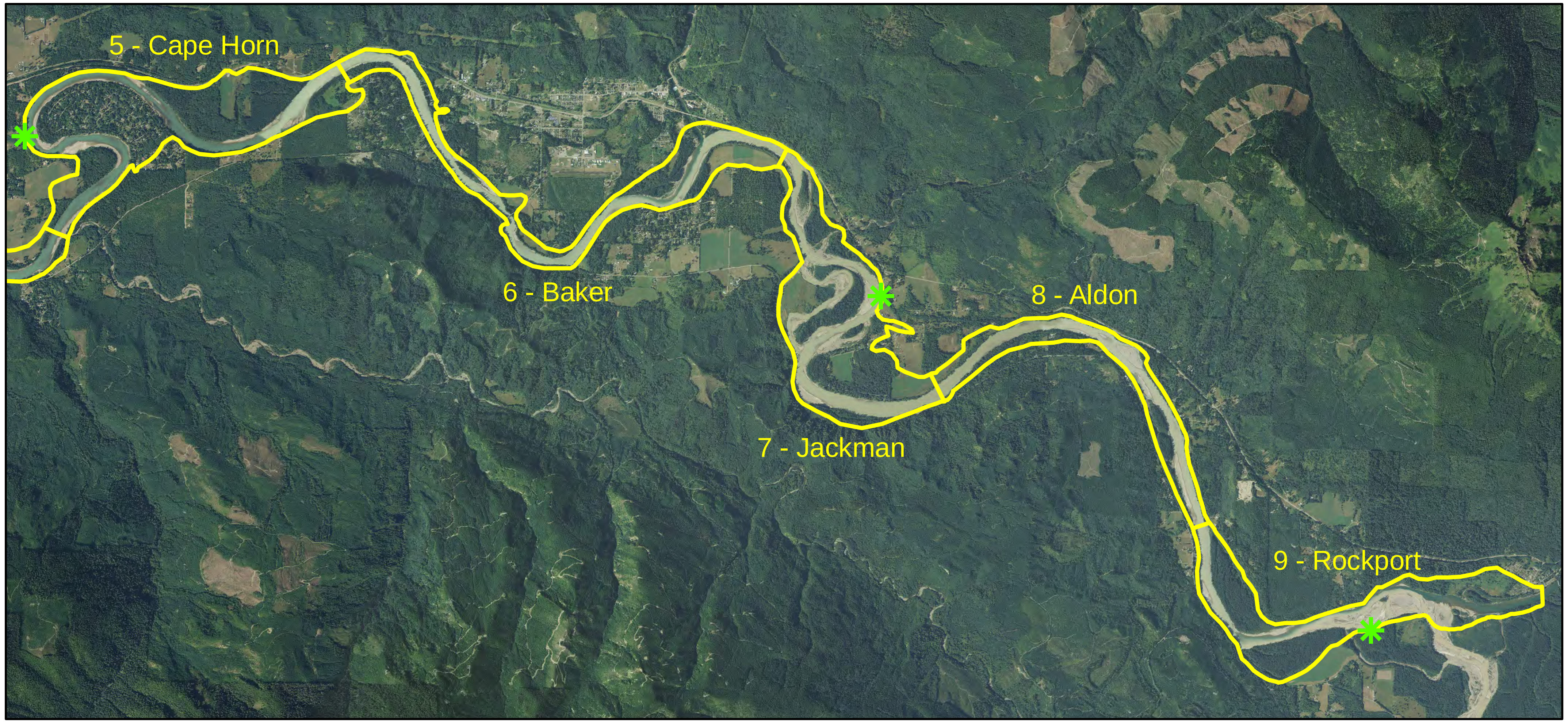
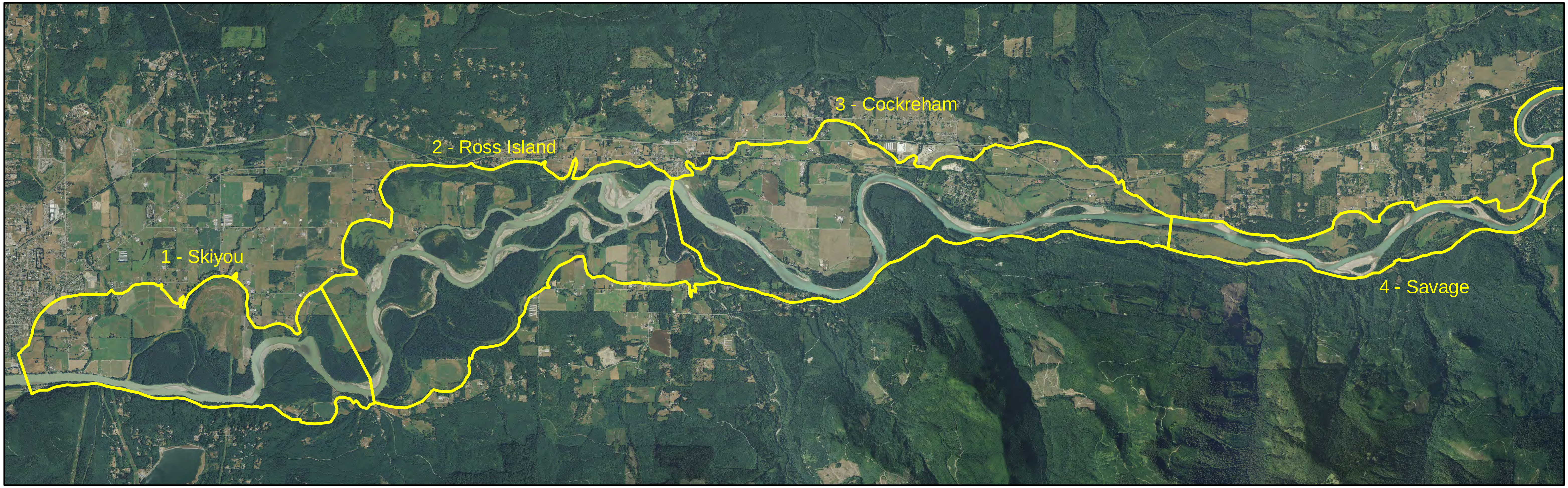
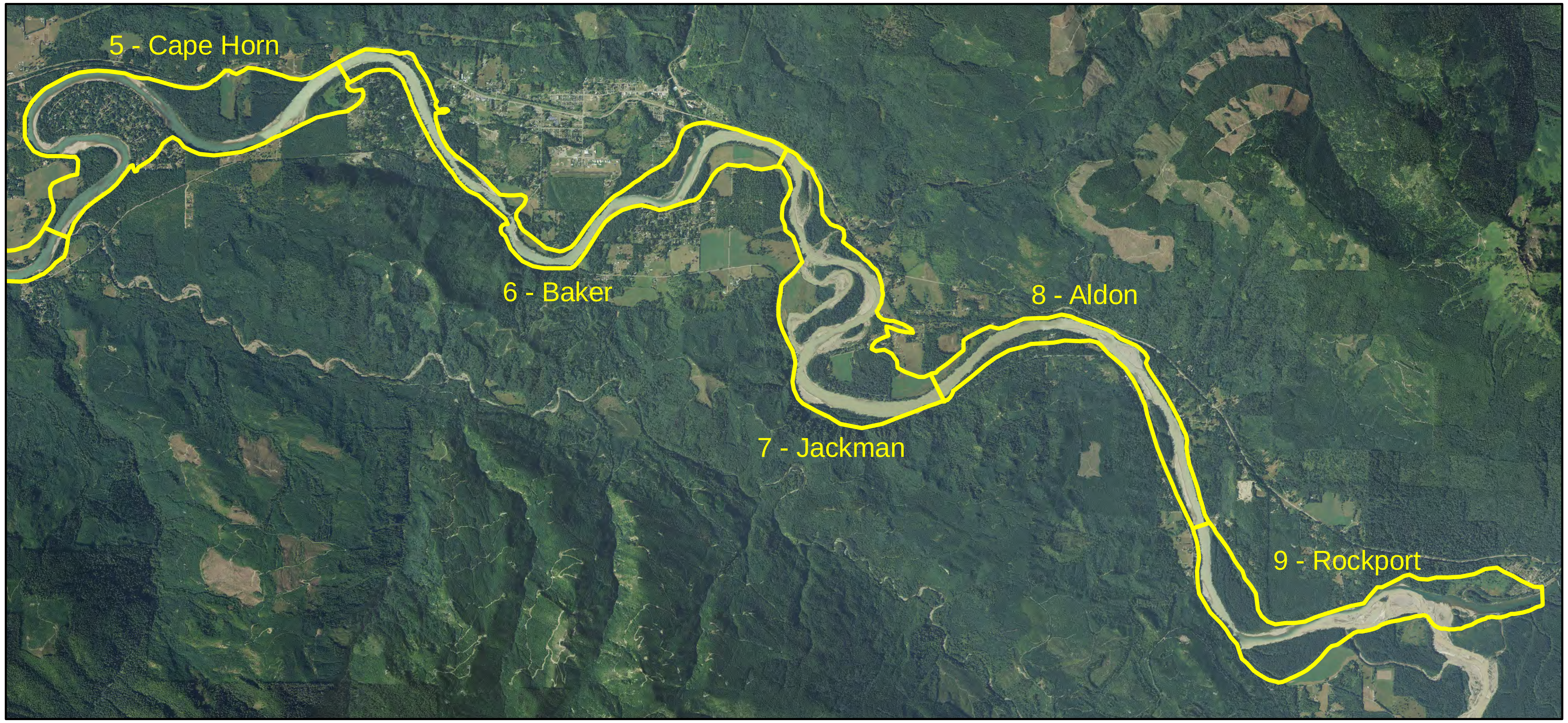
2009 Air Photo: USDA-NAIP

Skagit River System Cooperative






## Middle Skagit Floodplain Reaches

Floodplain reaches

0 1 2 Miles

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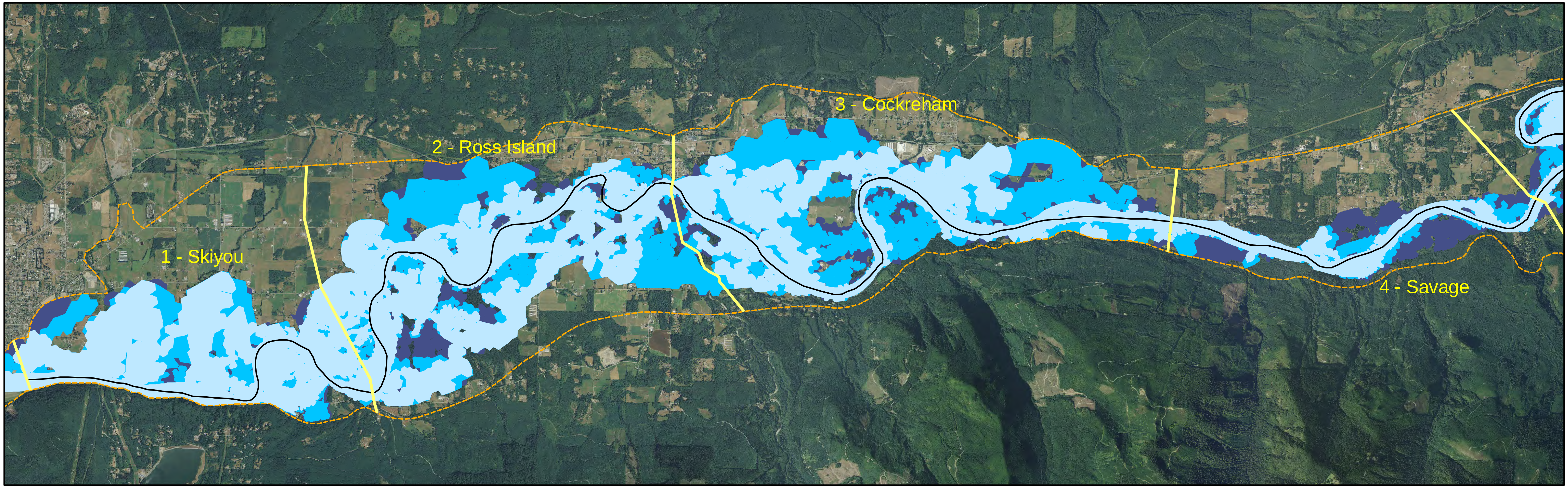


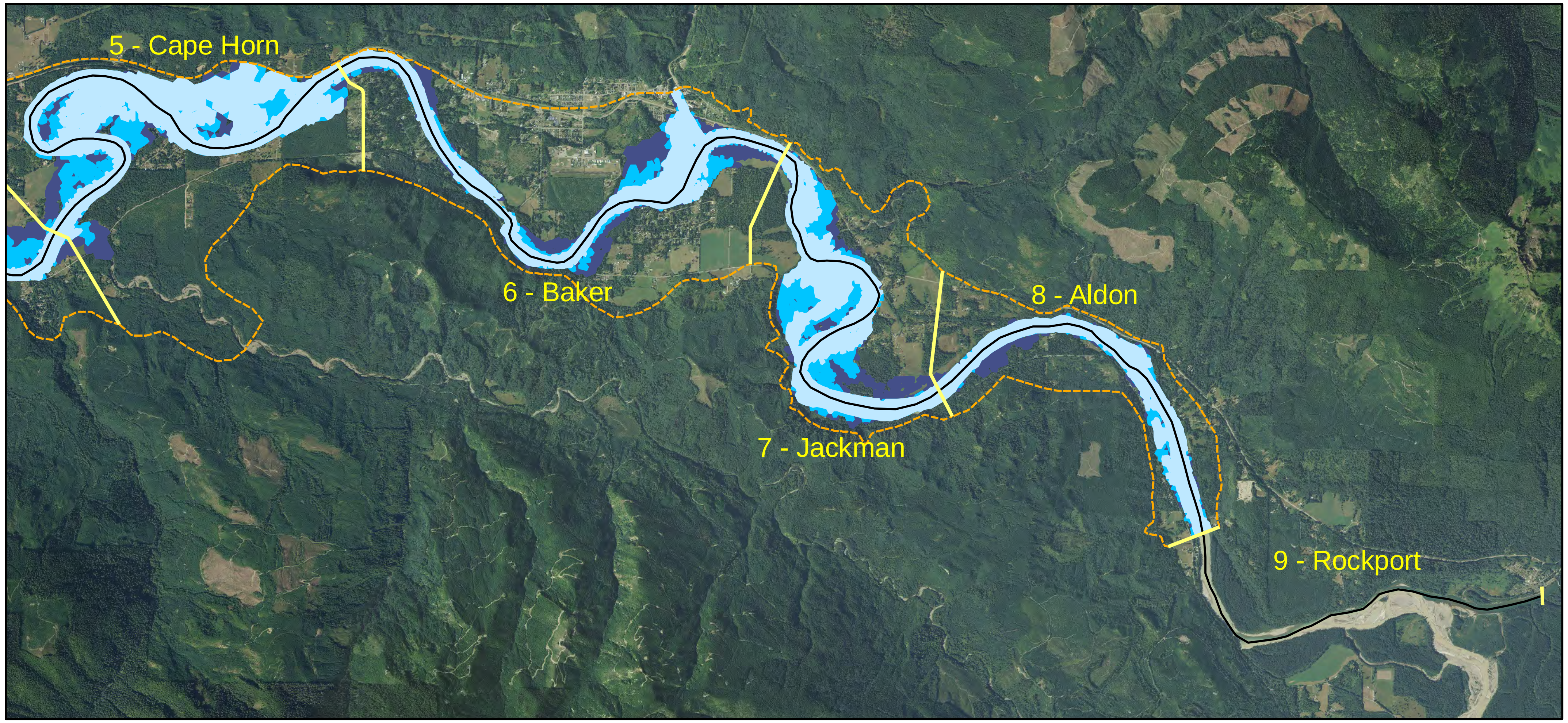


**Middle Skagit Hydrodynamic Model**
**Area of Inundation Under Existing Conditions**

- Floodplain reach breaks
- Model boundary
- Mainstem centerline
- 2-year flow inundation area
- 5-year flow inundation area
- 25-year flow inundation area

N

0 1 2 Miles

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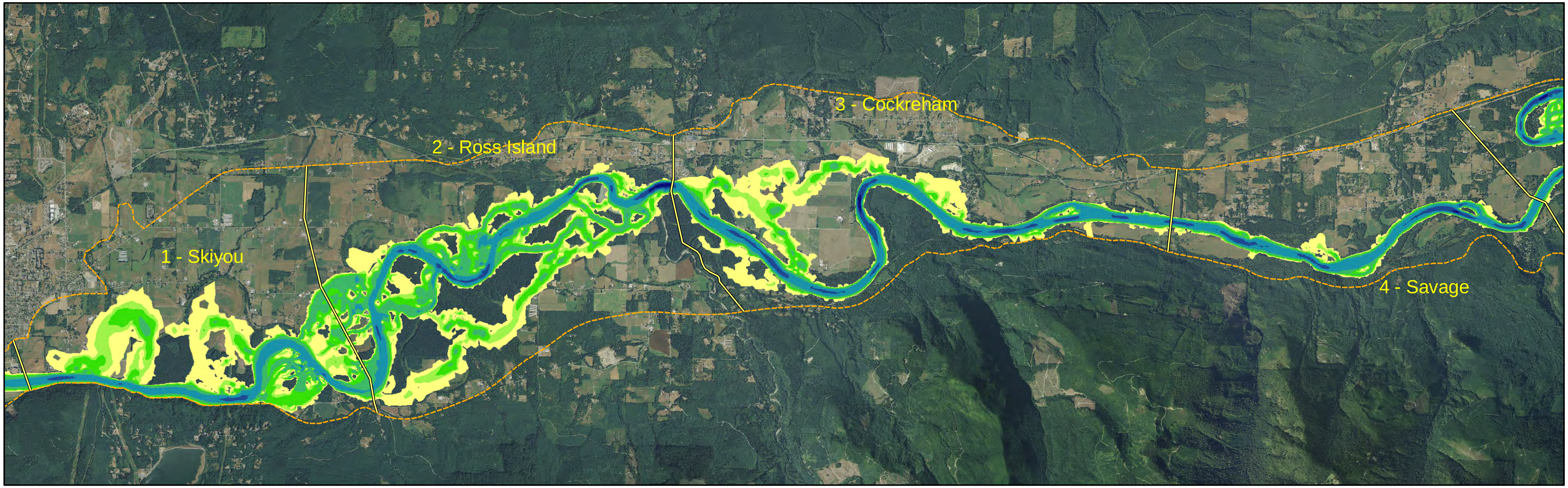
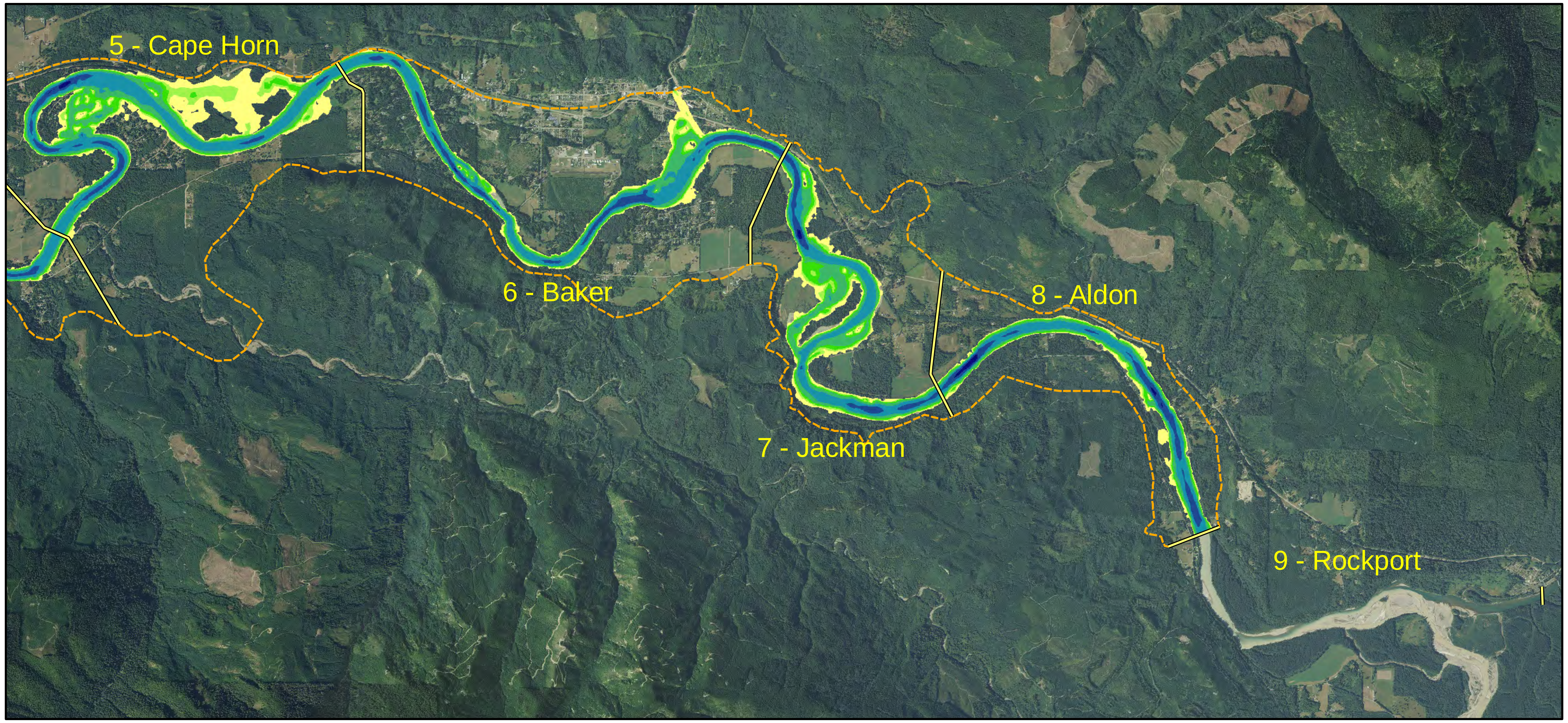
2009 Air Photo: USDA-NAIP
Model results generated from FV-COM model developed by PNNL.

Skagit River System Cooperative




**Middle Skagit Hydrodynamic Model**
**Velocity Under Existing Conditions**
**for the 2-Year Flow**

Floodplain reach breaks

Model boundary

Velocity

- < 0.5 ft/s
- 0.5 - 1.0 ft/s
- 1.0 - 2.0 ft/s
- 2.0 - 5.0 ft/s
- 5.0 - 10.0 ft/s
- 10.0 - 15.0 ft/s
- > 15.0 ft/s

0 1 2 Miles

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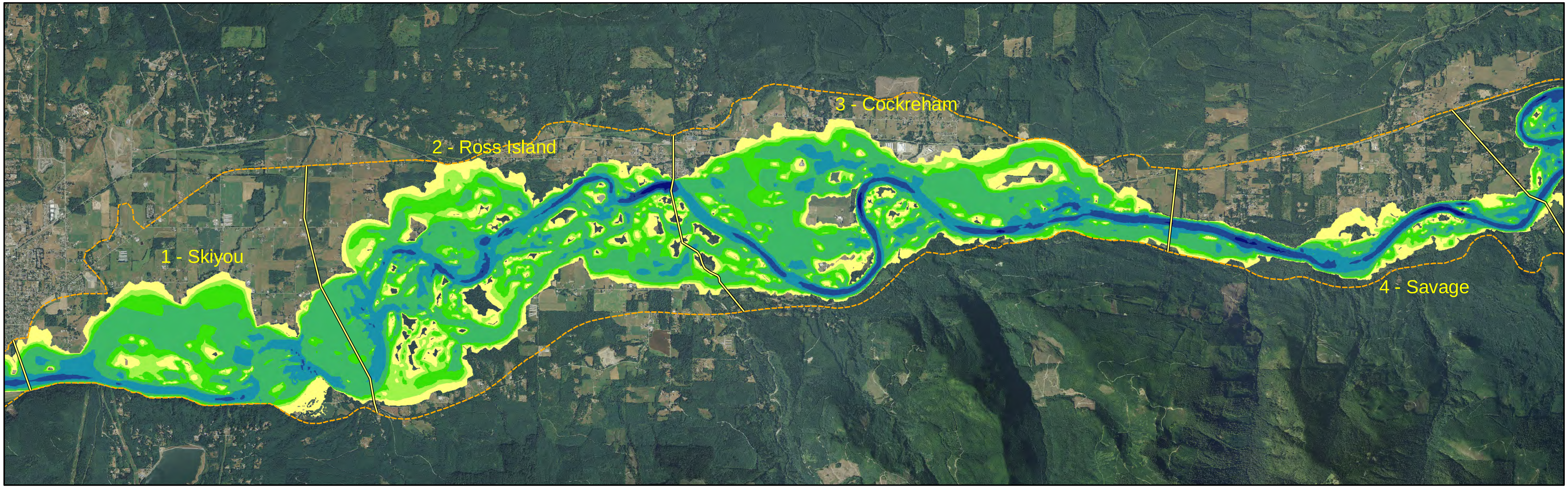


## Middle Skagit Hydrodynamic Model Velocity Under Existing Conditions for the 25-Year Flow

Floodplain reach breaks
Model boundary

Velocity
- < 0.5 ft/s
- 0.5 - 1.0 ft/s
- 1.0 - 2.0 ft/s
- 2.0 - 5.0 ft/s
- 5.0 - 10.0 ft/s
- 10.0 - 15.0 ft/s
- > 15.0 ft/s

N

0 1 2 Miles

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Model results generated from FV-COM model developed by PNNL.

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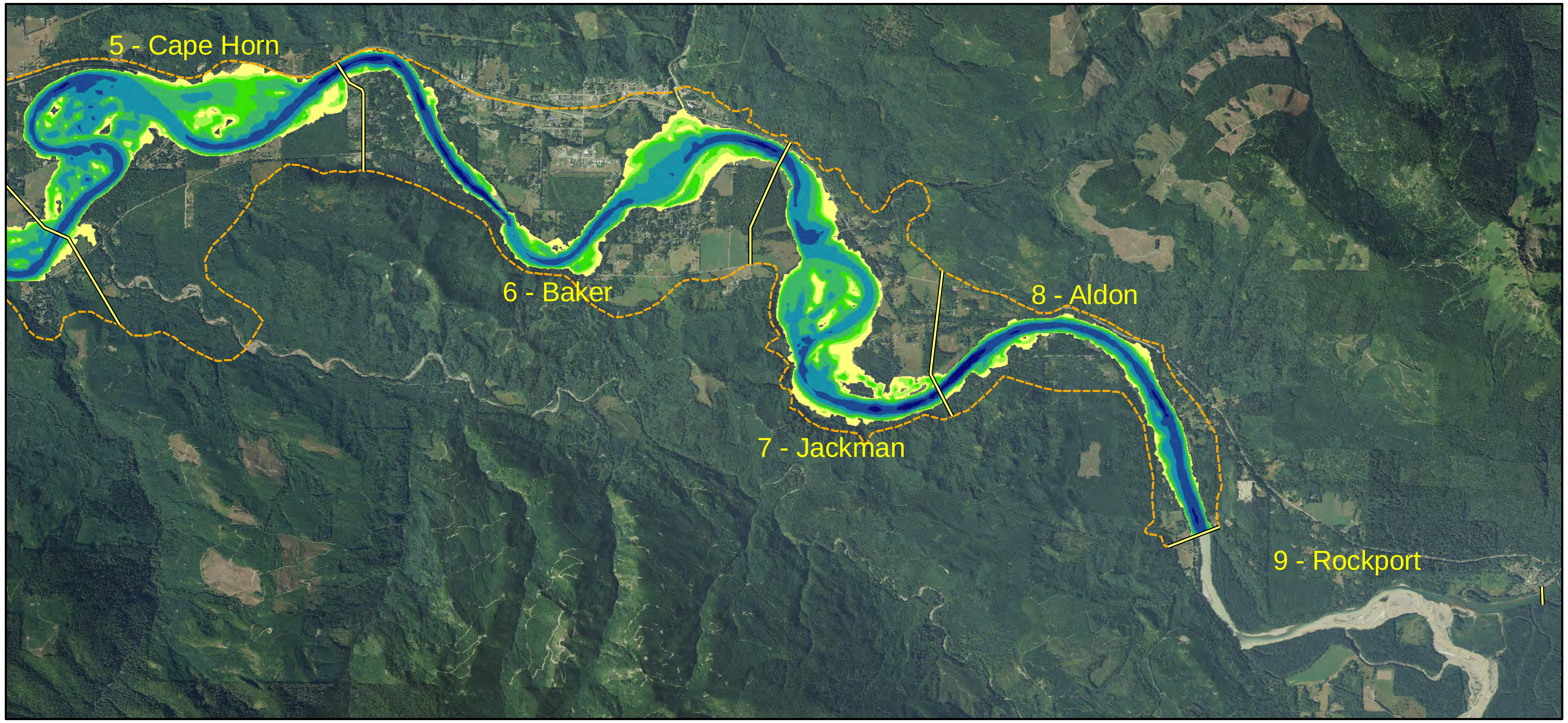

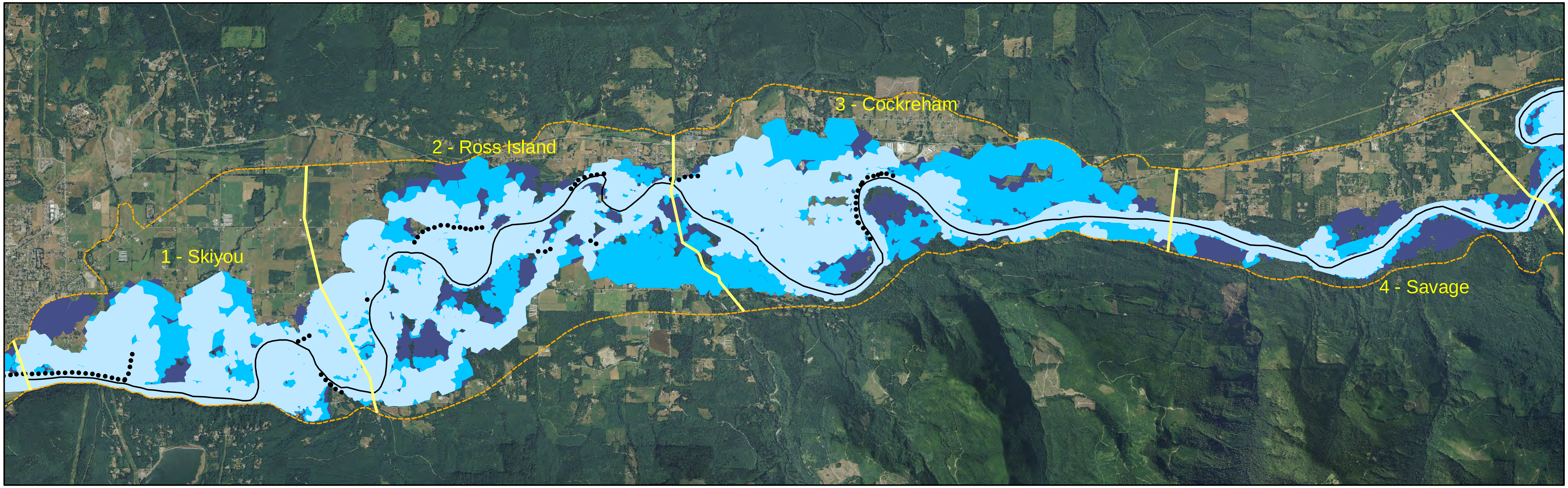


**Middle Skagit Hydrodynamic Model**
**Area of Inundation Under Alternative Conditions**

- Floodplain reach breaks
- Model boundary
- Mainstem centerline
- Hydromodifications removed from model
- 2-year flow inundation area
- 5-year flow inundation area
- 25-year flow inundation area

0 1 2 Miles

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Model results generated from FV-COM model developed by PNNL

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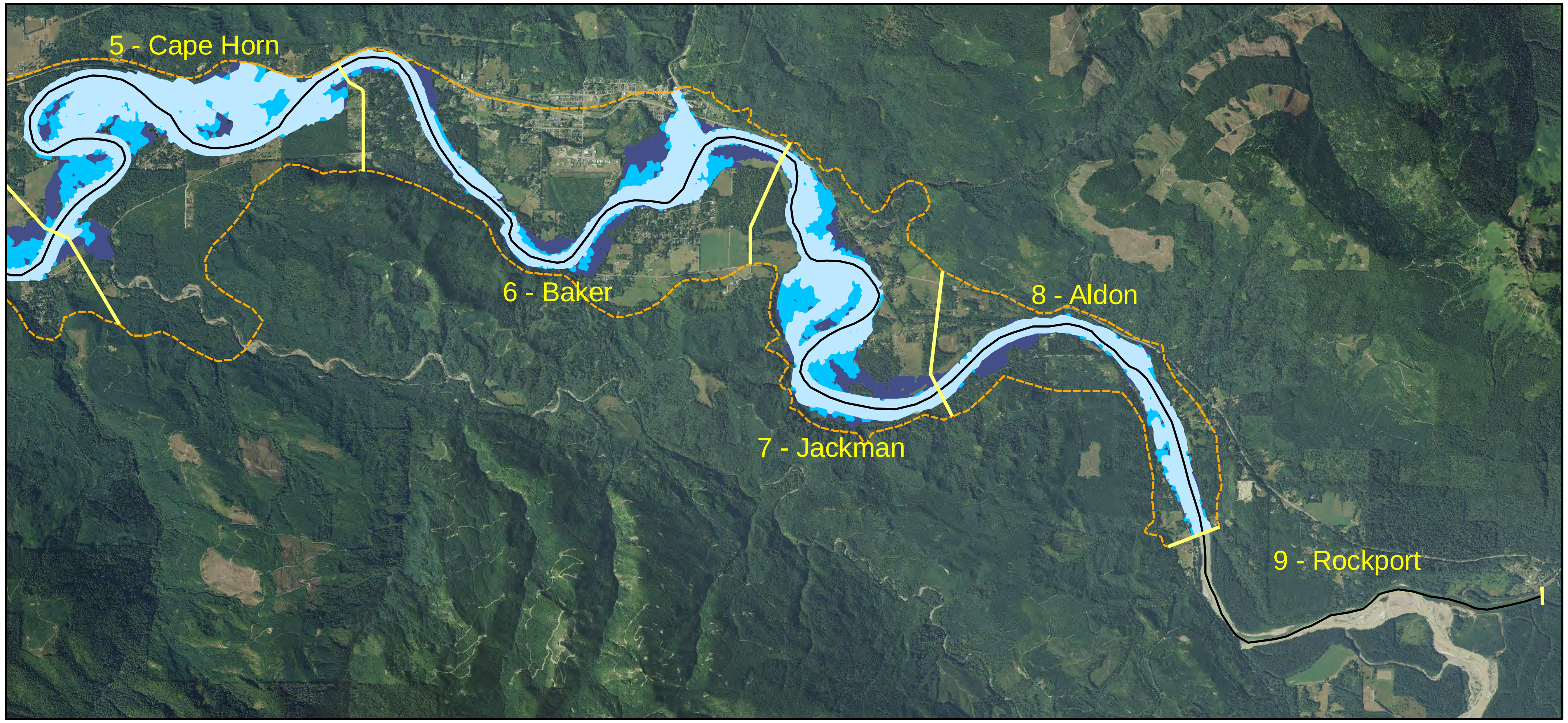

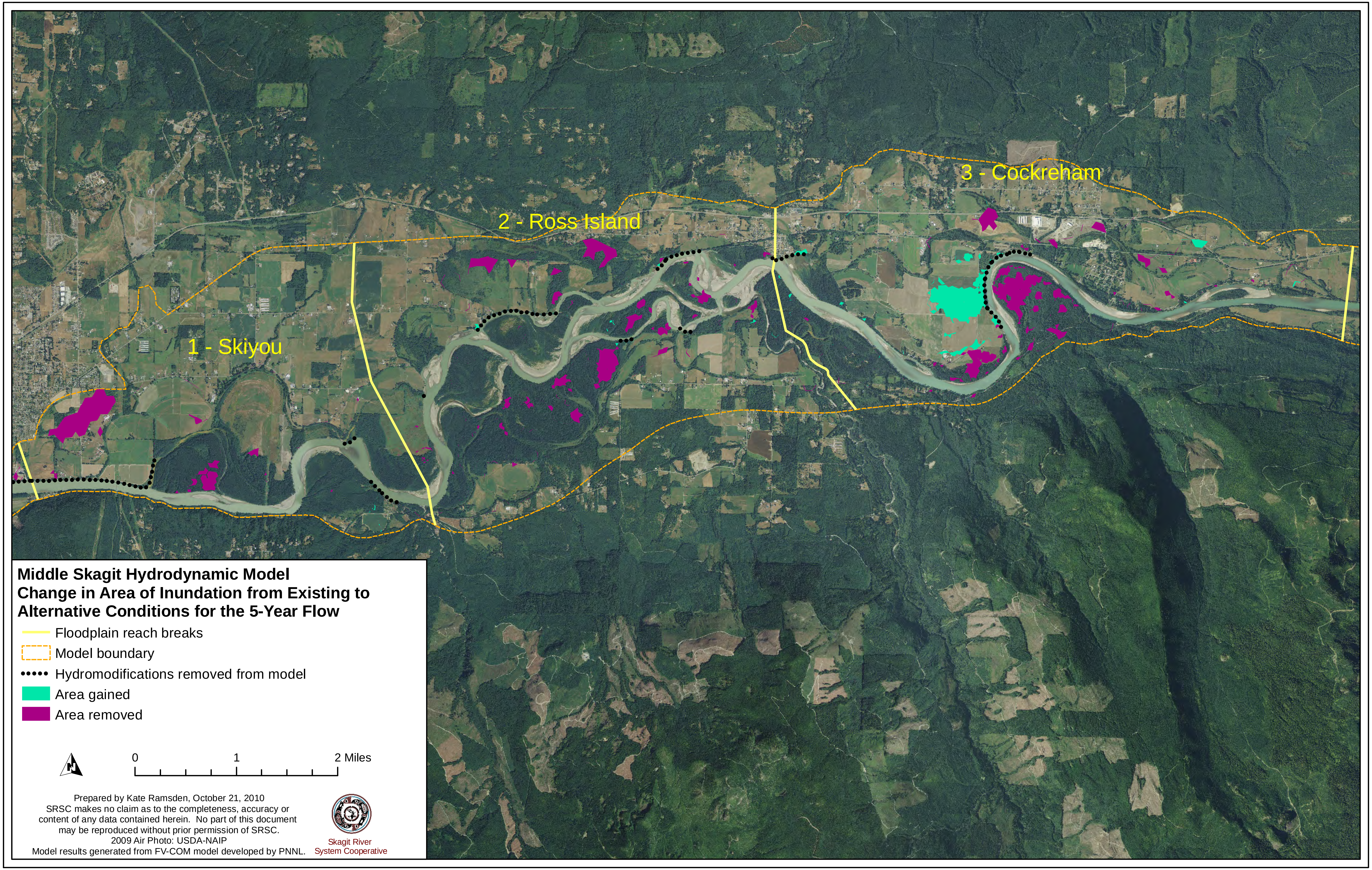

3 - Cockreham
2 - Ross Island
1 - Skiyou
Middle Skagit Hydrodynamic Model
Change in Area of Inundation from Existing to Alternative Conditions for the 5-Year Flow
Floodplain reach breaks
Model boundary
Hydromodifications removed from model
Area gained
Area removed
0
1
2 Miles
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2009 Air Photo: USDA-NAIP
Model results generated from FV-COM model developed by PNNL.
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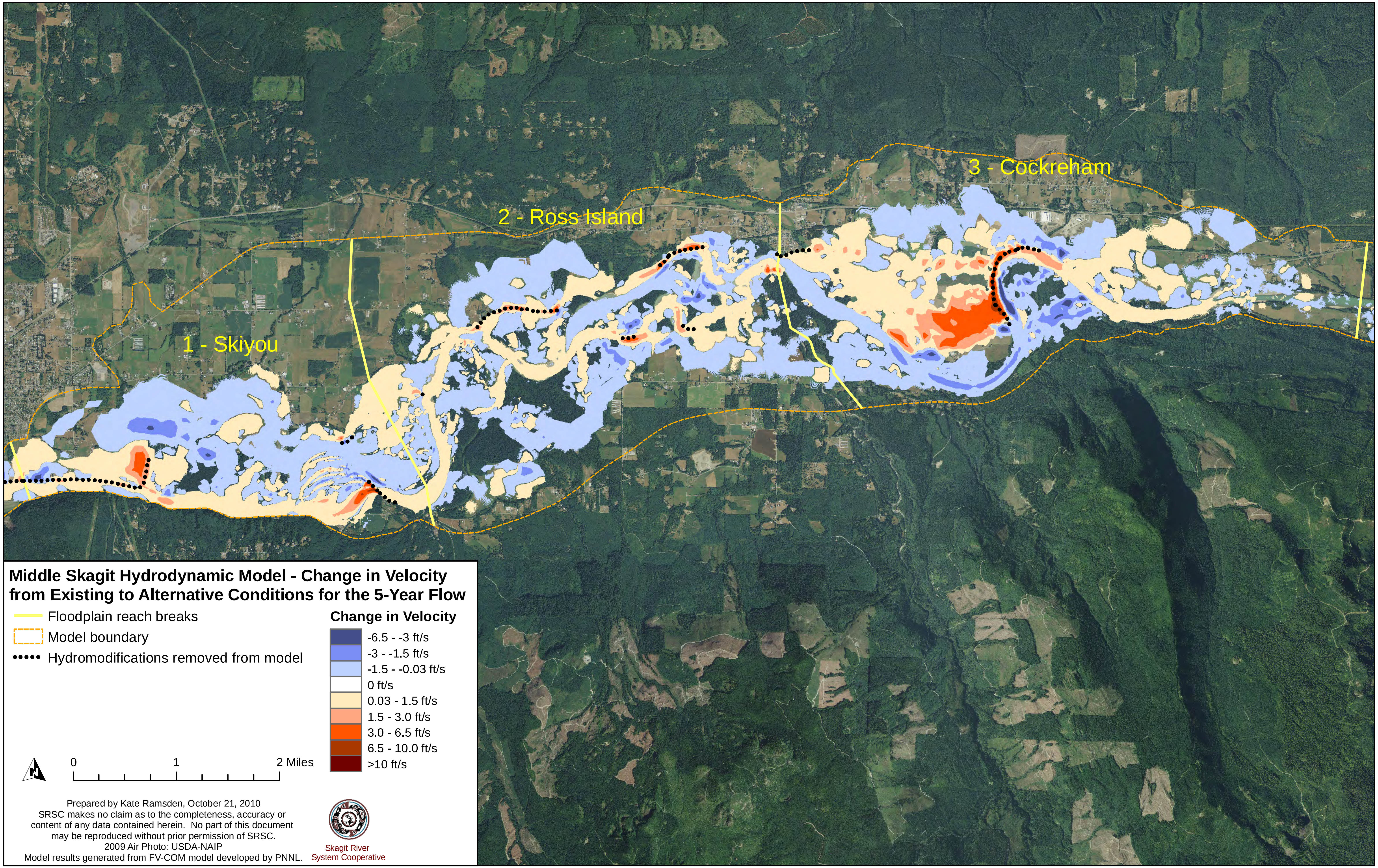
3 - Cockreham
2 - Ross Island
1 - Skiyou
Middle Skagit Hydrodynamic Model - Change in Velocity from Existing to Alternative Conditions for the 5-Year Flow
Floodplain reach breaks
Model boundary
Hydromodifications removed from model
Change in Velocity
-6.5 - -3 ft/s
-3 - -1.5 ft/s
-1.5 - -0.03 ft/s
0 ft/s
0.03 - 1.5 ft/s
1.5 - 3.0 ft/s
3.0 - 6.5 ft/s
6.5 - 10.0 ft/s
>10 ft/s
0
1
2 Miles
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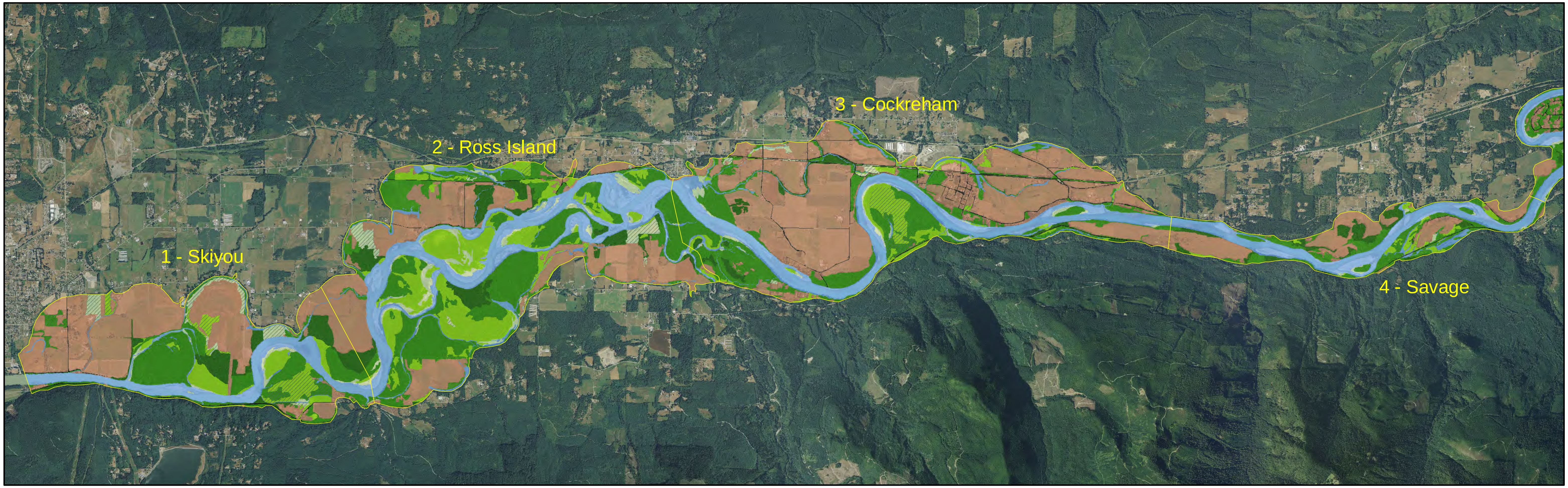
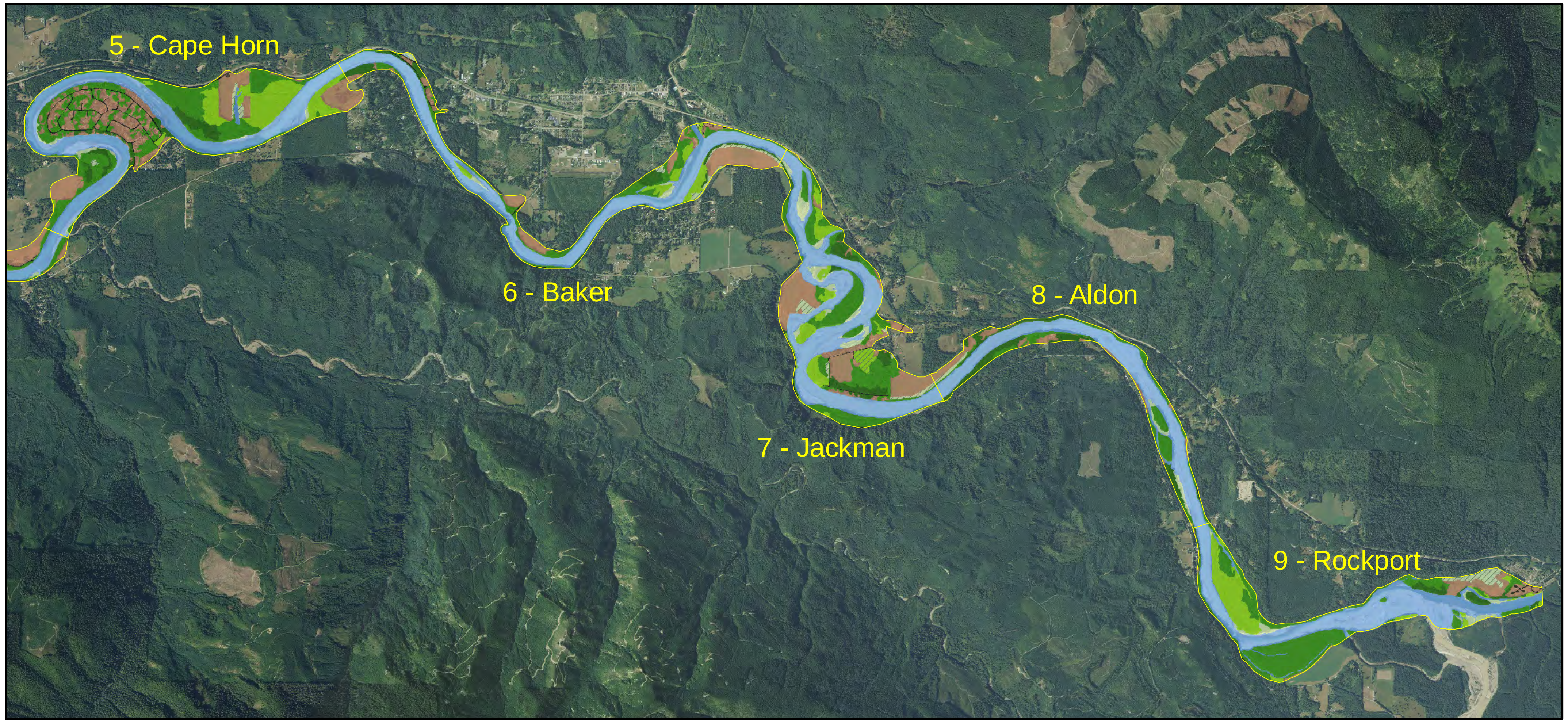



**Middle Skagit Floodplain Dynamics and Vegetation Mapping**

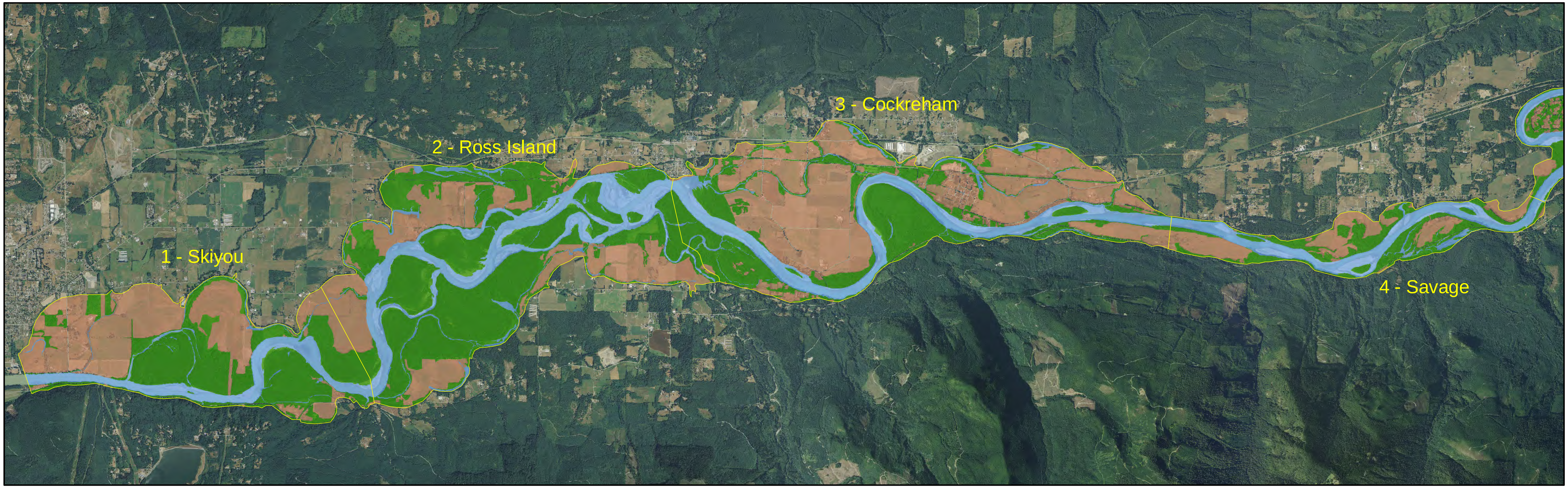
- Floodplain reaches
- Active channels
- Unforested
- Roads
- V1 - newly established vegetation
- V2 - crown diameter <16 ft
- V3 - crown diameter 16 - 33 ft
- V4 - crown diameter >33 ft
- Human-modified forest vegetation

0 1 2 Miles

Prepared by Kate Ramsden, January 27, 2011

2009 Air Photo: USDA-NAIP

Skagit River System Cooperative




## Middle Skagit Floodplain Vegetation Forested vs Unforested

Floodplain reaches
Active channels
Unforested
Forested

0 1 2 Miles

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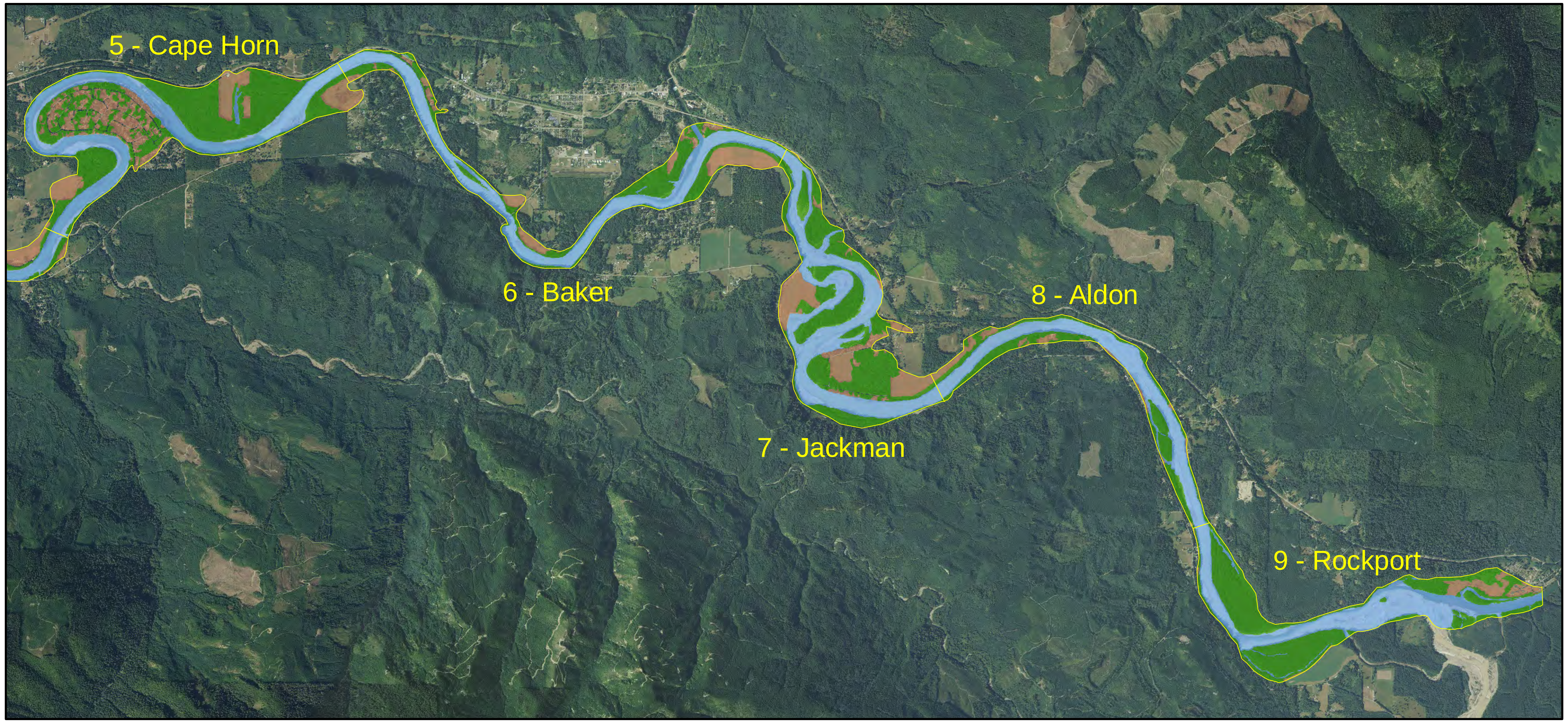

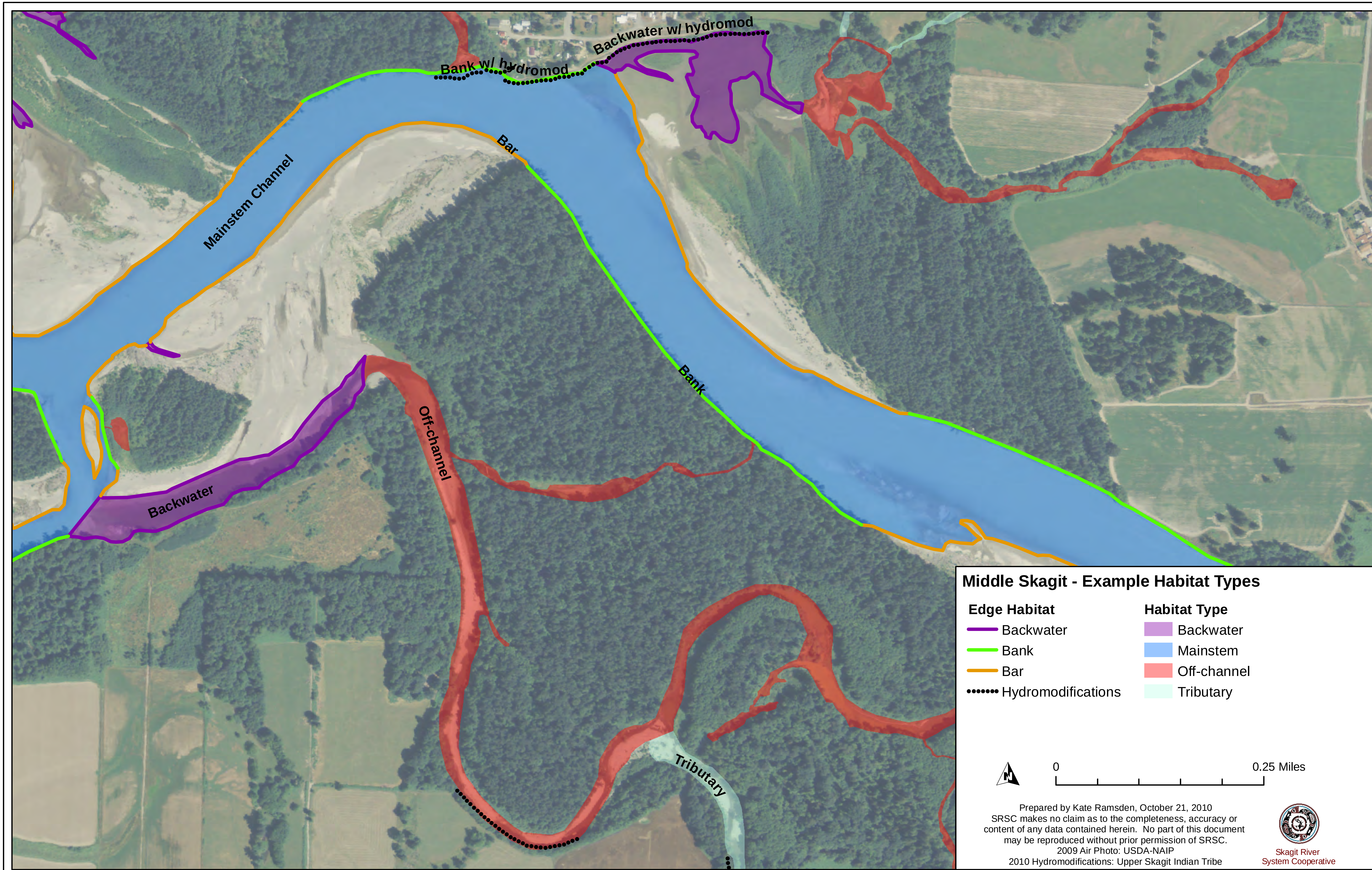

Backwater w/ hydromod
Bank w/ hydromod
Bar
Mainstem Channel
Bank
Off-channel
Backwater
Tributary
Middle Skagit - Example Habitat Types
Edge Habitat
Backwater
Bank
Bar
Hydromodifications
Habitat Type
Backwater
Mainstem
Off-channel
Tributary
0
0.25 Miles
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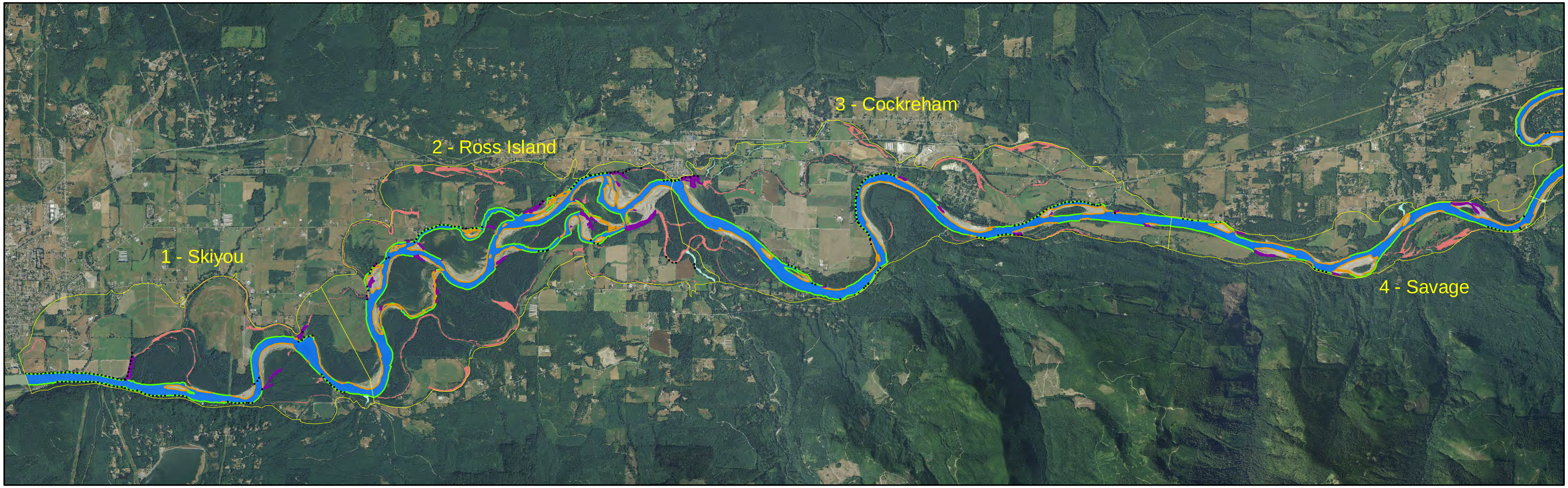
2009 Air Photo: USDA-NAIP
2010 Hydromodifications: Upper Skagit Indian Tribe
Skagit River System Cooperative




## Middle Skagit Habitat Types

Floodplain reaches

**Edge Habitat**

- Backwater
- Bank
- Bar
- Hydromodifications

**Habitat Type**

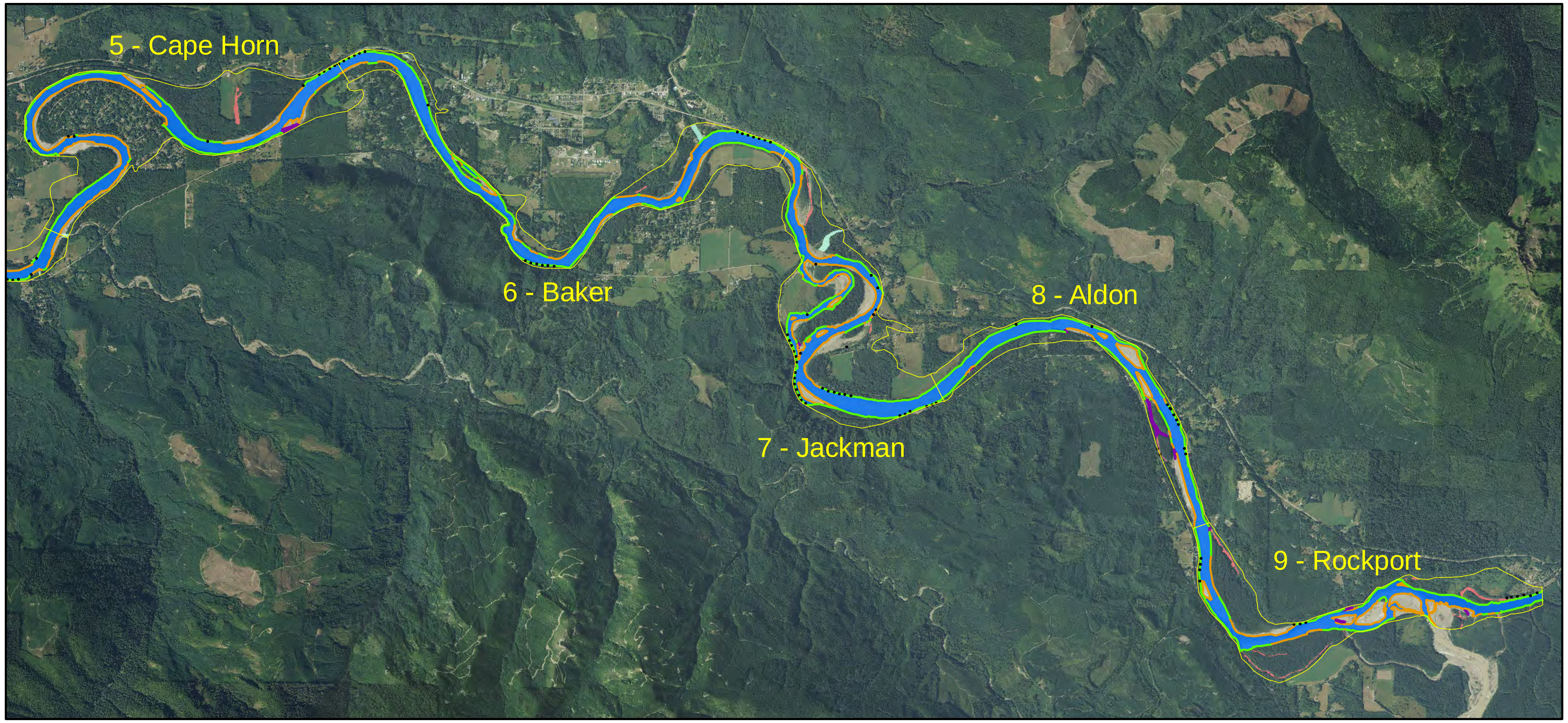
- Backwater
- Mainstem
- Off-channel
- Tributary

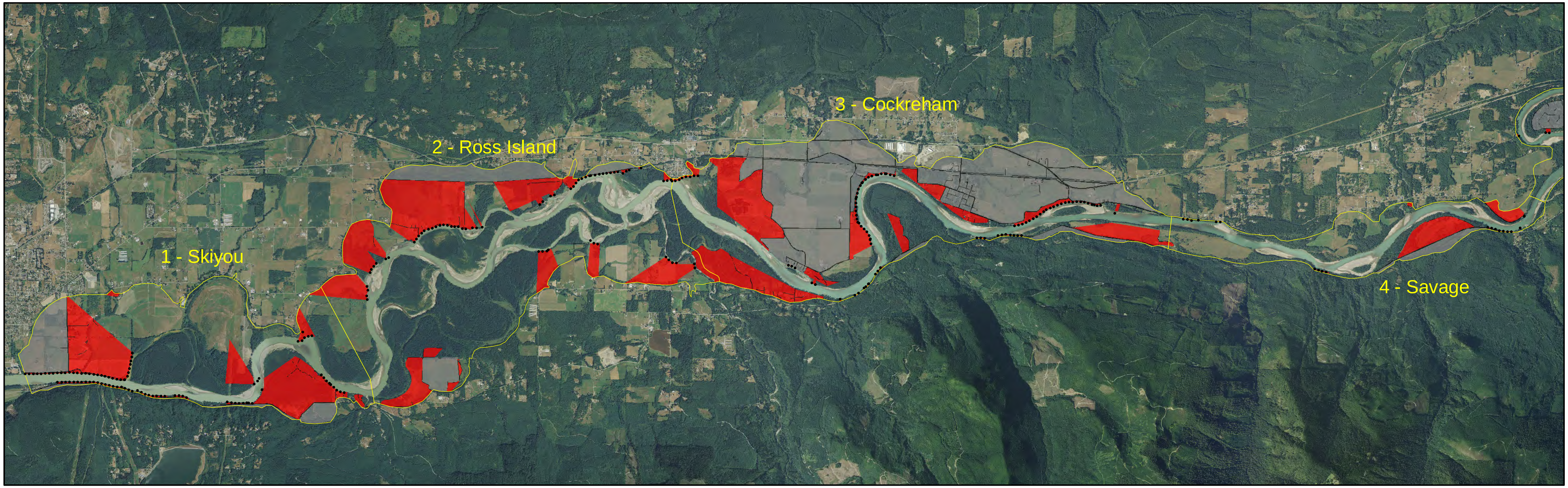
0 1 2 Miles

Prepared by Kate Ramsden, October 21, 2010

2009 Air Photo: USDA-NAIP
2010 Hydromodifications: Upper Skagit Indian Tribe

Skagit River System Cooperative






## Middle Skagit Floodplain Impairment

Floodplain reaches

**Impairment Type**

Isolated

Shadowed (by hydromod and/or road)

Hydromodifications

Roads

0 1 2 Miles

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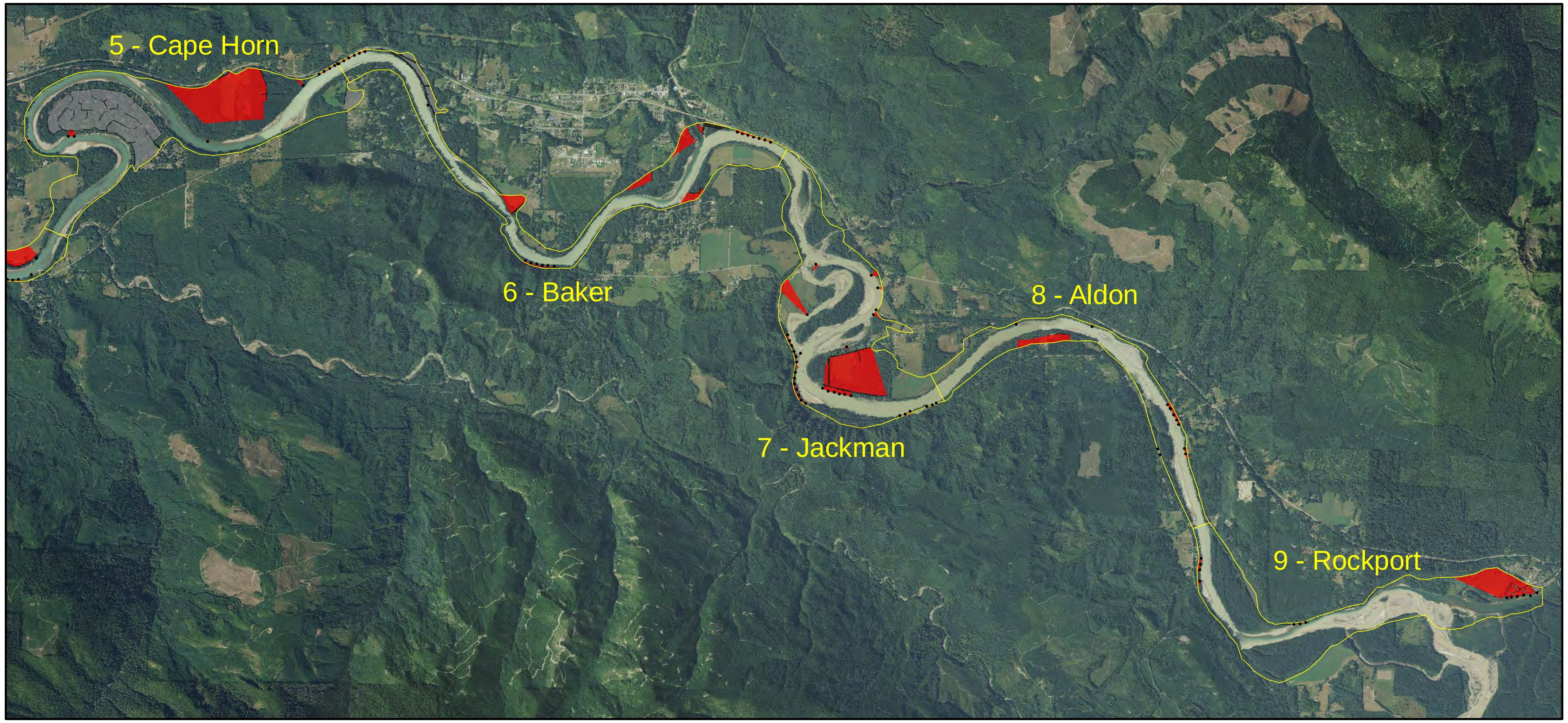
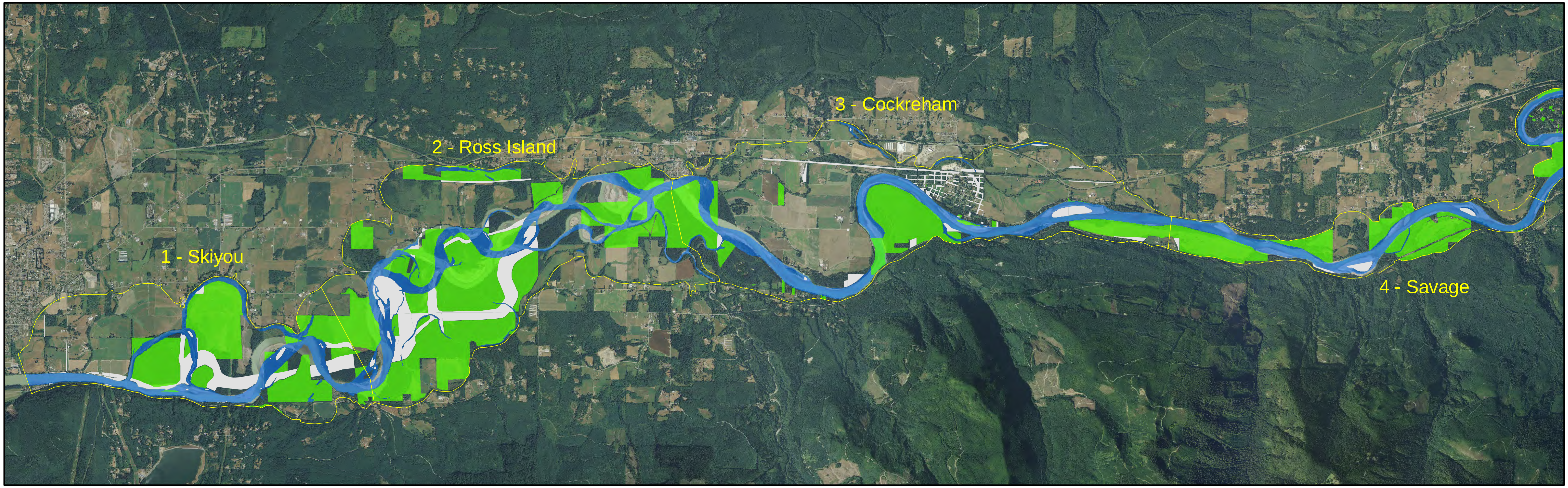
2010 Hydromodifications: Upper Skagit Indian Tribe

Skagit River System Cooperative






## Middle Skagit Parcels in Protected Status

- Floodplain reaches
- Water parcels
- Protected parcels
- Unknown parcels

0 1 2 Miles

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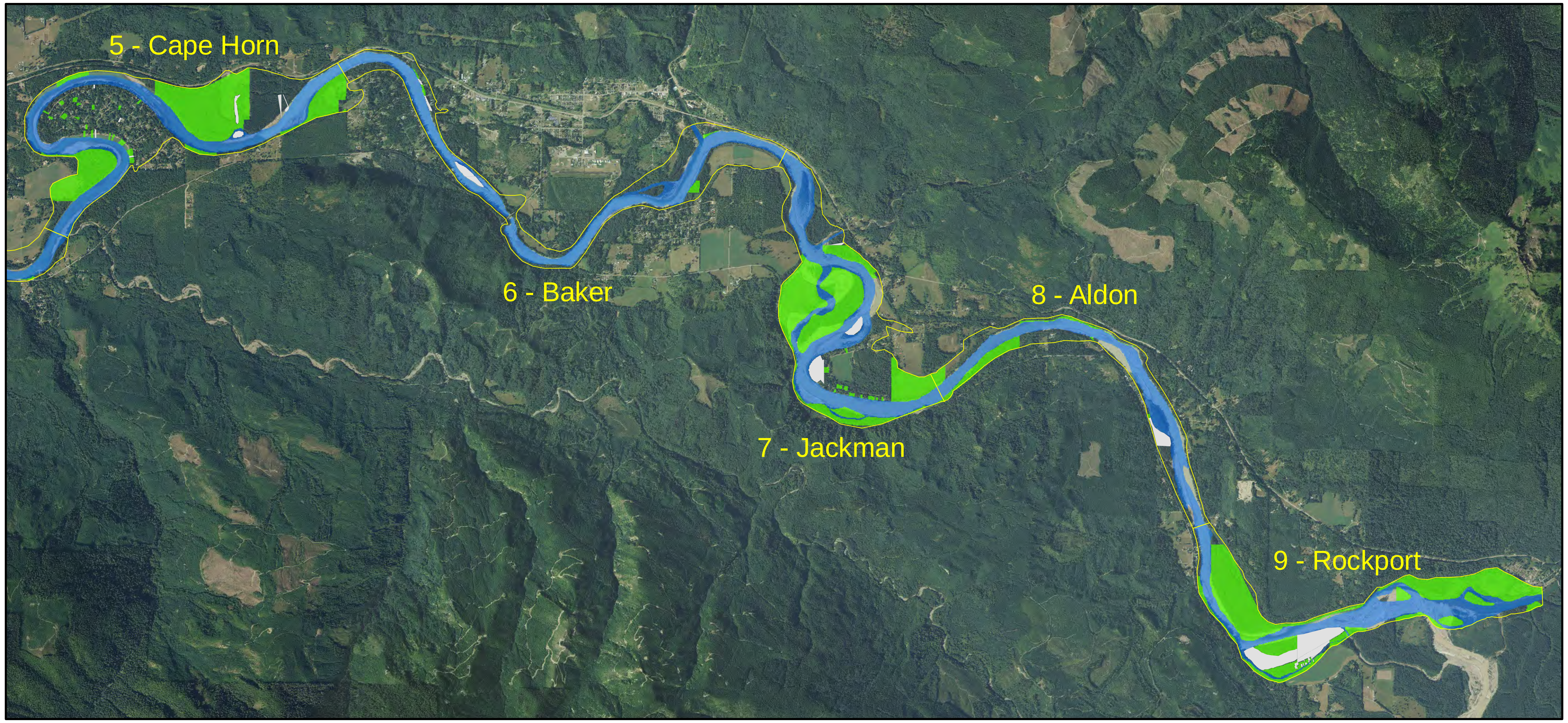
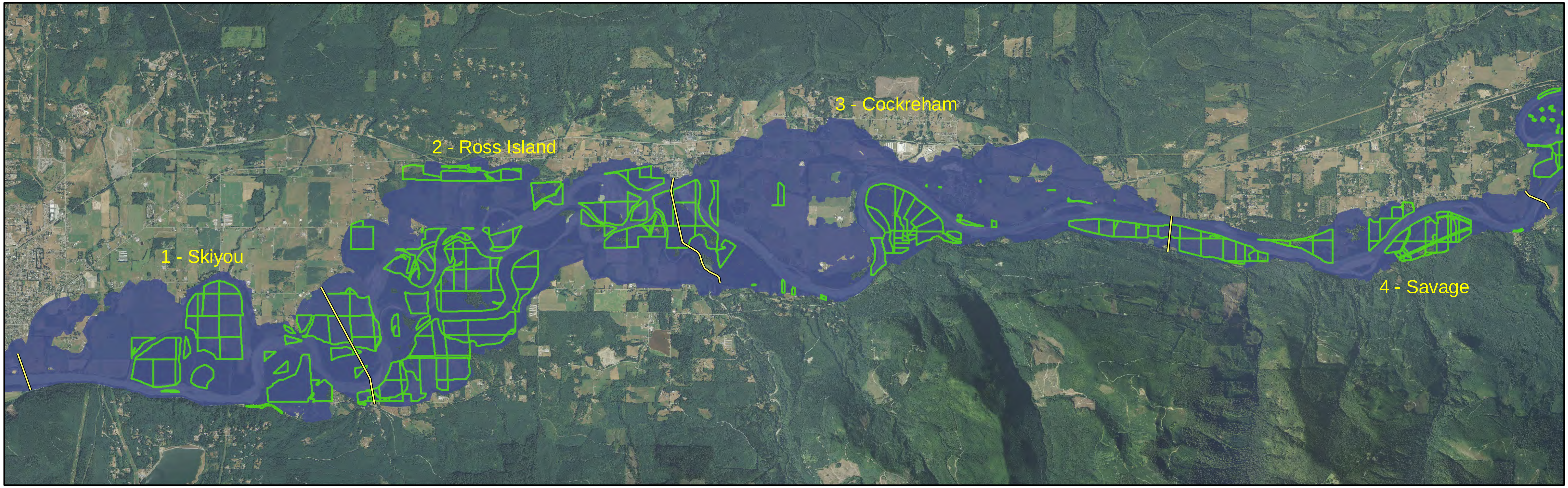
2009 Air Photo: USDA-NAIP
2010 Parcels: Skagit County

Skagit River System Cooperative






## Middle Skagit Parcels in Protected Status with the 25-Year Existing Flow Inundation Area

Floodplain reach breaks
Protected parcels
25-year flow inundation area

0 1 2 Miles

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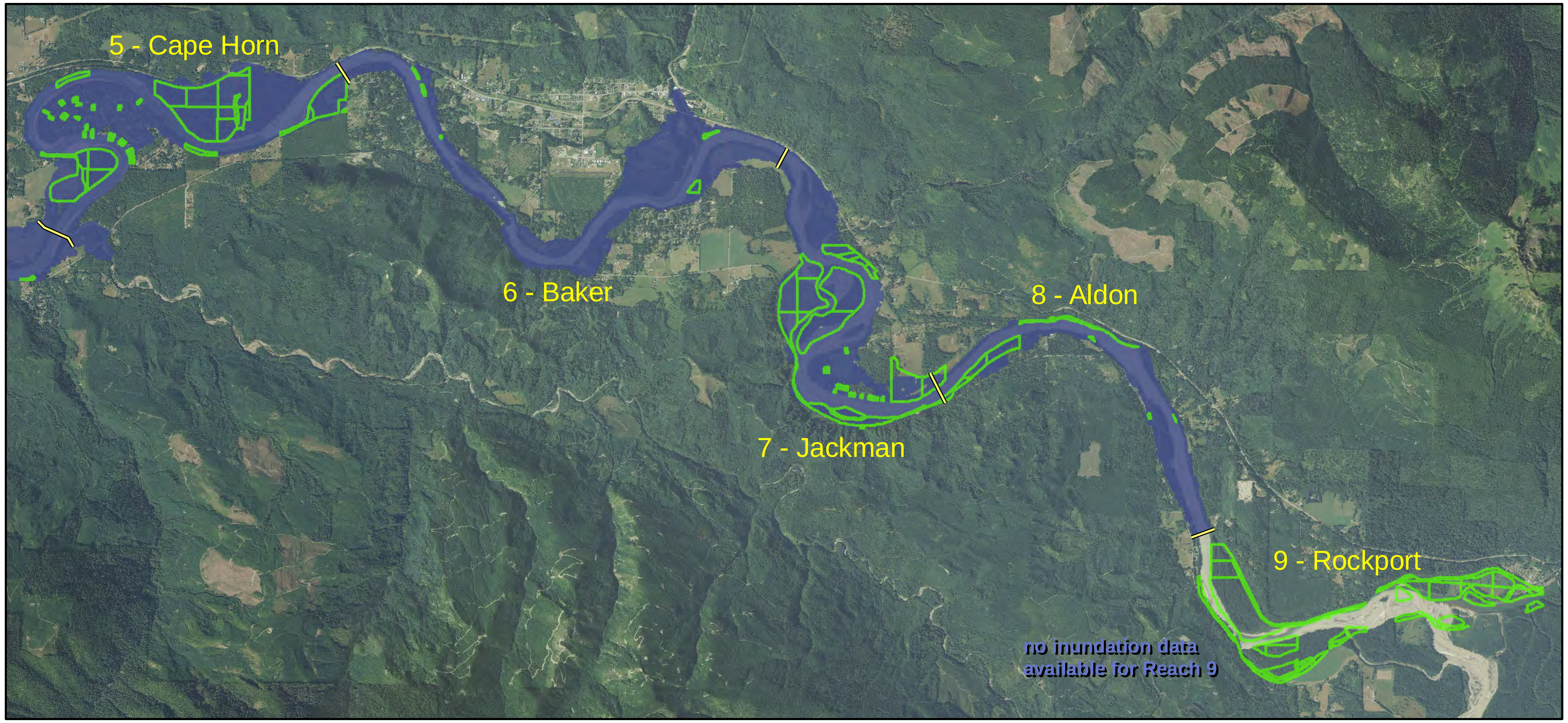
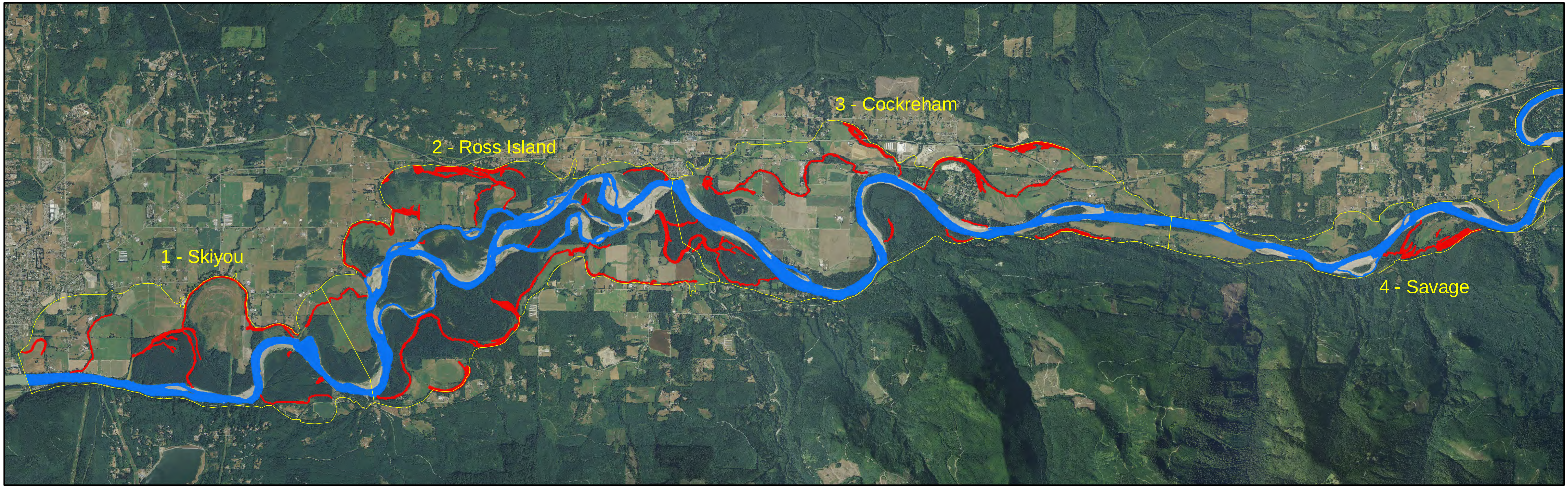
2009 Air Photo: USDA-NAIP
2010 Parcels: Skagit County
Model results generated from FV-COM model developed by PNNL.

Skagit River System Cooperative






## Middle Skagit Floodplain Channels

- Floodplain reaches
- Floodplain channels
- Mainstem channel

0 1 2 Miles

Prepared by Kate Ramsden, October 21, 2010
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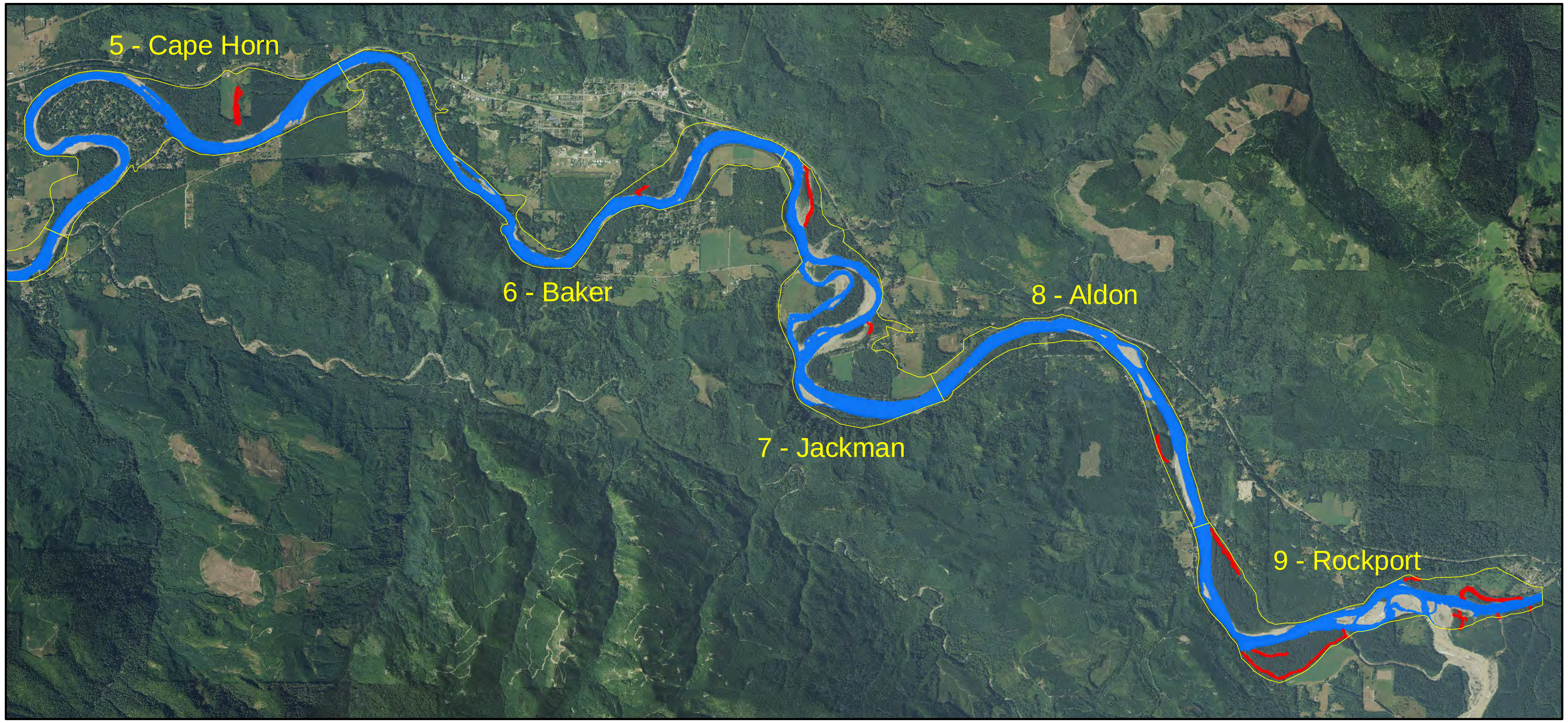
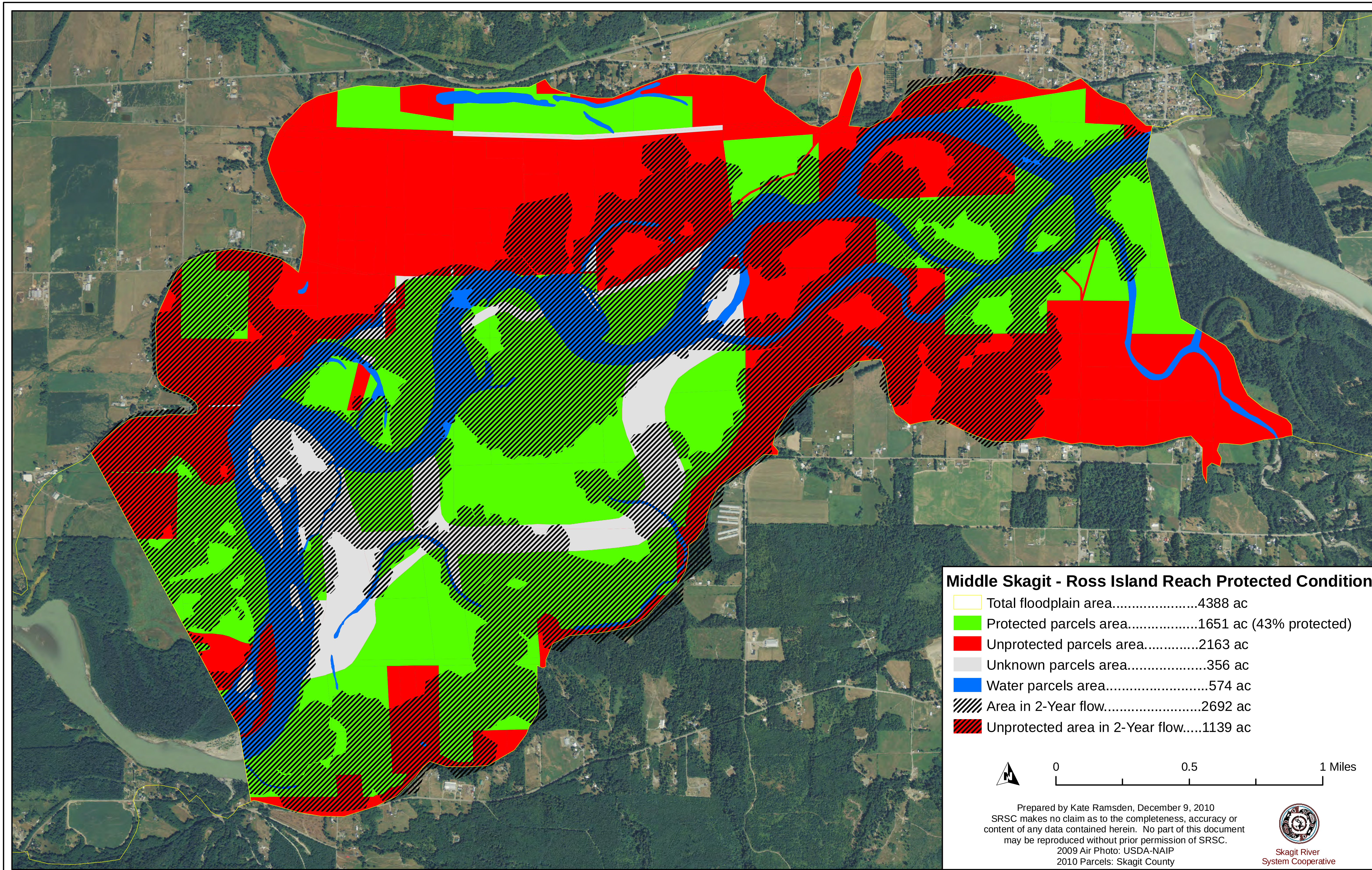
2009 Air Photo: USDA-NAIP

Skagit River System Cooperative





Middle Skagit - Ross Island Reach Protected Condition
Total floodplain area......................4388 ac
Protected parcels area.................1651 ac (43% protected)
Unprotected parcels area.............2163 ac
Unknown parcels area...................356 ac
Water parcels area.........................574 ac
Area in 2-Year flow........................2692 ac
Unprotected area in 2-Year flow.....1139 ac
N
0
0.5
1 Miles
Prepared by Kate Ramsden, December 9, 2010
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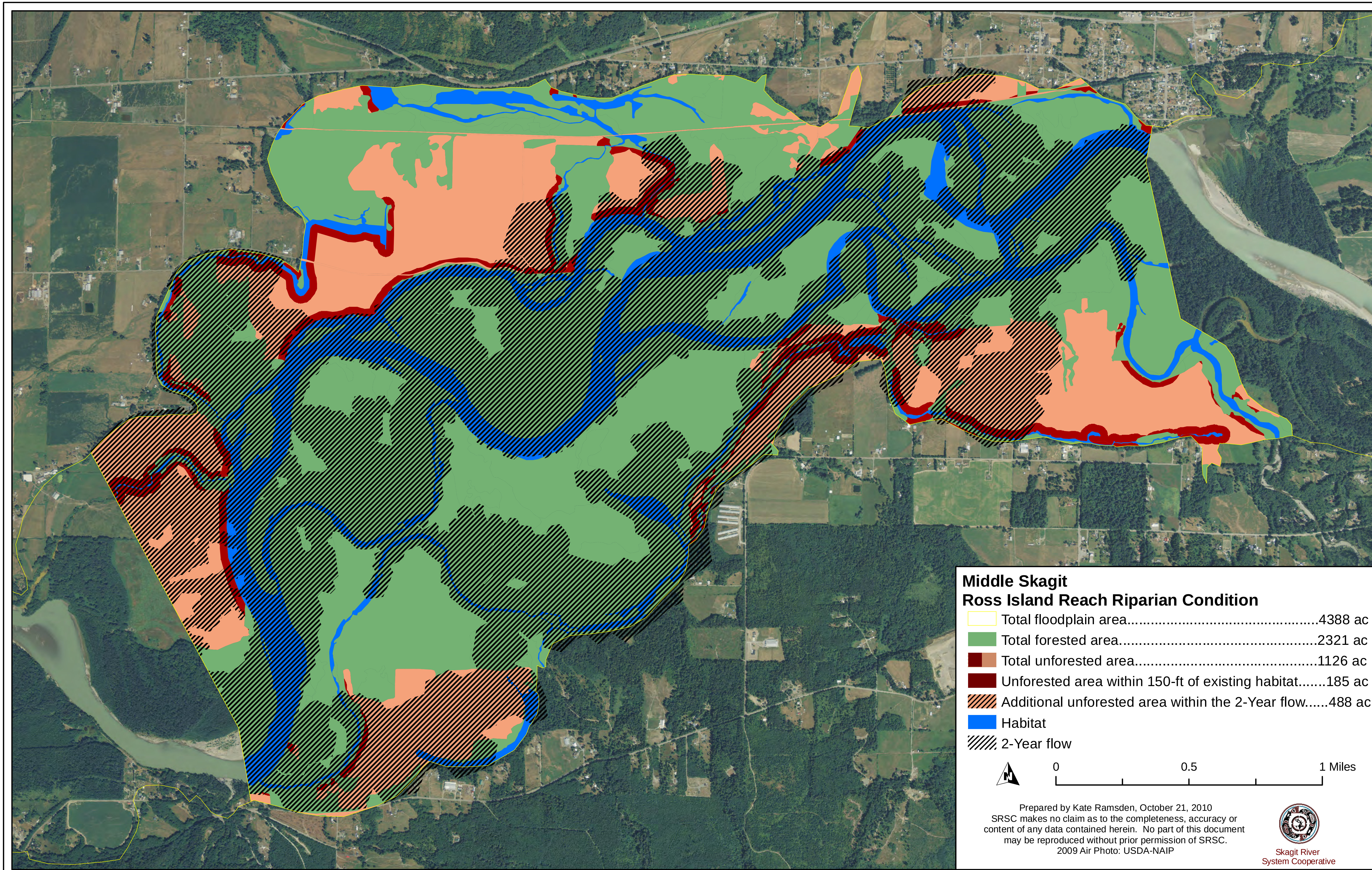
2009 Air Photo: USDA-NAIP
2010 Parcels: Skagit County
Skagit River System Cooperative


Middle Skagit
Ross Island Reach Riparian Condition
Total floodplain area..............................................4388 ac
Total forested area..............................................2321 ac
Total unforested area..............................................1126 ac
Unforested area within 150-ft of existing habitat.......185 ac
Additional unforested area within the 2-Year flow......488 ac
Habitat
2-Year flow
0
0.5
1 Miles
Prepared by Kate Ramsden, October 21, 2010
SRSC makes no claim as to the completeness, accuracy or content of any data contained herein. No part of this document may be reproduced without prior permission of SRSC.
2009 Air Photo: USDA-NAIP
Skagit River System Cooperative

# Appendix B.  Middle Skagit Reach Analysis Methods and Data

This appendix describes the data sources, methods, and datasets that were developed to complete the Middle Skagit River reach level analysis.  To support this analysis, a number of datasets were developed in order to characterize reach-level metrics including information about available floodplain and floodplain impairments, flow inundation and velocity models, habitat types, and protected lands.  All datasets were created as layers in a Geographic Information System (GIS) using ESRI's ArcGIS 9.3 software.  Several existing GIS files were used in the development of the data presented here, and are listed in Table 1.

**Table 1.  Existing GIS layers used in the Middle Skagit reach level analysis.**

| Data | Format | Date | Source |
|---|---|---|---|
| Aerial photography | Mr Sid | 2009 | NAIP, Skagit County/Pictometry |
| LiDAR | Bare earth grid | 2006 | USGS |
| Hydromodification inventory | polyline shapefile | 2010 | Upper Skagit Indian Tribe |
| Roads | polyline shapefile | 2005 | SRSC (Skagit Chinook Recovery Plan) |
| Floodplain | Polygon shapefile | 2005 | SRSC (Skagit Chinook Recovery Plan) |
| Parcels | Polygon shapefile | 2010 | Skagit County Assessor & Skagit County GIS |
| SCDC protected lands database | Polygon shapefile | 2010 | Skagit County Database Consortium |
| Protected parcels | Polygon shapefile | 2008 | SRSC |
| Depth inundation and velocity points | X, Y, Z text file | 2010 | PNNL, Integrated Coastal Ocean Monitoring Group |
| Floodplain centerline | polyline shapefile | 2005 | SRSC (Skagit Chinook Recovery Plan) |

The existing GIS files were used as base layers for guidance in creating and developing the reach-level metrics, and were sometimes updated with more current information or modified to fit the objectives of the project.  The usage and modification of these existing files, as well as development of new information, are described below.

## <u>Floodplain Reaches</u>

The floodplain reach layer used for the Middle Skagit analysis was a modification of an existing floodplain polygon layer developed by SRSC (2005).   The floodplain layer was clipped down to the project extent, and a few modifications were made to the outer boundary and sub-reach breaks.   The outer floodplain boundary was modified in 12 locations, where the more recent 2009 NAIP aerial photography showed clear channel erosion that had occurred outside of the previously delineated floodplain boundary.  This erosion had occurred in the time since the floodplain layer was initially developed.  In areas where this occurred, the boundary was re-drawn around the wetted channel and eroded bank, but no effort was made to delineate a line that would predict future erosion at these locations.  The Middle Skagit reach was also delineated into 9 sub-reaches.  Five of the sub-reach breaks remained the same from the original layer, but modifications were made to the sub-reaches located in the downstream portion of the reach.
The Skagit Watershed Council requested these modifications in order to align the reaches with other analyses completed for the Middle Skagit project.  A reach break was added just upstream of Gilligan Creek, to delineate between the relatively straight reach downstream and the island-

braided reach upstream. The reach break that previously crossed through the middle of Cockreham Island was moved downstream approximately 1.25 miles to capture the backwater at Lyman that is influenced by the Cockreham reach. Lastly, two reaches that spanned from just downstream of O'Toole Creek to Finney Creek were combined into one reach. In addition to modifying the boundary and reach breaks of the floodplain layer, the sub-reaches were re-numbered and named (with a highly recognizable hydraulic feature or place name) for the purpose of providing an easier way to identify the reaches.

The attribute table of the floodplain layer was populated in GIS with the following metrics:

- "reach_nm" – Reach number and name.

- "CHLENGTH" - Mainstem channel length (mi). This was calculated using a polyline shapefile that was developed for the Current Habitat Conditions section. This polyline was drawn along the center of the mainstem wetted channel off of the 2009 NAIP imagery. The polyline was split at every reach break and the channel length for each reach was calculated in the GIS.

- "CHWIDTH" - Average channel width (ft). This was calculated using a polygon shapefile that was developed for the Floodplain Dynamics and Vegetation Mapping section. In that layer, the mainstem wetted channel and gravel bar areas were mapped together as an "active" channel area. The channel area was summed for each reach and divided by the mainstem channel length to calculate average channel width.

- "UPELEV" – Upstream channel elevation (ft). Elevation was identified using the 2006 USGS LiDAR. Four elevation points were taken along the channel at each reach break and averaged.

- "DNELEV" – Downstream channel elevation (ft). Elevation was identified using the 2006 USGS LiDAR. Four elevation points were taken along the channel at each reach break and averaged.

- "CHGRAD" - Channel gradient (%). Channel gradient was calculated by subtracting the reach's downstream elevation value from the upstream elevation value, and dividing by the mainstem channel length (ft).

- "FPLENGTH" - Floodplain length (mi). This was calculated using an existing polyline shapefile that was developed for the Skagit Chinook Recovery Plan (SRSC and WDFW 2005). This line was drawn along the center of the floodplain layer, and for this project was split at every reach break. Floodplain length for each reach was calculated in the GIS.

- "FPWIDTH" - Average floodplain width (ft). This was calculated by dividing floodplain area by floodplain length.

• "FPGRAD" - Floodplain gradient. This was calculated by subtracting downstream channel elevation from upstream channel elevation, divided by floodplain length.

• "SINUOSITY" – Sinuosity. Mainstem channel length divided by floodplain length.

• "Acres" - Floodplain area (ac) – Area of each sub-reach calculated in the GIS.

• "CONFINE" – Confinement. This was calculated by dividing floodplain width by channel width.

**Hydrodynamic Modeling**

Pacific Northwest National Laboratory's Integrated Coastal Ocean Modeling Group (ICOM 2010) modeled inundation depth and velocity for three flow scenarios and provided data in the format of XYZ text files to SRSC. The three flow scenarios represented the 2-year, 5-year, and 25-year flow conditions. Each flow was run under an existing conditions and an alternative conditions scenario. Existing conditions included information about existing hydromodifications present on the landscape, and the alternative conditions scenario had 13 hydromodifications removed from the model landscape. Information about the hydromodifications came from the 2010 hydromodification inventory completed by the Upper Skagit Indian Tribe (USIT 2010). The model output was in text file format containing X, Y, and Z information. The X, Y values represented latitude and longitude points, which were irregularly spaced with more points located near the channel and in the floodplain and in areas where better data were available (for example, the floodplain near Gilligan Creek), and fewer points near the outer zone of the study area. The Z values represented either depth (m) or velocity (m/s). Several steps were taken to convert these data into its final format. The text files were first imported into GIS as point shapefiles. ICOM ran the model with a minimum base depth of 0.05 m. Therefore, in order to remove false positive water inundation, any data points that had a depth = 0.05 and velocity = 0 were reclassified so that depth = 0. All Z values were multiplied by 100 so that the precision would be preserved throughout later datasets that can only handle integer numbers.

In order to interpolate values in between the irregularly spaced points, Triangulated Irregular Networks (TINs) were created from the point shapefiles using an extension of ArcGIS called 3D Analyst. Depth or velocity was input for the Z value and the perimeter of the study area was the outer boundary. ArcGIS 3D Analyst uses the Delaunay triangulation method to interpolate surfaces in between known points.

In order to calculate the area inundated by each flow scenario, the TINs displaying the depth data were converted to floating point raster grids with 2 m cell sizes, also using 3D Analyst. This cell size was the minimum size that created a functioning, but cumbersome, raster. The rasters were then converted to an integer raster set in order to handle the large raster file sizes more effectively.  The integer raster was reclassified to reflect two values: 0 for areas that indicated no water depth, and 1 for areas that indicated any amount of water depth.  The reclassified raster was then converted into a polygon shapefile, split by the floodplain reach breaks, and polygon areas were calculated.

Calculating and displaying the change in inundation between existing and alternative conditions was created by intersecting the corresponding polygon shapefiles in the GIS.

The velocity data was similarly processed by creating TINs from the point shapefiles and interpolating into integer raster grids with a 2 m cell size.  In order to examine change in velocity from existing to alternative conditions, the raster calculator in the Spatial Analyst toolbox was used to subtract the existing conditions raster from the alternative conditions raster for each flow scenario.  As in the depth methods, the values in the velocity raster datasets have been multiplied by 100 to create integer values (for example, a value of 500 is actually a value of 5 m/s).

## Floodplain Dynamics and Vegetation Mapping

Floodplain vegetation was mapped using methods outlined in Beechie et al (2006), which mapped forested stands within the floodplain and categorized them based on their canopy diameter.  Vegetation polygons were mapped at a scale no closer than 1:1500, using the 2009 Pictometry/Skagit County aerial photographs.  This imagery set was used because the higher resolution of the photos made it easier to measure canopy width and determine tree type (hardwood vs. conifer).  Crowns were measured manually in the GIS with the Measure Tool, and similarly sized vegetation patches were digitized.  Major roads and unforested areas (agricultural fields, pastures, and residential areas, etc) were also mapped.  It was noted where forested areas appeared to be human modified (tree farms, logged areas, riparian plantings, etc).  Lastly, channel areas were mapped. This includes both wetted channels and gravel bars.  All polygons were attributed with floodplain reach number and name and areas were calculated for each reach. Attributes of the floodplain dynamics shapefile include the following cover types:

- CH – Active unvegetated channel (includes both wetted channels and gravel bars)
- V1 - Newly established vegetation (crowns not distinguishable), usually dominated by hardwood species
- V2 - Forest with crown diameter <16 feet, usually dominated by hardwood species
- V3 - Forest with crown diameter 16-33 feet, usually mixed hardwood and conifer species
- V4 - Forest with crown diameter >33 feet, usually dominated by conifer species
- D – Unforested areas.  Includes agricultural, pasture, residential areas

- R - Road (public roads, not driveways or farm roads)
- HM-V1, 2, or 3 - Human modified forest (linear edges, even age classes), with age class falling within the V1, V2, or V3 category

## Current Habitat Conditions

Habitat within the floodplain area was mapped using the 2009 NAIP imagery and following methods presented in Hayman et al (1996). Two datasets were developed: 1) a polygon shapefile representing mainstem and side channel habitat, and 2) a polyline shapefile representing edge habitat along the mainstem of the river only.

Habitat polygons were delineated from channel areas that were developed as part of the Floodplain Vegetation Dynamics section. Polygon types include mainstem wetted channel, backwater, off-channel and tributary polygons. Lower flow conditions were present at the time the NAIP photos were flown and so this imagery was chosen over the 2009 Skagit County/Pictometry imagery because backwater areas were more distinguished. Backwater areas were defined as enclosed, low-velocity areas separate from the main river channel but lacking an independent hydraulic control from the river. Off-channel was defined as channels or other areas conveying water that were significantly smaller in size than mainstem channels (less than ½ mainstem channel width by visual estimates) and were separated from the main channel by an island of vegetated land, and represent potential relic mainstem river channels or have the potential for river occupation or have an inlet along the mainstem river. Tributaries within the floodplain, where mapped, were delineated as a separately from off-channel at the point where it was determined that the flow was likely independent of the mainstem flow. Small tributaries not visible on the photos because of their size or mostly obscured by vegetation were not mapped. Off-channel and tributaries were not delineated into further habitat types. Polygons were attributed with floodplain reach number and name, and area for each type was calculated within the GIS.

Mainstem edge habitat was mapped in a polyline format also following methods from Hayman et al (1996). The mainstem wetted channel and backwater polygons in the other habitat dataset were converted into a polyline shapefiles. Those lines were then split at habitat break points visible on the photos and attributed with the following habitat types: bank, bar, and backwater. Banks were delineated when a vegetated bank met the wetted channel. Bars were delineated along the length of exposed gravel bars. Backwaters were completely enclosed by a backwater line. The lines were also attributed with hydromodification presence or absence, which was derived from the hydromodification inventory completed by Upper Skagit Indian Tribe (2010). Habitat lines were attributed with floodplain reach and name, and length of each line segment was calculated within the GIS.

A mainstem channel centerline was also mapped in a polyline format along the center of the wetted mainstem channel.  The centerline was created using the Midpoint Tool within the Editor Toolbar.  In locations where there were multiple mainstem channels along a braided reach, the wider channel was chosen and mapped.  The channel centerline was attributed with floodplain reach number and name, and lengths were calculated in the GIS.

**Floodplain Impairment from Hydromodifications and Roads**

A hydromodification layer and a road layer were used to create a floodplain impairment layer based on methods used in the development of a similar layer used in the Skagit Chinook Recovery Plan (SRSC and WDFW 2005).  For the purpose of assisting with the Middle Skagit Project Development grant, a field-mapping inventory of hydromodifications in the Middle Skagit reach was completed by the Upper Skagit Indian Tribe (USIT) in the spring of 2010 (USIT 2010).  USIT provided the polyline shapefile of the inventory to SRSC.  The inventory completed by USIT labeled and attributed the hydromodifications with the floodplain reach break numbering system used in the previous iteration of the floodplain layer (SRSC 2005), therefore for this analysis, it was also updated with the Middle Skagit floodplain reach break names and numbers.  The mapped hydromodifications extended beyond the boundaries of the project area, so the polylines were clipped at the upstream and downstream ends to the reach boundary.  Lengths were updated in the GIS for the clipped polylines and for hydromodifications crossed and were split by the updated Middle Skagit reach break locations.  No other modifications were made to the 2010 hydromodification layer.  Secondly, the road layer that was used for this purpose was derived from the road layer used in the Skagit Chinook Recovery Plan. A visual assessment of the 2009 aerial photographs and this road layer did not reveal major changes in the location or presence of roads.  One minor change made to a road in the Iron Mountain Ranch area, because of a known road mapping area affecting a significantly large area of land.

Techniques previously developed for the Skagit Chinook Recover Plan were used to map the floodplain area that was impacted, or “shadowed”, by the presence of a hydromodification or road. Floodplain areas could be shadowed by hydromodification, by road, or by a combination of the two.  Floodplain areas could also be considered “isolated” if the area was completely enclosed to the floodplain boundary by road, hydromodification, or both.  Polygons were drawn that covered these areas of shadowed or isolated floodplain impairment types.  The method followed that the line drawn on the upstream end of the impairment polygon was drawn perpendicular to the floodplain flow/direction, and the shadowed line on the downstream end of the impairment polygon was drawn perpendicular to the river flow/direction.  The polygon extended all the way to the outer boundary of the floodplain.  Shadowed areas were ended after one meander length for polygons that would have otherwise extended beyond that.  Floodplain areas that did not have an impairment were labeled as “connected”.  An additional attribute in the shapefile was created that shows the full footprint of hydromodification impairment, regardless of road influence. That attribute indicates presence of shadowed hydromod: "yes" or "no".

Impairment areas that were shadowed by hydromodifications were also attributed with the ID of the specific hydromodification or group of hydromodifications responsible for shadowing that area. The ID came from the 2010 hydromodification inventory (USIT 2010). The impairment polygons were also attributed with the updated Middle Skagit reach break numbers and names.

## Protected Lands

Protected lands within the Middle Skagit floodplain were identified using a combination of two existing protected lands layers – one from the Skagit County Database Consortium (SCDC), last updated in spring 2010, and one from a project completed by SRSC in April of 2008 – and newly purchased protected parcels from the more current version of the Skagit County parcel layer (2010). The rationale behind using multiple layers is that no one layer appeared to be complete. The SCDC was created in 1998 for the purpose of collecting environmental data in the Skagit River watershed, and an effort was made at identifying conservation lands and creating a single dataset. Members of the SCDC are responsible for submitting parcel information to the database manager for updating the dataset. The SRSC 2008 layer contained parcels exported from the Skagit County parcel layer that were owned by state and federal public agencies, cities, towns, and counties (with no effort made at identifying the land use), and agencies holding land for conservation purposes such as The Nature Conservancy and Seattle City Light. Some of the parcels in this layer area are held by public agencies that were not included in the SCDC database. Additional parcels were added from the most recent version of the Skagit County parcel layer (2010) that were missed in the other two layers. With guidance from Skagit Watershed Council, the following rules were applied to combine the layers and create a new protected lands layer:

- All properties from the SCDC database were included except for agricultural easements or limited term easements of any kind.
- All properties from SRSC database were included except for:
  - Puget Sound Energy parcels at the mouth of the Baker River
  - Parcels representing the Cascade Trail
  - Parcels owned by and within the city limits of the Town of Hamilton
- Properties added to the new database that were not identified in the other two databases include: a Skagit County-owned parcel in Cape Horn, a Skagit Land Trust property at Pressintin Ranch, a United States Forest Service property across from Cape Horn, a

Washington State Parks property downstream of Concrete, and a Seattle City Light property at Savage Slough/Creek.

All attributes from the SCDC database and the 2010 Skagit County Parcel layer were retained. A "source" attribute was added, that indicated if the parcel came from SCDC or SRSC.

Because parcels sometimes extended beyond the boundary of the floodplain, the protected parcels layer was clipped to the floodplain layer and attributed with floodplain reach number and name. Therefore, parcels that are clipped do not represent the entire ownership or coverage of that particular parcel. However, an "area" attribute (SC_AC) was retained from the Skagit County parcel layer that indicates total parcel size based on the Skagit County Assessor's database, and another "area" attribute (TotParc_AC) was created that indicates the GIS-computed area of the polygon prior to clipping to the floodplain layer. The other 'Acres' attribute contains GIS-calculated areas of individual polygons, computed after clipping to the floodplain layer.

Additionally, there were parcels that were coded as "water" by the Skagit County Assessor. These parcels were identified from the 2010 Skagit County Parcel layer from the attribute 'PARCELTYPE' and value = 1. These were selected and clipped to the floodplain layer in order to help determine approximate land base vs. water area. However, these water parcels do not always match up with the current location of the river and the area calculation was used as an approximation only. Due to movement in the river, the water parcels may or may not be located in an area currently occupied by water or the river channel although for the most part they do occur on or near the current river channel. There are also several polygons within the Skagit County parcel layer that have no parcel number, no ownership information, and are not identified as water within the parcel type attribute. These parcels often appear to correspond with historic river channels, and may have been mapped during the original GLO (General Land Office) surveys of the late 1800's or during some of the initial platted land maps of Skagit County. No attempt was made to assign an owner to these parcels with unknown ownership. It is not known by SRSC how frequently Skagit County updates parcel boundaries, and it is an extremely complicated endeavor and not in the scope of this project to determine ownership due to erosion or accretion of the river. Therefore even though the most current river channel location was mapped for other parts of the analysis, no attempt was made at determining how much erosion has occurred on parcels and who the actual ownership of unknown parcels belongs to.

## Final GIS Layers

The final GIS layers created for the Middle Skagit reach level analysis are listed in Table 2.

**Table 2. Final GIS layers created for the Middle Skagit reach level analysis.**

| Report Section | File Name | Description |
|---|---|---|
| Floodplain Reaches | Middle_Skagit_Floodplain_final.shp | floodplain reaches |
| Current Habitat Conditions | habitat_polys_2009_final.shp | mainstem polygon delineated into mainstem, bar, and backwater polygons, and side channel polygons |
| Current Habitat Conditions | mainstem_edge_habitat_lines_2009_final.shp | mainstem edge habitat delineated into bar, bank, and backwater, and presence/absence of hydromodifications |
| Current Habitat Conditions | mainstem_centerline_2009_final.shp | mainstem channel centerline digitized down center of mainstem polygon |
| Hydrodynamic Modeling | existing_2Y_flow_polygons.shp | inundation area modeled under the existing 2 year flow conditions |
| Hydrodynamic Modeling | existing_5Y_flow_polygons.shp | inundation area modeled under the existing 5 year flow conditions |
| Hydrodynamic Modeling | existing_25Y_flow_polygons.shp | inundation area modeled under the existing 25 year flow conditions |
| Hydrodynamic Modeling | alternative_2Y_flow_polygons.shp | inundation area modeled under the alternative (hydromods removed) 2 year flow conditions |
| Hydrodynamic Modeling | alternative_5Y_flow_polygons.shp | inundation area modeled under the alternative (hydromods removed) 5 year flow conditions |
| Hydrodynamic Modeling | alternative_25Y_flow_polygons.shp | inundation area modeled under the alternative (hydromods removed) 25 year flow conditions |
| Hydrodynamic Modeling | tin_existing2y_flow | existing depth TIN 2 yr flow |
| Hydrodynamic Modeling | tin_existing5y_flow | existing depth TIN 5 yr flow |
| Hydrodynamic Modeling | tin_existing25y_flow | existing depth TIN 25 yr flow |
| Hydrodynamic Modeling | tin_alternative2y_flow | alternative depth TIN 2 yr flow |
| Hydrodynamic Modeling | tin_alternative5y_flow | alternative depth TIN 5 yr flow |
| Hydrodynamic Modeling | tin_alternative25y_flow | alternative depth TIN 25 yr flow |
| Hydrodynamic Modeling | d_ex_2y_in | flow existing 2 yr flow integer raster |
| Hydrodynamic Modeling | d_ex_5y_in | flow existing 5 yr flow integer raster |
| Hydrodynamic Modeling | d_ex_25y_in | flow existing 25 yr flow integer raster |
| Hydrodynamic Modeling | d_alt_2y_in | flow alternative 2 yr flow integer raster |
| Hydrodynamic Modeling | d_alt_5y_in | flow alternative 5 yr flow integer raster |
| Hydrodynamic Modeling | d_alt_25y_in | flow alternative 25 yr integer flow raster |
| Hydrodynamic Modeling | tin_existingvelocity_2y | existing velocity TIN 2 yr flow |
| Hydrodynamic Modeling | tin_existingvelocity_5y | existing velocity TIN 5 yr flow |
| Hydrodynamic Modeling | tin_existingvelocity_25y | existing velocity TIN 25 yr flow |
| Hydrodynamic Modeling | tin_alternativevelocity_2y | alternative velocity TIN 2 yr flow |
| Hydrodynamic Modeling | tin_alternativevelocity_5y | alternative velocity TIN 5 yr flow |
| Hydrodynamic Modeling | tin_alternativevelocity_25y | alternative velocity TIN 25 yr flow |
| Hydrodynamic Modeling | v_ex_2y_in | velocity existing 2 yr flow integer raster |
| Hydrodynamic Modeling | v_ex_5y_in | velocity existing 5 yr flow integer raster |
| Hydrodynamic Modeling | v_ex_25y_in | velocity existing 25 yr flow integer raster |
| Hydrodynamic Modeling | v_alt_2y_in | velocity alternative 2 yr flow integer raster |
| Hydrodynamic Modeling | v_alt_5y_in | velocity alternative 5 yr flow integer raster |
| Hydrodynamic Modeling | v_alt_25y_in | velocity alternative 25 yr flow integer raster |
| Hydrodynamic Modeling | v_alt5y_diff | change in depth 5 yr flow polygon |
| Floodplain Impairment from Hydromodifications and Roads | floodplain_impairment_final.shp | floodplain reaches with isolated, shadowed, and road polygons cut into them |
| Floodplain Impairment from Hydromodifications and Roads | Hydromod_2010_MiddleSkagit_final.shp | hydromods within the Middle Skagit reach, used for shadowing exercise |
| Floodplain Impairment from Hydromodifications and Roads | Hydromod_2010_for_alternative_condition.shp | hydromods removed from the landscape for alternative flow modeling |
| Floodplain Vegetation Dynamics | vegetation_dynamics_2009_final.shp | vegetation size class layer, with developed/ag, roads, and channels |
| Protected Lands | MiddleSkagit_protected_parcels_cobined_2010_final.shp | protected parcels, a combination of multiple layers |
| Protected Lands | unknown_parcels_2010_final.shp | parcels with no ownership recorded by the Skagit County assessor |
| Protected Lands | water_parcels_2010_final.shp | parcels coded by Skagit County assessor as water |