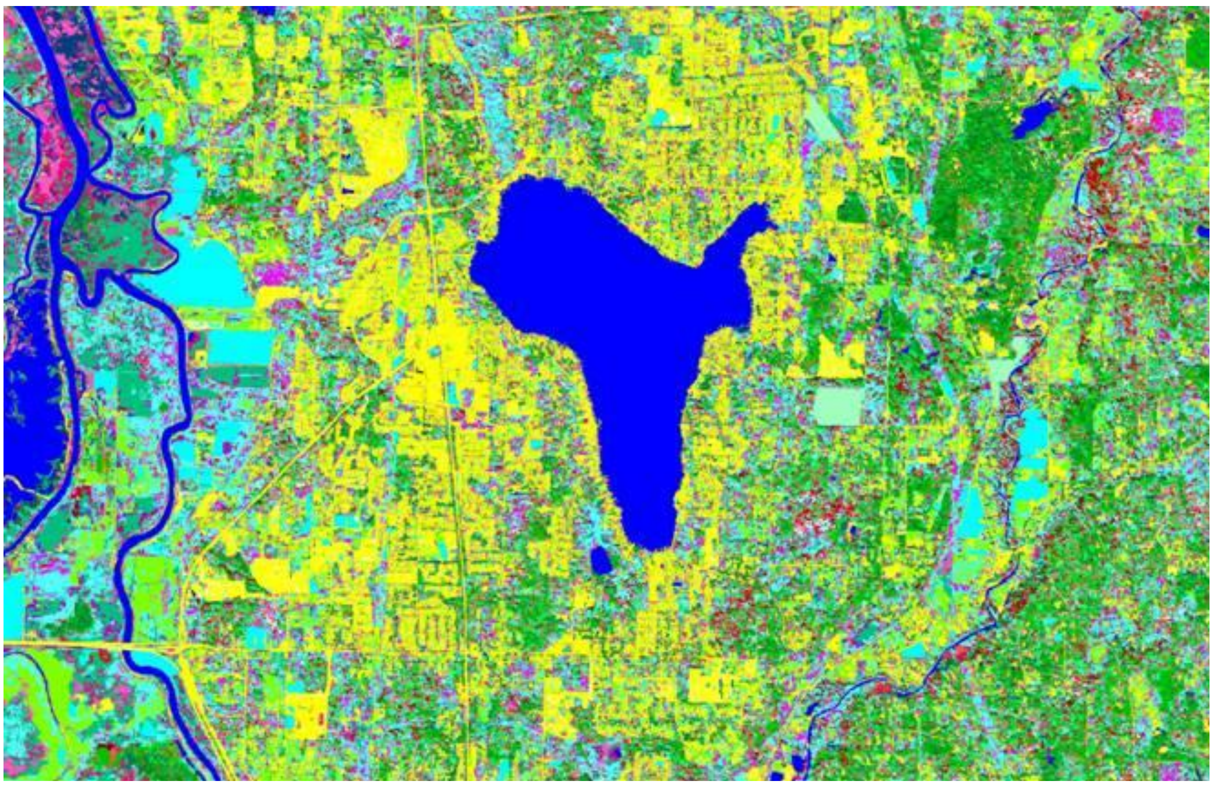
Snohomish County

Public Works

Surface Water Management



Critical Areas Monitoring 2008 Status Report

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February 2009

Executive Summary

This status report summarizes progress through 2008, results and next steps in establishing a baseline for monitoring the effectiveness of Snohomish County's efforts to protect the functions and values of critical areas. The monitoring and adaptive management program was developed to support implementation of Snohomish County's Critical Area Regulations (CAR) in order to meet the requirements of the Washington State Growth Management Act (GMA). The monitoring plan, designed to detect changes in indicators of critical area functions in a timely fashion, consists of three main components: (1) assessment of changes in land cover in Wetland and Fish and Wildlife Habitat Conservation Areas using primarily remote sensing[1] methods; (2) assessment of changes in shoreline conditions along major rivers and lakes; and (3) assessment of physical, chemical and biological conditions in small catchments developing under the new CAR relative to control sites. The monitoring plan is focused on Wetlands and Fish & Wildlife Habitat Conservation Areas (FWHCA) because the CAR contains greater flexibility in approach to protection of these types of critical areas, and thus greater uncertainty. The adaptive management component is designed to provide greater certainty that the conservation goal will be achieved. It will evaluate whether changes in indicators were related to the regulations and whether modifications to regulations or other County programs are needed to prevent a net loss of critical area functions and values.

The County has made great progress in establishing and implementing a quantitative, repeatable protocol for critical area monitoring. The project team classified high-resolution satellite imagery and other ancillary data for the 965 miles^2 (2,500 km^2) study area from the Puget Sound to the Cascade foothills to establish the baseline for monitoring trends in land cover within critical areas. Field crews gathered data on over 1,300 polygons to guide the classification process and evaluate accuracy. Over 80% overall map accuracy has been achieved to date. Shoreline conditions were documented quantitatively along approximately 137 miles (220 km) of river shoreline and 28 miles (45 km) of lake shoreline. An intensive catchment study was initiated to evaluate potential impacts of development under the new CAR on a broader range of indicators of critical area functions and values in small streams. Next steps include collecting additional field data and applying additional processing techniques to improve map accuracy, obtaining and classifying a second QuickBird satellite image for trend detection, increasing sample size for the catchment study and further integrating efforts with other County monitoring programs.

[1] Remote sensing is the acquisition of data about the earth's surface from planes and satellites

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1. Introduction

1.1 Overview

This report summarizes progress to date, results and next steps establishing a baseline for monitoring the effectiveness of Snohomish County's efforts to protect the functions and values of critical areas. Monitoring efforts focus on Wetlands and Fish and Wildlife Habitat Conservation Areas. Snohomish County has demonstrated a strong commitment to protecting critical areas through the implementation of critical area regulations (CAR) grounded in best available science, non-regulatory environmental programs, and a monitoring and adaptive management strategy to evaluate the effectiveness of critical area protection measures and make adjustments as needed. In this collaborative program, the Surface Water Management Division of Public Works (SWM) is responsible for implementing and reporting on results of the monitoring. Planning and Development Services (PDS) is tasked with tracking permits, enforcement actions, and alternative or innovative approaches applied to buffers. This report covers work conducted by SWM to establish the baseline data set for trend detection. Following a second round of data collection, analysis, and monitoring reporting, PDS will prepare a separate report summarizing adaptive management recommendations based on monitoring results.

The County initiated a critical areas monitoring and adaptive management program in 2007 with the development of a monitoring and adaptive management plan, assembly of a project team, and acquisition of high-resolution satellite imagery from the QuickBird satellite coincident with code adoption. Additional tasks included post-processing of satellite imagery, refinement of Geographic Information System (GIS) data layers essential for the analysis, field sampling site reconnaissance, and coordination between Public Works and Planning and Development Services departments on the evaluation and adjustment process.

In 2008 the project team classified high-resolution satellite imagery and other ancillary data to characterize streamside vegetation, impervious surfaces and wetlands to establish the baseline for monitoring trends in land cover within critical areas. Field crews gathered extensive field data to guide the classification process and evaluate accuracy, completed shoreline inventories of Snohomish County large rivers and lakes, and initiated an intensive catchment study to take a closer look at a broader range of indicators in small drainages that are likely to experience significant development under the new CAR.

To facilitate use and dissemination of information to multiple audiences, this document is organized as a summary report and three technical appendices, each focused on an element of the monitoring plan. The summary report is intended for a broad audience. The appendices, intended for a technical audience, provide much greater detail regarding methods, results and conclusions.

While this progress report includes a short overview of the program, the intent of this document is to provide a monitoring update, not to outline the monitoring and adaptive management framework. For additional contextual information on the program, including the rationale for the selection of specific program elements, indicators, and the evaluation and adjustment processes, please refer to the CAR Monitoring and Adaptive Management Plan (2007).

1.2 Growth Management Act Requirements

Washington State's Growth Management Act (GMA – chapter 36.70A RCW) requires Snohomish County to protect and manage the functions and values of critical areas. The GMA identifies critical areas as Wetlands, Fish and Wildlife Habitat Conservation Areas, Frequently Flooded Areas, Critical Aquifer Recharge Areas and Geologically Hazardous Areas. To protect and manage these areas, the County has included critical area protection policies in its General Policy Plan (GPP) and adopted science-based Critical Area Regulations.

In October of 2007, the County Council adopted Critical Area Regulation improvements to chapters 30.62A (Wetlands and Fish & Wildlife Habitat Conservation Areas), 30.62B (Geologic Hazard Areas) and 30.62C SCC (Critical Aquifer Recharge Areas). The County's flood hazard regulations (chapter 30.65 SCC) remain unchanged. CAR revisions were based on the State's guidelines for the designation and protection of critical areas contained in section 365-190-080 WAC and the Best Available Science requirements of section 365-195-905 WAC. In addition, the County has a number of other existing environmental protection and restoration programs that directly or indirectly manage, protect or restore critical areas.

The County's overall goal is to protect critical area functions and values through three principal tools: regulations; non-regulatory environmental programs; and a monitoring and adaptive management program. The monitoring plan measures indicators of critical area functions and values, evaluates changes, and supports adaptive management decision making regarding what changes may be needed to regulations or other County programs to protect critical area functions and values. Figure 1 shows the relationship of CAR, non-regulatory restoration and enhancement actions, and the monitoring and adaptive management program.

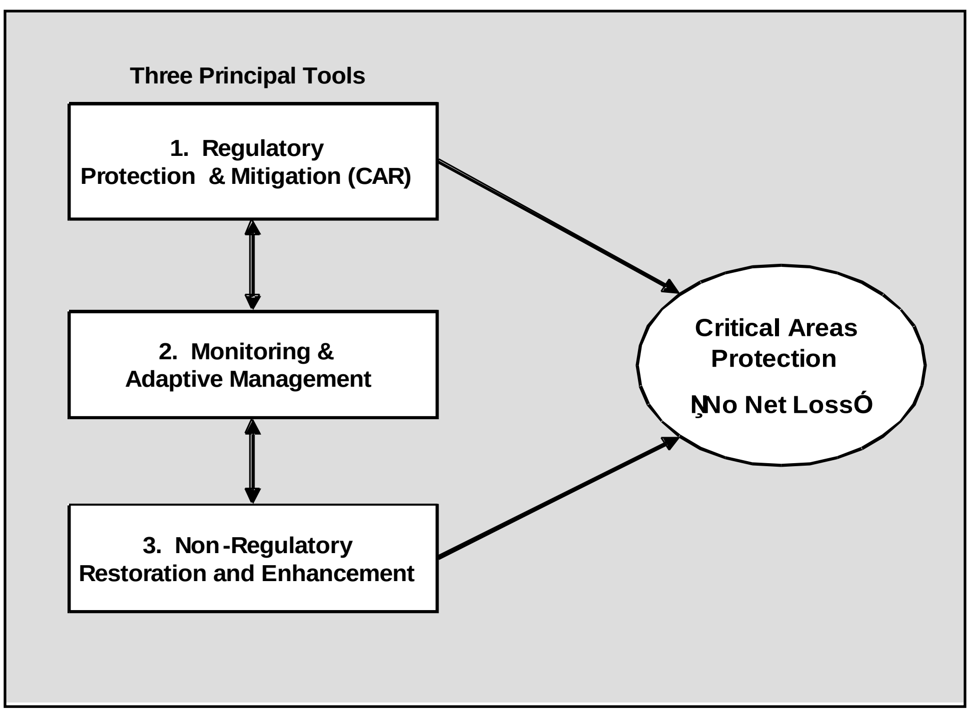

Figure 1. Conceptual Model of Snohomish County's Critical Area Program.

1.3 Critical Area Regulations and County Restoration Programs

The primary line of protection for critical areas is the implementation and enforcement of the regulations contained in chapter 30.62A of the CAR and other land use codes (i.e., Shoreline Master Program, drainage, grading and other development codes). Snohomish County's CAR contains standard science-based requirements such as buffers of prescribed widths. CAR also allows alternative or innovative approaches to critical area protection provided that the alternative or alternative approach achieves the same level of protection. The intent of these alternatives is to maximize protection of the functions and values through a tailored approach. A tailored approach accommodates site-specific conditions and allows flexibility to protect critical area functions and values, while balancing other County objectives such as providing for growth, a viable agricultural community and a healthy economy.

While alternative and innovative approaches allowed under the CAR may occur in many types of designated critical areas, they principally will affect Wetlands and Fish and Wildlife Habitat Conservation Areas (FWHCA). Thus, the monitoring plan focuses on Wetlands and FWHCA. The alternative and innovative approaches allowed in the regulations include: use of buffer reductions as incentive for specific mitigation measures; Innovative Development Design to encourage use of low impact development and implementation of watershed management or salmon recovery plans; and use of best management practices (BMPs) for minor development and agricultural activities. Table 1 provides a comprehensive list of alternative and innovative approaches.

Table 1. Alternative and Innovative Approaches Allowable under the CAR.

Allowed Buffer Impacts:
o Innovative development
o Reasonable use exception
o Fencing reduction
o Separate tract reduction
o Averaging
o Habitat corridor reduction
o Other mitigation measures from SCC 30.62A Table 5
o Single family residential exception
o Fee in lieu – via County parks
o Buffer loss/replacement
o Minor development activity
o Reasonable use exception
o Agriculture BMP
Allowed Wetlands Impacts:
o Fill mitigation
o Enhancement mitigation
o Wetland banking
o Innovative development design

Potential environmental impacts that may result from alternative and innovative approaches include a reduction in mature riparian forest cover, reduction in total riparian forest cover (including younger trees and shrubs), increased impervious surface within and outside of riparian and buffer areas, loss of wetlands, modification of shorelines and stream banks, and associated water quality and habitat impacts.

In addition to the mitigation measures required in the CAR regulations, impacts to functions and values will be further offset by the County's on-going non-regulatory restoration and enhancement actions. Restoration and enhancement actions include outreach and technical assistance to increase voluntary planting and wetland enhancement (e.g. native plant and community partners stewardship programs) and County-led restoration actions such as riparian planting, removal of invasive species, placement of large woody debris in streams and rivers, riparian fencing, wetland creation and restoration, fish-passage barrier removal, side-channel reconnection, improved stormwater infiltration, and water quality pollution reduction. These actions are prioritized and implemented consistent with the salmon recovery strategies outlined in the Puget Sound Salmon Recovery Plan (2005), the County's National Pollution Discharge Elimination System (NPDES) municipal stormwater management program, and other regulatory and strategic efforts.

1.4 Monitoring and Adaptive Management Program Overview

The CAR monitoring program is part of broader County monitoring efforts, which include monitoring required for Shorelines Master Plan compliance, Endangered Species Act (ESA) salmon recovery planning support and NPDES permit compliance. The CAR monitoring program directly supports Shoreline Master Plan compliance and elements of Salmon recovery plan monitoring. Monitoring efforts to support ESA salmon recovery planning and NPDES permit compliance are complimentary, but also distinct because they are designed to inform different questions.

The status and trends of critical area functions and values for FWHCA and Wetlands are being assessed through a three-part monitoring approach. The first component consists of analyses of riparian conditions, impervious surface and wetland extent using remote sensing data (aerial images and maps) with field-verification throughout the area under the County's jurisdiction. Specific riparian and wetland area metrics were selected for monitoring because they are directly regulated through the CAR, and because they are leading indicators of change, which exert a strong influence on critical area functions and values. The second part of the monitoring program involves assessing shoreline conditions along major rivers and lakes, providing information to support effective implementation of CAR as well as the Shoreline Master Plan. The third component, an intensive catchment study, is designed to evaluate the effectiveness of code provisions over the longer term in protecting riparian, water quality and in-stream habitat functions and values.

This three-part monitoring approach balances the need to detect change over a short time frame (components 1 and 2) so that program improvements can be made in a timely manner with the need to evaluate a range of functions and values over a longer time frame (component 3) to provide a complete assessment and advance the development of Best Available Science . Initial monitoring results will establish the baseline for the selected environmental indicators, and subsequent monitoring will track changes that may warrant a programmatic or regulatory adjustment through the adaptive management framework. Figure 2 is a decision-tree developed by Planning and Development Services, outlining the adaptive management decision-making process.

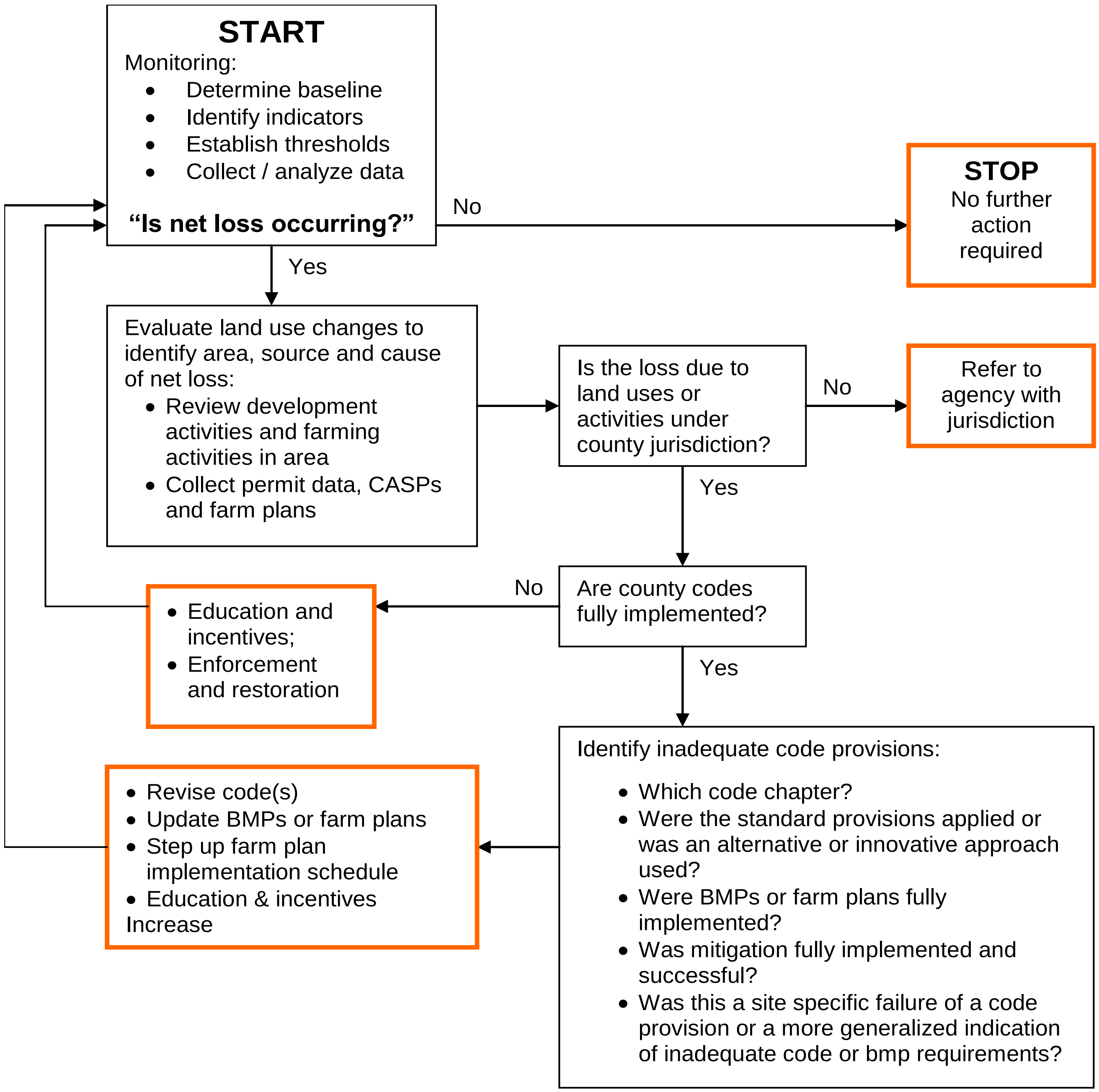

Figure 2. Adaptive Management Decision Tree.

Proposed monitoring indicators were selected that are representative of a range of functions and values of concern, sensitive to change, accurately and precisely measured, well documented in the scientific literature, and cost effective to measure. Indicators that will be measured, tracked over time and reported are included in Table 2. For more information on these indicators, please refer to the CAR Monitoring and Adaptive Management Plan (2008).

Table 2. Critical Area Monitoring Indicators.

Critical Areas	Function and Values	Indicators[1]	Source	Monitoring Plan Component
Wetlands	Fish and wildlife habitat; habitat for locally important and threatened species; runoff absorption, pollution assimilation, water quality maintenance, floodwater storage and attenuation; stream base-flow, groundwater	Wetland area by type (open water, emergent, scrub/shrub, forested)	NOAA Pathways and Indicators, 1996	One
FWHCA – Riparian (including lakes and marine shorelines)	Fish and wildlife habitat; habitat for locally important and threatened species, large woody debris recruitment, nutrients, water quality maintenance, stream bank stabilization	% mature forest cover	None reported	One
		%young forest cover	None reported	One
		% total vegetation cover (mature evergreen, medium evergreen, deciduous, scrub-shrub)	NOAA Pathways and Indicators, 1996	One
		% total impervious area (TIA)[2]	Summary of reports referenced in Spence *et al*., 1996	One
FWHCA – Aquatic	Fish and wildlife habitat; habitat for locally important and threatened species, refugia in side-channels; large woody debris (LWD) and small woody debris; sediment storage and transport; water conveyance; clean water, nutrients	% bank modifications	NOAA Stormwater Matrix, 2003	Two
		Bankfull channel width (CW) :depth ratio	NOAA Pathways and Indicators, 1996	Three
		Pool frequency	NOAA Pathways and Indicators, 1996	Three
		Temperature	EPA, 2003	Three
		Conductivity	Snohomish County, 2000	Three
		Benthic Index of Biological Integrity	Karr, 1998	Three

Snohomish County is using a six-step monitoring and adaptive process outlined in Figure 3 as the conceptual framework. The six steps are (1) problem assessment, (2) plan development, (3) implementation, (4) monitoring, (5) evaluation, and (6) adjustment. Step 1 consists of the official recognition by the County and the State of the need to protect critical area functions and values that are at risk of degradation. Step 2 consists of the development and adoption of the GPP, CAR, underlying Best Available Science (BAS), restoration programs, and this monitoring and adaptive management program. Step 3 is the implementation of the elements of Step 2. This report summarizes efforts to date related to monitoring (step 4). Establishing the monitoring baseline will set the stage for the evaluation process, whereby the sufficiency of steps 2 and 3 are evaluated (step 5). Results from the evaluation process will inform the adaptive management decision-making regarding any changes that may be needed to meet conservation goals (step 6).

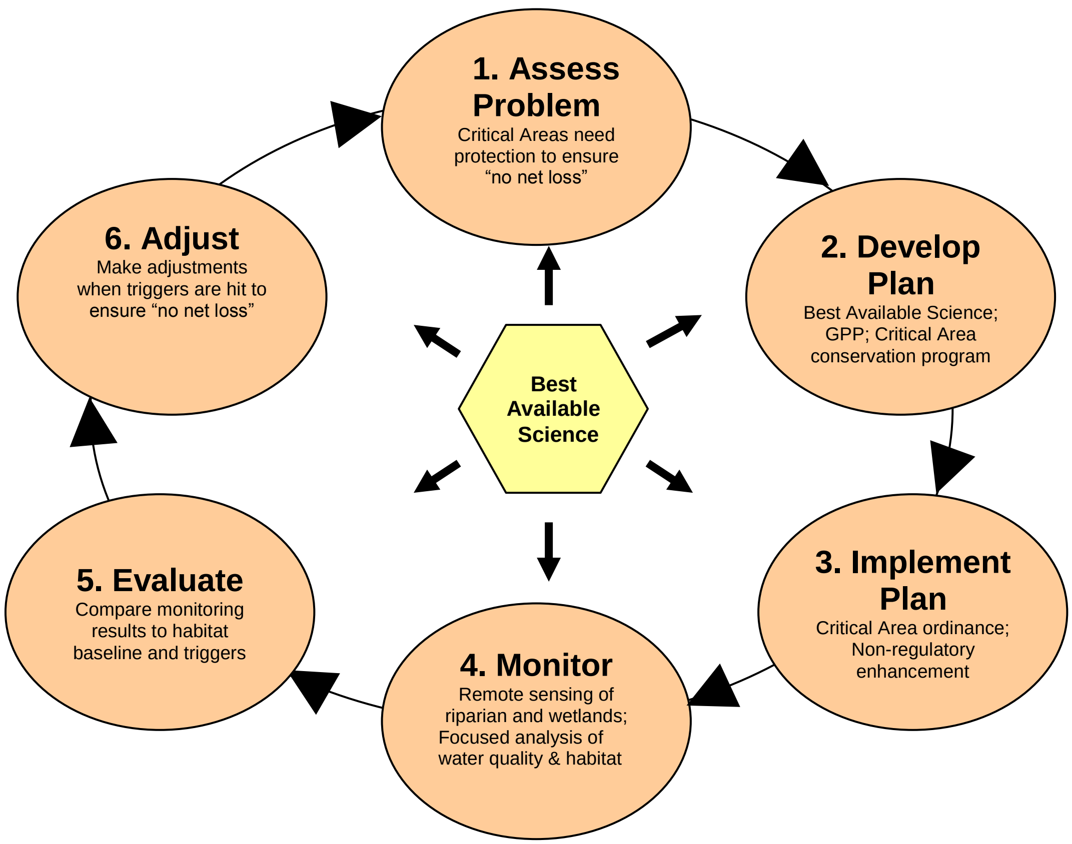

Figure 3. Monitoring and Adaptive Management Framework.

1.5 Key Management Questions

The monitoring and adaptive management program has been designed to inform the following key management questions and sub-questions:

1. Are gains or losses of critical area functions and values occurring in Fish and Wildlife Habitat Conservation Areas and Wetlands?
   a) Are changes in land cover within critical areas and their buffers evident?
   b) Are changes in shorelines along major waterways evident?
   c) Are regulatory and non-regulatory environmental programs protecting the physical habitat, biological integrity, and water quality of small streams?
2. If loss is occurring, what and where are programmatic adjustments needed to protect functions and values in FWHCA and Wetlands?
   a) Are losses of functions and values occurring not as a result of County actions, but rather actions taken outside the County's jurisdiction?
   b) Are losses of functions and values occurring in a specific land use or geographic area?
   c) Are losses of functions and values resulting from code violations?
   d) Are losses of functions and values occurring despite the County's programmatic approach to managing critical areas?

The order of questions follows the sequence outlined in the monitoring and adaptive management framework (Figure 3). The monitoring plan (step 4), implemented by the Surface Water Management Division of Public Works (SWM), is designed to inform the first question and sub-questions. The evaluation and adjustment processes (steps 5 and 6), which are framed by the second question and sub-questions, respectively, will be implemented by the Planning and Development Services Department (PDS), with monitoring results provided by SWM.

Together the questions and answers to them guide the adaptive management response. For example, if no change in critical area functions and values or a gain is observed (question 1), no further action would be required. If a loss is observed, the answers to the evaluation sub-questions (question 2) direct treatment toward the root cause to correct problems identified through referral, enforcement, public outreach, or code adjustment.

1.6 Work Plan and Schedule

Table 3 provides a general summary of the work plan and timeline for the monitoring and adaptive management. Table 4 outlines the roles and interaction between the Surface Water Management Division of Public Works and Planning and Development Services in the monitoring and adaptive management process. Public Works is responsible for implementing and reporting on results of the monitoring. Planning and Development Services is tasked with tracking permits, enforcement actions, and alternative or innovative approaches applied to buffers. PDS will prepare a report summarizing adaptive management recommendations based on monitoring results.

Table 3. Monitoring, Evaluation and Adjustment Schedule.

Steps	Monitoring and Adaptive Management Cycle 2008	2009	2010
Monitoring			
Monitoring Component 1	Improve hydrography; acquire winter satellite image; finalize imagery classification protocol; conduct field verification; prepare report summarizing baseline dataset, including an assessment of accuracy and precision	Acquire and process a second summer image; Gather additional field data to verify results. Improve wetland data classification using radar and LiDAR DEM topographic model.	Acquire and process a second winter satellite image. Gather additional field data to verify results.
Monitoring Component 2	Survey major river and lake shorelines to establish baseline.	Fill in remaining gaps in shoreline survey as needed.	Resurvey shorelines and report results.
Monitoring Component 3	Refine sampling design and study questions; select sites; begin data collection.	Collect data on chemical/biological/physical indicators using a replicable method.	Collect data on chemical/biological/physical indicators using a replicable method.
Evaluation			
	Refine permit review process (PDS). Prepare report summarizing baseline data collection (SWM).	Provide update on monitoring results to date. (SWM). Query AMANDA to evaluate permitted actions within critical areas	Evaluate changes in land cover and shoreline conditions and prepare monitoring report (SWM)[1].
Adjustment			
	Refine adjustment process; refine trigger levels as needed based on literature review and replicate surveys.	Continue to refine adjustment process as needed.	Produce adaptive management report (PDS). Adjust program based on results relative to triggers (referral; education; enforcement; mitigation; code adjustment).

[1] PDS is the lead for evaluation and ground-truthing related to permits

Table 4. Public Works SWM and PDS Roles and Responsibilities.

Public Works SWM	Planning and Development Services
1. Complete effectiveness monitoring • remote sensing • shorelines • Intensive catchments study 2. Evaluate changes in indicators relative to baseline conditions 3. Produce monitoring reports summarizing baseline conditions, changes, a discussion of probable causes, and an assessment of data accuracy and completeness	1. Complete implementation monitoring • permits issued • enforcement actions taken • buffer reduction location/extent 2. Provide data to SWM on the location and area of buffer reductions and exemptions allowed under the CAR to aid in evaluation 3. Produce adaptive management reports recommending and summarizing changes made to protect critical areas based on monitoring results

2. Monitoring Status

2.1 Approach

Substantial progress has been made in establishing the monitoring baseline. In addition to the three main components of the monitoring program outlined in the monitoring plan, the program includes tracking of permits issued, alternative or innovative buffer provisions applied, and non-regulatory environmental enhancement actions implemented by the County to assist in the evaluation of monitoring results. The status of each element of the monitoring program is summarized below.

2.2 Land Cover Classification

The land cover classification report prepared in collaboration between Battelle Pacific Northwest National Laboratory and Snohomish County is included in Appendix A.

Data Acquisition and Processing

New remote sensing data were acquired, and existing County GIS layers were improved. QuickBird satellite imagery for the study area was obtained in 7 images between July 31 and September 5, 2007. The project team attempted to obtain a winter image in 2007 and 2008, but was unsuccessful due to weather and competing projects. AVINIR-2 satellite summer and winter imagery was obtained on July 31, 2007 and January 28, 2007, respectively. LiDAR data, used to estimate tree height and to identify areas of potential flow accumulation, were obtained for 81% of the study area between 2003 and 2008. Radar data were obtained from the Radarsat-1, Radarsat-2, ERS-2, and PALSAR satellites through a NASA grant, and will be incorporated into the wetland classification protocol in 2009. The County's hydrography layer was greatly improved over 44% of the sub-basins within the study area by realigning it with a digital elevation model generated from LiDAR data. An imagery classification protocol was developed and a preliminary land cover classification completed using these data and other County ancillary GIS layers.

Field Data Collection

The project team developed a field data collection protocol to support imagery classification. Field crews gathered data on 1,336 land cover polygons delineated from the QuickBird satellite imagery. Three-quarters were used in rule set development for imagery classification, and 25% were randomly selected and set aside for an accuracy assessment. Vegetation height field data were also gathered to validate LiDAR-derived tree height estimates.

Classification

Snohomish County and Battelle Pacific Northwest National Laboratory developed a land cover classification protocol using both object-based and rule-based classification techniques and prepared the baseline dataset. In addition to satellite imagery, the rule-based classification methodology used County ancillary GIS layers including slope, parcels, streets, railroads, hydrography, lakes, coastlines, 100-yr floodplain, soils, and mapped wetlands. Wetland delineations for Critical Area Site Plans (CASPs) and a wetland inventory commissioned by the Snohomish Public Utility Department in the Sultan Basin were used to guide rule set development for wetland identification. Battelle applied a flow accumulation model based on a LiDAR digital elevation model to assist with wetland identification for four sections of the study area to further improve the wetland classification. An accuracy assessment was completed, comparing predicted land cover with field data. In early 2009, the flow accumulation model will be applied to the entire study area and the baseline dataset completed.

2.3 Shoreline Inventory

The baseline shoreline survey, summarized in Appendix B, was completed for Snohomish County's major lakes and rivers. The population of lakes in Snohomish County was stratified into three size classes to provide a representative sample, and 50% were randomly selected for survey. The aerial extent of docks was estimated from 2007 aerial photos for the stratified random sample of lakes. Shoreline conditions along navigable river reaches of the Skykomish, Snohomish, and Stillaguamish rivers were surveyed. None were surveyed in the Lake Washington Watershed, which contains no navigable river reaches. The Skykomish was surveyed from river mile 23.1 in Goldbar down to the confluence with the Snoqualmie River. The Snohomish River was surveyed from the confluence to the upper extent of tidal influence. The Stillaguamish River was surveyed from river mile 16.2 on the South Fork and river mile 21.4 on the North Fork to the confluence. The mainstem Stillaguamish River was surveyed along its entire length to Port Susan. In total 137 miles (220 km) of river shoreline were surveyed.

2.4 Intensive Catchment Study

An intensive catchment study was initiated to take a closer look at impacts to critical area functions and values in small drainages (Appendix C). Small drainages were selected for inclusion in the intensive catchment study following review of permit applications and zoning maps to identify sites and small drainages that will likely develop in the near future under the new CAR regulations. These sites were paired with small drainages with similar characteristics that were deemed unlikely to experience significant development. The project team contacted landowners to obtain permission for data collection and established long-term monitoring sites. At each site survey crews measured channel cross sections and habitat conditions, conducted aquatic macroinvertebrate sampling, and measured temperature continuously in July and August using temperature loggers. Seven sites were sampled in 2008, and additional sites will be added to the study in 2009.

2.5 Permit Tracking

Improvements were made to the permit tracking system (AMANDA) in order to identify those permitted activities on or near FWHCA and Wetlands. PDS biologists will gather additional information on critical areas when permits are received. New fields were added to the AMANDA database so projects with Wetlands or FWHCA that employ the use of any of the alternative or innovative protection approaches can be easily identified and queried. By tracking this information, the County will be able to distinguish between impacts in the near-stream environment allowable under the code, and those that are not. AMANDA will be tracking all of the buffer and wetland alterations allowed in CAR for further analysis.

2.6 Enhancement Project Tracking

Snohomish County and other lead entities for watershed planning across Washington have been working with the Washington Department of Fish and Wildlife over the last two years to develop a project database called the Habitat Work Schedule (HWS). The HWS will be used to highlight accountability for implementation of the salmon recovery plan and as an integral part of adaptive management. It is a comprehensive project management system that will greatly improve project tracking, sharing of results, and reporting organization. Once online, the HWS will be used to track and report non-regulatory restoration and enhancement actions completed by the County for the purposes of CAR monitoring. Since the HWS is still in development, staff consulted County restoration project managers to generate a list of all riparian enhancements, stream restoration, and culvert replacement completed in 2007 and 2008.

3. Results

3.1 Land Cover Classification

The land cover classification encompassed a 965 miles^2 (2,500 km^2) study area from Puget Sound to the Cascade foothills. Figure 4 graphically illustrates results from the initial classification of the baseline dataset in four test panels within the study area. The classification delineated land cover into 14 classes: lakes/open water, impervious surface, bare earth, gravel bars, invasive species, grass/pasture/lawn, shrubs/small trees, emergent wetland, scrub/shrub wetland, forested wetland, medium evergreen forest, mature evergreen forest, medium deciduous forest, and mature deciduous forest.

Field data gathered for 334 polygons were used to evaluate accuracy of results. Remote sensing accuracy in the context of this project refers to the correctness of the land cover map compared with the true land cover. Overall accuracy achieved to date is 80.1%. Among individual land cover classes, impervious surface (94.7%) and water (98%) had the highest user’s accuracy. Deciduous forest (88.6%) and evergreen forest (83.6%) land cover types also were classified with moderately high user’s accuracy. The wetland classification, completed and evaluated through a separate process and later merged to form the final land cover map, had an overall accuracy of 82.9%. Further work is needed to detect forested wetlands and improve classification results for the shrubs/small trees (56%) and grass/pasture (62.2%) classes These classes had high heterogeneity and similar reflectance values, and thus further training data and analyses are needed.

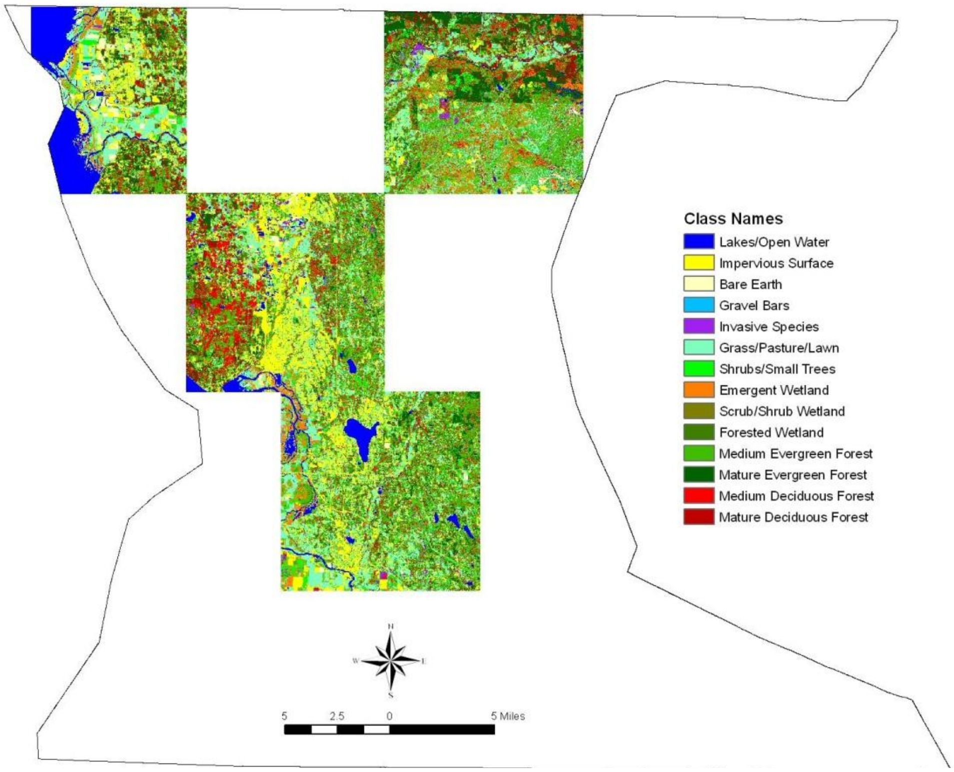

Figure 4. Land Cover Map for Four Test Blocks.

3.2 Shoreline Inventory

The shoreline inventory included the County's navigable rivers and a stratified random sample of 50% of lakes within the study area (Figure 5). Rivers surveyed included the Skykomish, Snoqualmie, Snohomish, North Fork Stillaguamish, South Fork Stillaguamish and the mainstem Stillaguamish. In total County field crews surveyed approximately 137 miles (220 km) of river shoreline and 28 miles (45 km) of lake shoreline. Cumulatively, 44 and 24 percent of lake and river shorelines were armored, respectively.

Lakes modifications ranged from <1% (Lake Armstrong and Chain Lake) to 78% (Lake Stevens). Large lakes were more heavily modified than smaller lakes. Bulkheads were the most common type of lake modification (73%), followed in decreasing order by revetment (23%), grade/fill (2%) and boat ramp (1%). Armoring included materials such as concrete, various wall blocks, wood structures and rock. No substantial bank instability was recorded in lakes as most banks were flat or gently sloping. Steep or vertical shoreline segments were few in number and were generally protected by armoring or vegetation. Lakes with few modifications, generally also had more intact vegetation along the shoreline. Lakes with a high degree of shoreline modification also had the most docks. In total 1,256 docks were identified with an aerial extent of more than 17.5 acres (7.1 hec).

Similarly, the extent of bank modification and instability along river reaches varied widely. Mainstem Reach 4, Hat Slough and Cook Slough in Lower Stillaguamish River valley had the highest level of bank modification at 37%, 35% and 34%, respectively. Stillaguamish Mainstem Reach 2, NF Stillaguamish Reach 3, Snohomish Reach 1, and Skykomish reaches 1 through 4 had 20% or greater bank modification. Only Skykomish Reach 6 had less than 10% modified banks. The extent of river modification generally increased in a downstream direction. The Stillaguamish River mainstem had the highest percentage of modified banks (29%), followed by the Snohomish River mainstem (25%), however, it is important to note that the Snohomish survey is incomplete. The Skykomish River and the North Fork Stillaguamish River had a comparable level of modification (18-19%). Bank modifications were predominantly revetments comprised of riprap. Unstable banks comprised 15% of the total surveyed length and ranged from a low of 6% in Hat Slough to a high of 32% in Skykomish Reach 6.

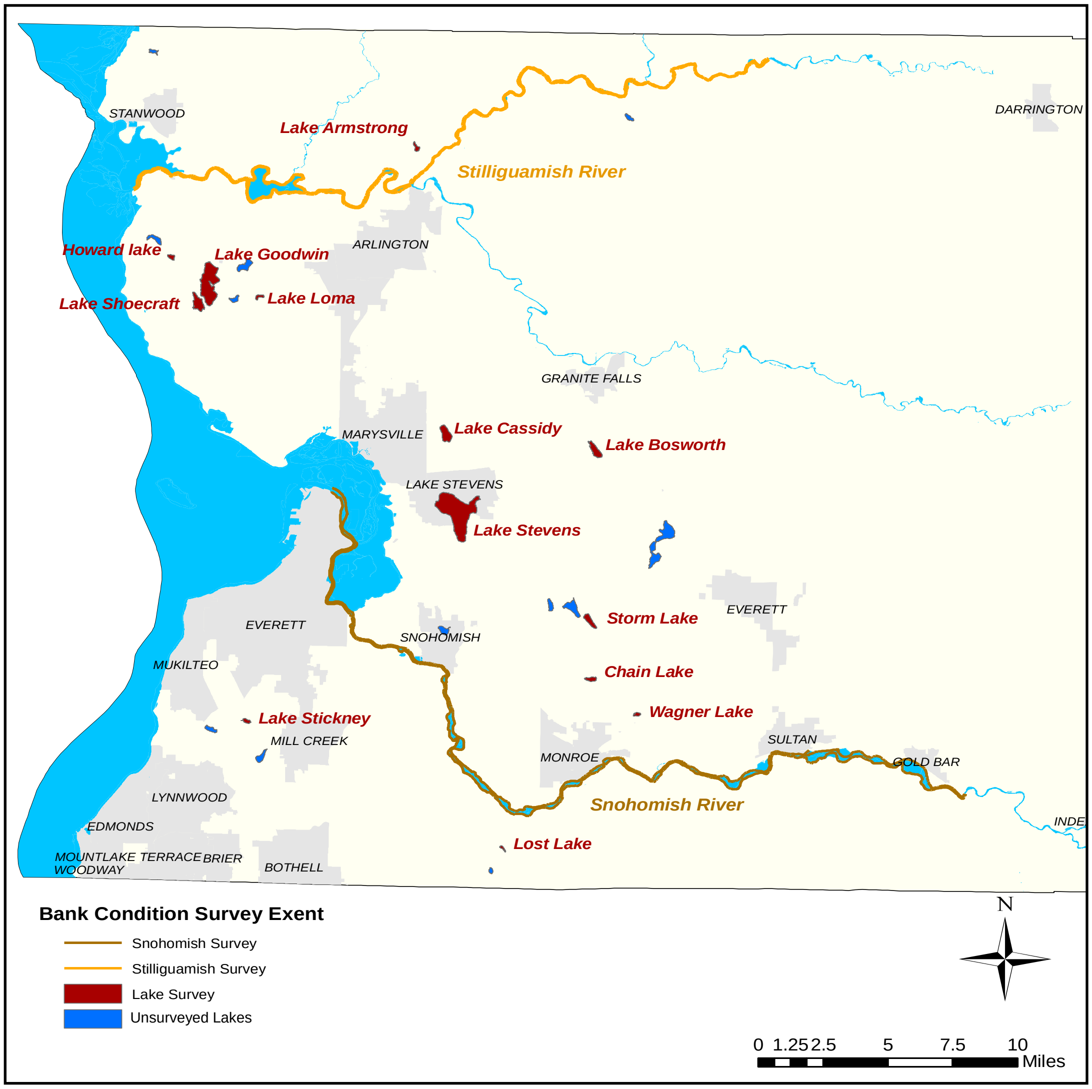

Figure 5. Lakes and Rivers Included in the 2008 Bank Conditions Survey. The South Fork Stillaguamish River was surveyed in 2007.

3.3 Intensive Catchment Study

Initially 12 catchments were selected (6 pairs), but only 7 were sampled related to challenges with permissions and dry channels (Figure 6). Drainages selected ranged in size from 0.2 to 1.9 miles^2 (0.4 to 5.0 km^2), and had average bankfull widths from 5.3 to 12.7 feet (1.63 to 3.86 m). Bankfull depths in these small channels were shallow at less than 1ft in each representative riffle. Water and air temperatures varied by only a few degrees among most sites with Catchment 1A producing the highest stream temperatures at over 64 °F (18 °C) during the warmest days in August. Catchments 1B and 2A had relatively cool temperatures, potentially due to groundwater influence. Pool frequency was highest in Catchments 1A and 1B though pools were small and shallow. Catchment 3A had the lowest pool frequency with only one pool in a 197 ft (60 m) reach, but this one pool was deepest among all the pools with a maximum depth of over 1 ft (0.3 m). Aquatic insect samples were gathered for a calculation of the streams health as measured by the benthic index of biotic integrity (B-IBI). Samples are currently being processed at a certified lab.

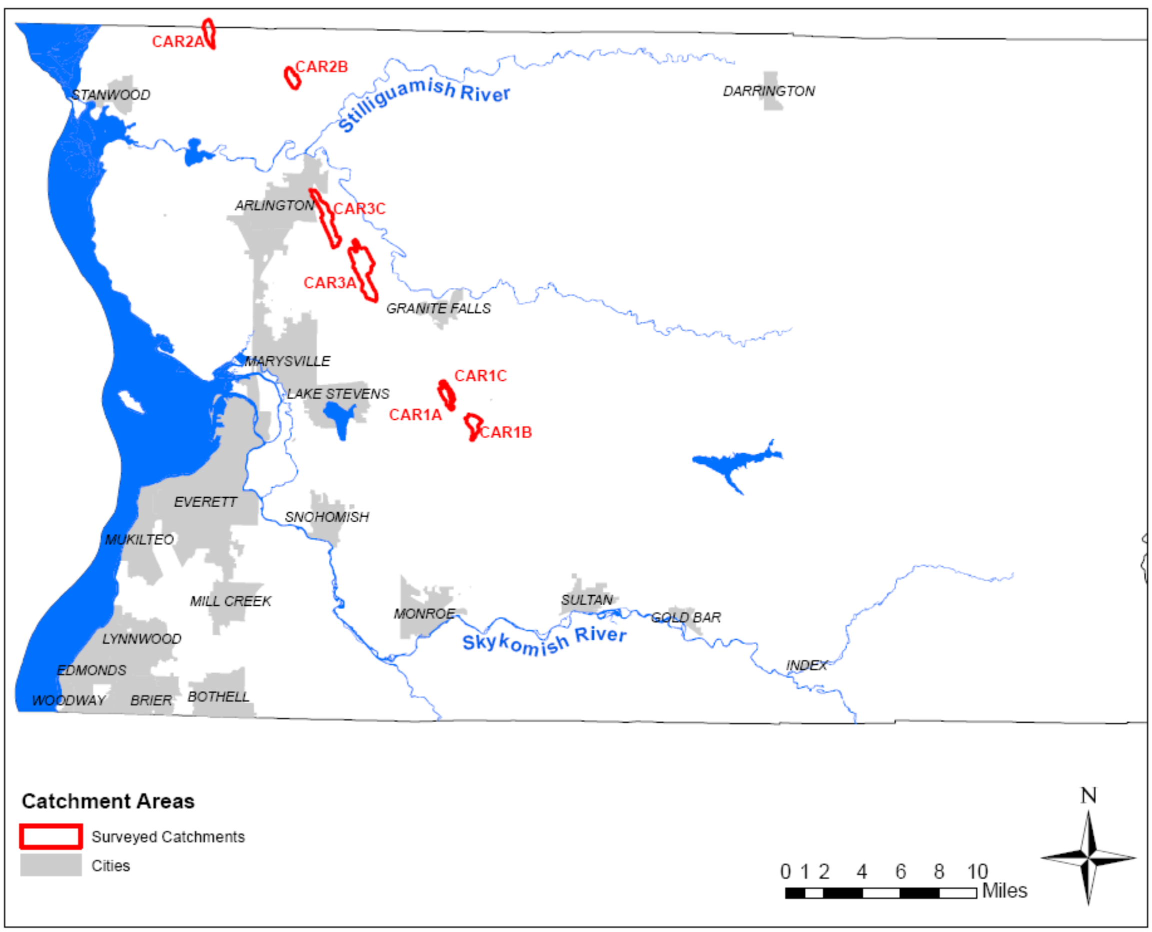

Figure 6. Location of sampled catchments sampled in 2008. They are identified by their Site ID.

3.4 Permit Tracking

The adoption of the new CAR in October 2007 coincided with a regional and national economic slowdown and drop in development permits. PDS made changes to the AMANDA database in October 2008 to allow for future queries of sites with critical areas and any alternative or innovative approaches applied. Data are available for the previous year, but due to staff reductions, PDS was unable to summarize information on the number of permits issued, location and impact of alternative and innovative approaches applied, and mitigating measures for this progress report.

3.5 Enhancement Project Tracking

The County completed non-regulatory enhancement actions on 22 sites across the County. Enhancement actions included culvert replacement, invasive plant species control, riparian planting, small stream restoration and large river restoration. In 2007 and 2008, Snohomish County replaced 10 culverts, opening and/or improving access for anadromous salmonids to 8.6 miles (13.8 km) of stream habitat. Approximately 41 acres were planted with native riparian forest trees and shrubs. The majority of riparian enhancement (28 acres) occurred in the Snohomish River basin. In Stillaguamish and Cedar-Lake Washington river basins, 12 and 1.5 acres were planted, respectively. Stream habitat enhancement projects, located on Lundeen Creek, Creswell Creek, Mosher Creek, North Creek, Fish Creek and Church Creek, enhanced 1 mile (1.6 km) of stream habitat. Large river habitat enhancement projects were implemented at Fields Riffle, Norwegian Bay, and Twin Rivers along the Snohomish River, and at North Meander on the Stillaguamish River. In total Snohomish County placed approximately 675 pieces of large woody debris at enhancement project sites and reconnected 7 acres of off-channel habitat.

4 Conclusions

4.1 Challenges and Limitations

As with any nascent program, and particularly one relying on cutting edge technology, challenges arose. None of the challenges are insurmountable, and many have already been remedied. Remaining issues will be addressed in 2009, and the baseline dataset will be updated accordingly.

<u>Land Cover Classification</u>

While initial results from the land cover classification are promising, spatial data have some intrinsic challenges and limitations:

- The classification process involves huge datasets that pushed (and sometimes exceeded) the memory and processing capabilities of existing computer hardware. This slowed down the classification process, and in some cases, eliminated options to complete the analysis.
- A winter scene from the QuickBird satellite was not obtained, despite two seasons attempting to do so. Five satellite passes are required to obtain imagery for the entire study area. Cloud cover, competing projects, and satellite memory problems make the acquisition

of a winter image very challenging. Instead, we relied on the AVNIR 2 satellite, a lower resolution satellite that can capture an image of the entire study area in one pass, for the winter image.

- Cloud cover, haze and shadows in the summer QuickBird image also posed challenges for classification. Various techniques were applied to improve the classification of portions of the image impacted by these factors.
- Wetland classification through remote sensing techniques is challenging due to the heterogeneity of these features. A LiDAR DEM flow accumulation model was applied to improve the wetland classification. Radar satellite data and additional field-collected data to support rule-set development may also be helpful in improving the classification.
- Small streams are easily confused with shadows in the satellite imagery. Hydro-realignment data derived from LiDAR DEM will greatly improve the classification accuracy on the water category.
- Current LiDAR DEM and vegetation height data are out-dated and variable in quality and accuracy throughout the study area. In the final vegetation map, plant height data were directly used to classify vegetation types. Having LiDAR data acquired during the CAR monitoring cycle would help distinguish among grass, shrub/small tree and deciduous forest, thereby improving classification accuracy.
- To improve our ability to accurately characterize riparian areas affected by CAR, this project allocated significant resources to update spatial accuracy of County stream GIS lines using LiDAR elevation models, survey data and critical area site plan information. With this and previous efforts, 41 percent of the sub-basin area within the study area where LiDAR data exists has been improved. Though much work still remains to complete the spatial corrections, improve stream type attributes and incorporate the changes into the County's master dataset, the stream updates completed to date are currently being used to strengthen the land cover data model.

<u>Shoreline Inventory</u>

The shoreline inventory was based on a methodology that was previously developed and implemented by County staff. As a result data collection went very smoothly. Challenges and limitation include:

- Shallow water, docks and currents make it challenging to maneuver boats close to the transition point between bank segments exhibiting different characteristics. With post processing using high resolution aerial photos, however, it is fairly easy to "snap" data to the County shoreline layer to the correct location with a high degree of accuracy.
- Lake shoreline modifications are highly complex, and thus time consuming to collect. Landowners have used a broad range of material and techniques to modify the shoreline.
- River surveys are straightforward but labor intensive given the need for two watercrafts and a drop-off vehicle.

<u>Intensive Catchment Study</u>

The catchment study began slowly, but went well once it was underway. Challenges and limitations include:

- Identifying appropriate field sites was more challenging than anticipated. The drop in permit applications made it difficult to identify sub-basins that are likely to experience significant development in the next several years. We had originally intended to establish field sites on small streams directly adjacent to large development projects applying alternative or innovative buffer designs, but new permits for such developments were not found.

- Obtaining permissions to sample on private property also constrained site selection. Access was requested and granted for most sites, however, several landowners denied access, thus eliminating prospective sites from the sample.
- Field conditions also limited potential site suitability. Initial field assessments revealed some sites had no summer flow, and others were altered by beaver activity. One site was not sampled because of an adjacent road construction project. In some cases sample site locations were adjusted up or down stream or moved to a neighboring catchment which affected catchment size and characteristics and similarities between pairs. In other cases sites were removed from the study further reducing sample size.
- Instruments for measuring continuous water conductivity levels were not available to the project. The metric was not measured in 2008.

4.2 Next Steps

Despite challenges, the CAR monitoring program is off to a successful start. Building on a solid foundation, the following additional actions will be taken in 2009 to fill remaining gaps and improve upon results:

<u>Land Cover Classification</u>

- ***Apply the LiDAR Dem hydrologic model to the entire study area***. This model approach to aid in the detection of wetlands was applied in four subareas with promising results. It will be applied to the entire study area in the first quarter of 2009.
- ***Investigate the use of radar data to improve wetland classification***. Radar data were obtained for the project through a NASA grant. The scientific literatures and preliminary analysis show promise for improving wetland classification. Radar data can detect soil moisture, an indicator of the presence of wetland conditions.
- ***Evaluate the QuickBird satellite's panchromatic band to improve impervious surface***. QuickBird's panchromatic band is at a higher resolution of 0.61 meter. Use of the panchromatic band over the entire study area will increase the accuracy of impervious surface estimates further. To complete this step, it will be necessary to address data processing hardware challenges created by the huge dataset.
- ***Gather additional field data to refine the classification.*** The field protocol was established for ground truthing the QuickBird satellite imagery. Additional data points are needed to characterize unclassified areas and assist with classification of AVNIR 2 and Radar satellite data.
- ***Continue to improve the County stream hydrography layer and create a buffer layer.*** The County hydrography layer will be updated to better align with the LiDAR DEM. Once complete, a buffer layer will be created based on buffer widths for various stream types identified in the CAR.
- ***Finalize the baseline data set.*** Once these additional techniques are fully explored, the baseline dataset will be finalized, and data will be reported on multiple scales (i.e., watershed and sub-basin).

- ***Obtain a second QuickBird summer image.*** QuickBird imagery will be acquired in August 2009 for the entire study area. Post processing and classification will begin in the fall, and will be completed in 2010 to evaluate trends.
- ***Improve geometric correction accuracy.*** Accurate QuickBird geometric correction for future QuickBird data is essential for change detection. Development of a change detection algorithm is required in the next mapping cycle. Therefore, it is critical to have QuickBird data that are geometrically corrected within 0.5-pixel accuracy.

Shoreline Inventory

- ***Fill data gaps in baseline shoreline inventory***. Shoreline surveys were completed for a majority of navigable waters within the study area in 2008. A few areas remain to be surveyed in 2009 to complete the baseline dataset.
- ***Explore use of Pictometry for completing shoreline survey.*** Pictometry, a remote sensing application using oblique aerial photos, if available for the study area, may provide a cost effective alternative to field data collection.

Intensive Catchment Study

- ***Increase sample size***. Using permit applications and zoning maps as a guide, additional catchments will be identified and added to the sample. These may be added as new pairs or to improve existing pairs affected by changes to sample site locations in 2008.
- ***Further integrate with other County monitoring programs***. Incorporate select sampling sites that overlay with established B-IBI and ambient water quality sampling sites
- ***Add additional sampling indicators***. Conductivity, an indicator identified in the monitoring plan, will be added to the monitoring effort in 2009. The use of other indicators, including those that assess level of ecological functions, will also be explored further.
- ***Add a functional assessment of wetlands within the catchments.*** Current data collection efforts within catchments focus on functions associated with Fish and Wildlife Habitat Conservation Areas. If resources are available, a wetland functional assessment may be added to the study.
- ***Analyze results in the context of other County and regional monitoring data.*** Larger data sets will allow us to more quickly establish a baseline and identify trends. A statistician will be consulted further to refine the study design.
- ***Complete detailed land cover and permit analysis within the contributing area.*** The drainage area above long-term monitoring sites will be characterized in great detail. Additional cross-sections may be added upstream for earlier detection of channel adjustment to watershed changes.

Adaptive Management

- ***Improve AMANDA reporting.*** PDS made updates in the AMANDA database to facilitate the identification of parcels with critical areas and the types of actions implemented on those parcels. These changes were enacted in October 2008. PDS will review and revise reporting in AMANDA for permits issued under the new CAR prior to making the updates to AMANDA. PDS will also review input data to ensure staff are filling out the new field completely and correctly and to verify that changes are sufficient to inform adaptive management decision-making.

- ***Improve enhancement project tracking.*** Effort are underway to improve the tracking of habitat enhancement activities and the locations of projects through refinements to the restoration project data base and Habitat Work Schedule.
- ***Adaptive management reporting.*** SWM will compare monitoring results in subsequent years to the monitoring baseline to track changes in Wetland and FWHCA functions and values and inform adaptive management decision-making. PDS will prepare an adaptive management report to the Executive and Council with recommendations regarding County actions to protect critical area functions and values.