Final Technical Report 2

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Acronyms and Definitions

CHaMP	Columbia Habitat Monitoring Program
Ecology	Washington Department of Ecology
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
GIS	Geographic Information Systems
GRTS	Generalized Random Tessellation Survey
ISTM	Integrated Status and Trends Monitoring
LCFRB	Lower Columbia Fish Recovery Board
Metric	the value resulting from measuring a monitoring attribute (parameter), or the value resulting from processing measurements, such as taking their average
Non-constructed channel	excludes irrigation channels, power canals, drainage ditches, and other waterways that may exhibit many of the following criteria: built where no waterbody previously existed; constructed of impervious material; not used for recreation or potable water; constructed, operated, and maintained for a specific purpose or need; controlled ingress and egress; or surface continuity with a natural water body interrupted by a pipe, pump, dike, etc. (Ecology 2012c)
NPDES	National Pollutant Discharge Elimination System
ODEQ	Oregon Department of Environmental Quality
ODFW	Oregon Department of Fish and Wildlife
PNAMP	Pacific Northwest Aquatic Monitoring Partnership
RME	Lower Columbia Research, Monitoring, and Evaluation Program
SRFB	Salmon Recovery Funding Board
Stage	synonymous with the term “phase” used in the Statement of Work to describe the three steps in this effort; used “stage” to avoid confusion with Ecology permitting terminology used for Phase I and Phase II permits

stream reach	a section of stream that has consistent morphology through its entire length, particularly in terms of gradient, flow volume, width and confinement
stream segment	a section of stream between two specified points, such as tributary junctions or monitoring stations
target population	refers to the resource to be described
water Qa/Qx	water quality/quantity
WDFW	Washington Department of Fish and Wildlife
WRIA	Water Resource Inventory Area
UGA	Urban Growth Area
USFS	US Forest Service

Introduction

The Lower Columbia Habitat Status and Trends Monitoring Project was initiated to develop recommendations for a coordinated habitat and water quality/quantity (water Qa/Qx) status and trends monitoring program in the Lower Columbia region. Large-scale status and trends monitoring is essential to assess whether current efforts to address the factors limiting salmon recovery are making progress. Actions that promote salmon recovery also help ensure that habitat and water Qa/Qx are safe for other beneficial uses such as domestic water supplies and recreation.

The Lower Columbia Habitat Status and Trends Monitoring Project builds on the Lower Columbia Research, Monitoring, and Evaluation (RME) Program for Lower Columbia Salmon and Steelhead, which details the elements of a coordinated regional program supporting Lower Columbia salmon and steelhead recovery and watershed plan implementation efforts (LCFRB 2010a). The Pacific Northwest Aquatic Monitoring Partnership (PNAMP) Integrated Status and Trends Monitoring (ISTM) demonstration project furthers this progress by moving towards a specific monitoring design for the region. The RME program was designed to integrate and complement other state and regional planning and research, monitoring and evaluation efforts for salmon and steelhead recovery and watershed restoration.

The Lower Columbia Habitat Status and Trends Monitoring Project (project) builds on the ongoing ISTM project by integrating the monitoring priorities and existing programs of ISTM partners (Table 1) with receiving water Qa/Qx monitoring programs implemented by municipal stormwater National Pollutant Discharge Elimination System (NPDES) permittees in southwest Washington. Stormwater permittees of large and medium municipalities in the Lower Columbia region (Phase I permittees; Table 1) currently conduct receiving water monitoring; permittees of small municipalities (Phase II permittees) may begin participating in stream water Qa/Qx, benthos, habitat, and sediment chemistry monitoring by the 2018-2023 permit cycle (Lisa Cox, pers. comm., January 15 2013). The project study area is shown in Figures 1 and 2, and includes the Lower Columbia region, encompassing all Columbia River tributary subbasins from the mouth of the Columbia River up to the White Salmon River in Washington and the Hood River in Oregon, and the Willamette River up to Willamette Falls. The project will also incorporate status and trends monitoring needs of stormwater permittees within Water Resource Inventory Areas (WRIAs) 22 and 23 (the City of Aberdeen and the City of Centralia).

Table 1. Lower Columbia Habitat Status and Trends Monitoring Project participants

Integrated Status and Trends Monitoring (ISTM) project partners			
Pacific Northwest Aquatic Monitoring Partnership (PNAMP)			
Lower Columbia Fish Recovery Board (LCFRB)			
Washington Department of Ecology (Ecology)			
US Forest Service (USFS)			
Columbia Habitat Monitoring Program (CHaMP)			
Oregon Department of Environmental Quality (ODEQ)			
Oregon Department of Fish and Wildlife (ODFW)			
Governor's Salmon Recovery Office - Salmon Recovery Funding Board (SRFB)			
SW Washington stormwater permittees (Water Resource Inventory Areas 22, 23, 25, 26, 27, 28)			
Phase I	Phase II		
Clark County (also an ISTM partner)	Cowlitz County	City of Camas	City of Longview
	City of Aberdeen	City of Centralia	City of Vancouver
	City of Battle Ground	City of Kelso	City of Washougal

This project will involve the development of recommendations for a region-wide habitat and water Qa/Qx status and trends monitoring design in three phases, or stages, as follows:

- Stage 1 - identify potential status and trends alternative monitoring scenarios
- Stage 2 - complete a trade-off analysis between alternative monitoring scenarios
- Stage 3 - develop final recommendations for a unified monitoring program

In Stage 1, stormwater managers' priority management questions were identified, and existing stormwater monitoring programs documented. This information was then integrated with similar information from ISTM partners to develop a summary list of management questions and the monitoring metrics needed to answer them. Sets of management questions that focused on the same set of metrics were organized into Management Question Groups (MQG). These MQGs formed the basis for analyzing the gaps where additional data collection was needed to answer management questions. Input on these management questions, associated metrics, and gap analysis were gathered in a technical workshop held in January of 2013. Workshop feedback, along with feedback solicited via email, contributed to the development of three alternative monitoring scenarios, which were presented at a second technical workshop in February of 2013. Simultaneously, statistical evaluation was conducted to determine the feasibility of combining probabilistic and non-probabilistic (opportunistic) sampling designs. Results and discussion of Stage 1 progress are available in Technical Report 1 (Tetra Tech 2013).

This report describes Stage 2 of this process. In Stage 2, a tradeoff analysis of the alternative monitoring scenarios was conducted to evaluate ways in which the monitoring program could be scaled up or down to more completely address priority monitoring questions, and the relative costs and benefits of making

protocol adjustments to existing monitoring programs. This tradeoff analysis proceeded based on the varying design options for one of the alternative monitoring scenarios presented at the February technical workshop. Participants of that workshop, and entities that provided input following the workshop, agreed that the moderate scenario, Scenario 2, was the most feasible option. The metrics under Scenario 2 were prioritized, or tiered, to create three levels of effort, which were then taken through the tradeoff analysis. As part of this analysis, target monitoring populations and related spatial scales were clarified, and resulting discrepancies in water Qa/Qx and habitat monitoring designs addressed. A stormwater technical subgroup meeting/workshop was also held during Stage 2 to further refine priorities for water Qa/Qx metrics, and to finalize monitoring frequencies, timing, and field collection methodologies. Meanwhile, statistical evaluation explored the utility of a GRTS-based design versus other spatial designs for reducing bias and increasing precision. Other efforts assessed potential funding mechanisms and collaboration options for stormwater permittees, and other considerations. Monitoring design options and participant interests were further explored in the April technical workshop where the many design options within alternative monitoring scenarios were vetted. This report includes results from that workshop.

Stage 2 tasks have progressed to date as follows:

- Redevelopment of Alternative Monitoring Scenarios based on February Technical Workshop feedback – February/March 2013
- Statistical evaluation – February/March 2013
- Tradeoff analysis among Alternative Monitoring Scenarios and other design options – February/March 2013
- Water Quality/Quantity Technical Subgroup – March 11, 2013
- Task 2.1 scope revised via memo – March 19, 2013
- Draft Technical Report 2 – March 27, 2013
- April Technical Workshop – April 2, 2013
- Final Technical Report 2 – April 25, 2013

Regional Strategy for Research, Monitoring, and Evaluation

The goal of the Lower Columbia Habitat Status and Trends Monitoring Project is to develop recommendations for a regionally integrated habitat and water Qa/Qx status and trends monitoring program. Status monitoring assesses conditions at a particular point in time, and can also be used to evaluate spatial and temporal variability and to set a baseline against which future conditions can be examined. Trends monitoring assesses change in conditions in the long-term by repeating site measurements over time. This status and trends project, however, is only one component of a viable research, monitoring, and evaluation program needed to protect the resources necessary to support salmon and steelhead recovery, clean drinking water, and other beneficial uses. In addition to developing a status and trends monitoring program, a regional strategy must include evaluation of existing programs, available data and information gaps, and compliance requirements; and identification of needs and priorities, as detailed in the Lower Columbia RME Plan (LCFRB 2010a); and research into

poorly understood ecological associations and postulated cause and effect relationships. Additionally, a habitat and water Qa/Qx status and trends monitoring program will need to be complemented by other monitoring programs designed to identify water Qa/Qx or habitat impairments, consider the effectiveness of best management practices and other current approaches, and assess the status and trends of ESA-listed salmonid populations and progress in addressing limiting factors not monitored by other programs.

The LCFRB has recently evaluated RME needs for the Lower Columbia region and made recommendations for a coordinated RME program that would support salmonid recovery and implementation of watershed plans (LCFRB 2010a). RME reviews have also been conducted by a number of other regional programs with interconnected objectives (see LCFRB 2010a). Three monitoring programs (i.e. monitoring programs for stream flow, remote sensing, and salmon and steelhead) with goals closely aligned to a habitat and water Qa/Qx status and trends monitoring program are outlined below. Together with these programs, a habitat and water Qa/Qx status and trends monitoring program would comprise the core of an integrated status and trends monitoring strategy for the Lower Columbia region. Coordination and communication among all research, monitoring, and evaluation efforts to the maximum extent possible is most likely to result in effective use of limited resources to successfully attain salmonid recovery and the protection of other resources.

Stream Flow Monitoring Program

Ongoing continuous flow monitoring at the existing network of stream gauges should continue. The number of gauge stations, however, is being reduced from 72 to 53, and determinations for which gauge stations will be retained should consider the complementarity of the data to the instantaneous flow monitoring recommended as part of the habitat and water Qa/Qx status and trends monitoring program. All existing stream gauge sites have been selected opportunistically. To integrate continuous flow data with data from status and trends monitoring sites, a statistical model would need to be applied to define the extent of the inference of flow gauge sites and convert them to a pseudo-probability design. This would allow the data collected under both monitoring programs to be compatible.

Remote Sensing Monitoring Program

Several habitat metrics are currently being monitored by various entities, or were identified as high priority metrics for addressing monitoring questions, but can best be evaluated using remote sensing data analysis within a geographic information system (GIS). These metrics are related to vegetation cover, land use, disturbance presence, wetland availability, floodplain connectivity, and impervious surfaces. Ideally, these factors would be monitored using GIS analysis at habitat monitoring sites. Data layers in this GIS analysis may include Landsat, land use/land cover, stream hydrography, aerial photos, digital elevation models, LiDAR, or other layers. A region-wide remote sensing monitoring program implemented by one or a few entities, rather than many programs focusing on each entity's particular area of interest, would concentrate technical expertise, support the efficient use of technologies needed to process digital media and gather data, and increase consistency in data interpretation. Ongoing AREMP and Pacific Intermountain Biological Opinion (PIBO) satellite imagery analysis projects may provide suitable frameworks for such a regional program. Remotely-sensed habitat monitoring has

also been recommended by NOAA to assess the threat to salmonids from habitat loss (Crawford and Rumsey 2011).

Salmon and Steelhead Monitoring Programs

Salmon and steelhead monitoring program designs should be integrated with the habitat monitoring design, as they both monitor the same population of stream reaches and the resulting metrics are correlated. Sampling designs used in the habitat and water Qa/Qx status and trends monitoring project should be linked to adult salmon monitoring programs, such as that which was recently implemented by the Washington Department of Fish and Wildlife (WDFW), to collect the information in the most cost-effective manner possible. Extrapolating water Qa/Qx monitoring results to larger spatial scales relevant to salmonid recovery goals (i.e., subbasins, salmonid distinct population segments [DPS]) could be accomplished using statistical models. Habitat monitoring results could be extrapolated to these larger spatial scales using a life cycle model such as EDT.

The remainder of this document describes a habitat and water Qa/Qx status and trends monitoring program that integrates the monitoring priorities and existing programs of ISTM partners and municipal stormwater permittees. This program consists of two complementary designs: one for water Qa/Qx monitoring, and one for habitat monitoring. These designs are integrated into a single monitoring program in a number of ways. The three alternative monitoring scenarios presented below provide numerous options for scaling monitoring effort while also providing scientific and statistical rigor required by scientists and decision-makers.

Management Questions and Objectives Addressed by the Habitat and Water Quality/Quantity Status and Trends Monitoring Program

The development of monitoring designs and tradeoff analysis of alternative monitoring scenarios is driven by the management questions. Management questions identified earlier in this project included those related to: 1) water quality and quantity, 2) habitat, and 3) human impacts at the watershed/landscape process level (Tetra Tech 2013). Based on discussions with workshop participants and other interested parties in Stage 2 of the project, management questions related to water Qa/Qx were further refined, with some questions being revised and one question being omitted because it focused on effectiveness monitoring (see Appendix A for detailed revisions). These changes were submitted to all program participants for review; management questions will be further refined as needed. Overall, revisions did not alter the focus of the monitoring program or the direction of its development.

Based on the priority management questions identified by monitoring entities, stormwater permittees, and other project participants, the LCFRB developed objectives associated with each question that define actionable goals for salmon habitat and water quality/quantity in the Lower Columbia region. The regional habitat status and trends monitoring program will generate the information required to assess whether these goals are being met. The revised management questions and associated objectives are presented below.

Habitat:

Question: What are the status and trends of in-stream biological and both in-stream and riparian habitat conditions (in terms of both quality and quantity)?

Objective: In-stream biological metrics and habitat conditions show improving trends in concert with increased and improved restoration projects, habitat stewardship efforts and land use regulations implemented.

Question: Are there significant effects of habitat degradation or improvement on the observed abundance, productivity, spatial structure, and diversity of the natural-origin fish in this population (reach/subwatershed scale)?

Objective: Fish population biological metrics (abundance, productivity, spatial structure, and diversity) show an improving trend in concert with increased and improved restoration projects, habitat stewardship efforts and land use regulations implemented.

Water Quality and Quantity:

Question: What is the status and trends of water quality and stream flow in surface waters?

Objective: In-stream water quality and quantity metrics show improving trends in concert with increased and improved stormwater management efforts.
In-stream water quality and quantity metrics show improving trends in concert with implementation of water improvement (i.e. TMDL's) and water use management programs (i.e Conservation Source Substitutions or Flow Augmentation).

Question: Where do water quality/quantity conditions support beneficial/water dependent uses?

Objective: The number of subwatersheds where water quality and quantity conditions support beneficial/water dependent uses are increasing.

Question: To what extent are regional surface waters in compliance with water quality standards?

Objective: The number of subwatersheds that are in compliance with water quality standards are increasing.

Landscape-Level Conditions[1,2]:

Question: What are the overall impacts of human activities on freshwater habitat and landscape processes?

Objective: Large scale landscape features (e.g. vegetative cover types) are trending towards historic conditions in concert with increased and improved restoration efforts.

Objective: Impact of man-made changes on large scale landscape features (e.g. increased impervious surfaces) are being reduced through increased and improved mitigation and restoration efforts and adoption of land use regulations.

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[1] Information regarding assessment of landscape-level conditions through monitoring will continue to be included in this process to gain input as needed.

[2] "Landscape-Level Conditions" refers to the management question group that was previously called "Human Activity."

During the January Technical Workshop, it was determined that the use of remote-sensing technologies, instead of field-based assessments such as those being used for water Qa/Qx and habitat, would be best suited for addressing the management questions regarding status and trends of landscape-levelconditions[1, 2]. Such a remote sensing program is briefly discussed above. The monitoring program described in the remainder of this document focuses on addressing management questions and objectives concerning habitat and water Qa/Qx.

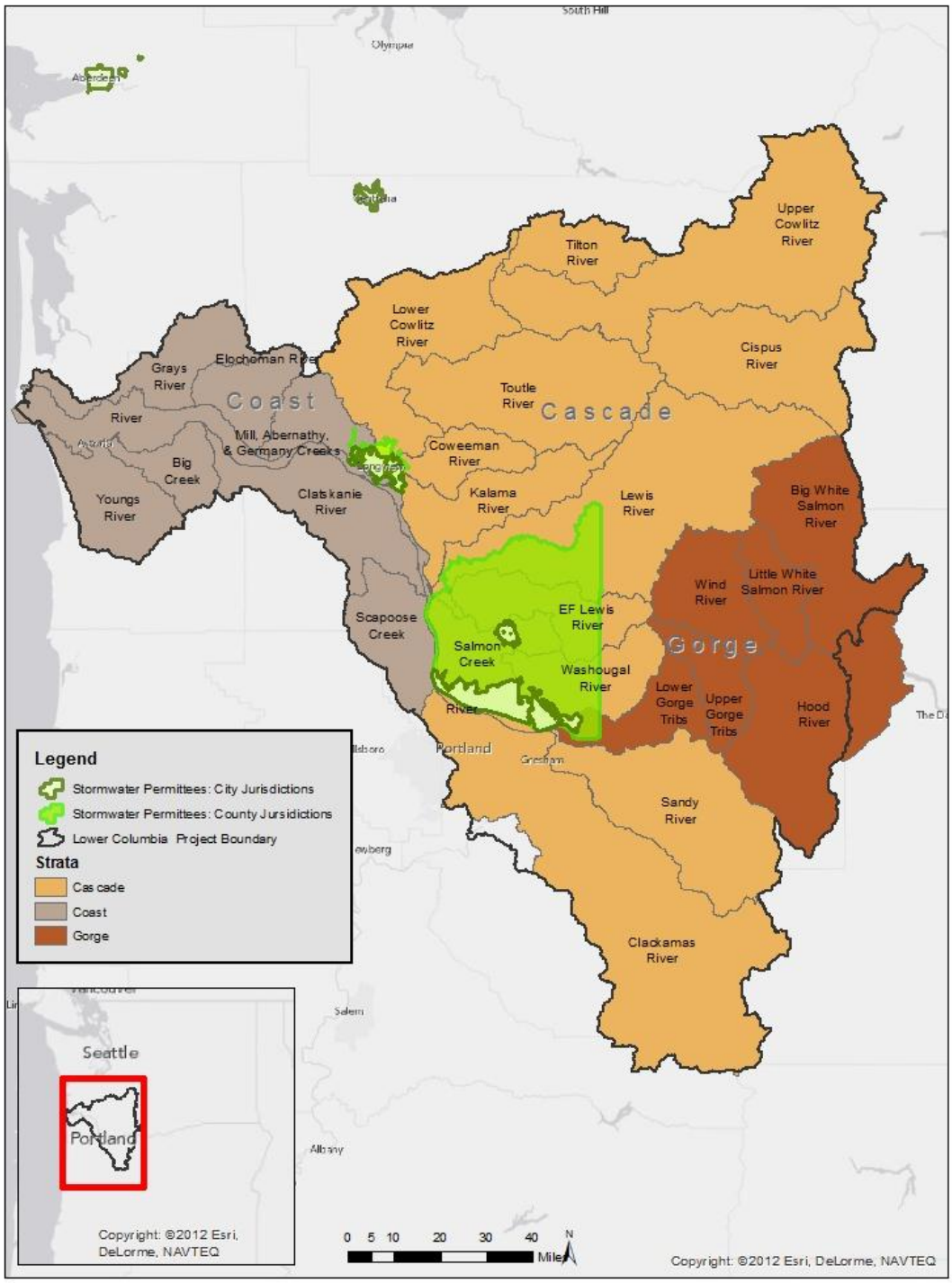

Figure 1. Lower Columbia Habitat Status and Trends Monitoring Project study area, strata, sub-basins, and jurisdictions of participating stormwater permittees

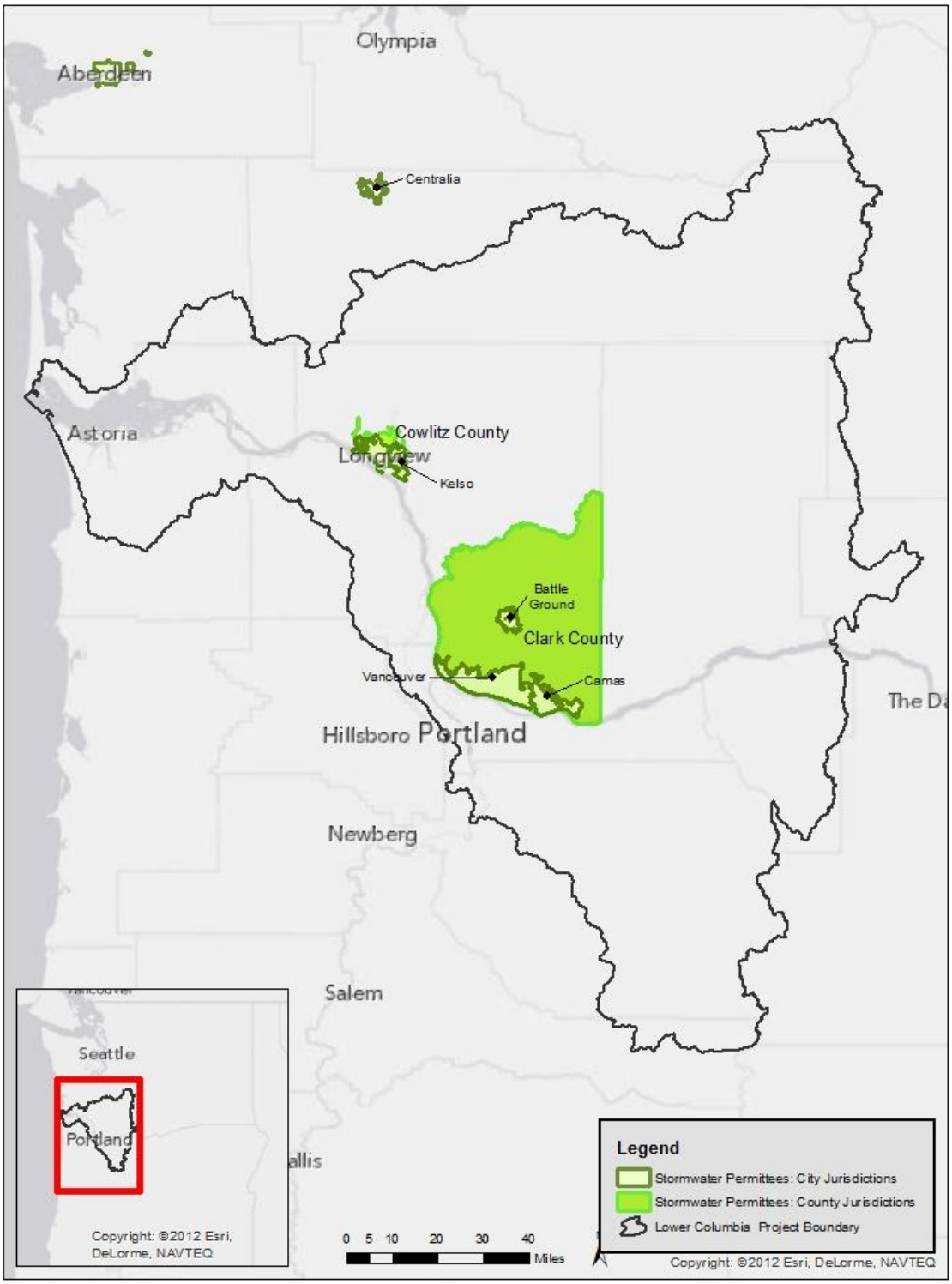

Figure 2. Lower Columbia Habitat Status and Trends Monitoring Project study area and jurisdictions of participating stormwater permittees

Methods

Stage 2 of this project involved several levels of data collection and analysis. The methods used to gather and evaluate those data are described in the following sections. The results of these analyses are described in the Results section of this report. Additionally, information and feedback gathered during the April Technical Workshop has been integrated into the analysis and is described in this report. Final recommendations for a monitoring program will be presented in Technical Report 3.

Monitoring Program Designs

Three alternative monitoring scenarios, each describing monitoring designs involving different levels of effort to implement, were developed as part of Stage 1 of this project and were presented to monitoring entities, stormwater permittees, and other participants in the February Technical Workshop (these scenarios are provided as Appendix E of the Technical Report 1; Tetra Tech 2013). At this workshop, a discussion regarding the advantages and disadvantages of each scenario ultimately resulted in consensus that two of the three scenarios were not feasible options. Participants agreed that Scenario 1, a no-change scenario, would not allow stormwater permittees to meet upcoming regulatory requirements that will likely be added by the Department of Ecology during future permit cycles. The group also reached consensus that Scenario 3, the full monitoring effort scenario, would be too costly for the amount of value added, and that many of the entities involved lacked the funding that would be necessary to implement that option. While discussing Scenario 2, it was suggested that the list of potential metrics could be tiered to provide options for levels of data collection (e.g., standard, expanded, and full suite). Based on this discussion and on feedback provided after this workshop (see Appendix B), Scenario 2 was redeveloped into three additional alternative monitoring scenarios that are presented in the Results section of this report. This minor change to project approach was approved by the LCFRB (final memorandum provided in Appendix C).

A critical step in developing a monitoring program is identifying the population of interest and the spatial scale for monitoring and reporting. In addressing questions about status and trends of water quality, water quantity, and stream habitat, there is a need to report on both the cumulative status of watersheds and on the status of reaches within watersheds. One objective of Stage 2 was to explore whether a single integrated study design could be implemented where water quality, water quantity, and stream habitat were monitored at both reach and watershed-scales, or whether multiple study designs would need to be implemented to address each of these various components.

Water Quality/Quantity Technical Subgroup

Based on the results of the February Technical Workshop, it was decided to convene a focused work session with a smaller group of experts in water Qa/Qx monitoring (the list of workshop participants is provided in Appendix D). The work session focused on two key topics: 1) what is the appropriate population of interest and spatial scale (watershed vs. reach) for water Qa/Qx sampling, and 2) prioritization of water Qa/Qx metrics. Technical subgroup participants also helped define monitoring frequency, timing, and methods for each water Qa/Qx metric. To support this discussion, participants were provided with a technical summary of the Draft Puget Sound Quality Assurance Plan (Ecology 2011a), and recommendations for Water Quantity and Quantity and Stream Corridor monitoring

included in LCFRB's RME Program(LCRFB 2010). The input from this work session helped to guide redevelopment of the alternative monitoring scenarios and provide direction for the tradeoff analysis.

Tradeoff Analysis

In addition to varying the number of metrics sampled at each site, alternative monitoring scenarios have options for varying sampling frequency, as well as the number of sampling sites. Tradeoffs among these options are discussed below in terms of effects on confidence, bias, and precision in status and trends assessments. Although workshop participants currently favor a probability-based design, the influence of opportunistic and model-based sampling designs on bias and precision is summarized in the context of design trade-offs to provide more information to support final monitoring design selection. Discussion also includes how monitoring design choices affect the completeness of the data available to address monitoring questions; balance in the need for status information versus the need for trend information; and relative cost and effort required for implementation of the monitoring program. To further flush out the foundation for a status and trends monitoring program as a whole, other considerations such as funding options, reporting requirements of the agencies involved, and recommendations for complementary monitoring programs are also outlined.

Revised alternative monitoring scenarios and tradeoffs among monitoring designs were discussed further during the April Technical Workshop, and feedback has been incorporated into this report. A list of workshop participants and their comments are provided in Appendices E and F, respectively. Once consensus is reached on the various aspects of the monitoring designs, tradeoff analysis will be revised to include specific design option choices, as needed.

Results

Monitoring Program Designs

The designs of the three alternative monitoring scenarios advanced for tradeoff analysis were based on the scenarios developed for the February Technical Workshop and workshop-related comments, results of the water Qa/Qx technical subgroup meeting, and monitoring design recommendations developed in the Puget Sound Draft Status and Trends Stormwater Monitoring and Assessment Strategy for Small Streams (Ecology 2011a) and the Status and Trends Monitoring for Watershed Health and Salmon Recovery Quality Assurance Monitoring Plan (Ecology 2006).

Spatial Design

Sites currently being monitored in the Lower Columbia region have been chosen using a mixture of opportunistic sampling designs and probability sampling designs. In an opportunistic design, sites are selected based on ease of access, expert opinion, or other subjective criteria. In a probability design, sites are randomly selected across the entire area of interest (see http://www.monitoringadvisor.org for more information on spatial designs). In the monitoring program favored by workshop participants, sites chosen using both spatial design approaches would be retained. Retaining opportunistically-chosen sites and using a statistical model to convert them to a pseudo-probability design would take advantage of the existing data record at these sites. This statistical model would be applied to

opportunistic sites to define the extent of their inference, which would allow the data collected at both types of sites (opportunistic and probabilistic) to be compatible. Probability-based inference relies on the design to define the extent of the population represented by each sample point (the weight of the sample point), so the pseudo-probability model would be essential in estimating the appropriate weights of each existing opportunistically-selected site. This model would 'weight' each opportunistic site such that some sites would contribute less statistical power for drawing inference at larger spatial scales (e.g. watersheds, WRIAs, or subbasins).

There are two ways that the pseudo-probability model could be implemented. One way is to use a methodology that selects a GRTS sample and simultaneously incorporates existing sites. If this is applied, existing sites are automatically assigned a pseudo-probability weight. The other way is to apply a model inferring a probability, such as a Dirichlet polygon or a post-stratification technique.

Selection of new monitoring sites would be drawn from a probability sampling design such as a GRTS survey. Sites chosen using a probability design are advantageous because there is a known degree of certainty in how well they represent the study area; because of this, unbiased conclusions about the Lower Columbia region as a whole can be drawn with high confidence. The probability design approach also facilitates data sharing and avoidance of duplicated sampling effort. A probabilistic, GRTS-based spatial design has also been recommended by NOAA to assess the threat to salmonids from habitat loss (Crawford and Rumsey 2011).

Spatial Domain

Monitoring sites will be distributed across the spatial domain (area of interest for sampling) of the Lower Columbia region.

Target Monitoring Populations

Water Qa/Qx and habitat monitoring together make up the core of a single status and trend monitoring program for the Lower Columbia region. However, the conceptual representations of their target populations are very different even though these two monitoring efforts ultimately target the same physical entity, that is, the same network of streams. Water quality technical experts consulted during the design process identified two populations of interest and related spatial scales for monitoring. Water quality was decided to be best evaluated near the outlet of subwatersheds rather than in stream reaches. Because water at the subwatershed outlet comprises a composite of all the upstream waters, sampling at these locations assumes that outlets represent the cumulative status of the upstream area. Consideration of an alternative sampling scheme in which water quality is monitored at randomly-chosen stream reaches within a subwatershed would be a less viable option because reach sampling could produce less useful information if no sites near the outlet were selected, and potentially unnecessary expense would be incurred by sampling more than one site per subwatershed.

In habitat monitoring, stream reaches were decided to be the appropriate target population for assessing habitat. Habitat characteristics are likely to vary more or less independently across stream reaches on the same stream; unlike the outlet of watersheds, lower stream reaches cannot be assumed to be representative of the cumulative status of the upstream area.

For the reasons discussed above, water Qa/Qx and habitat monitoring designs differ in their target monitoring populations, which are defined as follows:

- **Water quality/quantity target monitoring populations: subwatersheds**.
  Subwatersheds are defined in the Washington Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan (LCFRB 2010b) as encompassing basins of 3,000-12,000 acres. Sampling sites will be located approximately 1,500-3,500 ft upstream from the outlet of these subwatersheds. Sampling sites would be randomly selected from all subwatersheds in the region.

- **Habitat target monitoring populations: stream reaches.**
  Sampling sites will be located in reaches of continuous, freshwater streams with non-constructed channels[3] and lotic, perennial flow. To adequately represent variability across stream reaches, habitat monitoring will sample randomly-chosen sites selected from all stream reaches within a subwatershed.

All sampling sites will be accessible. Sites may be rejected if field sampling would pose risks to crew safety, if physical barriers would result in sampling taking longer than a day, or if landowner permission for field sampling is not granted.

In addition to the conceptual reasons discussed above, allowing target monitoring populations to differ between water Qa/Qx monitoring and habitat monitoring generally provides consistency with existing monitoring designs currently being implemented by ongoing monitoring programs. However, integrating data collected from two different target monitoring populations presents many challenges; these challenges, and their resolutions, are discussed below.

Integrating Target Populations through Sample Weights

The two different target populations make it difficult to utilize data collected under one design in conjunction with data collected under the other, even if the data is collected on the same metric using the same protocol. Such difficulty stems from the lack of a well-defined weighting framework that could be used to merge data from the two designs. Even if both designs selected sample points using probability-based selection (so that both designs have well-defined internal weights), the different perspectives means that the weights are incompatible across designs.

In the water Qa/Qx design, sampling sites are outfalls in subwatersheds that occur throughout the Lower Columbia region. The weight of the sample point in each randomly-selected subwatershed will represent the *number* of subwatersheds represented by that point. For example, in southwest Washington, if 50 subwatersheds were randomly selected from the 545 available in that area, then each

[3] Non-constructed channels exclude irrigation channels, power canals, drainage ditches, and other waterways that may exhibit many of the following criteria (Ecology 2012c): built where no waterbody previously existed; constructed of impervious material; not used for recreation or potable water; constructed, operated, and maintained for a specific purpose or need; controlled ingress and egress; or surface continuity with a natural water body interrupted by a pipe, pump, dike, etc.

sampled subwatershed would have a weight of 545/50 = 10.9, so each sample represents 10.9 subwatersheds. This factor would be used to weight individual observations in extrapolations from sample totals or means up to population totals or means.

In the habitat design, sampling sites can be chosen from the entire length of stream in the network. The probability density of sample points (the probability that any point in the network is selected) is given by the sample size divided by the length of the stream network, so that the weight assigned to each sample point is the total length of the stream network divided by the number of samples. For example, there are approximately 44,016 mi of streams in the Lower Columbia. A sample of 50 points from this network would result in each sample point having a weight of 44,016/50 = 880.32, so each sample point "represents" 880.32 mi of stream network.

As this example shows, the weights resulting from these two designs are incompatible: one gives the number of subwatersheds represented by a sample point, while the other gives the length of stream represented by the point. In order to utilize data from one design in combination with data from the other design, we need to derive compatible weights. One might, for example, weight data from the water Qa/Qx design by the total length of stream in the associated subwatershed. That approach will work for some metrics and some attributes. For example, we could estimate the mean nitrogen concentration of the entire population by pooling water Qa/Qx data weighted by subwatershed stream length, and habitat data weighted by total network length divided by number of samples. Some adjustments to the weights would have to be made to account the potential for habitat sample points to fall with subwatersheds that are also being sampled for water Qa/Qx (the "multiple frame problem"), but those details can be worked out. However, it would not be appropriate to estimate the distribution function of nitrogen concentration (or the per cent of stream length with nitrogen concentration exceeding some standard) using this approach, because the water Qa/Qx measurements do not properly represent the extremes within the subwatershed.

Conversely, habitat data could be put on a compatible basis with water Qa/Qx data by averaging over the habitat sample sites within a subwatershed in which water Qa/Qx was also measured (presuming there were multiple habitat sites present in the subwatershed). Theoretically, a single habitat site within a subwatershed could be interpreted as representing that subwatershed, but the associated variance would be so high as to make the representation meaningless.

Sharing data between water Qa/Qx and habitat designs is possible as long as sampling sites in both cases are probabilistically-selected from each target population. If sites from either one are not chosen using a probability design, then derivation of a compatible weighting scheme becomes much more difficult.

Integrating Target Populations through Spatial Design

Integrating data from water Qa/Qx sites and habitat sites could also be facilitated using a spatially coherent design. For example, a two-phase site selection scheme could be used wherein a sample of subwatersheds is randomly selected at the first phase, and then a sample of stream points within those subwatersheds is selected at the second phase. Figure 3 below illustrates this concept. In the example

shown in Figure 3, a two-phase site selection scheme was used to randomly select the Kalama subwatershed in the first phase; subwatershed water quality would be monitored near the subwatershed mouth (gold point). In the second phase of site selection, a sample of points on stream reaches is randomly within the subwatershed, and habitat is monitored at those sites (green points). This type of scheme would help ensure that each subwatershed in which water Qa/Qx was measured also had sufficient habitat sampling sites to provide meaningful averaging. A two-phase site selection design is compatible with other design structures, such as rotating panels, variable probability, and stratification.

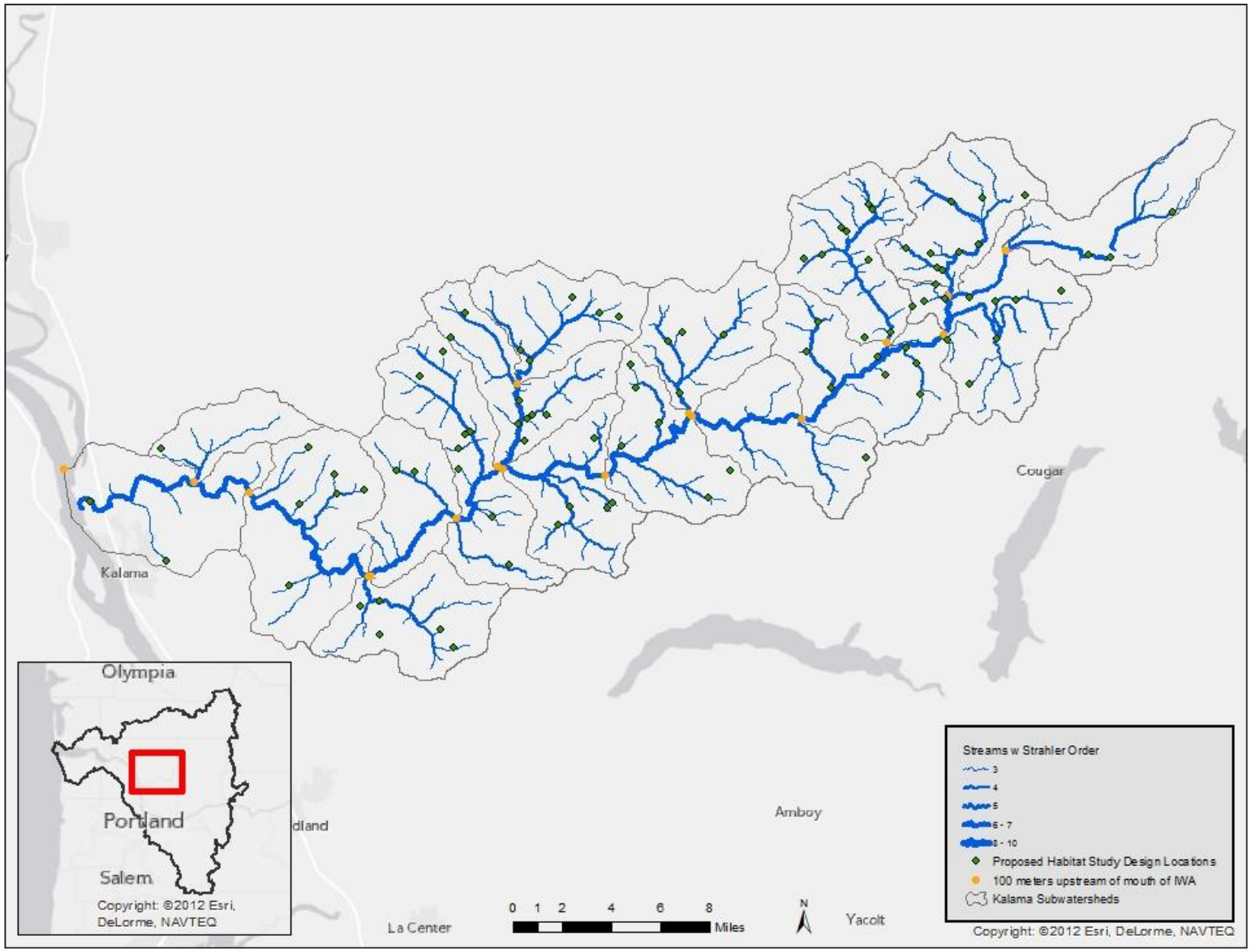

Figure 3. Example of integrating subwatershed and stream reach target populations through spatial design.

Such a two-phase site selection design could be implemented in several different ways, each of which would produce a different balance of water Qa/Qx sampling sites versus habitat sampling sites. In the simplest arrangement, every selected subwatershed would be sampled for water Qa/Qx at the outfall, and would also be sampled for habitat at multiple points. Another alternative would be that every selected subwatershed would be sampled for habitat at several sites, but not all subwatersheds would be sampled for water Qa/Qx, so that the habitat sample is more extensive than the water Qa/Qx sample. A third alternative is to vary the number of habitat sample points in each subwatershed, so that some selected subwatersheds get multiple habitat points, but others may only get one point.

The important constraints on a two-phase site selection design are primarily level of effort and sample size, especially the relative sizes of the water Qa/Qx and habitat sample. Each water Qa/Qx site is typically visited multiple times per year, so the level of effort per site can be high. Because habitat metrics tend to be more temporally stable, there is no need for multiple visits on an annual basis. Potentially, then, the habitat sample could have substantially more sites than the water Qa/Qx sample. If that is the case, then the option where not every selected subwatershed is sampled for water Qa/Qx may be the most attractive (see the Temporal Scale section for further discussion of site variations in monitoring frequency).

A drawback of a two-phase site selection design is that it results in a clustered sample design for the habitat sample. Generally, a clustered sample will have less precision than a spatially balanced sample of the same size, and may be more likely to not represent some areas of interest. This is a consequence of most environmental responses having some positive spatial correlation (measurements from points close together will tend to more similar than from points far apart). A spatially balanced design such as GRTS minimizes sample clustering by distributing sample points more or less evenly, and so reduces between-point correlation. In a two-phase site selection design, samples can be selected using GRTS during each phase, but the second phase will have less spatial balance than a completely random GRTS design.

Integrating Target Populations through Temporal Design

Sharing data across water Qa/Qx and habitat monitoring sites could also be supported by temporally coupling sampling: in any particular subwatershed, outfall water Qa/Qx and stream reach habitat would be measured in the same year. In this way, uncertainties related to inter-annual variation would be reduced. A challenge in implementing this scheme is that the pace of water Qa/Qx and habitat sampling would need to be coordinated across multiple entities, such that the appropriate number of each kind of site is sampled each year.

Integrating Target Populations through Sampled Metrics

Although water Qa/Qx and habitat monitoring differ in their target populations, these two components can generate complimentary sets of information by building in some overlap in the metrics measured at each site. At water Qa/Qx sites, a short list of basic habitat metrics will be monitored to characterize the subwatershed outlet in-stream environment, and allow better interpretation of water Qa/Qx data. At habitat sites, a few basic water Qa/Qx metrics will be monitored to generate information on how water Qa/Qx varies among stream reaches (see the Metrics section for discussion of metrics to be monitored

at each site type). Together, water Qa/Qx and habitat monitoring will integrate to produce a robust portrayal of the health of the Lower Columbia region.

Spatial Strata and Site Allocation

To focus monitoring toward answering management questions of interest, and to ensure that sites adequately represent the variability evident within the Lower Columbia region, the region will be divided into several spatial strata and new sites will be selected relative to these strata. Because water Qa/Qx monitoring and habitat monitoring each focus on different target populations, different strata are appropriate for each kind of monitoring. Input from the April workshop is incorporated into the recommended strata shown below. Additional discussion regarding habitat strata may take place during the Habitat Technical Subgroup Meeting scheduled for the end of April. Any changes to the habitat strata will be reflected in Technical Report 3 and in the final design recommendations. Figures 4 and 5 illustrate the water Qa/Qx and habitat monitoring strata.

Water Quality/Quantity Monitoring Strata (6 strata combinations total):

- Inside/outside the jurisdiction of an NPDES stormwater permittee = **2 strata**
- Recovery Plan Strata (Cascade/Coast/Gorge) = **3 strata**

Habitat Monitoring Strata (150 strata combinations total):

- Inside/outside the combined area within an incorporated City boundary and/or an unincorporated Urban Growth Area (UGA) = **2 strata**
- Subbasin (as defined in recovery plan) = **25 strata**
- Stream Power = **3 strata**
    - Strahler Order Groups (0-1, 2-3, 4-11) or
    - Stream Gradient Groups (<1%, 1-3%, >3%)

The recommendation to allocate new monitoring sites relative to multiple spatial strata is intended to accommodate the multiple scales at which monitoring entities are interested in addressing management questions. For example, the strata scale is used by NMFS to delineate major salmon populations that together constitute an evolutionarily significant unit (ESU) (LCFRB 2010a). Monitoring sites located relative to NPDES permittee areas of jurisdiction and City boundaries/UGAs help to focus assessment on subwatersheds likely to experience larger impacts from stormwater runoff. However, a tradeoff exists because the number of sites needed to adequately represent the spatial domain (area of interest) increases rapidly as more strata are used to divide up the spatial domain. As a general rule of thumb, 4-6 sites are needed in each strata combination to minimally represent the variability in that area. For example, for water quality monitoring, 6 strata combinations (3x2) with 4-6 sites in each yields a minimum of 24-36 water quality sites. Habitat monitoring used more strata, and so many more habitat sites would be needed: 150 strata combinations (25x2x3) with 4-6 sites in each yields a minimum of 600-900 habitat sites. Further, this 'rule of thumb' number does not take into account desired levels of data confidence or precision; setting targets for these measures of data quality will increase the number of sites needed.

Regardless of the spatial stratifications used to allocate new sites, analysts with individual monitoring programs can post-stratify the monitoring data in different ways to answer management questions of interest to their particular programs.

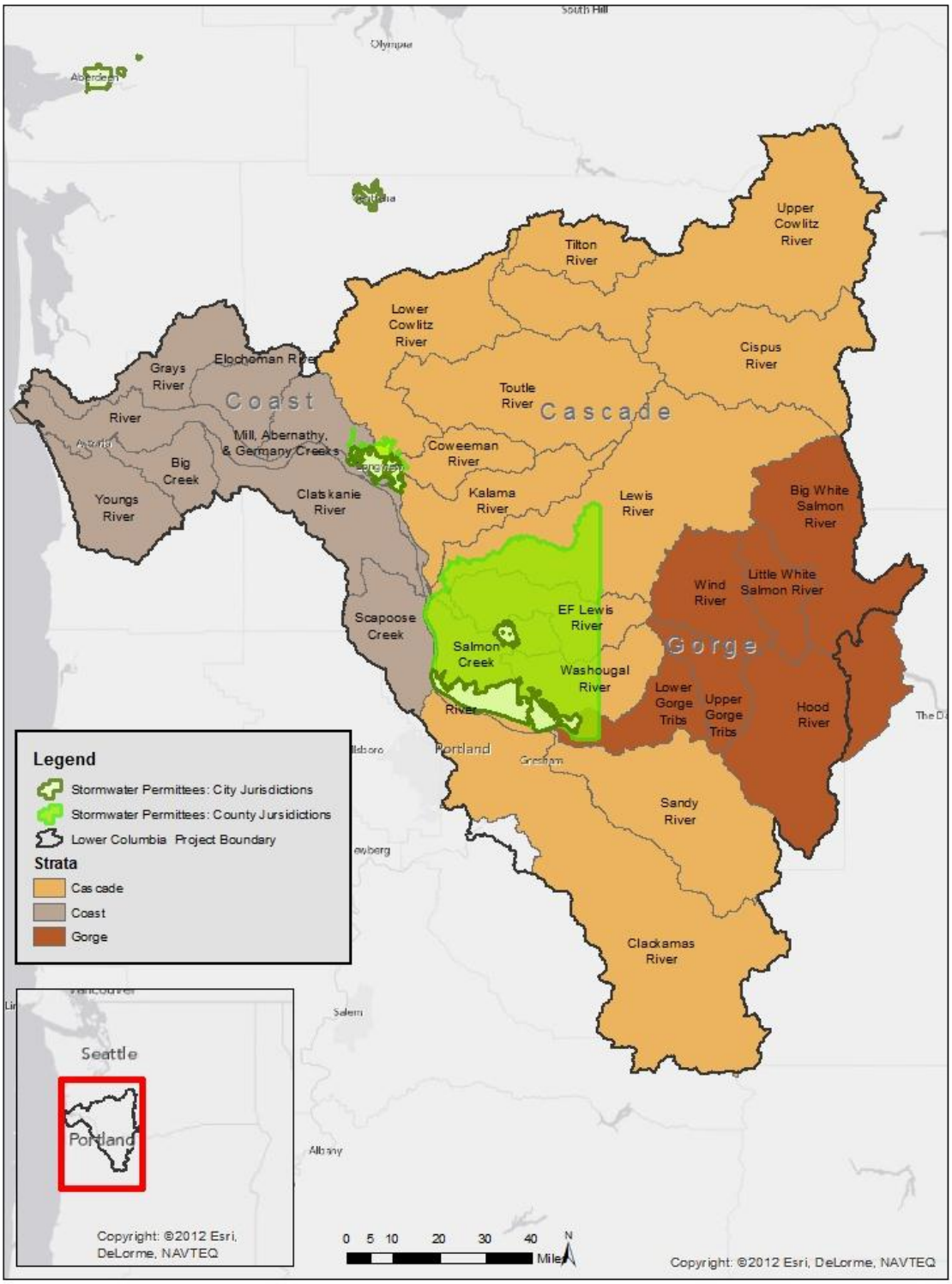

Figure 4. Water quality/quantity monitoring strata

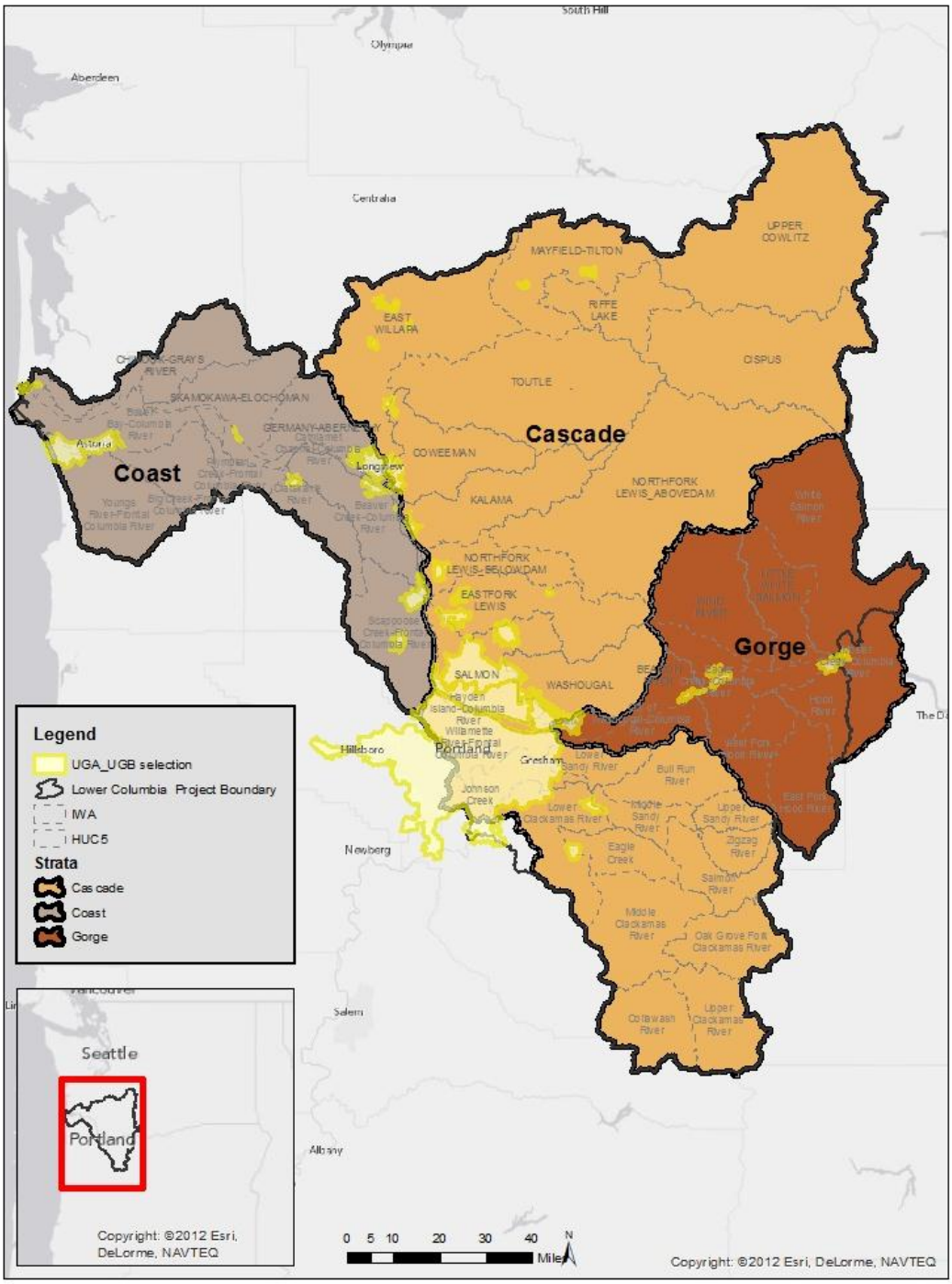

Figure 5. Habitat monitoring strata. Subbasins are approximately represented here by IWA and HUC 5 boundaries. The Stream Power strata is omitted from this map for visual clarity.

Temporal Scale

All sites will be monitored over a 5-year sampling period, using a rotating split-panel sample design. In the split-panel design, most sites would be monitored once during the 5-year sampling period, resulting in about 20% of the sites sampled each year; this kind of monitoring would be useful for assessing status at a snapshot in time over a relatively large number of sites. A subset of sites would be monitored every year of the 5-year sampling period; this kind of monitoring would be useful to assess trends by capturing inter-annual variation at a smaller number of sites. The proportion of sites sampled once every five years versus that sampled annually depends on the relative priorities given to being able to assess status versus trends. The number of sites sampled each year will also be driven by the level of precision needed and available budget.

Because some sites will be monitored every year, entities can evaluate the data on hand and so meet reporting needs that occur more often than every five years. The five-year temporal scale is therefore compatible with the annual reporting requirements of NPDES stormwater permittees (Ecology 2012a,b), as well as NMFS's requirement to prepare reports to Congress every other year and to review the status of listed salmon and steelhead every five years (NMFS 2012). A proposed recovery plan was developed in 2012 that integrates three separate plans covering the Oregon Lower Columbia region, the southwest Washington Lower Columbia region, and the White Salmon River Subbasin. Each of these recovery plans implements status and trends reviews and reporting on different schedules that may need to be resolved as part of implementing a unified monitoring program across the region (see the section entitled Agency Reporting Requirements, below, for further information). The sampling time of year monitoring frequency varies with metric and with site location, and is discussed in the Metrics section, below.

Metrics

Three alternative monitoring scenarios are defined in terms of the number of metrics sampled. In Alternative 1, the Standard scenario, only high-priority metrics (green shading), are sampled; in Alternative 2, the Expanded scenario, medium-priority metrics (orange shading) as well as high-priority metrics are sampled; and in Alternative 3, the Full Suite scenario, all metrics are sampled (red shading). Varying the number of metrics sampled is one method for scaling the level of effort needed to implement a regional monitoring design. Within each alternative monitoring scenario, there are also options for adjusting monitoring frequency for some metrics, as discussed in the section immediately below. For other ways in which monitoring effort can be scaled up or down, see the section entitled "Approach for multi-scale monitoring".

Water Quality/Quantity Metrics

Water Qa/Qx is measured within subwatersheds. For water Qa/Qx metrics, monitoring frequency and the time of year at which a metric is sampled varies by metric. Monitoring frequency is higher for those metrics thought to have higher temporal variation. Monitoring timing is based on when measurements are most likely to deviate from normal, and will therefore more accurately characterize potential limiting conditions. Table 2 shows the water Qa/Qx metrics sampled under each alternative, along with sampling frequency and timing.

Water Qa/Qx monitoring may change depending on the land use or land class in which a site is located. Metrics strongly related to human disturbance are not monitored in sites with forested land use/land class because these metrics are presumed to be unlikely to occur at detectable levels. Typically, metrics are monitored less often in forested sites relative to sites with other land uses, because variability between serial measurements is presumed to decrease as human disturbance is reduced. Timing may also differ between sites with forested land use/land class and sites with other land uses if different processes are thought to influence when limiting conditions are produced. Sampling frequency and timing of water Qa/Qx metrics in sites with forested land use/class is provided in Table 2.

To refine the temporal scale, minimum sampling frequency should be confirmed by calculating the serial autocorrelation (similarity of subsequent measurements) for various sites, based on existing data, in an effort to prevent oversampling and reduce costs. Variance of each metric should be calculated to determine the length of the sampling period needed for trend detection. This task may be best accomplished as part of the implementation phase of a monitoring program design.

Table 2. Water quality/quantity monitoring metrics sampled, monitoring frequency and timing, and field collection group at forested land use/class and other sites

Sampled in Alternative	Metric Category	Metric Sub Category	Monitoring Frequency Required at Most Sites [1]	Monitoring Timing of Sampling at Most Sites[3]	Monitoring Frequency in Forested Land Use/Land Class[1,2]	Monitoring Timing in Forested Land Use/Land Class[2,3]	Field Collection Group
All	Bacteria	Fecal Coliform	Routine (e.g., monthly)	Wet/Dry Season Events	Once per year	Wet Season Events	Grab Sample
All	Conventional Parameters	Conductivity	Routine (e.g., monthly)	Seasonal patterns	Once per year	May-Jun	Multi-parameter Probe
All	Conventional Parameters	Dissolved Oxygen	Routine (e.g., monthly)	Seasonal patterns	Once per year	Low flows	Multi-parameter Probe
All	Conventional Parameters	pH	Routine (e.g., monthly)	Seasonal patterns	Once per year	Low flows	Multi-parameter Probe
All	Conventional Parameters	Turbidity	Routine (e.g., monthly)	Hydrologic disturbance	Once per year	High flows	Multi-parameter Probe
All	Conventional Parameters	Water Temperature	Hourly	Low flows	Hourly	Low flows	Multi-parameter Probe
All	Conventional Parameters	Chloride	Routine (e.g., monthly)	Low flows	N/A		Grab Sample

Sampled in Alternative	Metric Category	Metric Sub Category	Monitoring Frequency Required at Most Sites [1]	Monitoring Timing of Sampling at Most Sites[3]	Monitoring Frequency in Forested Land Use/Land Class[1,2]	Monitoring Timing in Forested Land Use/Land Class[2,3]	Field Collection Group
All	In Sediments	Poly-aromatic hydro-carbons	Once per 5 years based on permit cycle; possibly 3yr rotation based on hydro cycle	October Storm Event	Once per 5 years based on permit cycle; possibly 3yr rotation based on hydro cycle	October Storm Event	Sediment Set
All	Metals - In Sediments	Copper (dissolved)	Once per 5 years based on permit cycle; possibly 3yr rotation based on hydro cycle	Exposure-high flows	Once per 5 years based on permit cycle; possibly 3yr rotation based on hydro cycle	Exposure-high flows	Sediment Set
All	Metals - In Sediments	Lead	Once per 5 years based on permit cycle; possibly 3yr rotation based on hydro cycle	Exposure-high flows	Once per 5 years based on permit cycle; possibly 3yr rotation based on hydro cycle	Exposure-high flows	Sediment Set
All	Metals - In Sediments	Zinc (dissolved)	Once per 5 years based on permit cycle; possibly 3yr rotation based on hydro cycle	Exposure-high flows	Once per 5 years based on permit cycle; possibly 3yr rotation based on hydro cycle	Exposure-high flows	Sediment Set

Sampled in Alternative	Metric Category	Metric Sub Category	Monitoring Frequency Required at Most Sites [1]	Monitoring Timing of Sampling at Most Sites[3]	Monitoring Frequency in Forested Land Use/Land Class[1,2]	Monitoring Timing in Forested Land Use/Land Class[2,3]	Field Collection Group
All	Nutrients	Total Nitrogen	Routine (e.g., monthly)	High Flows	Once per year	Beginning of wet season	Grab Sample
All	Nutrients	Total Phosphorus	Routine (e.g., monthly)	High Flows	Routine (e.g., monthly)	Beginning of wet season	Grab Sample
All	Nutrients	Ammonia	Routine (e.g., monthly)	Low Flows	Once per year	Low flows	Grab Sample
All	Nutrients	Nitrate+ Nitrite-Nitrogen	Routine (e.g., monthly)	High Flows	Once per year	Beginning of wet season	Grab Sample
All	Hydrology/ Water Quantity	Instantaneous Flow	Once per year	Low Flow	Once per year	Low flows	Handheld flow meter
All	Macro-invertebrates	Macro-invertebrate Index	Once per year	Low flow period (Index)	Once per year	Low flows	Benthic Sample
All	Water Column	Suspended Solids	Frequent (e.g., biweekly)	Hydrologic disturbance	Routine (e.g., monthly)	Beginning of wet season	Grab Sample
All	Water Column	Total Solids	Routine (e.g., monthly)	Hydrologic disturbance	Routine (e.g., monthly)	Beginning of wet season	Grab Sample
All	Vegetation/ Plants	Periphyton	Once per year	Low flow period (Index)	Once per year	Low flows	Substrate Sample

Sampled in Alternative	Metric Category	Metric Sub Category	Monitoring Frequency Required at Most Sites [1]	Monitoring Timing of Sampling at Most Sites[3]	Monitoring Frequency in Forested Land Use/Land Class[1,2]	Monitoring Timing in Forested Land Use/Land Class[2,3]	Field Collection Group
Alts. 2 & 3	In Sediments	Polychlorin-ated Biphenyls (PCBs)	Once per 5 years based on permit cycle; possibly 3yr rotation based on hydro cycle	October Storm Event	N/A		Sediment Set
Alts. 2 & 3	In Sediments	Volatile Organic Compounds	Once per 5 years based on permit cycle; possibly 3yr rotation based on hydro cycle	October Storm Event	N/A		Sediment Set
Alts. 2 & 3	Metals - In Sediments	Arsenic	Once per 5 years based on permit cycle; possibly 3yr rotation based on hydro cycle	Exposure-high flows	Once per 5 years based on permit cycle; possibly 3yr rotation based on hydro cycle	Low flows	Sediment Set
Alts. 2 & 3	Metals - In Sediments	Cadmium	Once per 5 years based on permit cycle; possibly 3yr rotation based on hydro cycle	Exposure-high flows	N/A		Sediment Set

Sampled in Alternative	Metric Category	Metric Sub Category	Monitoring Frequency Required at Most Sites [1]	Monitoring Timing of Sampling at Most Sites[3]	Monitoring Frequency in Forested Land Use/Land Class[1,2]	Monitoring Timing in Forested Land Use/Land Class[2,3]	Field Collection Group
Alts. 2 & 3	Metals - In Sediments	Mercury	Once per 5 years based on permit cycle; possibly 3yr rotation based on hydro cycle	Exposure-high flows	Once per 5 years based on permit cycle; possibly 3yr rotation based on hydro cycle	Low flows	Sediment Set
Alts. 2 & 3	Other	Soluble Reactive Phosphorous	Routine (e.g., monthly)	High flow/Low flow months	Routine (e.g., monthly)	Low flows	Grab Sample
Alts. 2 & 3	Pesticides[4]	Organo-chlorines	Once per year	Exposure-high flows	N/A		Grab Sample
Alts. 2 & 3	Pesticides[4]	Organo-phosphates	Once per year	Exposure-high flows	N/A		Grab Sample
Alts. 2 & 3	Pesticides[4]	Herbicides	Once per year	Exposure-high flows	N/A		Grab Sample
Alts. 2 & 3	Pesticides[4]	Insecticides	Once per year	Exposure-high flows	N/A		Grab Sample
Alts. 2 & 3	Hydrology/ Water Quantity	Flow (instant-aneous)	Frequent (e.g., biweekly)	Range of flows	Continuous/ Frequent	Range of flows	handheld flow meter
Alt. 3 only	Base/Neutral/ Acids	2-Fluoro-biphenyl	Once per year	Summer Survey - Low flow	N/A		Grab Sample

Sampled in Alternative	Metric Category	Metric Sub Category	Monitoring Frequency Required at Most Sites [1]	Monitoring Timing of Sampling at Most Sites[3]	Monitoring Frequency in Forested Land Use/Land Class[1,2]	Monitoring Timing in Forested Land Use/Land Class[2,3]	Field Collection Group
Alt. 3 only	Conventional Parameters	Oil and Grease	Storm Events	October Storm Event	N/A		Grab Sample
Alt. 3 only	Conventional Parameters	Biochemical Oxygen Demand	Routine (e.g., monthly)	Late Summer/Low flow	N/A		Grab Sample
Alt. 3 only	Conventional Parameters	Hardness	Routine (e.g., monthly)	Seasonal patterns	Once per 5 years based on permit cycle; possibly 3yr rotation based on hydro cycle	Seasonal patterns	Grab Sample
Alt. 3 only	In Sediments	Endocrine Disruptors[4]	Once per 5 years based on permit cycle; possibly 3yr rotation based on hydro cycle	October Storm Event	N/A		Sediment Set
Alt. 3 only	Nutrients	Nitrate-Nitrogen	Routine (e.g., monthly)	High Flows	N/A		Grab Sample
Alt. 3 only	Other	Other 303(d) Parameters	Annual	Timing depends on parameter	N/A		Varies with parameter - grab sample or sediment

Sampled in Alternative	Metric Category	Metric Sub Category	Monitoring Frequency Required at Most Sites [1]	Monitoring Timing of Sampling at Most Sites[3]	Monitoring Frequency in Forested Land Use/Land Class[1,2]	Monitoring Timing in Forested Land Use/Land Class[2,3]	Field Collection Group
Alt. 3 only	Sediment/ Substrate/ Soils	Percent Solids	Frequent (e.g., biweekly)	Hydrologic disturbance	Once per year	Exposure - high flows	Sediment Set

[1] The monitoring frequency provides guidance for sites monitored annually. In a split-panel design, a subset of sites would be monitored annually to detect trends, and this monitoring frequency would be implemented. However, most sites would be monitored only once during the 5-year sampling period to detect status, and this monitoring frequency would be implemented only during the year in which the site was monitored.

[2] Forested land use/land class is defined in the National Land Cover Dataset (http://www.webgis.com/lulc_data/1_background.html). Other land uses/classes include urban, suburban, and rural. A subwatershed would be assigned to either the forested land use/class category, or a combined urban/suburban/rural land use/class category, based on the category with at least 51% cover in that subwatershed.

[3] Ecology's Phase I permit (Ecology 2012) defines the wet season as Oct 1-Apr 30, and the dry season as May 1-Sep 30. Some monitoring timing terms refer to individual events within the wet season. Low flows are equivalent to the biomonitoring index period (Jul 1 through September 30). Sampling later in the dry or low flow season would occur from the end of August through September. Seasonal Patterns refers to distinct differences in water quality patterns that can be determined by grouping data by one of four categories: spring (April-June), summer (July-September), fall (October-December), and winter (January-March).

[4]A list of recommended pesticides and endocrine disruptors is provided in Appendix G.

By monitoring a subset of water Qa/Qx metrics at habitat sites and vice versa, basic water Qa/Qx and habitat data are available from all sites region-wide. At the same time, monitoring only this subset of metrics avoids placing an undue burden on entities to whom more in-depth data has low utility. Habitat metrics measured at water Qa/Qx sites include those most useful for evaluating habitat, and are shown in Table 3. Habitat metrics are sampled at the same frequency and timing regardless of land class or land use.

Table 3. Habitat metrics sampled, monitoring frequency and timing, and field collection group at water quality/quantity monitoring sites

Sampled in Alternative	Metric Subcategory	Monitoring frequency (all sites) [1]	Monitoring timing (all sites)	Field Collection Group
All	Bankfull width	Once per year	Jul-Oct	Site
All	Wetted width	Once per year	Jul-Oct	Site
All	Width to depth ratio	Once per year	Jul-Oct	Site
All	Gradient	Once per year	Jul-Oct	Site
All	Depth	Once per year	Jul-Oct	Site
All	Substrate cover	Once per year	Jul-Oct	Site

[1] The monitoring frequency provides guidance for sites monitored annually. In a split-panel design, a subset of sites would be monitored annually to detect trends, and this monitoring frequency would be implemented. However, most sites would be monitored only once during the 5-year sampling period to detect status, and this monitoring frequency would be implemented only during the year in which the site was monitored.

Habitat Metrics

Unlike water Qa/Qx metrics, habitat metric measurements are unlikely to change quickly or vary widely between different times of year. Therefore, all habitat metrics are monitored once per year, during July through October. Sampling during this period maximizes sensitivity to human disturbance, may best represent limiting factors, and is most logistically feasible. Table 4 describes the habitat monitoring metrics sampled, monitoring population, and sampling frequency and timing for all sites. All of the metrics are measured in stream reaches, except for two metrics in Alternative 3 (abundance of man-made structures and abundance of species migration barriers), which require surveys of road or stream networks.

As with water Qa/Qx metrics, serial autocorrelation (similarity of subsequent measurements) for habitat metrics at various sites to confirm minimum sampling frequency and prevent oversampling and reduce

costs. Variance of each metric should be calculated to determine the length of the sampling period needed for trend detection. This task may be best accomplished as part of the implementation phase of a monitoring design.

Table 4. Habitat monitoring metrics sampled, monitoring frequency and timing, and field collection group at all sites

Sampled in Alternative	Metric Subcategory	Monitoring frequency[1]	Monitoring timing	Field Collection Group
All	Composition: substrate/soil - size (sedimentation, substrate characterization)	Once per year	Jul-Oct	Channel Unit
All	Light	Once per year	Jul-Oct	Site
All	Channel cross-section form (length/width/area)	Once per year	Jul-Oct	Site
All	Sinuosity	Once per year	Jul-Oct	Site
All	Gradient	Once per year	Jul-Oct	Site
All	Density/distribution instream wood	Once per year	Jul-Oct	Channel Unit
All	Erosion	Once per year	Jul-Oct	Site
All	Form/morphology (channel form)	Once per year	Jul-Oct	Site
All	Density of habitat type	Once per year	Jul-Oct	Channel Unit
All	Flow (instantaneous)	Once per year	Jul-Oct	Site
All	Macroinvertebrates	Once per year	Jul-Oct	Benthic
All	Periphyton	Once per year	Jul-Oct	Substrate
Alts. 2&3	Bank stability	Once per year	Jul-Oct	Site
Alts. 2&3	Bed stability	Once per year	Jul-Oct	Site
Alt. 3	Abundance of man-made structures (stream crossing frequency)	Once per year	Jul-Oct	Stream Network
Alt. 3	Abundance of species migration barriers (anthropogenic and natural barriers)	Once per year	Jul-Oct	Stream Network
Alt. 3	Abundance of invasive species	Once per year	Jul-Oct	Site

[1] The monitoring frequency provides guidance for sites monitored annually. In a split-panel design, a subset of sites would be monitored annually to detect trends, and this monitoring frequency would be implemented. However, most sites would be monitored only once during the 5-year sampling period to detect status, and this monitoring frequency would be implemented only during the year in which the site was monitored.

By monitoring a subset of water Qa/Qx metrics at habitat sites and vice versa, basic water Qa/Qx and habitat data are available from all sites region-wide. At the same time, monitoring only this subset of metrics avoids placing an undue burden on entities to whom more in-depth data has low utility. Water

Qa/Qx metrics measured at habitat sites include those most useful for evaluating water Qa/Qx, and are shown in Table 5.

Table 5. Water quality/quantity metrics sampled, monitoring frequency and timing, and field collection group at habitat quality/quantity monitoring sites

Sampled in Alternative	Metric Subcategory	Monitoring Frequency[1]	Monitoring Timing	Field Collection Group
All alts	Temperature (continuous)	Hourly	Jul-Oct	Multi-parameter Probe
All alts	Alkalinity	Once per year	Jul-Oct	Multi-parameter Probe
All alts	Conductivity	Once per year	Jul-Oct	Multi-parameter Probe
All alts	pH	Once per year	Jul-Oct	Multi-parameter Probe
All alts	Turbidity	Once per year	Jul-Oct	Multi-parameter Probe
All alts	Flow (instantaneous)	Once per year	Jul-Oct	Handheld flow meter

[1] The monitoring frequency provides guidance for sites monitored annually. In a split-panel design, a subset of sites would be monitored annually to detect trends, and this monitoring frequency would be implemented. However, most sites would be monitored only once during the 5-year sampling period to detect status, and this monitoring frequency would be implemented only during the year in which the site was monitored.

Sampling design and data bias, precision, and confidence

Bias and precision are two measures of how "close" an estimated quantity is to the true quantity. Bias is how well estimated values are centered on the true value and is also described as accuracy or systematic error; precision is the variation in multiple estimates of the same quantity and is also described as random error or scatter. It is quite possible for an estimator to be both highly precise and highly biased. Both quantities are influenced by sampling design, measurement processes (including both field and laboratory protocols), and data analysis. This discussion focuses on the influence of sampling design. Although workshop participants currently favor a probability-based design, the influence of opportunistic and model-based sampling designs on bias and precision is also discussed in the context of design trade-offs to provide more information to support final monitoring design selection.

Precision can be easier to evaluate than bias, because we always have an empirical means to evaluate precision. We can take multiple replicate measurements, either over time, space, or both, and calculate the variation of the replicates about their mean value. The key to a proper evaluation of precision is the selection of replicates. The replicates should encompass all of the sources of variation that influence the result at the level it is reported. For example, if a metric is reported as the annual mean value of an attribute of a subwatershed, then we need only consider temporal variation at that subwatershed. If, however, the metric is a regional annual mean value, then we must include spatial variation by measuring multiple subwatersheds at multiple times. Temporal replication may need to span diurnal

and seasonal replications or flow regime, and spatial replication may need to span watershed size, vegetation cover type, urban/rural, or topography to take into account possible sources of replicate measurement variation.

Bias can be much more difficult to evaluate than precision, and, for some sample designs, evaluation is effectively impossible. Consider three classes of designs: opportunistic, model-based, and probability. In an opportunistic design, sample locations are selected based on ease of access or presumed representativeness. Representativeness may be evaluated according to site attributes, such as landscape factors, stream size, watershed size, ownership, and other characteristics. The ultimate selection is nevertheless based on human judgment that the sites are representative of the population. Studies in human cognition, however, have shown that humans are very poor at integrating various attributes to arrive at a conception of multivariate representativeness. Bias of an opportunistic design is evaluated by comparison to a truly representative data set, e.g., data from a census or probability sample. Such data sets are rarely available, but when they are, numerous examples in the statistical literature of such comparisons show that convenience samples are often severely biased. Evaluation of precision estimates produced from opportunistic designs find that such a design tends to overstate precision, because the sites selected as "representative" tend to have metric values near the center of the metric distribution, and so understate the true variability.

Model-based selection may also incorporate site attributes, but this sampling design adds an explicit quantitative component to the selection process. The selection model may be a process-based model, a spatial statistics model, or both. Model-based designs are rooted in assumptions about the nature of the population, e.g., a spatial statistics model might assume that the population is a realization of a Gaussian spatial random field. Properties such as stationarity, isotropy, the nature of the spatial covariance, and the form of the mean function are assumed. Model-based selection often picks sites to optimize some criterion, for example, to minimize prediction variance. Bias and precision can be evaluated relative to the model because the distribution of estimators or predictors is specified by the model assumptions. If the model assumptions are good representations of reality, then so will be the model-based quantification of bias and precision. Model-based designs and inference have the property that much of the burden prediction or estimation is transferred from data to the model; therefore, a model can lead to highly precise results with a minimal reliance on data. However, if the model assumptions are not satisfied, then the apparent high precision can be misleading.

A probability design uses an explicit probability distribution to select sites. The distribution must assign a positive selection probability to every unit in the population, and that selection probability must be known. Unlike opportunistic and model-based designs, probability designs have a built-in mechanism for evaluating bias. Because there is a known probability distribution, we can explicitly evaluate the expectations of estimators of population attributes such as means, percentiles, or distribution functions, and we can prove that the commonly used estimators associated with probability designs are unbiased.

Precision of a probability design depends on design structure, sample size, and design choices related to intrinsic population variability and covariance between population elements. As one example of how design structure can impact precision, consider that a variable probability design with inclusion

probability strongly correlated with response magnitude can result in very high precision. Precision of a probability design also very much depends on sample size because precision generally increases in approximate proportion to the square root of sample size; i.e., to double precision, sample size must be increased by a factor of four. Precision can also be improved based on knowledge of variance and covariance within a population, and through choices concerning how the population is spatially divided into strata. Most environmental responses exhibit some degree of spatial covariance in the sense that elements near one another tend to be more similar that elements far apart. If the relative variances of several strata are known, then allocating samples proportional to stratum variance will increase precision. Choices related to spatial stratification and site selection, however, depend on the sampling objectives. In general, if the objective is to address management questions at the spatial scale of individual strata, then consideration should be for a design that allocates approximately equal number of sample sites to each stratum. This strategy will result in an unequal probability design, and will likely not be the most precise for answering the questions at the population level. Conversely, designs with sample points more or less evenly distributed over the population domain (e.g., a GRTS design) tend to have higher precision than designs without such spatial balance, but the most precise design may not serve to provide answers for each individual stratum. Given a clear objective, some optimization of sample allocation can be attempted, provided insight into variability within strata is available. In the absence of good information showing some strong differences in variability, then equal allocation is generally best. Other design choices, such as temporal scale, also affect precision. A rotating panel design can enhance precision of designs that are in place for multiple years. Enhanced precision is possible if there is substantial between-year correlation. For example, the response for a panel visited last year can be predicted for the panel this year, and the predicted response can be pooled with the measured responses from this year's panel. Depending on the strength of the inter-annual correlation, the effective sample size for status estimation can be substantially larger than the actual number of sites measured in any year.

Many data quality indicators depend on sample design factors that have not yet been defined, and will need to be discussed among monitoring entities. For example, confidence in measurement estimates depends on whether confidence limits are being calculated for metric mean values, or for the proportion of a population meeting some acceptable standard. The concept of data confidence, however, does not apply if the sample design is not a probability, or pseudo-probability, design. Most monitoring programs have multiple objectives, and objectives compete for samples in the sense that optimizing precision for one objective will usually compromise precision for other objectives. One consideration is that the choice to optimize precision of status estimates will require tradeoffs in the precision of trend estimates. Because site allocation is driven by the objective, these objectives will need to be decided upon through further discussions among monitoring entities.

Data Collection Methods

To ensure data comparability across multiple monitoring entities and field crews, data collection methods will adhere as closely as possible to the EPA's Environmental Monitoring and Assessment Program (EMAP). Methods closely related to those used by EMAP are already used widely across the Pacific Northwest (Ecology 2006). Regardless of their similarity of methods used to EMAP protocols, all

monitoring programs should thoroughly document their data collection and other methods. Useable data may be collected by a variety of personnel, including volunteers, as long as personnel are appropriately trained and strictly adhere to protocols.

Measurement accuracy and non-bias will be optimized by correctly calibrating equipment and checking measurements against reference solutions, where applicable. Measurement precision will be assessed using field duplicates. Representativeness of water Qa/Qx samples to field conditions will be ensured by observing maximum holding time requirements, and laboratories at which samples are processed will adhere to quality controls such as those described in the Quality Assurance Monitoring Plan for the Status and Trends Monitoring for Watershed Health and Salmon Recovery (Ecology 2006). Other quality control procedures will also follow those described in this Quality Assurance Monitoring Plan.

Data Capture Logistics

Some water Qa/Qx metrics will be measured in the field using a handheld flow meter or multimeter probe. Crews may also collect water grab samples, sediment samples, and benthic macroinvertebrate samples for laboratory processing. Continuous stream flow data must be downloaded periodically from gauges.

Laboratories must receive most samples promptly after collection, with sample preparation methods and holding times varying by metric. Fecal coliform samples have the shortest holding time and must be received within 24 hours, and therefore must be immediately transported by hand or shipped overnight (Ecology 2006). In some cases, a second crew may be required for fecal coliform sampling, and fecal coliform sampling at all sites may not be feasible.

Crew of 2-4 individuals will be needed to collect habitat metrics and will generally require one field day per site. Habitat metrics are measured along multiple transects per site, as described in EMAP protocols (Ecology 2006).

Data Evaluation

Site status is determined by the measurement of metrics at each monitoring site. Trends are assessed by comparing the measurements between 5-year periods within a geographic area. A subset of sites sampled more than once during the 5-year period will be used to help understand inter-annual variation. Statistical analysis will follow EMAP protocols (see Ecology 2006 for sources).

Defining quantifiable benchmarks or goals against which water Qa/Qx status and trends can be measured will be necessary to effectively interpret monitoring data and guide adaptive management. These benchmarks should be developed in partnership with NOAA, regulatory agencies such as the Washington Department of Ecology, monitoring entities, and other conservation organizations. This task would be best approached as part of a suite of actions in the implementation phase of a status and trends monitoring program.

Data Management and Reporting

Information sharing among all monitoring entities, scientists, managers, and decision-makers will facilitate answering multi-scale questions about the condition of the Lower Columbia region. A central

electronic data repository and management program will need to be established that coordinates data sharing across multiple monitoring entities and programs. Evaluation of Ecology's Environmental Information Management database, currently used to accept and manage NPDES stormwater permittee monitoring data, may be useful for developing recommendations on database design and user interface modules.

Monitoring program managers should ensure that their methods are well-documented, and that data has undergone a rigorous quality review prior to electronic submission. Regional standardization at all steps of the monitoring process will increase confidence in data compatibility and analysis results. Reporting guidelines and deadlines will need to be established to ensure that accurate information is available to data users in a timely way. The experience of the Washington Forum on Monitoring Watershed Health and Salmon Recovery, the Pacific Northwest Aquatic Monitoring Partnership, and other groups with existing information management systems will be important in guiding data sharing in the Lower Columbia region.

Annual reports should consist of a brief description of the monitoring implemented, and an interpretative summary of water Qa/Qx and habitat status and trends based on data from sites monitored that year. Data collection is complete by mid-October, but sample analysis may extend beyond that time. Annual reports and verified, validated data should be submitted to the regional data management entity by January 31st of the next year. A more complete assessment based on data from all monitoring sites in each entity's jurisdiction should be submitted in place of the annual report in the sixth year after each five-year rotation of data collection. In addition to the brief description of monitoring implemented and the interpretation of status and trends, this report should address the priority management questions, and discuss likely causes of impaired conditions. A similar, region-wide assessment should also be completed based on data from all entities collected over five-year data period.

Approach for Multi-scale Monitoring

Scaling of monitoring efforts can be accomplished several ways, including:

- Varying the number of sampling sites,
- Varying the number of metrics sampled at each site, or
- Varying the frequency at which a metric is sampled.

The number of sampling sites needed to adequately represent water Qa/Qx and habitat status and trends in the Lower Columbia region depends on a number of factors. Increasing the number of spatial strata helps answer management questions at smaller spatial scales, but also increases the number of sites required to adequately represent variability in each of the strata combinations; further, a larger number of sampling sites is needed to represent areas with higher variability in measurements. More sampling sites are needed to achieve targets set for higher statistical power and confidence in estimates, and targets for higher precision. Determining the approximate sample size needed to achieve certain statistical power can be accomplished using existing datasets of metrics measured within the Lower Columbia, such as Ecology's EIM database, AREMP/PiBO databases, or others. Sample size analysis will

occur in the implementation phase of this project, after other monitoring design components have been selected.

Options for varying the number of metrics sampled at each site are discussed in the Metrics section, above. Tradeoffs in selecting which metrics are monitored occur because the number of metrics sampled determines the completeness of the data available to address monitoring questions, as discussed further in the following section.

Scaling of monitoring frequency can be accomplished by measuring some metrics more often at sites at which the metric is likely to change more rapidly, depending on site land use. For example, chlorine would be sampled at urban sites more often than at forested sites (see the Metrics section for other metrics for which frequency would change with site land use). Frequency can also be scaled by increasing or decreasing how often a metric is measured at all sites, with the tradeoff that monitoring at higher frequencies can better capture temporal variability.

Scaling in both the number of sites and sampling frequency influences the data available to assess status and trends, as discussed above in the section on Temporal Scale. The number of sampling sites drives the power to make inference about status, and also decides the precision in status estimate. Sampling frequency drives power to make inference about trends, and influences precision in the trend estimate. (Additional information on this topic can be found at http://www.monitoringadvisor.org/design/status-and-trend-monitoring-design/.) Monitoring at a larger number of sites increases the confidence in status and trends assessments at the regional scale, and also results in water Qa/Qx and habitat evaluations of a larger number of those subwatersheds thought to be particularly important to salmonid recovery.

Balancing the information gained from monitoring at a large number of sites, many metrics, or high sampling frequencies will need to be considered against monitoring design cost and resource investment (see the section titled Relative Costs for Implementation of Alternative, below).

Advantages and Disadvantages of Implementing this Monitoring Design

Participants at the February Technical Workshop selected a monitoring design that directs water Qa/Qx and habitat status and trends monitoring by selecting new monitoring sites probabilistically, and incorporating existing monitoring sites using a pseudo-probability model. In this monitoring design, new monitoring sites would be identified from across the Lower Columbia region using spatial strata intended to accommodate the multiple scales at which monitoring entities are interested in addressing management questions.

Implementing a regional integrated monitoring program that spans multiple organization and ecological resources (e.g. water and fish habitat), as outlined in the sections above, has the following potential benefits:

- A coordinated, region-wide monitoring program saves resources by reducing redundancy among individual monitoring programs and increases opportunities to share resources;

- Existing sites initially chosen to pursue a management question of interest to particular stakeholders are retained; one result may be increased participation and support;
- Programmatic investments in existing sites are maintained, and resource use may be optimized by using one site for multiple purposes;
- Longer data records from existing sites can be leveraged to evaluate status and trends;
- Monitoring sites are expanded to generate information on a regional scale, but selecting sites based on spatial strata such as the Urban Growth Boundary ensures information is generated at scales relevant to multiple users;
- With a sufficient number of sites across the region, questions critical to permittees and resource managers about where particular habitat or water quality impairments exist can be addressed, at least on a coarse scale; and
- By monitoring a subset of water Qa/Qx metrics at habitat sites and vice versa, basic water Qa/Qx and habitat data are available from all sites region-wide, allowing additional insight into relationships between ecological resources. Simultaneously, monitoring only this subset of metrics avoids placing an undue burden on entities to whom more in-depth data has low utility.

The disadvantages of implementing this monitoring design are:

- The statistical model used to combine data from existing, opportunistically-selected sites with new and existing probabilistically-selected sites is complex;
- As part of the pseudo-probabilistic model used to integrate opportunistically-selected sites into the new design, some of these sites will be assigned low 'weights' (data importance) and will contribute less to assessing status and trends at the regional scale;
- Locating new monitoring sites at probabilistically-selected points will result in some areas of interest to particular managers not being monitored under this program;
- Setting up a region-wide monitoring system will require a commitment of time, money, infrastructure, and expertise;
- Increasing the number of monitoring sites, and the metrics monitored at these sites, will require a substantial resource investment; and
- An increase in water Qa/Qx sampling may result in an increase in impaired waterbody listings, and the accompanied regulatory requirements.

The three different alternative monitoring scenarios described in this document are based on a shared design of other monitoring attributes, and so the advantages and disadvantages of implementing this monitoring design are shared across alternative scenarios. However, each alternative scenario differs in the metrics monitored. Each monitoring scenario produces information allowing evaluation of all the habitat and water Qa/Qx management questions, but alternatives that recommend monitoring a larger number of metrics would produce more data, and therefore allow the management questions to be addressed more completely (see the section titled Management Questions Addressed by the Habitat and Water Quality Status and Trends Monitoring Program for a complete list of management questions). For example, evaluating surface water compliance with Washington State surface water quality

standards (Ecology 2011c) can be accomplished under all three water quality alternatives, because all alternatives recommend measuring temperature, dissolved oxygen, pH, turbidity, bacteria, nutrients, and toxics. However, because a larger number of nutrients and toxics would be measured under the Full Suite alternative (Alternative 3), compliance could be assessed more completely if this water quality monitoring scenario were implemented than if Alternatives 1 or 2 were implemented. In general, water quality metrics recommended under Alternatives 2 and 3, such as heavy metal and pesticide runoff, tend to be more strongly related to urban and suburban development impacts, and therefore may produce information of greater interest to some monitoring partners, but may be less relevant to assessing regional status and trends in mitigation of salmonids limiting factors, drinking water, and other beneficial uses.

All three alternatives also allow habitat management questions to be addressed, at varying levels of detail. Many of the habitat metrics needed to assess in-stream and riparian biological and habitat conditions would be monitored under Alternative 1, but more of those that NOAA prioritizes in assessing the threat of habitat loss to salmonids would be monitored under Alternatives 2 and 3. Management questions are intended to be broadly stated in order to capture all of the interrelated management priorities of multiple entities. The extent to which each management question is addressed under a particular alternative will largely depend on the criteria against which it is assessed, which will vary by entity.

Other Considerations

To reduce constraints to monitoring program implementation, additional factors must be considered such as the relative costs of each alternative monitoring scenario, potential mechanisms for funding monitoring, and integration with the reporting requirements of agencies conducting salmon and steelhead monitoring, NPDES stormwater permittees, and other monitoring entities.

Relative Costs for Implementation of Alternative

The expenditures necessary to implement the monitoring program are related to a number of start-up and recurring costs, including finalizing a Quality Assurance Monitoring Plan and field and data management protocols; negotiating site access and reconnaissance to finalize monitoring locations; acquisition and maintenance of equipment and materials, and contracting with laboratories for water quality sample analysis; and developing a data management and reporting system. Alternative monitoring scenarios differ primarily in the number of metrics monitored at each site. Increasing the number of metrics that are monitored is associated with higher relative cost resulting from:

- Paid staff time required to monitor a larger number of metrics at each site;
- Larger number of laboratory analyses of water quality samples;
- The number of staff needed to manage more extensive data; and
- Paid staff time required to write more extensive annual reports.

Because the largest number of metrics is monitored under Alternative 3, implementing this alternative will require the most resource investment, followed by Alternative 2. The fewest number of metrics are monitored under Alternative 1, so this option will be the least expensive to implement. The tradeoff is

that sampling a larger number of metrics increases the completeness of the data available to address management questions (see examples provided under Advantages and Disadvantages of Implementing this Monitoring Design).

Although laboratory analysis costs vary across the three alternatives, how much they vary will depend on the laboratory contracted to do the analysis. For instance, analysis costs may be reduced if the chosen laboratory offers a reduced cost per sample when greater than a certain number of samples are submitted.

Based on information obtained from a single laboratory, a rough estimate of water Qa/Qx metric analysis costs per site was developed for each of the three alternatives (Alternative 1 - Standard, Alternative 2 - Expanded, and Alternative 3 - Full Suite). This serves only as a general means of comparison between the alternatives, as it is only based on those metrics that require analysis and on the costs provided by one laboratory. Actual analysis costs could vary substantially depending on some of the factors identified above. Figure 6 illustrates the comparison of laboratory analysis costs across the three alternatives. Alternative 3 would require analysis of the full suite of metrics, so the cost of the other two alternatives are shown as a percentage of what it would cost to analyze all metrics under Alternative 3. Water Qa/Qx metric analysis costs for Alternative 1 would be approximately half (49 percent) what they would be for Alternative 3, while Alternative 2 would be approximately two thirds (66 percent) of the cost of Alternative 3 (Figure 6). Implementing Alternative 2 would only increase laboratory analysis costs by approximately 17 percent over the cost of Alternative 1. Therefore, while implementing monitoring of the full suite of metrics (Alternative 3) would require substantially more funds for laboratory analysis than the standard metrics, implementing the expanded Alternative 2 set of metrics would only increase costs slightly, but would provide additional information to address management questions more extensively (see examples provided under Advantages and Disadvantages of Implementing this Monitoring Design).

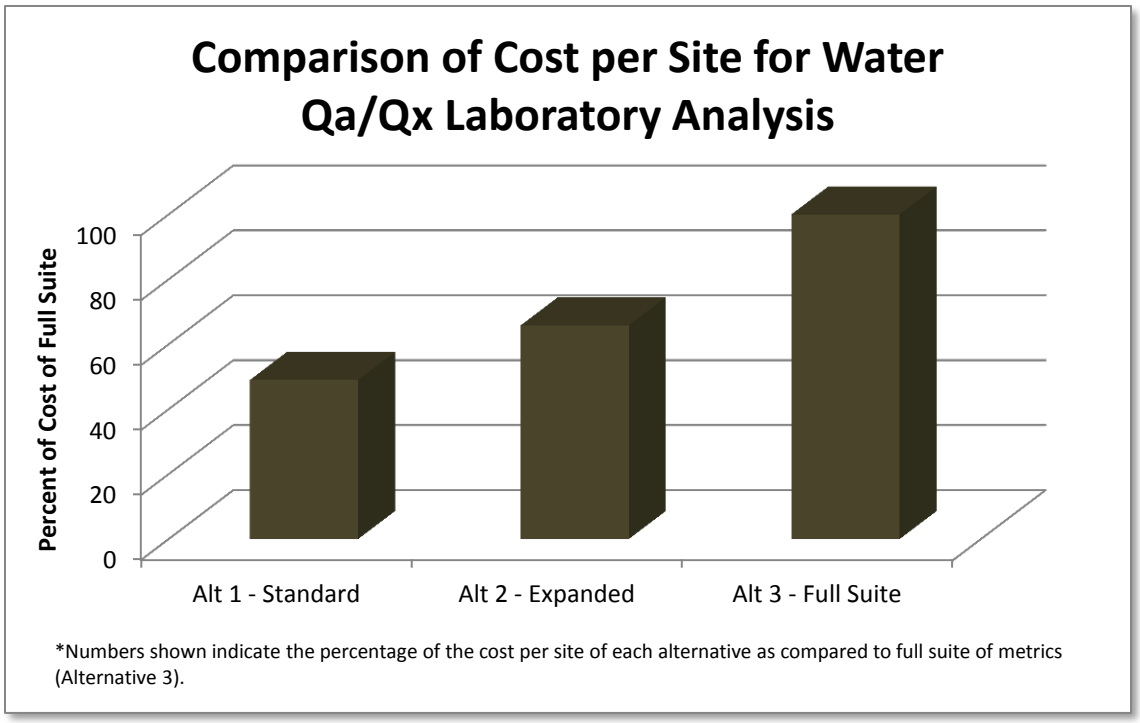

Figure 6. Comparison of cost per site for water Qa/Qx laboratory analysis

Apart from the monitoring alternative selected, there are also choices to be made regarding the scale of monitoring effort, including the number of sampling sites, and the frequency at which each site is visited. These factors will have a far larger impact on monitoring costs than that number of metrics monitored at each site, and costs associated with these metrics cannot be estimated until the final sampling design is completed. While it is not feasible to conduct a full cost analysis at this time, as was completed for Puget Sound, the information presented in Figure 3 portrays the relative cost increases associated with increasing data collection efforts. As mentioned above, the number of sampling sites drives the power to make inference about status, while sampling frequency drives the power to make inference about trends. Cost considerations must balance the need for status information versus trend information. A more substantial cost analysis will be conducted during the implementation phase of this project, at which time more specific costs estimates can be developed.

Funding Options and Resources

Costs of implementing a regional status and trends monitoring program will need to be distributed among federal, state, and local governments, and among local jurisdictions. Coordination among programs at all levels of government and leveraging shared resources is likely to maximize savings. Federal and state partners should continue support for their existing monitoring programs, and work to expand them in accord with regional strategies. Grants from federal agencies, Ecology, and other entities may also be available to help stormwater permittees implement monitoring. This section explores potential funding options for a regional status and trends monitoring program, with a focus on mechanisms for stormwater permittee participation.

A funding structure that maximizes flexibility and choice is likely to best facilitate stormwater permittees' participation in a regional status and trends monitoring program. Such a strategy has recently been adopted by Ecology in the current Phase I NPDES 2013-2018 permit cycle to fund stormwater status and trends monitoring in the Puget Sound region (Ecology 2012a). Permittees may choose to implement their own monitoring projects as part of the unified regional monitoring program outlined in this report, or they may prefer to contribute to a collective fund used to implement such projects. The Puget Sound Stormwater Work Group identified the Washington Department of Ecology as the initial administrative entity to manage monitoring activities, data, and reporting (Ecology 2011b), and a similar entity would need to be identified to administer the Lower Columbia region status and trends monitoring program. The collective pay-in option may be an advantageous strategy in that it centralizes the monitoring program and thereby reduces redundancy, and facilitates decision-making that prioritizes regional objectives.

Alternatively, permittees may want to assume responsibility for monitoring at sites within their jurisdiction to promote consistency with their existing monitoring programs. Established monitoring programs have already developed a site selection process and a list of metrics that are currently used for reporting as part of the permit requirements, and permittees with existing programs may wish to continue this investment. Incorporating add-on projects such as effectiveness monitoring may help permittees focus on individual management questions of interest while also fulfilling status and trends monitoring responsibilities. Other jurisdictions that have not yet implemented monitoring programs, however, will have the advantage of generating a data set that is consistent with the goals of the regional habitat status and trends monitoring program. Finally, a combination of strategies including contribution to a collective fund and independent implementation of monitoring may best suit some permittees' needs.

Agency Reporting Requirements

ESA-Listed Salmon and Steelhead Recovery Plans

NOAA's National Marine Fisheries Service (NMFS) is required to develop recovery plans for all listed salmon and steelhead species that set of goals and actions for each ESU or DPS that, if implemented, would reverse the ESU or DPS's decline and lead to its recovery (NMFS 2012). A proposed recovery plan for Lower Columbia River Chinook salmon, Lower Columbia River steelhead, Lower Columbia River coho salmon, and Columbia River chum salmon was developed in 2012 that integrates three separate plans previously developed for the salmon and steelhead recovery in the Oregon Lower Columbia region, the southwest Washington Lower Columbia region, and the White Salmon River Subbasin. NMFS is required to review the status of listed salmon and steelhead every 5 years, and prepare reports to Congress every other year (NMFS 2012).

Recovery actions are implemented over a 25-year period, led by the Lower Columbia Fish Recovery Board in southwest Washington, the Oregon Department of Fish and Wildlife in Oregon, and the National Marine Fisheries Service in White Salmon. However, recovery regions structure this time in different ways that are reflected in individual reporting requirements. In Oregon, recovery actions are implemented on schedules with 5-year intervals (3 years for priority actions) (NMFS 2012). Southwest

Washington uses a 6-year adaptive management checkpoint, with possible revisions every 2 years, and completes assessments at 12 year intervals (LCFRB 2010a, NMFS 2012).

National Pollution Discharge Elimination System Permits

The State of Washington Department of Ecology requires NPDES municipal stormwater permittees to submit annual reports by March 31st covering permit-related activities implemented the previous year (Ecology 2012a,b). Phase I permittees in the Puget Sound area are also required to implement and report on stormwater-related monitoring (Ecology 2012a). Ecology is considering adding a similar responsibility to Lower Columbia region Phase I and Phase II permittees in future permit cycles (L. Cox, Washington Department of Ecology, pers. comm. January 15, 2013).

Internal Reporting Requirements

Apart from reporting requirements related to involvement with Recovery Plan or NPDES Permits, many entities currently implementing status and trends monitoring have individual requirements and timelines that have been established internally to meet institutional objectives.

Implementation Phase of the Project

The work that is being conducted currently involves the development of a recommended monitoring framework for the Lower Columbia Habitat Status and Trends Project. As described in the sections above, this portion of the project includes three stages through which potential monitoring scenarios were developed, and trade-off analyses were completed to compare the alternatives; a final recommendation for a coordinated monitoring program will be presented in the third stage. Although many design options related to the proposed monitoring program are being defined through this process, some aspects of this large-scale monitoring program cannot be determined until implementation planning is underway.

Following the completion of the final recommendation, the Implementation Phase of the project will begin. This phase will allow entities involved in the program to develop a specific approach to implementing the recommended program. Through collaboration between the LCFRB, PNAMP, stormwater permittees, ISTM partners, and other stakeholders, the finer details of monitoring coordination, data management processes, funding resources, and many other program components will be resolved.

In addition to developing new monitoring efforts, existing monitoring programs will need to be reviewed and probably refined to allow integration into a regional monitoring design. In particular, challenges exist in integrating monitoring programs currently operated by individual NPDES stormwater permittees, as those programs have been designed to satisfy specific regulatory and data needs that often preceded those outlined in the NPDES Stormwater permits. Examination of existing programs in the Lower Columbia Fish Recovery Region demonstrates the variety of current monitoring program approaches, from targeted site locations chosen opportunistically, to programs that have yet to be implemented by individual permittees. Monitoring populations targeted by current permittee monitoring programs, and those covered by the NPDES Stormwater Permits, tend to be smaller, wadeable streams within each individual permittee jurisdiction that will more easily show response to stormwater impacts in both

water Qa/Qx and biological parameters. Despite differences in monitoring design across stormwater permittees and other monitoring entities, integration and collaboration across all monitoring programs is essential to assess whether current efforts to address the factors limiting salmon recovery are making progress. Actions that promote salmon recovery also help ensure that habitat and water Qa/Qx are safe for other beneficial uses important to permittees, such as domestic water supplies and recreation.

Convergence of permittee monitoring efforts with those of other monitoring entities in the Lower Columbia region will need to occur over time. Existing programs require that some components of their current monitoring effort remain intact in order to support other regulatory reporting requirements. There are a large variety of strategies that could be employed to effectively implement a habitat and water Qa/Qx status and trends monitoring program. Keys to successful implementation include support from those entities required to conduct data collection efforts (i.e. stormwater permittees) and agencies with regulatory authority (i.e. Ecology). Development of a successful implementation strategy will require a collaborative process that, in this case, includes stormwater permittees and Ecology and involves other key stakeholders such as PNAMP and the ISTM partners.

Additionally, during the Implementation Phase, the potential for volunteer involvement in the program will also be explored. Any volunteers taking part in the program would be required to follow the protocols identified for the monitoring program, undergo training on field data collection methods and learn how to utilize the proper equipment. Volunteer opportunities may be identified at particular sites, for the collection of particular metrics, or with other criteria to be determined through the Implementation Phase of the project.

Discussion and Summary

Monitoring multiple ecological resources, such as water Qa/Qx and habitat, at common locations (i.e., co-locating sites) can provide additional insights into regional status and trends and to the relationships between ecological resources. This potential benefit has appeal to monitoring practitioners as it provides the broader perspective required to evaluate salmonid recovery and resource protection programs, along with many other advantages. However, developing and implementing a large-scale, integrated sampling design is complicated as a result of competing objectives and organizational constraints. A particular challenge is that the appropriate populations targeted by water Qa/Qx monitoring and by habitat monitoring differ (outlet of watersheds vs. stream reaches), resulting in the recommendation that each type of monitoring be implemented at different sites.

The monitoring design described in this document offers several solutions for integrating water Qa/Qx and habitat monitoring data, and attempts to resolve many other constraints through, for example, the use of spatial strata to identify new monitoring sites in a way that accounts for multiple objectives. Of the three alternative monitoring scenarios outlined earlier in this project, one was favored by workshop participants, and this design was evaluated for ways in which it could be scaled up or down to better address priority monitoring questions, how sampling designs affect precision and bias, and the relative costs and benefits of making protocol adjustments to existing monitoring programs. Ongoing discussions with monitoring entities and other interested parties will be necessary to determine priorities for balancing the need for status information versus the need to trend information, and select

among the alternative monitoring scenarios and other design options. Such input will be the basis for developing a final recommendation for a regional monitoring design. Together with complementary monitoring programs, a habitat and water Qa/Qx status and trends monitoring program would comprise the core of an integrated status and trends monitoring strategy for the Lower Columbia region.

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Appendix A –Management Question Revisions

Management questions were revised based on discussion and comments received following the February Technical Workshop to clarify intent. Revised management questions were all in the Water Quality and Quantity Management Question Group. The revised questions were submitted for re-review to workshop participants and other interested parties. The table below details these revisions.

Original question	Revised question	Rationale
Water Quality and Quantity:		
What is the status and trend of water quality and flow in receiving waters/surface waters/stormwater?	What is the status and trends of water quality and **stream** flow in **[text omitted]** surface waters?	Target monitoring population is not stormwater, but rather surface water. Stormwater is monitored at a stormwater outfall. Assessing the impact of stormwater on surface water can be accomplished through spatial stratification that places monitoring sites inside/outside Urban Growth Areas, etc. This would be consistent with results from the Puget Sound workgroup, which emphasizes surface water rather than stormwater monitoring.
Where do water quality conditions not support beneficial/water dependent uses?	Where do water quality/quantity conditions ~~**not**~~ support beneficial/water dependent uses?	Question is better expressed as a positive.
How effective are clean water programs at meeting water quality criteria or standards?	**[Omitted in entirety.]**	This is a program effectiveness question that will not be answered by this monitoring program, which focused on status and trends.
Are receiving waters in compliance with water quality standards?	**To what extent** are **regional surface waters [~~receiving waters~~]** in compliance with water quality standards?	Target monitoring population is broader than just receiving waters. Reworded to clarify that monitoring will more effectively address the overall extent to which streams are in compliance with standards on a regional scale, rather than a census of which streams are in compliance.

Appendix B –Additional Feedback from February Technical Workshop Participants and Other Interested Parties

Comments were made in response to the February Technical Workshop, held as part of Stage 1 of this project. However, comments were received after the final Technical Report 1 was submitted, and so are included here in the Technical Report 2. Comments and responses were used to help complete the trade-off analysis as part of Stage 2. Many of the comments concern monitoring design attributes that are continually being clarified and revised with stakeholder feedback.

Name	Affiliation	Comment	Response
Dan Rawding	WDFW	Need to link Lower Columbia River habitat and fish monitoring designs. WDFW used PNAMP GRST master sample draw for adult coho monitoring and will do same for parr if funding becomes available. Linking fish and habitat designs will improve cost efficiency.	Salmonid monitoring programs are described as complementary to a water quality/quantity and habitat status and trends monitoring program, with the recommendation that their designs be integrated to the extent possible. Developing design linkages between the two programs is possible through the proposed design, but the detailed strategy to accomplish this was determined to best be approached through a separate project.
Jim Fisher	LCFRB TAC	1) Should focus on broader questions: A) what is monitoring telling us about efforts to conserve/restore salmon habitat in quantifiable terms, B) What are quantifiable targets for amount of habitat necessary to achieve delisting, C) How is current monitoring efforts measuring progress to habitat targets, D) Is horizontal sampling (spot checking multiple locations) the most effective way to evaluate trends in habitat status.	Current regional habitat monitoring efforts were summarized as a part of this project in Stage 1, and are summarized in Technical Report 1. A discussion on the effectiveness of different monitoring designs, including opportunistic sampling, was initiated in Stage 1, and is ongoing. The final recommendation resulting from this project is a sampling design framework that will provide the data necessary to answer management questions for both water quality/quantity and habitat. Defining quantifiable benchmarks or goals against which water quality/quantity status and trends can be measured will be necessary to effectively interpret monitoring data and guide adaptive management. These benchmarks should be developed in partnership with NOAA, regulatory agencies

Name	Affiliation	Comment	Response
			such as the Washington Department of Ecology, monitoring entities, and other conservation organizations. This task would be best approached as part of a suite of actions in the implementation phase of a status and trends monitoring program.
		2) Stormwater is more straightforward: A) Directed at compliance with NPDES permits and state water quality standards, B) directed at point source discharges generally associated with toxicity to aquatic organisms, C) threshold over water quality limits already set; therefore, it is likely that any on-going long-term occurrences from stormwater into ESA waters is already covered, D) reduces this to exercise to satisfy Ecology's need to assure ambient water quality in-stream is maintained within state water quality limits.	Water quality/quantity monitoring designs are intended to implement widespread data collection of metrics used to assess compliance with NPDES permits, calculate water quality indices used by Oregon and Washington, and evaluate the overall extent of the stream network within state water quality limits on a coarse scale. Monitoring designs currently being considered use probabilistically-selected sites, and so are less effective for detecting point source discharges and impaired water bodies. Monitoring focused on these objectives is currently implemented by NPDES stormwater permittees.
Jeff Schnabel, Ron Swanson	Clark County	Provided comments on the background document regarding: 1) need to better define/clarify management questions, 2) metrics to be collected needs further review, 3) need to better describe effort level in relation to scenario and 4) sampling design. Also provided specific comments about each scenario and the discussion questions presented in each scenario summary document. Provided comments regarding the management questions. Primarily focused on clarifying the intent of the management questions, including several terminology changes. Provided comments regarding the list of metrics being considered. Expressed concerns about some metrics on the list and provided links to other Ecology monitoring programs that might help in development of a list for SW Washington.	Management questions were revised to clarify intent and submitted for re-review to workshop participants and other interested parties. Tables and maps illustrating the metrics currently being collected and existing monitoring sites were updated. The list of priority monitoring metrics was developed in consultation with the recommended Ecology and other monitoring programs. Comments on alternative monitoring scenarios and discussion questions were helpful in report content development. Comments considered follow-up to the January Technical Workshop and therefore are also included and addressed in Technical Report 1.

Name	Affiliation	Comment	Response
Bill Feddeler	Citizen/ stakeholder	Scenario #2 is an upgrade which is always good. Scenario #3 uses expensive testing. Scenario #3 could be done under Scenario #2 on a case by case based for dangerous spill events.	Comments on alternative monitoring scenarios and discussion questions were helpful in report content development.
Ron Rhew	USFWS	1) For some metrics level may vary depending on what portion of the hydrograph is sampled (e.g. turbidity, solids & nutrients attached to soil particles). Sampling at programmed levels may not characterize maximum levels by missing events that elevate stream concentrations (e.g. metals from first flush off roads). Must consider to accurately characterize potential limiting conditions.	Recommendations for the timing of monitoring were developed for each metric and land use type that would target sampling toward those times of year during which maximum levels of pollutants would be most likely, and potential limiting conditions would be most accurately characterized.
		2) Some metrics can be determined remotely across area (e.g. impervious surfaces, stream crossing frequency, land use, vegetative cover). For these metrics look at departure from historic conditions, which will allow for comparison over time.	Metrics important for habitat monitoring but best monitored using remote sensing techniques were included in recommendations for a separate remote sensing program that would be complimentary to the status and trends monitoring program. Defining quantifiable benchmarks or goals against which to measure departure from historic conditions would be an important part of the remote sensing program.
		3) Advantages of Scenario #2 are ability to retain existing sites and information. Disadvantages for Scenario #2 are not having uniform probability sampling across entire area. Pseudo probabilistic model may lack accurate characterization of some water quality parameters depending on temporal sampling strategy.	Comments on alternative monitoring scenarios and discussion questions were helpful in report content development.
		4) Range of metrics looks ok.	Comments on alternative monitoring scenario metrics were helpful in report content development.
Larry Schaffner	WSDOT	Worthy goal to collect data to assess trends in conditions of receiving waters. Multiple stressors beyond municipal stormwater discharges make it extremely difficult to identify andy stormwater-	As outlined in the project scope, monitoring program designs focus on status and trends monitoring. Status and trends monitoring is generally not designed to identify cause and effect or assess best management practice

Name	Affiliation	Comment	Response
		related cause and effect signal. Will not provide actionable information to direct adaptive management of stormwater management programs.	effectiveness.
Dorie Sutton	City of Vancouver	1) A lot of focus on metrics to date. Need to have common understanding of basic (minimum needs) and expanded (helpful to have) parameters so cost and scope can be evaluated. More important questions are not what is being collected but where it is being collected. Monitoring and assessment needs to occur where stormwater runoff from urban areas impacts water quality to meet regional requirements under NPDES.	Alternative monitoring scenarios provide three levels of monitoring effort to allow relative comparisons of utility and cost. Detailed data on which metrics are being monitored where was collected as part of Stage 1, and is broadly illustrated in maps made available during Stage 1. Monitoring program designs recommend allocating new monitoring sites relative to NPDES permittee areas of jurisdiction and UGA/City boundaries to focus assessment on subwatersheds likely to experience larger impacts from stormwater runoff.
		2) Advantages to Scenario 2: A) Retains opportunistic sites important to MS4 programs, B) Potentially add habitat monitoring to Water Quality sites, 3) Regional monitoring efforts receive more support if enhance or build on existing programs & D) City of Vancouver needs to continue investment in Burnt Bridge Creek.	Comments on alternative monitoring scenarios and discussion questions were helpful in report content development.
		3) Concern: A) Will new sites be meaningful to Stormwater Permittees and acceptable as regionally significant to Ecology, B) Need map showing ISTM watershed boundaries, NPDES stormwater permit coverage in SW Washington & how probabilistic sites relate to MS4 area of influence.	A map illustrating the master sample of potential monitoring sites, or the selected sample of monitoring sites, relative to subwatershed boundaries and NPDES permittee areas of jurisdiction will be provided when consensus on monitoring designs allows identification of new monitoring sites.
		4) List of metrics for Scenario 3 is better starting point then list for Scenario 1.	Comments on alternative monitoring scenarios and metrics were helpful in report content development. Metric lists will be further refined during upcoming workshops and discussions.
		5) Most MS4 managers do not work directly with monitoring so focusing on specific parameters will not be beneficial to those stakeholders at this time.	Discussion of metrics to be included in a future status and trends monitoring program is intended to gather feedback from monitoring entities, stormwater permittees, and other stakeholders on their monitoring priorities.

Name	Affiliation	Comment	Response
		6) Ecology is not likely to add monitoring to Phase II permits until 2018 so difficult to come up with more specifics at this time.	See above comment.
Randy Anhorn, Karen Adams, Lisa Cox, Karen Dinicola, Brandi Lubliner	Washington Department of Ecology	Multiple comments provided regarding Scenario #2 and the metrics being collected. Commented that increased clarification in sample design and sampling strategies (e.g. geographic extent, intensity, data collection protocols). Need to clearly articulate management questions and objectives to provide context to data collection activities described in Scenario #2.	Monitoring designs were revised to recommend that both water quality/quantity and habitat metrics be collected at all sites. Detailed sample designs and sampling strategies are continually being clarified and revised with stakeholder feedback. Management questions were developed in Stage 1, but were integrated into Technical Report 2 and will be included in future documents for context. Management objectives will need to be developed in consultation with monitoring entities, stormwater permittees, and other stakeholders and may be most appropriately accomplished in the implementation phase of a status and trends monitoring program.

Appendix C –Memorandum Revising the Technical Approach for Task 2.1, Lower Columbia Habitat Status and Trends Project

To: Jeff Breckel, Lower Columbia Fish Recovery Board

From: Tricia Gross, Tetra Tech

Subject: Technical Approach for Task 2.1, Lower Columbia Habitat Status and Trends Project

Date: March 19, 2013

cc: Pat Frazier, LCFRB
Melody Tereski, LCFRB
Steve Rentmeester, Sitka Technology Group
Don Stevens, Stevens Environmental Statistics

Mr. Breckel,

Based on several discussions with LCFRB staff and feedback from the Department of Ecology and stormwater permittees during Workshop 2 in Ridgefield, WA on February 15, 2013, the technical approach to Task 2.1 will vary slightly from what was originally described in the Statement of Work for this project. Originally, the three scenarios that were presented to stakeholders at Workshop 2 were to be taken through trade-off analysis during Task 2.1. However, at Workshop 2, a discussion session took place regarding the advantages and disadvantages of each scenario, which ultimately resulted in consensus that two of the three scenarios were not feasible options. Participants agreed that Scenario 1, a no-change scenario, would not allow stormwater permittees to meet upcoming regulatory requirements that will likely be iadded by the Department of Ecology during the next permit cycle. The group also reached consensus that Scenario 3, the full monitoring effort scenario, would be too costly for the amount of value added, and that many of the entities involved lacked the funding that would necessary to implement that option. While discussing Scenario 2, it was suggested that the list of potential metrics could be tiered to provide options for level of effort (e.g., high, medium, low). Task 2.1 will be conducted using three options under Scenario 2, which still meets the original intent of the task.

Several key issues have come to light that must be addressed in order to move forward with a technically sound approach in Task 2.1, including:

- What is the appropriate population of interest and spatial scale for monitoring and reporting?
- Should a single integrated study design be implemented to address water quality, water quantity and habitat at both the reach and watershed-scales? Or should multiple study designs be developed to address each of these?

Under Task 2.1, these questions will be evaluated through a trade-off analysis. This information will also allow scaling of each option to be considered, as well as the relative costs involved. Potential funding resources that may be available to monitoring entities will generally be described; however, specific funding opportunities and resources will not be identified. Various possible funding methods or approaches will also be compiled as part of this task. The technical approach to Task 2.1 will be as follows:

> Consultants will conduct a trade-off analysis of alternative monitoring scenarios developed under Task 1.8 to evaluate ways in which the monitoring design can be scaled up or down to meet priority monitoring questions. A critical step in developing a monitoring program is identifying the population of interest and the spatial scale for monitoring and reporting. In addressing questions about status and trends of water quality, water quantity, and stream habitat, there is a need to report on both the cumulative status of watersheds and on the status of reaches within watersheds. Additionally, there will be a need to define what constitutes a watershed. The Consultants will conduct a trade-off analysis of implementing a single integrated study design where water quality, water quantity, and stream habitat are monitored at both reach and watershed-scales versus, implementing multiple study designs to address each of these various components of the regional monitoring program. The trade-off analysis will consider agency reporting requirements; regional strategy for research, monitoring, and evaluation; scientific feasibility to estimate watershed condition from reach-level information; and logistical considerations for monitoring and analysis. Additionally, the metrics, sampling design, spatial scale, and temporal scale will be used to evaluate each of the options through the trade-off analysis.
>
> For existing monitoring programs, Consultants will evaluate the relative benefit/value of making study design adjustments under each scenario in terms of answering priority management questions and improvements in the general level of precision and reduction of bias, if applicable. Consultants will consider constraints to implementing each scenario, which may be temporal, spatial, monetary, related to data quality, or may reduce the likelihood of potential implementation. Consultants will also consider the utility of a GRTS-based design versus other spatially-balanced design techniques. A GRTS-based design provides a built-in method for maintaining spatial balance while dynamically scaling sample size up or down to adapt to changing monitoring needs or funding levels. Other designs, however, will require some careful evaluation to develop scaling scenarios (i.e., where to add or remove sample sites).

The deliverables under Stage 2 of this project will remain as specified in the scope of work and include the following:

- Draft report (Technical Report 2) documenting results of trade-off analysis and mechanisms for local government participation in monitoring design implementation;
- Co-lead 2 Workshops and document attendance, observations and conclusions; and
- Final report (Technical Report 2) summarizing results of trade-off analysis and mechanisms for local government participation in monitoring design implementation

Under the approach to Task 2.1 described above, these reporting and workshop deliverables will still be delivered within the contract period, although schedules for the workshops and deliverables have been modified, as agreed to by the LCFRB, to ensure that the most complete and accurate information is provided to stakeholders.

Regards, Tricia Gross, Project Manager, Tetra Tech

Appendix D –Participants in Water Quality/Quantity Technical Subgroup Meeting/Workshop

Table D-1. List of Participants in Water Quality/Quantity Technical Subgroup Meeting/Workshop, March 11, 2013		
Last Name	**First Name**	**Affiliation**
Adams	Karen	Washington Department of Ecology
Anhorn	Randy	Washington Department of Ecology
Bayer	Jen	USGS/PNAMP
Breckel	Jeff	Lower Columbia Fish Recover Board
Cox	Lisa	Washington Department of Ecology
Cusimano	Bob	Washington Department of Ecology
Frazier	Pat	Lower Columbia Fish Recover Board
Plotnikoff	Rob	Tetra Tech
Puls	Amy	USGS/PNAMP
Rentmeester	Steve	Sitka Technologies
Schnabel	Jeff	Clark County
Sutton	Dorie	City of Vancouver
Swanson	Rod	Clark County
Tereski	Melody	Lower Columbia Fish Recover Board

Appendix E –Participants in April Technical Workshop

Table E-1. List of Participants – April Technical Workshop, April 2, 2013		
Last Name	**First Name**	**Affiliation**
Adams	Karen	LCFRB
Anhorn	Randy	WA Ecology
Bayer	Jen	USGS/PNAMP
Breckel	Jeff	LCFRB
Collyard	Scott	WA Ecology
Cox	Lisa	WA Ecology
Dyrland	Richard	Fish First
Duren	Olivia	Tetra Tech
Griffy	Annette	City of Vancouver
Gross	Tricia	Tetra Tech
Irving	Kathy	USGS
Johnson	Josh	City of Longview
Joregensen	Kelley	LCFRB TAC/Private Consultant
McKay	Van	City of Kelso
Puls	Amy	USGS/PNAMP
Rentmeester	Steve	Sitka
Rhew	Ron	LCFRB TAC/USFWS
Sutton	Dorie	City of Vancouver
Swanson	Rod	Clark County
Tereski	Melody	LCFRB

Appendix F – Feedback from April Technical Workshop Participants and Other Interested Parties

Appendix F – Feedback from April Technical Workshop Participants and Other Interested Parties**Habitat Status and Trends Monitoring Integration Stormwater and ISTM - April 2, 2013**		
April Technical Workshop Comment Matrix		
Name/Affiliation	***Comment***	***Response***
Josh Johnson City of Longview	Provided comments regarding strata: consider 3 strata (urban, rural and resource land) or 2 strata (inside/outside UGA/NPDES areas). Consider limiting scope to Cascade strata. Reduce stream size strata from 5 to 2 or 3: Wadeable/non-wadeable streams or fish/non-fish bearing streams or 3 Valley Classes. Clarify differences between rotating panels and sampling frequency in metrics table.	Strata were updated.
	Recommendations regarding metrics: a) Move Oil & Grease from Alternative 3 to Alternative1; b) consider another alternative, Alternative 1A that includes Water Quality Index and Macro-invertebrates; c)move sediments out of Alternative 1 or extend sampling frequency to 5 years; d) move chloride from Alternative 1 to Alternative 2 or Alternative 3; e) reduce the number of nutrient metrics in Alternative 1 and f) reduce the number of "water quality" metrics Alternative 1 (e.g. move SS 7 TS to Alternative 2).	Comment noted; however, input from panel that attended the Stormwater Technical Subgroup Meeting differed from these suggestions. Retained guidance provided by and agreed upon by larger group.
Brian Franzen Weyerhaeuser	Will sampling be occurring on private forestlands because it isn't clear from the maps. If so need to contact landowners sooner rather than later.	The precise location of sampling would be determined during the implementation phase of the project. Negotiating access to private lands is described as one of the considerations under costs related to implementation. Additionally, under the proposed design, sites for which landowner permission for access cannot be obtained will be rejected.

Rod Swanson Clark County	Appears that "pseudo-probabilistic" sample design and the subwatershed based sample set really coincide with needs of Clark County. Need to include Clark County's relatively new subwatershed -based census project as part of the site selection process.	Clark County's historic monitoring locations have been included in the GIS file of legacy sites. When Don, Keith, and I run the GRTS function to create the study design, legacy sites will be selected first to fill the strata allocation, then new master samples sites will be selected. This will be the process for all legacy/historic monitoring locations.
	Characterizing Clark County sites as opportunistic - Clark County sites are probably better characterized as some combination of representative and model.	Clark County's combined LTI and SNAP programs make up a complete census of all subwatersheds within the county. It would be easiest and valid to call it a census (all 52 watersheds get monitored over 5 years). The LTI program samples 10 of those every year.
	Consider strata of urban, rural and forest as a stormwater quality strata.	Technical sub-group recommended lumping urban, suburban, and rural as one group and forest as a separate group for determining with metrics to measure. However, is classification was not seen as important for driving site allocation
	NPDES permit vs. non-permit should be retained. Retains the ability to compare rural county under permit to rural county not under permit.	No action, already included
	Subwatershed WQ target population fits well with LCFRB Salmon Recovery plan scale and county programs.	Noted.
	Pseudo-Probability design is a good approach for integrating non-probability sites into regional analysis to improve power.	Noted.
	Census sampling is also included in the county monitoring. While not part of the initial submittal to PNAMP used for this project, Clark County is conducting a 5-year census to gather water quality data at each subwatershed (42 above LISP) in subwatersheds containing county roads. Clark County believes the census monitoring project for wadeable streams is an important aspect of its program for the next five years.	52 sampling locations are included. 10 are coded as LTI. 42 are coded as SNAP

	5-year temporal scale is a good time step for Clark County. The current five-year program began in Water Year 2012 and will end in 2016. Works well with Clark County scheme for census and periodic reports at five year intervals for updating stream health reports.	Noted.
	Use Alt. 1 as default alternative. This is the current level of effort by monitoring agencies.	Noted.
	Fecal Coliform metric frequency should default to monthly. Samples taken with other routine grabs. Poor cost/benefit for bimonthly sampling.	Updated.
	Water Temperature frequency-drop bi-monthly and add monthly, and continuous during summer months (May-October). Meter readings collected with monthly grab samples. Continuous temperature is required to assess compliance with state standards.	Updated.
	Total Solids in water collected every month, not bimonthly. Part of routine monthly grab samples of current programs. Poor cost/benefit for bimonthly sampling.	Updated.
	Copper and Zinc-use dissolved. Provides status information for salmon use.	Updated.
	Copper and Zinc-collect for one year (every five years) at ongoing monthly grab sites. Provides status information but not likely to provide trend data,	Technical sub-group recommended lumping urban, suburban, and rural as one group and forest as a separate group for determining with metrics to measure. However, is classification was not seen as important for driving site allocation
	PAH sample frequency-make the sample frequency no less than five years at sites monitored every year. This data will probably not be useful as trend information but as a status indicator.	No action- already included.

Jeff Fisher NOAA	Consider applying stratified random approach, which would allow focus on habitat areas where changes could occur, a random strategy includes habitat areas where change is not expected to occur (e.g., bedrock lined reaches with steeper gradient), not the most effective use of limited funds.	Stratified random sample is the recommendation.
	Habitat elements to be monitored are appropriate but habitat types (e.g. pool, riffle, glide) should be identified, habitat analysis focusing on summer flows is appropriate, monitoring of flow should occur on same date within reaches monitored and recent precipitation information should be provided.	Included in “density of habitat type” metric.
	Measuring water quality near tributary confluence is valuable for monitoring mass loading but it may not identify source attribution, dilution effect may result in 'non-detects' from analytical lab, need to account for current requirements so this effort is additive not redundant.	Source attribution is an important issue, however, it will not be addressed under this status and trends program. That issue is more related to causal factors, which is a more challenging question to address then the status and trend questions. During the stormwater technical subgroup meeting, the expert water quality technical group did not feel it was necessary to understand where the pollutants came from. They felt it was only necessary to characterize whether they are detectable at the outlet of watersheds. A monitoring program can be multi-staged; the “response’ reach being the lower drainage site mentioned in the comment. Additional sites can be placed upstream for source-tracing, but targeted site selection needs to account for existing monitoring effort and combine the two to ensure no redundancy. This sort of design is beyond the scope of the current project, but could be explored through a separate process.

	Provided comments on several metrics: a) fecal coliform is not really a bad actor for salmon; b) when collecting turbidity should collect TSS; c) For metals monitoring sediment samples is okay for some (e.g. mercury, arsenic); however, divalent cations of copper and zinc assert biological effects through waterborne processes so when these are most concentrated in water column (e.g. after first flush fall rains) would be useful, consider ranking priority of a suite of analytics based on budget availability; d) agree with sediment sampling, should limit sites tested to ones where expect to convey industrial pollutants; e) for pesticides and herbicides need to flesh out what the list of constituents to monitor would be, fewer concerns with herbicides than pesticides, cost can be an issue with these constituents, non-reversible cholinesteraise inhibitors should be top of priority list; and f) very good to have endocrine disruptors on the list, primary source of these constituents is WWTP rather than stormwater so monitoring for constituents (e.g., beta estradiol, etc., need to define list) should focus sampling on areas downstream of WWTP rather than on a broad scale.	a) Fecal Coliform does not have a relationship with salmon health, but is associated indirectly with stressors that cause habitat degradation (e.g., cattle grazing, etc.). b) TSS is a signature of stream bank erosion and stormwater runoff. c) Divalent cations like Cu and Zn can be collected in both sediments and surface water; the sediments accumulation will influence BMIs and the water column will affect fish. d) Greatest likelihood for detecting toxics in sediments is in urbanized areas that include commercial/industrial areas. e) and f) Pesticides and endocrine disruptors are offered by labs in “analysis packages”; Set of analytes based on toxics normally encountered in the Lower Columbia area has been recommended (Appendix G).
Kathi Irvine USGS	A glossary of terminology might be helpful. Defining a reach, target population, GRTS, panel designs etc	There is an Acronyms and Definitions section at the beginning of the report.
	Figures 1 and 2 I wasn't sure how these programs overlay with the existing monitoring in the region. Are these spatial gaps in current efforts [the stormwater permittee areas]?	Figures 1 and 2 illustrate jurisdictional boundaries of the stormwater permittees, strata boundaries, and boundaries of the project area. Existing monitoring efforts within the region were illustrated in figures included in Tech Report 1.
	Is the intended suggestions for initiating a new monitoring program? I presume so based on p. 17 descriptions.	Yes, this would be a new habitat status and trends monitoring program, if implemented.

	The suggested approach for integrating water and habitat monitoring seems reasonable. I wondered about the field logistics and what effort would be feasible under the suggested approach.	Details regarding field logistics and level of effort will be evaluated during the implementation phase of the project.
	In describing the design it may be useful to use standard sampling terminology of primary sampling units/secondary sampling units. The description on page 17 was slightly unclear due to the apparent nonrandom selection of the location for water quality observation upstream from the outlet? I would imagine where a probe is placed could be very important...or whether multiple measurements would be taken along a transect with grab samples or something? These are response design details.	The proposed sampling units are not hierarchical or tiered. The report describes sampling units for two distinct monitoring programs (water quality and quantity versus stream habitat). We are using the PNAMP glossary of terms located at: https://www.monitoringresources.org/Resources/Glossary/Index The location of water quality/quantity monitoring upstream of the outlet of a watershed was determined through a technical subgroup meeting of stormwater experts. The subgroup agreed that monitoring at 1,500-3,500 ft upstream from the outlet of the subwatersheds was appropriate for the type of monitoring being conducted.
	There are several statistical suggestions that are interesting ideas, but without more information or citations the details are obtuse. Specifically, creating pseudo-weights for the non-probabilistic sites. At the extreme some would say the weight=1 to represent only itself; however, how to determine its representativeness? Would this be based on matching with other environmental characteristics similar to a non-response adjustment [propensity] scores]?	Tech Report 1 included a write up by Don Stevens that provided additional details regarding the statistical approach of the project. Some additional references have been added to references section of this document, including: Brus DJ, de Gruijter JJ (2003) A method to combine non-probability sample data with probability sample data in estimating spatial means of environmental variables. Environmental Monitoring and Assessment 83(3): 303–317. Overton J, Young T, Overton WS (1993) Using 'found' data to augment a probability sample: procedure and case study. Environmental Monitoring and Assessment 26:65–83.

Appendix G – Recommended List of Pesticides and Endocrine Disruptors to be Tested under Water Quantity and Quality Monitoring

The following are lists for Pesticides and Endocrine Disruptors that would be most applicable for sampling under the water Qa/Qx design for the Lower Columbia Habitat Status and Trends Monitoring Program. The groups of chemicals or compounds shown represent those most commonly detected, especially in salmon-bearing streams throughout Washington State.

PESTICIDES

Organophosphate Pesticides

- Insecticides: chlorpyrifos, DDVP, diazinon, ethoprop, malathion
- Herbicide: metolachlor

Chlorinated Pesticides

- Insecticides: endosulfan
- Endosulfan degradate: endosulfan sulfate
- Legacy pesticide: DDT and its degradates

Carbamates

- bifenthrin,
- methiocarb
- methomyl

Source for above list: Washington Department of Ecology. 2013. Surface Water Monitoring Program for Pesticides in Salmon-Bearing Streams, 2009-2011 Triennial Report. Ecology Publication No. 13-03-002. Olympia, WA. 305p.

ENDOCRINE DISRUPTORS

Polychlorinated dibenzo-dioxins
Polychlorinated dibenzo-furans
Polycyclic Aromatic Hydrocarbons (PAHs)
Phenol derivatives
Organochlorine Pesticides
DDT and derivatives
Atrizine
Vinclozolin (fungicide)
Phytoestrogens
Mycoestrogens

Source for above list: IEH. 2005. Chemicals Purported to be Endocrine Disruptors: A Compilation of Published Lists (Web Report W20), Leicester, UK, MRC Institute for Environment and Health. 91p.