Lower Columbia Habitat Status and Trends Project

Technical Report 3

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Lower Columbia Fish Recovery Board

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Acronyms and Definitions

AREMP	Aquatic and Riparian Effectiveness Monitoring Plan
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
Lower Columbia Region	Generally refers to NOAA ESU areas within Oregon and/or Washington Management Units
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
PIBO	PACFISH/INFISH Biological Effectiveness Program
PNAMP	Pacific Northwest Aquatic Monitoring Partnership
RME	LCFRB Research, Monitoring, and Evaluation Program for the WA portion of the Lower Columbia ESU

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 (project) was initiated to develop recommendations for a coordinated habitat and water quality/quantity (water Qa/Qx) status and trends monitoring strategy in the Lower Columbia Region. The project was intended to inform future Municipal Stormwater Permits by producing a monitoring design that addresses multi-scale questions about status and trends of physical, chemical and biological attributes, including those influenced by stormwater. The habitat and water Qa/Qx monitoring design produced by the project will complement fish status and trend monitoring programs and result in a large-scale status and trends monitoring program that is essential to assessing 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 built upon the LCFRB Research, Monitoring, and Evaluation (RME) Program for Lower Columbia Salmon and Steelhead. The Lower Columbia RME Program 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 supports this progress by recommending use of a spatially balanced design that is coordinated among partners in the Lower Columbia Region. The RME program was designed to integrate with other state and regional planning efforts and research, monitoring, and evaluation efforts for salmon and steelhead recovery and watershed restoration.

The project also built 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 Figure 1 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 also incorporates 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).

It is expected that the project will produce a habitat status and trends monitoring design for the Lower Columbia Region that uses scientific and statistical rigor to efficiently address priority monitoring questions related to stormwater runoff, surface water quality, salmon recovery, and watershed health.

Results from implementation of this monitoring design will inform adaptive management of municipal stormwater permit requirements.

Table 1. Lower Columbia Region Habitat and Water Quality 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)			
Bureau of Land Management (BLM)			
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)			
Participating SW Washington stormwater permittees[1] (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

[1] Grant is to develop initial monitoring design strategy focused on Washington Stormwater Permittees due to upcoming permitting cycle.

This project involved the development of recommendations for a region-wide habitat and water quality status and trends monitoring design in three stages as follows:

- Stage 1 – identified potential status and trends alternative monitoring scenarios;
- Stage 2 - completed a trade-off analysis between alternative monitoring scenarios; and
- Stage 3 - developed final recommendations for a coordinated monitoring strategy.

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 those questions. Sets of management questions that focused on the same set of metrics were organized into Management Question Groups. These groups formed the basis for analyzing gaps where monitoring data is needed to answer management questions. Input on these management questions, associated metrics, and gap analysis was 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 2013a).

Stage 2 included a trade-off analysis to evaluate the alternative monitoring scenarios. This analysis was conducted to investigate ways in which the monitoring strategy could be scaled up or down to address priority monitoring questions and the relative costs and benefits associated with varying the number of metrics sampled. This trade-off analysis proceeded based on the varying design options for one of the three 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 trade-off analysis. As part of this analysis, target 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 Generalized Random Tessellation Survey (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. Monitoring design options and participant interests were further explored in the April technical workshop where the many design options within each alternative monitoring scenario were vetted. Technical Report 2 included results from that workshop and other details regarding the methods and results from Stage 2 of the project (Tetra Tech 2013b).

During Stage 3, work continued toward developing final recommendations for the coordinated monitoring strategy. These recommendations included modifications based on feedback from the April workshop and a habitat technical subgroup meeting that was held on April 30, 2013 with primarily ISTM partners. Additional feedback was received during a meeting on April 29, 2013 with stormwater managers in the region. A brief overview of the project to date was provided and some feedback was offered, which was also incorporated during this stage of the project. Recommendations regarding habitat metrics and strata were incorporated into the draft final recommendations. The Lower Columbia Master Sample was completed during this phase of the project to include legacy sites from existing monitoring programs. The Lower Columbia Master Sample and the recommended methods for the program have been uploaded to MonitoringResources.org. The final technical workshop was held on May 22, 2013 and the results from that meeting are included in this report, which describes Stage 3 of the project.

Stage 3 tasks have been completed, as follows:

- Habitat Technical Subgroup – April 30, 2013
- Development of integrated Lower Columbia Master Sample – April/May 2013
- Uploading of Lower Columbia Master Sample and methods to MonitoringResources.org – May 2013

- Development of final monitoring recommendations – April/May 2013
- Draft Technical Report 3 – May 17, 2013
- May Workshop – May 22, 2013
- Final Technical Report 3 – June 24, 2013

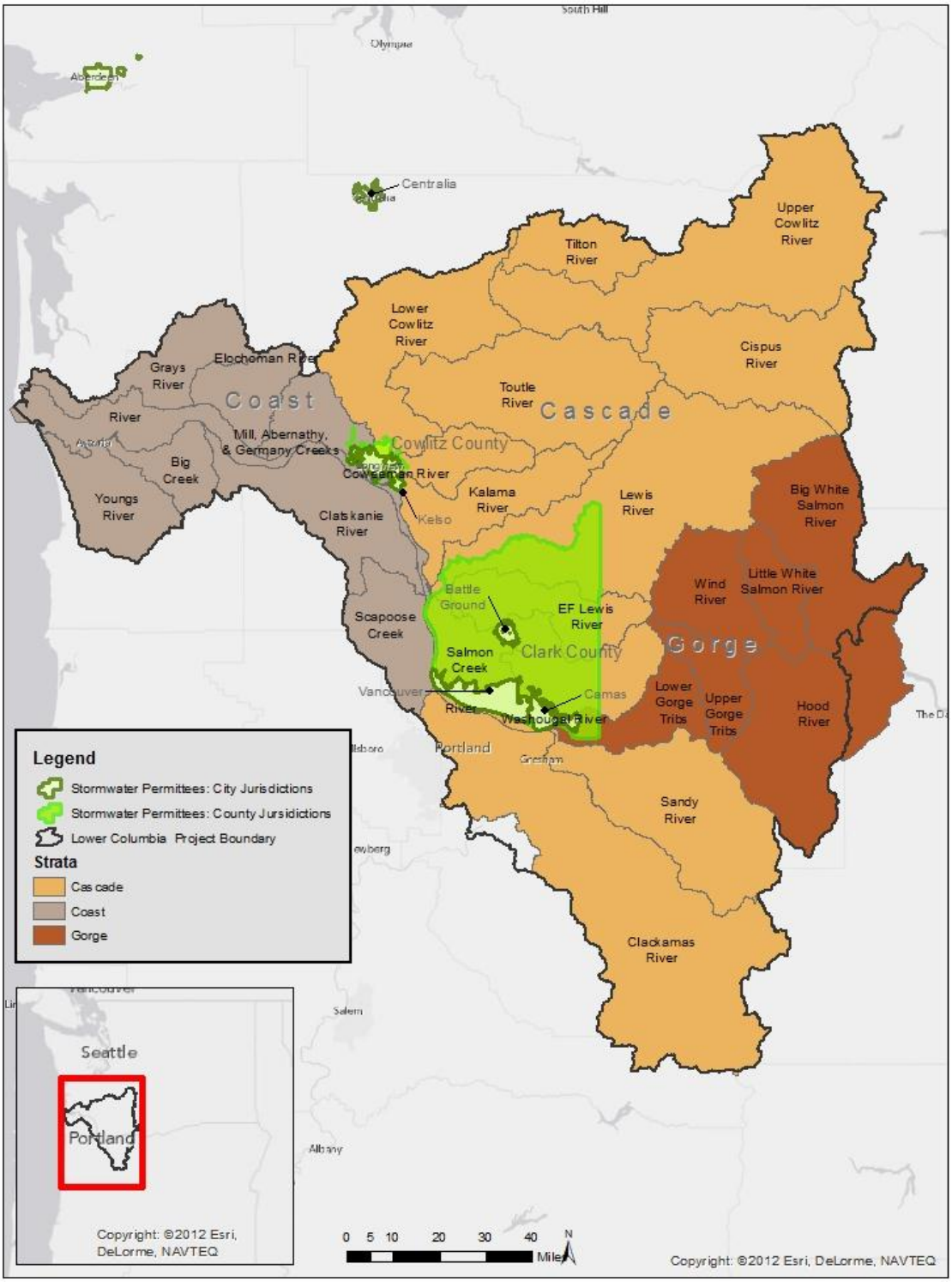


Figure 1. Lower Columbia Habitat Status and Trends Monitoring Project study area, strata, sub-basins, and jurisdictions of participating stormwater permittees

Regional Strategy for Research, Monitoring, and Evaluation

The LCFRB adopted a comprehensive RME Program that integrates the needs of salmon recovery and long-term watershed health (LCFRB 2010). The program outlines various monitoring types such as status and trends monitoring of salmon and steelhead and the habitat upon which they depend, and project and program implementation and effectiveness monitoring. Together, these monitoring programs will guide future policy decisions and adaptive management needs. In developing a regional monitoring program, the LCFRB recognized that an essential part of habitat monitoring includes water quantity and quality elements. At the same time, the status and trends monitoring needs of Southwest Washington stormwater permittees began to emerge as potential requirements associated with the upcoming permit cycle. As a result, the LCFRB undertook the development of recommendations for a regionally coordinated habitat and water Qa/Qx status and trends monitoring strategy that would integrate the ongoing habitat status and trends monitoring of the PNAMP ISTM partners with the monitoring needs of the regional stormwater permittees.

Status monitoring assesses conditions at a particular point in time. This data 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 changes in conditions in the long-term by repeating site measurements over time. Status and trends monitoring should also:

- evaluate current programs, other available data and information gaps, and compliance requirements;
- assess the status and trends of ESA-listed salmonid populations (LCFRB 2010a);
- identify needs and priorities consistent with the LCFRB RME Plan (LCFRB 2010a); and
- research poorly understood ecological associations and postulated cause and effect relationships.

Additionally, habitat and water Qa/Qx status and trends monitoring should:

- complement other monitoring programs that identify water Qa/Qx or habitat impairments;
- consider the effectiveness of best management practices and other current approaches;
- assess status and trends of habitat and water Qa/Qx; and
- address limiting factors not monitored by other programs.

Together with existing programs, a habitat and water Qa/Qx status and trends monitoring strategy would comprise the core of an integrated status and trends monitoring program 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 needs to continue at a minimum, and optimally should be expanded significantly. Under the guidance of the state's monitoring forum, monitoring requirements and high-level indicators have been adopted (Governor's Monitoring

Forum 2007). Stream flow monitoring is included as part of the state's framework. Furthermore, the Washington Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan (LCFRB 2010b) sets forth goals for flow levels during high and low flow periods that are intended to benefit juvenile and adult salmonid habitat. Increasing flow monitoring will be challenging under the current fiscal climate. Adequate flow data will be difficult to collect in the face of anticipated gauge reductions (from 72 to 53). As this project moves towards implementation, additional emphasis will need to be placed on flow monitoring, the metrics used to measure flow, and its importance to salmon recovery and stormwater assessments.

Where continuous, long-term gauges are available, calculation of Indicators of Hydrologic Alteration should be implemented using software developed by The Nature Conservancy. With the expected reduction in the number of gauge stations, 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, the relationship in flow between the gauge sites and other sites randomly selected for the program would have to be defined and sites would need to be included in a pseudo-probability design strategy. This would allow the data collected under both monitoring initiatives to be compatible.

Remote Sensing Monitoring Program

Several of the habitat metrics that were identified as high priority metrics for addressing monitoring questions could best be evaluated using remote sensing data analysis within a geographic information system (GIS). These metrics include vegetation cover, land use, disturbance presence, wetland availability, floodplain connectivity, and impervious surfaces. Ideally, these factors would be monitored using remote sensing technologies and GIS analysis at the watershed scale. 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 Aquatic and Riparian Effectiveness Monitoring Plan (AREMP) and PACFISH/INFISH Biological Effectiveness Program (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 typically evaluated for correlations. Sampling designs used in the habitat and water Qa/Qx status and trends monitoring project could be linked to adult salmon monitoring programs, such as efforts recently implemented by the Washington Department of Fish and Wildlife (WDFW), to collect the information in the most cost-effective manner possible. Extrapolating water quality 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 the recovery plan EDT life cycle model.

The remainder of this document includes recommendations for a habitat and water Qa/Qx status and trends monitoring strategy that integrates the monitoring priorities and existing programs of ISTM partners and municipal stormwater permittees in the Lower Columbia Region. This strategy consists of two complementary designs: one for water Qa/Qx monitoring, and one for habitat monitoring. These designs are integrated into a single monitoring strategy. The process of integrating designs is more fully described in Technical Report 2 (Tetra Tech 2013b).

Management Questions and Objectives Addressed by the Habitat Status and Trends Monitoring Project

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 link expected trends for salmon habitat and water Qa/Qx to other restoration and regulatory actions in the Lower Columbia Region. This regional habitat status and trends monitoring strategy will generate the information necessary to support the evaluation of progress towards achieving stated objectives. Additional, data from fish habitat status and trends monitoring efforts will be necessary to fully achieve some of the stated objectives. The management questions and associated objectives are presented below.

Habitat

Question: What are the status and trends of in-stream biological health 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 metrics (abundance, productivity, spatial structure, and diversity) show an improving trend in concert with increased and improved restoration projects, habitat stewardship efforts and implemented land use regulations.

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.

Objective In-stream water quality and quantity metrics show improving trends in concert with implementation of water quality 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 is 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: Impacts 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.

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-level conditions[1, 2]. A remote sensing program is briefly discussed above, but will need to be fully developed as this project moves forward towards implementation. The monitoring strategy described in the remainder of this document focuses on addressing management questions and objectives concerning habitat and water Qa/Qx.

Methods

Stage 3 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 result of these analyses is a

[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."

recommendation for a monitoring strategy, which is described in the Results section of this report. Additionally, information and feedback gathered during the May 2013 workshop has been integrated into the analyses and the results presented in this report.

Monitoring Strategy Design

Three alternative monitoring scenarios were developed as part of Stage 1 of this project and were presented to monitoring entities, stormwater permittees, and other participants during technical workshops (these scenarios are provided as Appendix E of the Technical Report 1 (Tetra Tech 2013a)). Based in part on input from project participants, revised scenarios were developed and evaluated during Stage 2 of this project (revised scenarios provided in Technical Report 2 (Tetra Tech 2013b)). At these workshops, a consensus was reached that a monitoring strategy should be founded on a design that allowed existing, largely opportunistically-selected sites to be integrated with new and existing sites chosen probabilistically. The methods used to integrate sites into a single master sample are described in the following section and additional information is provided in the Results section below. A consensus was also reached that subwatersheds would be an appropriate target population for water Qa/Qx monitoring, while wadeable and non-wadeable stream reaches would be appropriate targets for habitat monitoring. During Stage 3 of the project, the appropriate metrics to be sampled at water Qa/Qx sites and habitat sites were further refined. Sampling strata were also revised based on input from project partners and discussions with project participants.

For this monitoring project it was determined that 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. As a result, unbiased conclusions about the Southwest Washington municipal stormwater permit jurisdictions and 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 Fisheries to assess the threat to salmonids from habitat loss (Crawford and Rumsey 2011).

Integrated Master Sample

An Integrated Master Sample was developed for the Lower Columbia Region by integrating legacy sampling locations during the creation of a new Lower Columbia Master Sample. The integration was performed by running a computer algorithm - the GRTS Linear Sample Function, developed by Don Stevens. The algorithm builds a new master sample for a stream network by placing sampling points along the stream in a random order. When incorporating legacy sampling locations, the algorithm uses the legacy point and then excludes the stream segment 250 meters upstream and downstream of the legacy point from the set of segments where the new sampling points are placed (e.g., the probability of inclusion for segments with legacy sampling locations is set to zero). Upon completion, a shapefile is created with points located along the stream network including both legacy locations and newly defined sampling locations.

Historic sampling locations over the past 10 years were compiled from known monitoring projects operating in the Lower Columbia Region. The legacy points were migrated and snapped to the High

Resolution National Hydrography Dataset. Sampling locations where habitat monitoring had been conducted (by ODFW, WaDOE, SRFB, and USFS) were included and saved as a shapefile. The length of the stream network was calculated and then divided by 500 meters to determine the number of points in the new Integrated Lower Columbia Master Sample. The GRTS Linear Sample Function was parameterized to generate 141,653 sampling locations at an average spacing of 500 meters.

Upon successful completion of the Integrated Lower Columbia Master Sample, the sampling locations were passed through an ESRI ArcGIS model to populate the following attributes on each point: Strahler order group, inside NPDES permit area, name of jurisdiction, city name, inside urban growth area, recovery plan subbasin, recovery plan strata, Omernik ecoregion level 4, water quality strata, and habitat strata. Evolutionarily Significant Units (ESUs) for Chinook, coho, chum and steelhead were included (NMFS 2012), as well as Lower Columbia population delineations for spring-run Chinook, early-run (brights) Chinook, fall-run Chinook, chum, coho, summer-run steelhead, and winter-run steelhead, which can be viewed at: http://www.nwfsc.noaa.gov. Once the attributes were updated and clean, the Integrated Lower Columbia Master Sample was loaded to the Monitoring Resources – Site Manager Tool available on online at https://www.monitoringresources.org.

Recommended Sampling Methods

During Stage 3, recommendations for sampling methods were finalized through review of available literature and currently implemented protocols and methods. Monitoring Methods is an online tool for documenting details about monitoring protocols and methods. Sampling methods and protocols that could be used to implement an Integrated Status and Trend Monitoring strategy in the Lower Columbia are represented in Monitoring Methods as a single protocol with multiple methods and metrics. The protocol captures the background, rational, objective, and study design described in this report and presents the protocol as a searchable, online reference that can be further advanced during the implementation phase of the project. All methods and metrics recommended in this report were added to the protocol, but can be refined as the project develops. The recommended methods were drawn from existing protocols (as described in the "Data Collection Methods" section below) and from methods associated with the Environmental Assessment Program (EAP) at Washington Ecology (https://www.monitoringresources.org). Methods associated with EAP were entered into Monitoring Methods from PDF documents as a result of the current project. The Draft Integrated Status and Trends Monitoring in Lower Columbia Region protocol, when finalized, can be viewed by following this link: https://www.monitoringmethods.org.

Results

Final Monitoring Strategy Design Recommendations

The final monitoring strategy design recommendations described below are the result of work that has been conducted during Stages 1 and 2 of this project (described in Technical Reports 1 and 2 (Tetra Tech 2013a and b). The recommendations are based largely on:

- the scenarios developed during earlier stages of this project;

- workshop-related comments;
- results of the water Qa/Qx and habitat technical subgroup meetings;
- 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).

A key expectation of this project was to also incorporate monitoring design information from the ongoing PNAMP ISTM Project. This was accomplished by developing a monitoring strategy for Southwest Washington that incorporated sites targeting the collection of either habitat or water Qa/Qx data to gain a regional perspective of the status and trends of habitat in the Lower Columbia Region. Details regarding the final monitoring strategy design are included in the following sections of this report.

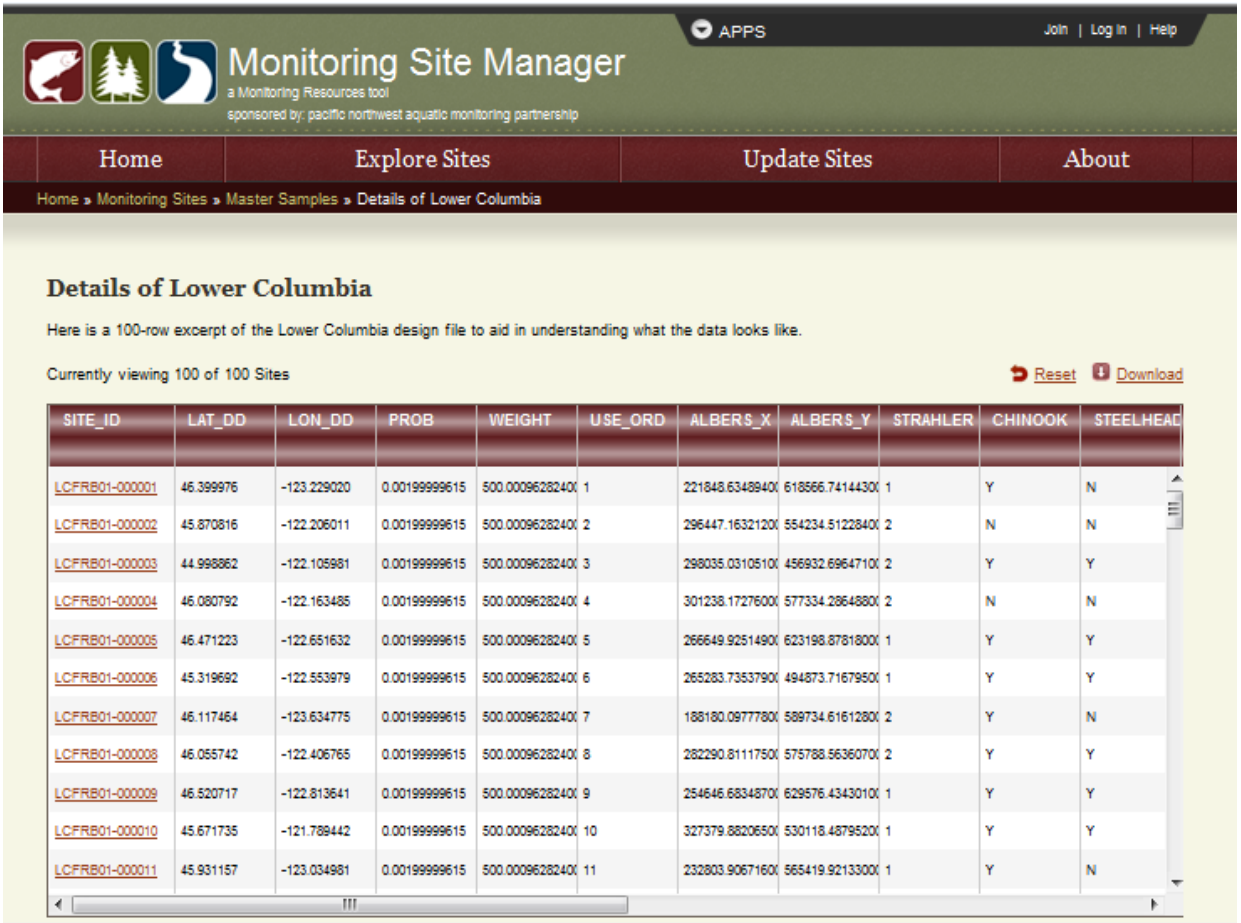
Spatial Design

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 probabilistic design, sites are randomly selected across the entire area of interest (see www.monitoringmethods.org for more information on spatial designs).

The recommended design for this monitoring strategy allows opportunistic sites to be integrated with probabilistic sites. 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).

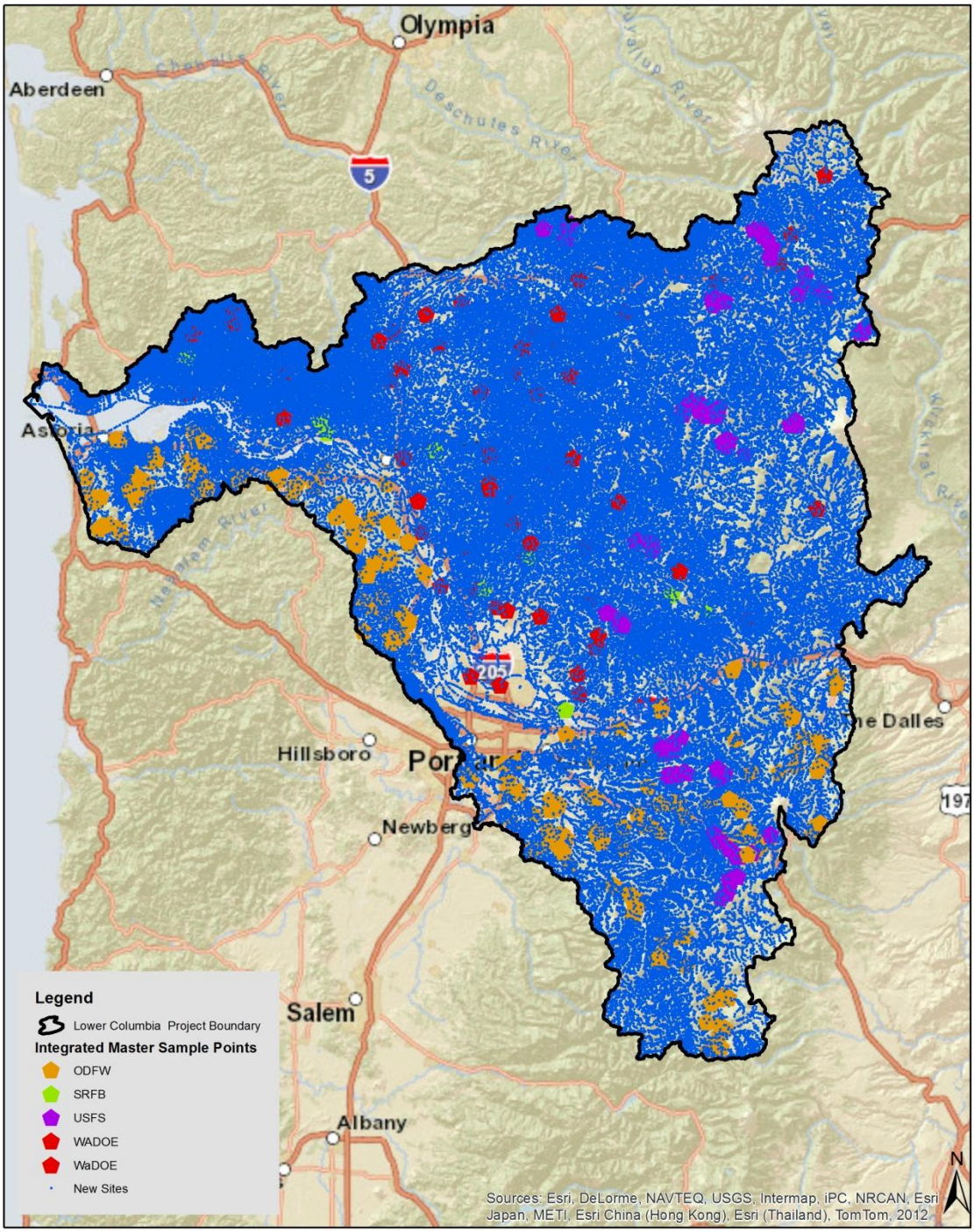
Integrated Master Sample

As described in the Methods section, an Integrated Lower Columbia Master Sample was created and loaded to the Monitoring Resources – Site Manager Tool. Figure 2 provides a screen shot of the Integrated Lower Columbia Master Sample on Monitoring Resources and Figure 3 is a map illustrating it.



SITE_ID	LAT_DD	LON_DD	PROB	WEIGHT	USE_ORD	ALBERS_X	ALBERS_Y	STRAHLER	CHINOOK	STEELHEAD
LCFRB01-000001	46.399976	-123.229020	0.00199999615	500.0009628240	1	221848.6348940	618566.7414430	1	Y	N
LCFRB01-000002	45.870816	-122.206011	0.00199999615	500.0009628240	2	296447.1632120	554234.5122840	2	N	N
LCFRB01-000003	44.998862	-122.105981	0.00199999615	500.0009628240	3	298035.0310510	456932.6964710	2	Y	Y
LCFRB01-000004	46.080792	-122.163485	0.00199999615	500.0009628240	4	301238.1727600	577334.2864880	2	N	N
LCFRB01-000005	46.471223	-122.651632	0.00199999615	500.0009628240	5	266649.9251490	623198.8781800	1	Y	Y
LCFRB01-000006	45.319692	-122.553979	0.00199999615	500.0009628240	6	265283.7353790	494873.7167950	1	Y	Y
LCFRB01-000007	46.117464	-123.634775	0.00199999615	500.0009628240	7	188180.0977780	589734.6161280	2	Y	N
LCFRB01-000008	46.055742	-122.406765	0.00199999615	500.0009628240	8	282290.8111750	575788.5636070	2	Y	Y
LCFRB01-000009	46.520717	-122.813641	0.00199999615	500.0009628240	9	254646.6834870	629576.4343010	1	Y	Y
LCFRB01-000010	45.671735	-121.789442	0.00199999615	500.0009628240	10	327379.8820650	530118.4879520	1	Y	Y
LCFRB01-000011	45.931157	-123.034981	0.00199999615	500.0009628240	11	232803.9067160	565419.9213300	1	Y	N

Figure 2. Screenshot of Monitoring Site Manager and Integrated Lower Columbia Master Sample



Integrated Master Sample for Lower Columbia

0 5 10 20 30 40 Miles

Figure 3. Map Illustrating the Integrated Lower Columbia Master Sample

Spatial Domain

Habitat and Water Qa/Qx monitoring sites will be distributed across the Lower Columbia Region.

Target Populations

Water Qa/Qx and habitat monitoring together make up the core of this status and trend monitoring strategy for the Lower Columbia Region. The conceptual representations of their target populations are very different even though these two monitoring efforts ultimately target the same network of streams. Through consultation with water quality and habitat technical experts during the design process, two populations of interest and related spatial scales were identified for monitoring. Water Qa/Qx was decided to be best evaluated near the mouths of subwatersheds rather than in stream reaches because water at the subwatershed mouths comprises a composite of all the upstream waters. Sampling at these locations assumes that mouths represent the cumulative status of the upstream area. Consideration was given to an alternative sampling scheme in which water quality is monitored at randomly-chosen stream reaches within a subwatershed; however, it was determined that it would be a less effective option because reach sampling may not provide information on the correct target population (i.e. subwatershed mouth) and potentially unnecessary expense would be incurred by sampling more than one site per subwatershed.

In habitat monitoring, stream reaches have been identified as 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 subwatershed mouths, 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 populations, which are defined as follows:

- **Water quality/quantity target 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 feet upstream from the mouths of these subwatersheds. Sampling sites would be randomly selected from all subwatersheds in the region.

- **Habitat target 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.

[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.

All sampling sites included in the final sampling design will be accessible. During the selection process 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 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 populations presents many challenges; these challenges, and their resolutions, are discussed below.

Integrating Target Populations through Spatial Design

Integrating data from water Qa/Qx sites and habitat sites will be facilitated using a spatially coherent design. A two-phase site selection scheme will 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 4 below illustrates this concept. In the example shown in Figure 4, the two-phase site selection scheme was used to randomly select subwatersheds within the Kalama basin in the first phase; subwatershed water quality will be monitored near the subwatershed mouths (gold points). In the second phase of site selection, a sample of points on stream reaches is randomly selected within the subwatersheds, and habitat is monitored at those sites (green points). The important constraints on a two-phase site selection design are 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. In contrast, habitat metrics tend to be more temporally stable, so there is no need for multiple visits on an annual basis. Every selected subwatershed would be sampled for water Qa/Qx at the mouth, and would also be sampled for habitat at multiple points. This scheme will help ensure that each subwatershed in which water Qa/Qx is measured also has sufficient habitat sampling sites to provide meaningful averaging. The two-phase site selection design is compatible with other design structures, such as rotating panels, variable probability, and stratification.

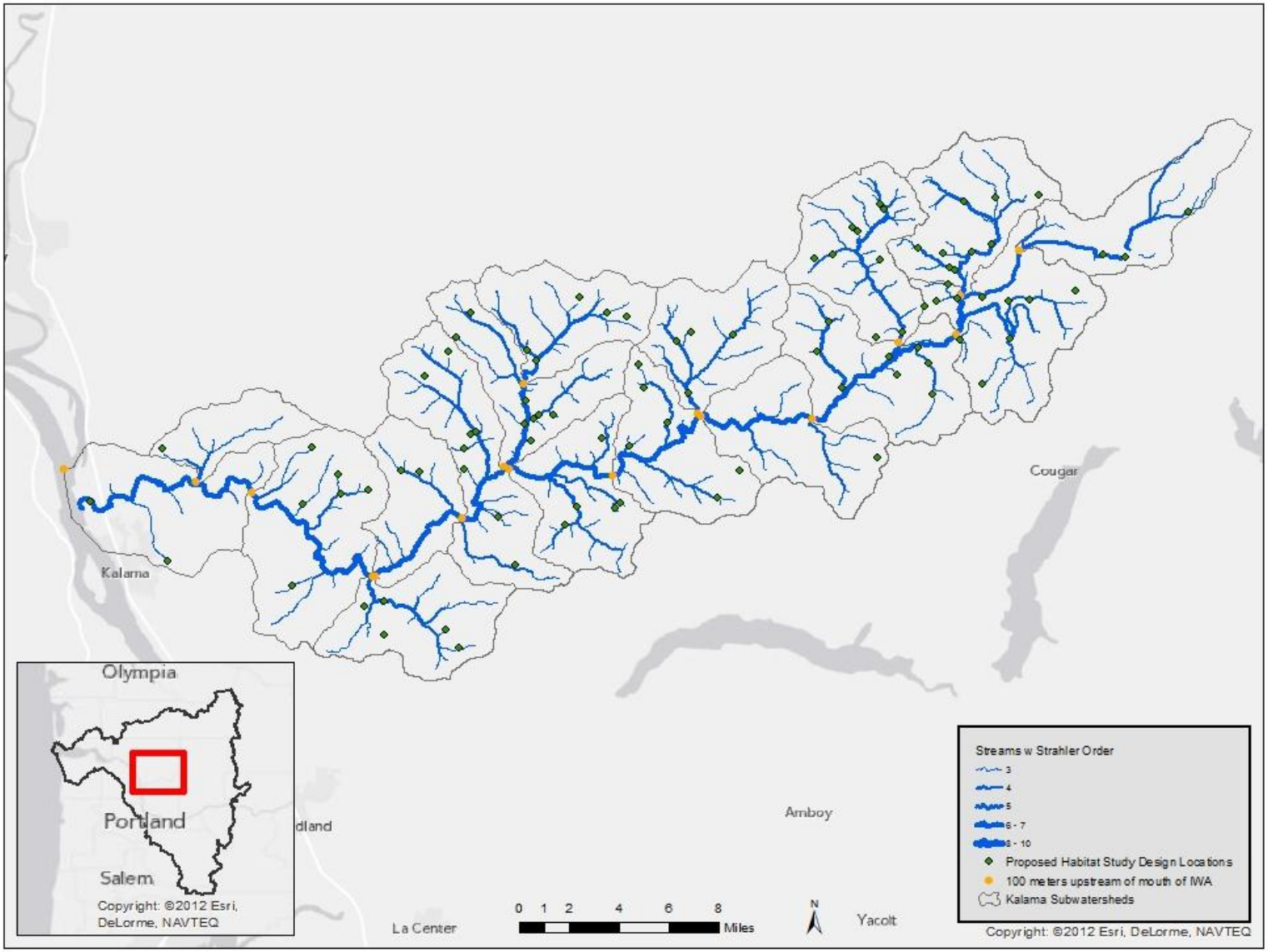


Figure 4. Example of integrating subwatershed and stream reach target populations through spatial design

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 be 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 because habitat sites are limited to randomly subwatersheds being sampled for water Qa/Qx.

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 in-stream environment at the subwatershed mouth, and allow better interpretation of water Qa/Qx data. At habitat sites, a few basic water quality metrics will be monitored to generate information on how water quality 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. A stratified or variable probability sample allows for unequal probability sampling where the proportion of samples in each strata does not match the observed distribution of these strata in the population. Unequal probability sampling allows larger sample size to be allocated to strata that have high variability or are of particular interest for monitoring or resource management. For example, salmon habitat monitoring programs will often allocate a greater sample size in higher order streams and decreased sample size in lower order stream relative to natural distribution of stream by Strahler order. This focuses sampling on streams where salmonids spawn and rear. Because water Qa/Qx monitoring and habitat monitoring each focus on different target populations, different strata are appropriate for each kind of monitoring.

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%)

While the NPDES stormwater permit areas and the incorporated city boundary/unincorporated Urban Growth Area (UGA) have significant spatial overlap, these two boundaries were retained as distinct strata for water Qa/Qx monitoring versus habitat monitoring. The rationale is based on the need to report on NPDES stormwater permit areas for water Qa/Qx monitoring and the need to report on incorporated city boundary/unincorporated UGA as a component of the Lower Columbia Region Recovery Plan. 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.

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, about 20% of the sites would be sampled each year in a 5-year rotation. 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 type 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 (see Relative Costs versus Benefits of Implementation section for additional discussion).

The five-year temporal scale is compatible with the annual reporting requirements of NPDES stormwater permittees (Ecology 2012a,b), as well as NMFS's requirement to review the status of listed salmon and steelhead every 5 years, and prepare reports to Congress every other year (NMFS 2012). 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. A proposed recovery plan was developed in 2012 that integrates five separate plans covering the Oregon Management Unit, Washington Management Unit, White Salmon Management Unit, Columbia River Estuary Module and Mainstem Columbia River Hydro Module (NMFS 2012). Each of these recovery plans implements status and trends reviews and reporting on different schedules that may need to be resolved as part of implementation across the region. The sampling time of year and monitoring frequency varies with metric and with site location, and is discussed in the Metrics section, below.

Metrics

Three alternative monitoring scenarios were evaluated during Stages 1 and 2 of this project. The scenarios varied in which metrics were collected and included the following:

- Standard scenario - high-priority metrics sampled
- Expanded scenario - medium- and high-priority metrics sampled
- Full Suite scenario - all metrics sampled

The scenarios were discussed in several forums, including technical workshops and subgroup meetings and in Technical Reports 1 and 2. Feedback received from project participants suggested that the Standard scenario was the preferred option. The metrics presented below are based on the Standard Scenario; however, the medium and low priority metrics can be found in Appendix A, which includes the complete metrics tables.

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.

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 of water Qa/Qx metrics in sites with forested land use/class is provided in Table 2.

Table 2. Water quality/quantity metrics sampled, monitoring population, and sampling frequency at forested land use/class and other sites

Metric Category	Metric Sub Category	Monitoring Frequency Required at Most Sites [1]	Monitoring Frequency in Forested Land Use/Land Class[1,2]	Field Collection Group
Bacteria	Fecal Coliform	Routine (e.g., monthly)	Once per year	Grab Sample
Conventional Parameters	Conductivity	Routine (e.g., monthly)	Once per year	Multi-parameter Probe

Metric Category	Metric Sub Category	Monitoring Frequency Required at Most Sites [1]	Monitoring Frequency in Forested Land Use/Land Class[1,2]	Field Collection Group
Conventional Parameters	Dissolved Oxygen	Routine (e.g., monthly)	Once per year	Multi-parameter Probe
Conventional Parameters	pH	Routine (e.g., monthly)	Once per year	Multi-parameter Probe
Conventional Parameters	Turbidity	Routine (e.g., monthly)	Once per year	Multi-parameter Probe
Conventional Parameters	Water Temperature (continuous)	Hourly	Hourly	Continuous Data Logger
Conventional Parameters	Water Temperature (instantaneous)	Monthly	Monthly	Multi-parameter Probe
Conventional Parameters	Chloride	Routine (e.g., monthly)	N/A	Grab Sample
In Sediments	Poly-aromatic hydrocarbons	Once per 5 years based on permit cycle; possibly 3-yr rotation based on hydro cycle	Once per 5 years based on permit cycle; possibly 3-yr rotation based on hydro cycle	Sediment Set
Metals - In Sediments	Total Copper	Once per 5 years based on permit cycle; possibly 3-yr rotation based on hydro cycle	Once per 5 years based on permit cycle; possibly 3-yr rotation based on hydro cycle	Sediment Set
Metals - In Sediments	Lead	Once per 5 years based on permit cycle; possibly 3-yr rotation based on hydro cycle	Once per 5 years based on permit cycle; possibly 3-yr rotation based on hydro cycle	Sediment Set
Metals - In Sediments	Total Zinc	Once per 5 years based on permit cycle; possibly 3-yr rotation based on hydro cycle	Once per 5 years based on permit cycle; possibly 3-yr rotation based on hydro cycle	Sediment Set
Nutrients	Total Nitrogen	Routine (e.g., monthly)	Once per year	Grab Sample
Nutrients	Total Phosphorus	Routine (e.g., monthly)	Routine (e.g., monthly)	Grab Sample
Nutrients	Ammonia	Routine (e.g., monthly)	Once per year	Grab Sample

Metric Category	Metric Sub Category	Monitoring Frequency Required at Most Sites [1]	Monitoring Frequency in Forested Land Use/Land Class[1,2]	Field Collection Group
Nutrients	Nitrate+ Nitrite-Nitrogen	Routine (e.g., monthly)	Once per year	Grab Sample
Hydrology/ Water Quantity	Instantaneous Flow	Routine (e.g., monthly)	Routine (e.g., monthly)	Handheld flow meter
Macro-invertebrates	Macro-invertebrate Index	Once per year	Once per year	Benthic Sample
Water Column	Suspended Solids	Routine (e.g., monthly)	Routine (e.g., monthly)	Grab Sample
Water Column	Total Solids	Routine (e.g., monthly)	Routine (e.g., monthly)	Grab Sample
Vegetation/ Plants	Periphyton	Once per year	Once per year	Substrate Sample

[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). 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.

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 for which 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, sampling frequency, and timing at water quality/quantity monitoring sites

Metric Subcategory	Monitoring frequency (all sites) [1]	Monitoring timing (all sites)	Field Collection Group
Bankfull width	Once per year/Once per 5 years	Jul-Oct	Site
Bankfull depth	Once per year/Once per 5 years	Jul-Oct	Site
Wetted width	Once per year/Once per 5 years	Jul-Oct	Site
Width to depth ratio	Once per year/Once per 5 years	Jul-Oct	Site
Gradient	Once per year/Once per 5 years	Jul-Oct	Site
Depth	Once per year/Once per 5 years	Jul-Oct	Site
Substrate	Once per year/Once per 5 years	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, sampling frequency, and timing for all sites. Water Qa/Qx metrics measured at habitat sites include those most useful for evaluating water Qa/Qx, and are shown in Table 5. All of the metrics are measured in stream reaches.

Table 4. Habitat metrics sampled, sampling frequency, and timing at all sites

Metric Subcategory	Monitoring frequency (all sites)[1]	Monitoring timing (all sites)	Field Collection Group
Composition: substrate/soil - size (sedimentation, substrate characterization)	Once per year	Jul-Oct	Channel Unit
Shade	Once per year	Jul-Oct	Site
Channel cross-section form (length/width/area)	Once per year	Jul-Oct	Site
Sinuosity	Once per year	Jul-Oct	Site
Gradient	Once per year	Jul-Oct	Site
Density/distribution instream wood	Once per year	Jul-Oct	Channel Unit
Erosion	Once per year	Jul-Oct	Site
Form/morphology (channel form)	Once per year	Jul-Oct	Site
Relative bed stability	Once per year	Jul-Oct	Site

Metric Subcategory	Monitoring frequency (all sites)[1]	Monitoring timing (all sites)	Field Collection Group
Density of habitat type	Once per year	Jul-Oct	Channel Unit
Flow (instantaneous)	Once per year	Jul-Oct	Site
Macroinvertebrates	Once per year	Jul-Oct	Benthic
Periphyton	Once per year	Jul-Oct	Substrate

[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.

Table 5. Water quality and quantity metrics sampled, sampling frequency, and timing at habitat monitoring sites

Metric Subcategory	Monitoring Frequency[1]	Monitoring Timing (all sites)	Field Collection Group
Temperature (instantaneous)	Once per year	Jul-Oct	Multi-parameter Probe
Alkalinity	Once per year	Jul-Oct	Field kit or grab sample
Conductivity	Once per year	Jul-Oct	Multi-parameter Probe
pH	Once per year	Jul-Oct	Multi-parameter Probe
Turbidity	Once per year	Jul-Oct	Multi-parameter Probe
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.

To refine the temporal scale for both habitat and water Qa/Qx metrics , 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 habitat and water Qa/Qx metric should also 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.

Data Collection Methods

To ensure data comparability across multiple monitoring entities and field crews, data collection methods should 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). The Quality Assurance Monitoring Plan (QAMP) (Ecology 2006) refers to the following publications for guidance on field methods:

- For wadeable streams (EMAP): Peck et al.(2003) (www)
- For non-wadeable rivers and streams (EMAP): Lazorchak et al. (2000) (www)
- For state fecal coliform methods: Ward et al. (2001) (www)
- For macroinvertebrate sampling: PNAMP (2006) (www)
- For aquatic vertebrate distribution in wadeable streams: AREMP (2006) (www)

Ecology continues to update these protocols on their website (www).

Additionally, each metric subcategory shown in Tables 2 through 5 can be found on MonitoringMethods.org and is associated with a list of protocols that reference the subcategory. 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. Data collection methods and protocols will be based on the aforementioned guidance documents and will be finalized during the implementation phase of this project. A brief discussion regarding the logistics associated with data collection methodologies and protocols is included in the "Data Capture Logistics" section of Technical Report 2 (Tetra Tech 2013b).

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 quality 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 the Quality Assurance Monitoring Plan.

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 Fisheries, 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 that will be conducted as this status and trends monitoring strategy moves towards implementation.

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 would facilitate data sharing across multiple monitoring entities and programs. Existing electronic data repositories (including Ecology's Environmental Information Management, Ecology's Status and Trends Riverine Ecology and Assessment Monitoring Database, BPA's CHaMP Monitoring, ODEQ's, and AREMP's systems) should be evaluated for their potential to be expanded to support data capture, quality assurance, metric generation and data sharing for the Lower Columbia Region.

A data crosswalk and processing tool is available in the River Bathymetry Toolkit, which allows comparison of data collected through direct measurements in the field (such as EMAP) with those that are derived from a total station survey (such as CHaMP). Although CHaMP does not currently monitor sites within the Lower Columbia Region, this tool would be particularly useful should the CHaMP program eventually cover sites in the Region, or if other programs utilize digital elevation models that are created using a total station. For instance, the SRFB Effectiveness Monitoring Program currently uses a topographic survey method for evaluating habitat at many of their floodplain enhancement sites. The RBT for EMap is available online at https://sites.google.com.

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, PNAMP, 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 managing entity by January 31st of the next year. A more complete assessment based on data from all monitoring sites in the 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.

Other Considerations

Relative Costs versus Benefits of Implementation

In Stage 2 of this project, three alternative monitoring scenarios were evaluated. Each monitoring scenario produced 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 Technical Report 2 (Tetra Tech 2013b) for more information). 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. Despite the information that could be gathered from collecting additional metrics, consensus was reached at the April workshop that the standard suite of metrics (see Tables 2 and 5) was most feasible under this program.

The expenditures necessary to implement this monitoring strategy are related to a number of start-up and recurring costs, which are expected to be similar regardless of the number of metrics collected.

These include costs for 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. Additional costs, which would increase as the number of metrics that are monitored increases, would primarily be associated with:

- paid staff time required to collect data for a larger number of metrics at each site;
- laboratory analyses costs;
- staff time necessary to manage and analyze more extensive data set; and
- paid staff time required to write more extensive annual reports.

The recommended standard suite of metrics will minimize the additional costs associated with implementing this program; however, if entities taking part in the program have additional funding or resources available, useful information could be gathered by collecting additional metrics (see Appendix A for complete lists of metrics). A relative cost analysis conducted during Stage 2 of the project compared laboratory analysis costs between the three suites of metrics (see Technical Report 2 (Tetra Tech 2013b). This evaluation showed that analysis costs for the standard suite of metrics would be approximately half (49 percent) what they would be for full suite, while the expanded suite would be approximately two thirds (66 percent) of the cost of full suite (Figure 5) (see Technical Report 2 for additional details (Tetra Tech 2013b)). Implementing the expanded suite would only increase laboratory analysis costs by approximately 17 percent over the cost of the standard suite (Figure 5). Therefore, while implementing monitoring of the full suite of metrics would require substantially more funds for laboratory analysis than the standard metrics, implementing the expanded set of metrics would only increase costs slightly, but would provide additional information to address management questions more extensively.

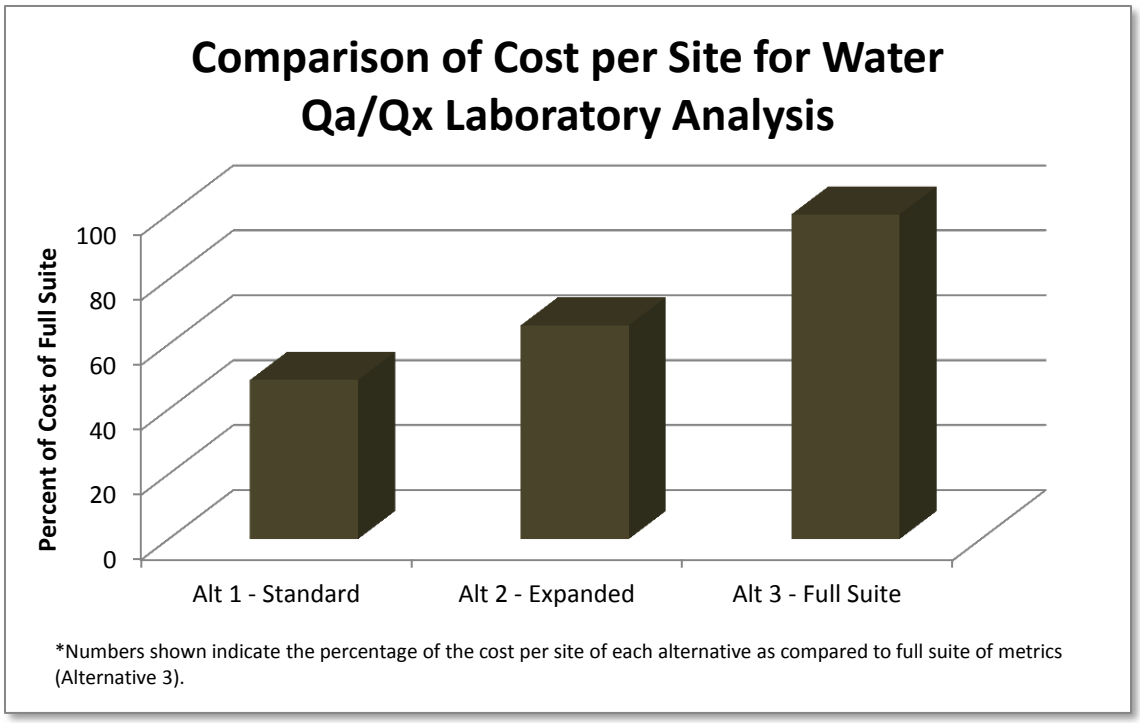


Figure 5. Comparison of cost per site for water Qa/Qx laboratory analysis.

In addition to the costs related to analysis, factors such as the scale of monitoring effort, including the number of sampling sites, the frequency at which each site is visited, and required level of precision for data collected will greatly influence costs. These factors will have a far larger impact on monitoring costs than the number of metrics monitored at each site; however, 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, it will be necessary to do so prior to implementation so that an appropriate level of funding can be secured for the program. The number of sampling sites drives the power to make inference about status, while sampling frequency drives the power to make inference about trends; and the level of precision impacts level of confidence in data collected. Cost considerations must balance the need for status information versus trend information and incorporate the required level of precision. As this project moves towards implementation, a power analysis could also be conducted to evaluate the number of samples needed to provide the level of precision desired for program metrics.

Next Steps

The final monitoring design recommendations described in this document provide a solid basis for implementing the Habitat Status and Trends Monitoring Strategy for the Lower Columbia Region. However, it will be important to address the following key questions prior to implementation to better understand what it will take to implement this strategy and fully assess feasibility.

1. Are the metrics being sampled adequate to answer management questions and achieve management objectives?

2. Have the correct strata been identified for this monitoring strategy?
3. Is the number of sampling site adequate to achieve necessary precision?
4. What are the most appropriate field data collection methodologies and protocols?
5. What are the logistics associated with implementing the recommended study design?
6. What will implementation of this strategy cost and what potential funding sources are available?

The following sections of this report provide additional information about near-term activities that will build upon the monitoring design strategy resulting from this project and help facilitate successful implementation of this program by addressing the key questions above.

Monitoring Design Strategy

This project produced a recommended monitoring strategy for the Lower Columbia Region that included a unique two phase study design that integrates habitat and water Qa/Qx monitoring efforts; however, additional tasks, analyses, and decisions are necessary to finalize this design, as described below.

- Water Quality and Quantity Monitoring Strategy
    - Develop GIS layer to represent sub-watersheds for Oregon at similar scale (3-12,000 acres) as the sub-watersheds presented in the Recovery Plan.
    - Develop GIS layer representing the mouths of the sub-watersheds for Oregon.
    - Generate an Integrated Master Sample for the population of points representing the mouths of sub-watershed (as defined in the Recovery Plan) for Oregon and Washington that incorporates legacy water Qa/Qx quantity monitoring in the Lower Columbia Region.
    - Determine sample size and allocation based on available funding, desired level of precision, and the variability observed in legacy water Qa/Qx monitoring data.
    - Evaluate strata to ensure they allow appropriate weighting for maninstem watersheds.
- Habitat Monitoring Strategy
    - Evaluate the relative power of both Strahler order groups (0-1, 2-3, and 4-11) and stream gradient groups (<1%, 1-3%, >3%) in partitioning the variability to stream habitat metrics using legacy habitat monitoring data from the Lower Columbia Region.
    - Evaluate utility of applying other strata to design (e.g ecoregion; wadeable vs. non-wadeable habitat; or urban, rural and forested subwatersheds for waterQa/Qx).
    - Determine sample size and allocation based on available funding, desired level of precision, and the variability observed in legacy habitat monitoring data.
    - Determine how best to address Landscape-Level Conditions, including necessary remote sensing analyses
- Analyses
    - Compare priority parameters of interest for fish vs. stormwater.

- Conduct stream flow gauging network analysis similar to that done in Puget Sound (https://sites.google.com/).
- Determine variance for each metric and length of sampling time required to detect a significant change in the metric.

Pilot Study

Conducting a small-scale pilot study could provide additional information needed to resolve many of the finer details related to implementation. Consequently, the LCFRB will commit to working with partners in the Lower Columbia Region to conduct a pilot study that implements this monitoring strategy in a limited number of basins in the Lower Columbia Region. The goal of this pilot study would be to "test drive" the design strategy and apply learn lessons at a small scale to assist in the development of an implementation strategy at the regional scale. Results of the pilot study would provide information regarding the following items:

- number of habitat and water Qa/Qx monitoring sites;
- process for selection of site locations;
- sampling schedule;
- sampling methodology and protocols;
- staffing levels and equipment needs;
- data management procedures;
- precision of data collected; and
- cost of field collection and data management activities.

Data collected during this pilot study would be analyzed to evaluate the precision and value of data collected under the current recommended strategy. Quantifiable benchmarks or goals against which water Qa/Qx status and trends can be measured will be identified and the pilot study will be used to determine if the recommended methods are adequate to collect data at the level of precision needed to evaluate those goals.

The pilot study will be conducted with the vision of future implementation of this monitoring strategy, especially for stormwater permittees. Implementation of this type of monitoring could occur as early as 2018 for stormwater permittees in SW Washington. The pilot study should inform the future structure of stormwater monitoring for SW Washington permittees and help to clarify logistics regarding implementation of this monitoring strategy. Results of this pilot study should ultimately lead to the development of a Quality Assurance Project Plan (QAPP) for the Lower Columbia Region that can be implemented as early as 2018.

Enhancing Regional Partnerships

The successful implementation of the program design will require ongoing communication and coordination between the LCFRB, PNAMP, Department of Ecology, stormwater permittees, ISTM partners and other project stakeholders throughout the Lower Columbia Region. Outreach efforts will be initiated through the pilot study with the goal of facilitating discussions to increase region-wide

understanding and support for the monitoring design developed by this project. Outreach efforts will include distribution of information regarding the results of this project and the proposed pilot study. This outreach effort should also include an information exchange between the Lower Columbia and Puget Sound Regions to benefit monitoring efforts occurring in both regions.

Implementation

Implementation of the monitoring design strategy will require additional information and decisions regarding various aspects of this strategy. A key to successful implementation will be establishing an environment where participants can discuss and resolve the finer aspects related to data collection methods and logistics, data evaluation, relative costs, data management, reporting of results and other parts of the strategy. A pilot study would allow field data to be collected and the strategy to be tested, which would inform many of the necessary decisions. The pilot study would also provide the catalyst for beginning to examine how a habitat and water Qa/Qx program would be structured for implementation in the Lower Columbia Region.

Costs related to conducting monitoring and potential funding alternatives will be important issues to be addressed as this project moves towards implementation. Relative cost information was provided under Stage 2 of this project, but a detailed cost analysis would be required to determine the level of funding needed to implement this program for various entities. That analysis will depend upon the number of sites selected for the program, implementation logistics, funding resources available, and many other details that have not yet been determined. The cost analysis will need to incorporate data management and analysis needs such as: 1) where would the data be stored, 2) who would be responsible for maintaining databases, 3) who would conduct data analyses, 4) how would data management and analysis be funded, and 5)how would monitoring results and data analyses be disseminated.

Ultimately, developing a framework through which this monitoring strategy will be implemented is a key to successful implementation of a monitoring program in the Lower Columbia Region. Development of this framework will need to include a process through which all partners can participate in the development of an implementation plan for the Lower Columbia Region. Throughout this process the goal should be to include all partners in the Lower Columbia Region, which includes portions of Washington and Oregon; however, SW Washington stormwater permittees may need to implement monitoring efforts as early as 2018, so implementation may need to occur initially in SW Washington only. This would allow the testing of this strategy on a larger scale before expanding to the entire Lower Columbia Region

Summary

Various types of monitoring are currently being conducted across the Lower Columbia Region. There are multiple large-scale status and trends programs in place that focus on evaluating salmon habitat conditions and assessing whether current salmon recovery efforts are making progress. Phase I stormwater permittees currently conduct receiving water monitoring and permittees of the smaller municipalities (Phase II) may begin monitoring water quality and quantity, benthos, habitat, and

sediment chemistry as early as 2018. Although monitoring efforts are underway, there is a need for regional coordination to implement a region-wide monitoring strategy that will improve data sharing and provide a more broad-scale understanding of the status and trends of habitat across the region. Furthermore, this monitoring strategy will need to collect the information necessary to identify habitat and water Qa/QX conditions that are limiting achievement of recovery goals. The Lower Columbia Habitat Status and Trends Project was initiated to develop recommendations for a coordinated habitat and water Qa/Qx status and trends monitoring strategy for the Lower Columbia Region that fills the aforementioned needs and builds upon ongoing work in the region. These final recommendations for an integrated monitoring strategy design build upon ongoing work within the region and provide a baseline upon which a monitoring strategy for the Lower Columbia Region can be crafted. Prior to implementation, additional work will be required to field test the design, apply lessons learned through that process, and work through process-related specifics. The results of this project have provided the basis for initiating the implementation process.

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Appendix A – Metrics Tables

Water Quality/Quantity Metrics

Table A-1. Water quality/quantity monitoring metrics sampled, monitoring frequency, 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 Frequency in Forested Land Use/Land Class[1,2]	Field Collection Group
All	Bacteria	Fecal Coliform	Routine (e.g., monthly)	Once per year	Grab Sample
All	Conventional Parameters	Conductivity	Routine (e.g., monthly)	Once per year	Multi-parameter Probe
All	Conventional Parameters	Dissolved Oxygen	Routine (e.g., monthly)	Once per year	Multi-parameter Probe
All	Conventional Parameters	pH	Routine (e.g., monthly)	Once per year	Multi-parameter Probe
All	Conventional Parameters	Turbidity	Routine (e.g., monthly)	Once per year	Multi-parameter Probe
All	Conventional Parameters	Water Temperature (continuous)	Hourly	Hourly	Continuous data logger
All	Conventional Parameters	Water Temperature (instantaneous)	Monthly	Monthly	Multi-parameter Probe
All	Conventional Parameters	Chloride	Routine (e.g., monthly)	N/A	Grab Sample
All	In Sediments	Poly-aromatic hydrocarbons	Once per 5 years based on permit cycle; possibly 3-yr rotation based on hydro cycle	Once per 5 years based on permit cycle; possibly 3-yr rotation based on hydro cycle	Sediment Set
All	Metals - In Sediments	Total Copper	Once per 5 years based on permit cycle; possibly 3-yr rotation based on hydro cycle	Once per 5 years based on permit cycle; possibly 3-yr rotation based on hydro cycle	Sediment Set

Sampled in Alternative	Metric Category	Metric Sub Category	Monitoring Frequency Required at Most Sites [1]	Monitoring Frequency in Forested Land Use/Land Class[1,2]	Field Collection Group
All	Metals - In Sediments	Lead	Once per 5 years based on permit cycle; possibly 3-yr rotation based on hydro cycle	Once per 5 years based on permit cycle; possibly 3-yr rotation based on hydro cycle	Sediment Set
All	Metals - In Sediments	Total Zinc	Once per 5 years based on permit cycle; possibly 3-yr rotation based on hydro cycle	Once per 5 years based on permit cycle; possibly 3-yr rotation based on hydro cycle	Sediment Set
All	Nutrients	Total Nitrogen	Routine (e.g., monthly)	Once per year	Grab Sample
All	Nutrients	Total Phosphorus	Routine (e.g., monthly)	Routine (e.g., monthly)	Grab Sample
All	Nutrients	Ammonia	Routine (e.g., monthly)	Once per year	Grab Sample
All	Nutrients	Nitrate+ Nitrite-Nitrogen	Routine (e.g., monthly)	Once per year	Grab Sample
All	Hydrology/ Water Quantity	Instantaneous Flow	Routine (e.g., monthly)	Routine (e.g., monthly)	Handheld flow meter
All	Macro-invertebrates	Macro-invertebrate Index	Once per year	Once per year	Benthic Sample
All	Water Column	Suspended Solids	Routine (e.g., monthly)	Routine (e.g., monthly)	Grab Sample
All	Water Column	Total Solids	Routine (e.g., monthly)	Routine (e.g., monthly)	Grab Sample
All	Vegetation/ Plants	Periphyton	Once per year	Once per year	Substrate Sample
Alts. 2 & 3	In Sediments	Polychlorin-ated Biphenyls (PCBs)	Once per 5 years based on permit cycle; possibly 3-yr rotation based on hydro cycle	N/A	Sediment Set

Sampled in Alternative	Metric Category	Metric Sub Category	Monitoring Frequency Required at Most Sites [1]	Monitoring Frequency in Forested Land Use/Land Class[1,2]	Field Collection Group
Alts. 2 & 3	In Sediments	Volatile Organic Compounds	Once per 5 years based on permit cycle; possibly 3-yr rotation based on hydro cycle	N/A	Sediment Set
Alts. 2 & 3	Metals - In Sediments	Arsenic	Once per 5 years based on permit cycle; possibly 3-yr rotation based on hydro cycle	Once per 5 years based on permit cycle; possibly 3-yr rotation based on hydro cycle	Sediment Set
Alts. 2 & 3	Metals - In Sediments	Cadmium	Once per 5 years based on permit cycle; possibly 3-yr rotation based on hydro cycle	N/A	Sediment Set
Alts. 2 & 3	Metals - In Sediments	Mercury	Once per 5 years based on permit cycle; possibly 3-yr rotation based on hydro cycle	Once per 5 years based on permit cycle; possibly 3-yr rotation based on hydro cycle	Sediment Set
Alts. 2 & 3	Other	Soluble Reactive Phosphorous	Routine (e.g., monthly)	Routine (e.g., monthly)	Grab Sample
Alts. 2 & 3	Pesticides[4]	Organo-chlorines	Once per year	N/A	Grab Sample
Alts. 2 & 3	Pesticides[4]	Organo-phosphates	Once per year	N/A	Grab Sample
Alts. 2 & 3	Pesticides[4]	Herbicides	Once per year	N/A	Grab Sample
Alts. 2 & 3	Pesticides[4]	Insecticides	Once per year	N/A	Grab Sample

Sampled in Alternative	Metric Category	Metric Sub Category	Monitoring Frequency Required at Most Sites [1]	Monitoring Frequency in Forested Land Use/Land Class[1,2]	Field Collection Group
Alts. 2 & 3	Hydrology/ Water Quantity	Flow (instant-aneous)	Frequent (e.g., biweekly)	Continuous/ Frequent	handheld flow meter
Alt. 3 only	Base/Neutral/ Acids	2-Fluoro-biphenyl	Once per year	N/A	Grab Sample
Alt. 3 only	Conventional Parameters	Oil and Grease	Storm Events	N/A	Grab Sample
Alt. 3 only	Conventional Parameters	Biochemical Oxygen Demand	Routine (e.g., monthly)	N/A	Grab Sample
Alt. 3 only	Conventional Parameters	Hardness	Routine (e.g., monthly)	Once per 5 years based on permit cycle; possibly 3-yr rotation based on hydro cycle	Grab Sample
Alt. 3 only	In Sediments	Endocrine Disruptors[2]	Once per 5 years based on permit cycle; possibly 3-yr rotation based on hydro cycle	N/A	Sediment Set
Alt. 3 only	Nutrients	Nitrate-Nitrogen	Routine (e.g., monthly)	N/A	Grab Sample
Alt. 3 only	Other	Other 303(d) Parameters	Annual	N/A	Varies with parameter - grab sample or sediment
Alt. 3 only	Sediment/ Substrate/ Soils	Percent Solids	Frequent (e.g., biweekly)	Once per year	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] A list of recommended pesticides and endocrine disruptors is provided in Appendix G of Technical Report 2 (Tetra Tech 2013b).

Table A-2. 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	Bankfull depth	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

Table A-3. 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	Relative bed stability	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.

Table A-4. 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.

Appendix B - Participants in ISTM Habitat Technical Subgroup Meeting/Workshop

Table B-1. List of Participants in ISTM Habitat Technical Subgroup Meeting/Workshop - April 30, 2013		
Last Name	**First Name**	**Affiliation**
Adams	Karen	Washington Department of Ecology
Anhorn	Randy	Washington Department of Ecology
Anlauf-Dunn	Kara	Oregon Department of Fish and Wildlife
Bayer	Jen	USGS/PNAMP
Breckel	Jeff	Lower Columbia Fish Recover Board
Cox	Lisa	Washington Department of Ecology
Frazier	Pat	Lower Columbia Fish Recover Board
Gross	Tricia	Tetra Tech
Irvine	Kathryn	USGS
Miller	Stephanie	USFS
Merritt	Glenn	Washington Department of Ecology
Puls	Amy	USGS/PNAMP
Rentmeester	Steve	Sitka Technologies
Schei	Jacquelyn	USGS/PNAMP
Schnabel	Jeff	Clark County

Appendix C – Feedback from Participants of ISTM Habitat Technical Subgroup Meeting/Workshop

Additional comments received following ISTM Habitat Technical Subgroup Meeting – April 30, 2013

Name	Affiliation	Comment	Response
Glenn Merritt	Ecology	Relative Bed stability is perhaps the most important habitat metric for all monitoring levels of effort. It relies on measuring: 1) Pebble counts to represent the site reach surface bed at bankfull stage. 2) The cross-sectional dimensions of the bankfull channel. 3) 100 or more wetted depths along the length of the thalweg profile 4) Site reach slope 5) Large woody debris volume across the area of the site's bankfull channel.	Added relative bed stability to the final recommended list of habitat metrics. The items listed below comment were already included on metrics list.
		IHA - Where continuous, long-term gages are available, I'd like to promote consideration of Indicators of Hydrologic Alteration.	Text inserted under Stream Flow Monitoring Program section to address this comment.
		Recommend adding bankfull depth to short list of habitat metrics	Added bankfull depth to short list of habitat metrics.

Appendix D - Participants in May Technical Workshop

Table D-1. List of Participants in May Technical Workshop – May 22, 2013		
Last Name	**First Name**	**Affiliation**
Adams	Karen	LCFRB
Anhorn	Randy	WA Ecology
Bayer	Jen	USGS/PNAMP
Breckel	Jeff	LCFRB
Cox	Lisa	WA Ecology
Frazier	Pat	LCFRB
Gross	Tricia	TetraTech
Johnson	Josh	City of Longview
McKay	Van	City of Kelso
Puls	Amy	USGS/PNAMP
Sangder	Rick	City of Aberdeen
Schnabel	Jeff	Clark County
Tereski	Melody	LCFRB
Wierenga	Ron	Clark County
Uhacz	Kelly	City of Battle Ground
Steele	Keith	Sitka Technologies
Weckback	Ann	Lewis County PW

Appendix E – Feedback Regarding Technical Report 3

Input was received from project participants during and following the May 22 technical workshop. Feedback focused on the final recommendations for the monitoring strategy and Draft Technical Report 3 that summarized the results of Stage 3 of this project. Due to the number of entities that submitted comments and the various formats in which that information was received, the comments could not be condensed into a table for inclusion in this report. Draft Technical Report 3 has been revised to produce the Final Technical Report 3 that incorporates the input received from participating parties. Project participants that provided input include:

- Clark County
- City of Vancouver
- City of Kelso
- USGS representatives of PNAMP
- Oregon Department of Fish and Wildlife
- Department of Ecology

Appendix F – Participants in Lower Columbia Habitat Status and Trends Monitoring Project

Table F-1. List of Project Participants		
Last Name	First Name	Affiliation
January Technical Workshop – January 15, 2013		
Adams	Karen	Washington Department of Ecology
Anhorn	Randy	Washington Department of Ecology
Bergdolt	Fred	Washington State Department of Transportation
Breckel	Jeff	Lower Columbia Fish Recover Board
Charles	Rob	City of Washougal
Cox	Lisa	Washington Department of Ecology
Duren	Olivia	Tetra Tech
Frazier	Pat	Lower Columbia Fish Recover Board
Gross	Tricia	Tetra Tech
Harbison	Patrick	Cowlitz County
Johnson	Josh	City of Longview
Kast	Bryan	City of Battle Ground
McKay	Van	City of Kelso
Ory	Jill	Sitka Technologies
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
February Technical Workshop – February 15, 2013		
Bayer	Jen	USGS/PNAMP
Breckel	Jeff	LCFRB
Charles	Rob	City of Washougal
Cox	Lisa	WA Ecology
Frazier	Pat	LCFRB
Griffy	Annette	City of Vancouver
Gross	Tricia	Tetra Tech
Kast	Bryan	City of Battle Ground
McKay	Van	City of Kelso
Puls	Amy	USGS/PNAMP
Rentmeester	Steve	Sitka
Sawyer	Scott	City of Battle Ground
Schnabel	Jeff	Clark County
Sutton	Dorie	City of Vancouver

Swanson	Rod	Clark County
Tereski	Melody	LCFRB
Crowley	Keven	WSU-Vancouver
Schwartz	Matt	LCREP
Dyrland	Richard	Fish First
Water Qa/Qx Technical Subgroup Meeting - March 11, 2013		
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
April Technical Workshop - April 2, 2013		
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
Habitat Technical Subgroup Meeting - April 30, 2013		
Adams	Karen	Washington Department of Ecology

Anhorn	Randy	Washington Department of Ecology
Anlauf-Dunn	Kara	Oregon Department of Fish and Wildlife
Bayer	Jen	USGS/PNAMP
Breckel	Jeff	Lower Columbia Fish Recover Board
Cox	Lisa	Washington Department of Ecology
Frazier	Pat	Lower Columbia Fish Recover Board
Gross	Tricia	Tetra Tech
Irvine	Kathryn	USGS
Miller	Stephanie	USFS
Merritt	Glenn	Washington Department of Ecology
Puls	Amy	USGS/PNAMP
Rentmeester	Steve	Sitka Technologies
Schei	Jacquelyn	USGS/PNAMP
Schnabel	Jeff	Clark County
May Technical Workshop – May 22, 2013		
Adams	Karen	LCFRB
Anhorn	Randy	WA Ecology
Bayer	Jen	USGS/PNAMP
Breckel	Jeff	LCFRB
Cox	Lisa	WA Ecology
Frazier	Pat	LCFRB
Gross	Tricia	Tetra Tech
Johnson	Josh	City of Longview
McKay	Van	City of Kelso
Puls	Amy	USGS/PNAMP
Sangder	Rick	City of Aberdeen
Schnabel	Jeff	Clark County
Tereski	Melody	LCFRB
Wierenga	Ron	Clark County
Uhacz	Kelly	City of Battle Ground
Steele	Keith	Sitka Technologies
Weckback	Ann	Lewis County PW