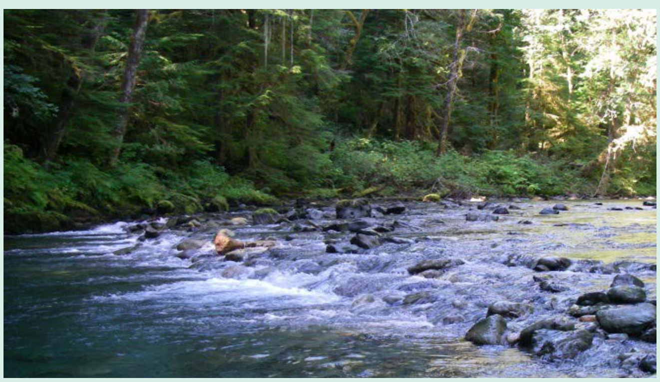
FINAL REPORT ◦ FEBRUARY 2015

Habitat Status and Trends Monitoring for the Lower Columbia Region Integrated Monitoring Design



P R E P A R E D F O R

Lower Columbia Fish Recovery Board
2127 8th Ave.
Longview, WA 98632

P R E P A R E D B Y

Stillwater Sciences
108 NW Ninth Ave., Suite 202
Portland, OR 97209

Stillwater Sciences

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Cover photos clockwise from top left: Abernathy Creek restoration site built by the Cowlitz Indian Tribe in the upper half of the basin (provided by LCFRB); Straight Creek, a tributary to the Suiattle River (provided by LCFRB); restoration project site built by the Cowlitz Conservation District in the middle reach of Abernathy Creek (photo provided by LCFRB); Diobsud Creek, a tributary to the Skagit (provided by LCFRB).

DEFINITIONS OF ABBREVIATIONS AND ACRONYMS

Term	Definition
AREMP	Northwest Forest Plan Aquatic and Riparian Effectiveness Monitoring Program
BFW	Bankfull Width
BLM	Bureau of Land Management
BMP	Best Management Practices
CDFG	California Department of Fish and Game
CHaMP	Columbia Habitat Monitoring Program
DA	Drainage Area
DPS	Distinct Population Segments
Ecology	Washington Department of Ecology
EMAP	EPA Environmental Monitoring and Assessment Program
ESA	Endangered Species Act
ESU	Evolutionarily Significant Units
GIS	Geographic Information System
GPS	Global Positioning System
GRSS	Grants of Regional and Statewide Significance
HSTM	Habitat and Water Quality Status and Trends Monitoring
ISTM	Integrated Status and Trends Monitoring
LC	Lower Columbia
LCFRB	Lower Columbia Fish Recovery Board
LCMS	Lower Columbia Master Sample
LCR	Lower Columbia River
LWD	Large Woody Debris
MS4	Municipal Separate Storm Sewer Systems
MSWPA	Municipal Stormwater Permit Area
NAWQA	National Water Quality Assessment
NIFC	Northwest Indian Fisheries Commission
NLCD	National Land Cover Dataset
NMFS	National Marine Fisheries Service
NPDES	National Pollutant Discharge Elimination System
NRC	National Research Council
ODEQ	Oregon Department of Environmental Quality
ODFW	Oregon Department of Fish and Wildlife
PAH	Polycyclic Aromatic Hydrocarbons
PIBO	USDA Forest Service-BLM (Effectiveness Monitoring Program for PACFISH/INFISH Biological Opinion)
PNAMP	Pacific Northwest and Aquatic Monitoring Partnership
PS RSMP	Puget Sound Regional Stormwater Monitoring Program
QA	Quality Assurance
Qa/Qx	Water Quality and Water Flow
QAMP	Quality Assurance Monitoring Plan
QAPP	Quality Assurance Project Plan
RSMP	Regional Stormwater Monitoring Program
S&T	Status and Trends
S/N	Signal to Noise

Term	Definition
SWG	Puget Sound Stormwater Ecosystem Monitoring Program Working Group
TR3	Tetra Tech 2013
UC	Upper Columbia Monitoring Strategy
UGA	Urban Growth Area
USFS	United States Forest Service
USGS	United States Geological Survey
WA	Washington
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WHM	Washington State Department of Ecology's Watershed Health Monitoring Project
WQI	Water Quality Index
WRIA	Water Resource Inventory Area

GLOSSARY OF TERMS

Term	Definition
bankfull width	the width of the bankfull channel measured at a section perpendicular to streamflow
legacy sites	sites with existing water quality and/or habitat monitoring data in the Lower Columbia
Lower Columbia Evolutionarily Significant Unit	also referenced as the Lower Columbia Region Recovery domain, the ESU comprises the Columbia River mainstem from its mouth up to Hood River, and all Columbia River tributary subbasins from the mouth of the Columbia River up to and including the White Salmon River in Washington and the Hood River in Oregon, and the Willamette River up to Willamette Falls
master sample	a common set of random sites along the state's rivers and streams developed for use in comparable, complementary monitoring among separate monitoring organizations and across geographic scales
metrics	measures of quantitative assessment
National Land-Cover Dataset	a 16-class land cover classification scheme based on satellite imagery that has been applied consistently across the conterminous United States at a spatial resolution of 30 meters
opportunistic design	a study design that selects sites based on ease of access, expert opinion, or other subjective criteria
persistence probability	the complement of a population's extinction risk (i.e., persistence probability = 1 - extinction risk)
Phase I municipal stormwater NPDES permittee	municipalities that operate separate storm sewer systems must obtain a National Pollutant Discharge Elimination System (NPDES) permit for their stormwater discharges. These permits require the implementation of a stormwater management program, which normally includes various types of monitoring. Phase I permittees are those cities and counties with populations of 100,000 or more. In the LCR, Clark County is the only Phase 1 municipal stormwater NPDES permittee.
Phase II municipal stormwater NPDES permittees	Phase II municipal stormwater NPDES permits cover small separate storm sewer systems in urbanized areas, as well as small systems outside the urbanized areas that are designated by the permitting authority (which, in Washington state, is the Department of Ecology). The LCR contains seven Phase II permittees: Cowlitz County and the cities of Camas, Longview, Vancouver, Battle Ground, Kelso and Washougal.
primary population	a population that is targeted for restoration to high or very high persistence probability
probabilistic design	a study design where sites are randomly selected across the entire area of interest
properly functioning condition	NMFS defines properly functioning condition as the sustained presence of natural habitat-forming processes that are necessary for the long-term survival and recovery of the species
pseudo-random	the addition of data (legacy sites) to a random sample of monitoring sites
signal to noise	analysis that compares the magnitude of "true" change in a metric with the magnitude of its random (or otherwise irreducible) variability

Term	**Definition**
site allocation and stratification	the framework for subdividing and categorizing the points of the master sample by some or all of their underlying attributes (such as drainage area or channel gradient) to ensure that monitoring of a subset of the categorized points will be representative of that group as a whole
statistical confidence	an expression of the expected variation in a given estimate
statistical power	ability of a test to detect an effect
stream segments (for Qa/Qx sampling)	a contiguous series of master sample points along a single stream with common drainage area classification (e.g., 2.5-50 km^2)
substrate size	the diameter of the sediment on the bed of a stream channel, normally presented as the percentage of particles within a series of size classes and summarized by the diameter of the median particle size (D_{50})
subwatersheds	drainage areas of 3,000-12,000 acres (about 12 to 49 km^2)
target population	candidate sampling sites drawn from the "Washington Master Sample," a common set of random sites along the state's rivers and streams developed for use in comparable, complementary monitoring among separate monitoring organizations and across geographic scales
TR3	Tetra Tech Lower Columbia Habitat Status and Trends Project Technical Report 3

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EXECUTIVE SUMMARY

In 2012, the Lower Columbia Fish Recovery Board (LCFRB) and the City of Longview initiated a collaborative project to design and implement an integrated Habitat and Water Quality Status and Trends Monitoring project (HSTM) in the Lower Columbia Region. Pursuit of such integration is motivated by two monitoring needs that face the region: supporting the recovery of salmonid species listed as threatened or endangered under the Endangered Species Act (Chinook, coho, chum, and steelhead), and addressing anticipated future monitoring requirements under municipal stormwater National Pollutant Discharge Elimination System (NPDES) permits for eight jurisdictions in southwest Washington. By developing a coordinated strategy across these two monitoring programs, fiscal efficiencies and more robust and meaningful regional assessments should be achieved.

The primary goal of the HSTM project is to complete a monitoring design to meet the status and trends monitoring needs of the Washington State Department of Ecology (Ecology), southwest Washington municipal stormwater permittees, LCFRB, and other partners of the Pacific Northwest Aquatic Monitoring Partnership's program for Integrated Status and Trends Monitoring. This Design Report represents the culmination of past and present efforts conducted over the last 18 months, representing "Phase 2" of an envisioned three-phase effort. Phase 1, completed in June 2013, developed the overarching framework for the coordinated strategy. Subsequently, this Design Report has now articulated the final goals and objectives for the integrated monitoring project, and it specifies the target populations, sampling stratification, and metrics to be used. Phase 3, currently planned for 2015-2016, will develop the final *implementation* plan, which will include the pragmatic details necessary for the actual initiation of monitoring--site selection, measurement protocols, data analyses, data management, and reporting—all of which are essential for successful on-the-ground execution, but none of which affect the design of the program as a whole.

The project study area is envisioned to include all of the Lower Columbia Region Recovery domain, also referenced as the Lower Columbia Evolutionarily Significant Unit (ESU), which comprises the Columbia River mainstem from its mouth up to Hood River, and all Columbia River tributary subbasins from the mouth of the Columbia River up to and including the White Salmon River in Washington and the Hood River in Oregon, and the Willamette River up to Willamette Falls. The current phase of the project addresses only the monitoring design for tributaries in the Washington portion of the ESU. Future phases hope to include the Oregon portion of the Region upon participation and funding by Oregon agencies, and to incorporate monitoring of the Columbia River mainstem and tidally influenced habitats, in order to generate a more complete picture of the landscape and its habitats. At present, the project also addresses the anticipated requirements for status and trends monitoring for the one Phase I and seven Phase II municipal stormwater NPDES permittees in western Washington.

Methods

The methods and materials used to develop this final design report followed the same basic approach of Phase 1 of the HSTM project, including agency documents, peer-reviewed scientific literature, and ongoing input from project partners and stakeholders through weekly and monthly meetings, four public workshops, and review comments on draft and final reports.

The work was organized using the framework established in Phase 1, addressing each of the key components of monitoring design in turn:

- Guiding monitoring questions and objectives
- Target population(s) for monitoring
- Site allocation and stratification
- Metric evaluation and selection

The original monitoring questions from Phase 1 were refined to achieve greater specificity in their associated monitoring objectives, and to ensure that the overarching goals of the participants would be addressed by the final set of questions and objectives. They were also modified so that the resulting monitoring program would more likely be feasible and affordable for participants in the region.

The target population of candidate sampling sites was drawn from the "Washington Master Sample," a common set of random sites along the state's rivers and streams developed for use in comparable, complementary monitoring among separate monitoring organizations and across geographic scales. The master site list has 387,237 points in Washington, of which more than 100,000 are located in the Lower Columbia ESU. Identifying suitable combinations of alternative strata and categories made use of the preliminary conceptual framework for stratification developed during Phase 1, followed by extensive querying of the Master Sample to satisfy diverse requirements.

Prospective candidate metrics were evaluated from the same perspectives as the strata: technical relevance, regulatory needs, and financial feasibility. These considerations were evaluated using the same types of source information as was applied to the Master Sample stratification, with a particular emphasis on the experiences of other monitoring programs in terms of both data usability and cost. In particular, development of a final set of metrics focused on identifying those with sufficient precision and replicability in order to select those that yield reliable results that could be shared with other monitoring programs. Signal to noise (S/N) analyses, which compare the magnitude of "true" change in a metric with the magnitude of its random (or otherwise irreducible) variability, were used extensively to evaluate this attribute. literature-reported ratings for S/N informed this determination, recognizing that strict equivalency between different monitoring programs is not commonly achieved in practice but that informed comparisons are nonetheless informative.

The integration of these considerations, based on both internal discussions and multiple consultations with project stakeholders, has led to the final suite of recommended metrics in this Design Report. Although this suite of metrics is tailored to the goals and objectives of this study, they are sufficiently universal in range and applicability that other monitoring programs, even those with a different suite of metrics or focus of study, should be able to achieve meaningful integration of data and understanding.

Results and Recommendations

Target populations, stratification, and site selection for water quality/water flow monitoring

Site selection for water quality/water flow ("Qa/Qx") sampling takes advantage of the continuity of flowing water, under the assumption that most of these metrics vary spatially only gradually, if at all, along a given channel in the absence of significant natural or manmade (i.e., stormwater outfall) tributary inputs. Thus, the population of Qa/Qx sites from which sampling locations will be drawn are channel *segments* (not individual *points*) within the Urban Growth Areas (UGAs) of NPDES permittees and draining predominantly urban watersheds with a drainage area of at least 2.5 km^2 and no more than 50 km^2. Within a selected segment, the specific location chosen for sampling should have little influence on most types of collected data, and thus ancillary considerations (such as site access or the reoccupation of legacy sampling sites that are located within the selected segments) can be incorporated without undermining the random spatial design that underlies the Master Sample.

Over 30 such channel segments are present within the Region that meet these criteria; about 15 such segments will be needed for monitoring to achieve adequate statistical confidence in the representativeness of monitoring data for the population of such channels as a whole. Selection can be strictly random, or on a combination of preemptive identification of stream segments with suitable long-term Qa/Qx data ("legacy sites") plus additional randomly selected segments as needed to achieve the necessary number. Because several of the monitoring objectives may be better addressed with a more directed, pseudo-randomized site selection approach, the final strategy will be determined during a review of preexisting data at specific locations, in consort with the other relevant details of implementation (see below).

Once a segment has been selected, identifying a specific sampling location will begin at the downstream end, moving upstream to find the first feasible sampling location as guided first by logistical considerations of access and adjacent land ownership as identifiable through GIS and aerial photographs, and then by a field visit to each candidate site to confirm access and overall suitability for monitoring (particularly benthic macroinvertebrate sampling, which has specific requirements for gradient and substrate in order to yield meaningful results).

Qa/Qx sampling *outside* of designated UGAs encompasses a more diverse landscape than found in the urban NPDES areas, and so a greater degree of stratification is needed to achieve meaningful representation of the population (recognizing that watersheds even outside of an Urban Growth Area may nonetheless have predominantly "urban" land cover):

- Drainage area (0.6-2.5 km^2, 2.5-50 km^2, 50-200 km^2) = 3 categories
- Predominant watershed land cover as classified in the National Land-Cover Dataset into three major types (forested, agricultural, urban) = 3 categories

These three broad land cover classes (forested, agricultural and urban) represent most, albeit not all, conditions within the basins (for example, bare rock and wetlands are not included in any of these classes).

In addition to these two strata, the relative importance of some subbasins to regional salmon recovery over others suggests the need to identify high-priority areas explicitly through the final stratification framework. This will ensure that sufficient monitoring sites are located in those high-priority subbasins in support of recovery efforts, rather than relying on the random distribution of sites selected from the entire Master Sample to achieve adequate coverage. The 25 subbasins of the region has been subdivided into three categories by the number of Primary Populations (defined in the 2013 Lower Columbia River Salmon and Steelhead Recovery Plan as "a population that is targeted for restoration to high or very high persistence probability") (0-2, 3, 4+ populations) and are included here in the final design for stratification.

The strategy used for allocating Qa/Qx sites among the approximately 400 segments in the region that lie outside of UGAs should proceed as described above for the urban NPDES Qa/Qx sampling. Candidate sampling locations should be evaluated from downstream to upstream, located where the logistics of access are first judged feasible, and then field-checked for actual suitability.

Target populations, stratification, and sample selection for habitat monitoring

Habitat monitoring will occur at selected Master Sample sites, located in continuous, freshwater streams with non-constructed channels above any influence of tides or backwatering of the Columbia River. Habitat monitoring will sample randomly-chosen sites selected from all points that meet a specific set of strata-based selection criteria. Habitat monitoring sites do not have identical target populations or strata to those of Qa/Qx sites, however, because the attributes being measured by these two types of monitoring are fundamentally different in several respects. Habitat data are collected on physical features at a site, rather than water-column attributes that are relatively constant over long distances. Habitat features are also more sensitive to instream channel dynamics, and so their dependency on stream power must be incorporated into the stratification to ensure representative results for the population as a whole.

Although future habitat-monitoring needs of municipal stormwater NPDES permittees may not differ from those in the rest of the region, the same urban/non-UGA discrimination as for Qa/Qx monitoring is maintained to retain future flexibility. As such, sites for monitoring in urban NPDES areas and non-UGA areas of the region will be considered independently, albeit with a common set of recommended strata for both:

Drainage Area (0.6-2.5, 2.5-50, 50-200, 200-1000, >1000 km^2) = 5 categories

Stream Gradient Groups (<1.5%, 1.5-3%, 3-7.5%, >7.5%) = 4 categories

Predominant watershed land cover as classified in the National Land-Cover Dataset (forested, agricultural, urban) = 3 categories

In addition to the three common strata, the number of Primary Populations in the subbasin [(0-2, 3, 4+) = 3 categories] is recommended as an additional strata for habitat monitoring non-UGA areas. This supports salmon recovery priorities defined in the 2013 Lower Columbia River Salmon and Steelhead Recovery Plan and consistent with Qa/Qx stratification.

Although the total recommended habitat strata nominally define 240 unique combinations (urban 5 × 4 × 3 + non-UGA 5 × 4 × 3 × 3), a significant fraction of those strata combinations have few to no monitoring sites in the Master Sample. For example, large, steep channels do not generally exist; and urban-NPDES sites will rarely have any predominant land cover aside from "urban". In order to be retained as a strata, a sufficient number of monitoring sites must exist. Absent more consistent data on the variance of habitat data, the number of sample sites within each category will match the recommended Qa/Qx sampling, resulting in the guidance that 15+ potential habitat monitoring sites be identified for any given strata combination.

Once a site has been identified for habitat monitoring, a preliminary review of access and adjacent land ownership using GIS and aerial photographs should be made. If the site appears to be a viable candidate, a field visit will still be necessary to confirm access and overall suitability. An identify reach length 20 times the average bankfull width should be identified to be sampled for all metrics requiring a "reach" (instead of a "point," such as LWD inventories). As with Qa/Qx monitoring, several of the monitoring objectives may be better addressed with a more directed, pseudo-randomized site selection approach, for which the final strategy will be made during implementation.

Metrics

Metrics were selected on the basis of their ability to provide meaningful information on water-quality, water quantity, and habitat conditions within broad, inferred limits of likely financial resources. A key evaluation for each metric was made on its typical signal-to-noise ratio (S/N, the degree to which actual trends in the data exceed the variability imposed on multiple measurements by virtue of random fluctuations or inconsistencies among different observers), making use of published studies to the extent they are available and relevant to the HSTM design. Literature values of S/N ratios for various candidate metrics were converted to letter grades using a preexisting scoring scale and used as a guide for metric selection. Metrics that consistently generated grades of D or F (i.e., S/N ratios less than 2) were removed from consideration.

Metrics recommended for collection at all Qa/Qx sites include water temperature, conductivity, and stage (all continuously measured and recorded); and sediment metals, macroinvertebrates, bankfull width, bankfull depth, wetted width, and substrate size (all annually). This list of recommended metrics errs on the side of minimizing cost, with the expectation that if additional funds become available then the value of spending them on additional data collection can then be explored and weighed against the value that is already being delivered by the monitoring program in-hand. Conversely, if a monitoring program is judged "too expensive" from the start, it risks an outcome wherein no data whatsoever is collected.

Metrics recommended for collection at all habitat sites fall in two broad categories: those that are not expected to change rapidly and need be measured only once per five years, and those for which annual re-measurement is appropriate. Five-year metrics comprise bankfull width/depth, reach length (20 times the bankfull width), channel type, number of habitat units (e.g., pool, riffle, run), sinuosity, floodplain area, and length of side channel habitat. Annual measurements, to be made during a single day's site visit in summer months, comprise (categorical) bank stability, pools per unit length, residual pool depth, thalweg depth, density/distribution instream wood, substrate particle size (% composition by grain diameter), embeddedness, relative bed stability, shade at mid channel, riparian canopy (% cover), riparian understory (% cover), and flow category. Temperature should be measured at every visit; those sites with critically high values may merit more intensive and frequent measurements, but this can be determined only once implementation has begun.

Next Steps

Following this Phase 2 monitoring design will be the development of a full Implementation Plan for the Lower Columbia Integrated HSTM Design, representing Phase 3 of the HSTM program. The overarching purpose of an implementation plan is to provide sufficient detail in data collection, management, and analysis to answer the management questions and objectives that drive the program as a whole, and to clarify stakeholder roles and responsibilities in order for data collection to begin.

During the process of implementation plan development, several outstanding issues will need to be resolved:

- What are the fiscal constraints on the scope of NPDES permittee-funded and regionally funded monitoring efforts?
- What and where are the high-priority legacy sites in the region, and how should pseudo-random site selection be integrated with fully random site-selection to incorporate them to greatest benefit?
- What should be the specific criteria for determining feasible access to candidate sampling sites?
- What should be the criteria and minimum standards for sharing data between programs?

Other tasks that will constitute the bulk of the implementation planning effort are the final identification of channel segments (for Qa/Qx monitoring) and sites (for habitat monitoring), quality-checking and integrating the GIS-based landscape analysis into the site-selection and data-interpretation processes, defining the data-collection protocols for every metric, defining the procedures for data management and analysis, and establishing the framework and requirements for communicating the findings in ways that ensure their utility for the widest range of prospective end-users. In addition, a final Quality Assurance Project Plan will need to be prepared, covering many of these and related issues of data-quality objectives, quality control, data verification and usability that can only be finalized after the implementation plan is itself complete.

1 INTRODUCTION

1.1 Background

In 2012, the Lower Columbia Fish Recovery Board (LCFRB) and the City of Longview initiated a collaborative project to design and implement an integrated Habitat and Water Quality Status and Trends Monitoring project (HSTM) in the Lower Columbia Region. Pursuit of such integration is motivated by two monitoring needs that face the region: supporting the recovery of salmonid species listed as threatened or endangered under the Endangered Species Act (Chinook, coho, chum, and steelhead), and addressing anticipated future monitoring requirements under municipal stormwater National Pollutant Discharge Elimination System (NPDES) permits for eight jurisdictions in southwest Washington. The project built on the progress of the Pacific Northwest Aquatic Monitoring Partnership's (PNAMP) Integrated Statues and Trends Monitoring (ISTM) Project, which sought ways to design and implement more coordinated, efficient, and effective aquatic ecosystem monitoring than under the independence by which the various monitoring program had historically been conducted. By integrating status and trends monitoring related to municipal stormwater permits with other existing monitoring efforts in the WA Lower Columbia ESU, the intent is to gain fiscal efficiencies and more robust and meaningful regional assessments than could be achieved by either program in isolation.

The primary goal of the HSTM project is to complete a monitoring design to meet the status and trends monitoring needs of Ecology, southwest Washington municipal stormwater permittees, LCFRB, and other partners of the Pacific Northwest Aquatic Monitoring Partnership's program for Integrated Status and Trends Monitoring. This Design Report represents the culmination of past and present efforts conducted over the last 18 months, representing "Phase 2" of an envisioned three-phase effort. Phase 1, completed in June 2013, developed the overarching framework for the coordinated strategy. Subsequently, this Design Report has now articulated the final goals and objectives for the integrated monitoring project, and it specifies the target populations, sampling stratification, and metrics to be used. Some preliminary recommendations are offered herein, in recognition that any plan that does not describe a range of credible, tractable alternatives does not contribute to progress towards true implementation. However, the funding available for such a program cannot be known with certainty, and so a plausible design is presented herein, scaled by recent examples from around the region to guide this essential step.

"Phase 3" of this project (the Implementation Plan) will be the next and final step of this HSTM program and will immediately follow completion of Phase 2. It will develop the final *implementation* plan, which will include the pragmatic details necessary for the actual initiation of monitoring—site selection, measurement protocols, data analyses, data management, and reporting—all of which are essential for successful on-the-ground execution, but none of which affect the design of the program as a whole.

1.2 Project Goals and Status

- Complete a monitoring design to meet the status and trends monitoring needs of Ecology, southwest Washington municipal stormwater NPDES permittees, LCFRB and other PNAMP ISTM partners. This is the primary goal of this project, and this Design Report represents the culmination and primary deliverable of the current effort.
- Secure the participation of Oregon agencies conducting monitoring and other PNAMP ISTM partners to the maximum extent possible to develop the Lower Columbia HSTM design. This goal was spearheaded by PNAMP but to date (January 2015) has not been achieved.
- Develop a draft Quality Assurance Project Plan (QAPP) to support the proposed monitoring as outlined in the Design Report. That document has been prepared in conjunction with this Design Report and has been issued separately as a secondary deliverable. It is intended to be completed in the next phase of this project as part of the implementation planning.

1.3 Project Study Area

The project study area includes the Lower Columbia Region, also referenced as the Lower Columbia Evolutionarily Significant Unit (ESU), which comprises the Columbia River mainstem from its mouth up to Hood River, and all Columbia River tributary subbasins from the mouth of the Columbia River up to the White Salmon River in Washington (WRIAs 25, 26, 27, 28 and 29) and the Hood River in Oregon, and the Willamette River up to Willamette Falls (Figure 1). The current phase of the HSTM project was focused on the Washington portion of the ESU with intent to include the Oregon portion of the ESU at a later time, subject to participation and funding by Oregon agencies. The project area also includes the one Phase I and seven Phase II municipal stormwater NPDES permittees that are likely to see future requirements for status and trends monitoring as part of the permits expected in 2018.

Figure 1. Lower Columbia ESU boundary, highlighting the Washington portion of the ESU. Source: LCFRB

1.4 Participants

Lower Columbia Region Habitat and Water Quality Status and Trends Monitoring Project participants include the following:

Integrated Status and Trends Monitoring (ISTM) project partners

Pacific Northwest Aquatic Monitoring Partnership (PNAMP)
Lower Columbia Fish Recovery Board (LCFRB)
Washington State 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)
National Marine Fisheries Service (NMFS)
Washington Department of Fish and Wildlife (WDFW)

Participating SW Washington municipal stormwater NPDES permittees

Phase I - Clark County (also an ISTM partner)

Phase II - Cowlitz County and the cities of Camas, Longview, Vancouver, Battle Ground, Kelso and Washougal

Stakeholder input was provided throughout this Phase of the project (Phase 2) in the form of weekly conference calls with a technical team, monthly calls with a leadership team, product reviews and four public workshops with associated questionnaires to elicit stakeholder feedback.

2 METHODS

The methods used to develop this final design report followed the basic strategy outlined in Phase 1 of the HSTM project, beginning with the preliminary recommendations of that phase's final report (Tetra Tech 2013; hereafter "TR3"). The original set of monitoring questions presented in that report was refined, and greater specificity was developed for their associated monitoring objectives. Through a series of meetings (technical team and leadership team), a public workshop and interim product review, extensive feedback was received from the diverse stakeholders engaged in this project to ensure that the overarching goals of the various participants would be adequately addressed by the final set of questions and objectives, and that the monitoring program designed to address those questions was likely to be meaningful, feasible, and affordable for participants in the region.

Once this foundation for the monitoring program was settled, the specifics of the monitoring design—target populations, spatial strata, and site allocation—were determined. As with the questions and objectives, the products of the Phase 1 effort provided the initial framework, but closer inspection of their underlying assumptions and of the actual distribution of streams and prospective monitoring sites has resulted in adjustments to that preliminary design, as described below in Section 3. This "Phase 2" monitoring design also benefited from stakeholder input throughout the process. Lastly, the final set of recommended monitoring metrics has benefitted from both the initial Phase 1 recommendations and from further evaluation of agency documents and peer-reviewed literature on the utility, accuracy, precision, and variability (the latter two collectively termed "signal to noise") of various metrics. The work was organized using the framework established in Phase 1, addressing each of these key components of monitoring design in turn.

2.1 Questions and Objectives

Although the goal of this project is to describe and implement a status and trends monitoring program that integrates the needs of both regional salmon recovery managers and municipal stormwater NPDES permittees, the geographic domains and regulatory requirements are sufficiently different that they require somewhat independent development and presentation. The following questions and objectives are thus organized to reflect the explicitly "nested" structure of the HSTM project, first with a focus on the status and trends of watershed health in support of salmon recovery, at the scale of the entire Lower Columbia Region; and secondly with a more narrowly defined focus on the geographic areas (and more specific needs) of the municipal stormwater NPDES permittees within the region. These nested monitoring needs are complementary, and they should each generate information of value to the other while avoiding duplication of effort or increase in cost. The questions and objectives below are provided in support of this expectation; however, explicitly distinguishing the monitoring needs at each of these two scales separately provides the clearest path forward for project partners.

2.1.1 Regional-scale questions and objectives

Because "regional" monitoring also spatially incorporates municipal stormwater NPDES monitoring in a nested hierarchy, all land uses and jurisdictional areas are included at this broad scale. However, land uses across the region as a whole are predominately forestry, agriculture, or rural residential, and so monitoring questions and randomly selected sites at the regional scale will primarily reflect the status and trends of watersheds covered by these non-urban land uses, and in areas not covered by municipal stormwater NPDES permits. Thus, additional monitoring questions that more specifically address the needs of these NPDES permittees are developed separately in Section 2.1.2.

2.1.1.1 Water quality and water quantity (Qa/Qx)

The goal for this component of the project, as articulated in TM3, is to evaluate the status and trends of water quality and stream flow in surface waters to support beneficial and other water-dependent uses. This goal is common to many such monitoring efforts, but it requires further refinement and definition to clearly guide the specific elements of a monitoring program.

Predominant land uses in the Lower Columbia Region are forestry, agriculture, and rural residential. Multiple prior studies across the Pacific Northwest and elsewhere have implicated these land uses in reduced watershed health and limiting the quality of salmonid habitat, primarily through increases in fine sediment and turbidity, temperature, pesticides, and nutrients (e.g. Horner et al. 1997, National Research Council 2009). Alterations to the flow regime from loss of mature forest vegetation is also widely discussed in the scientific literature, but most such studies yield statistically reliable results after only many decades of carefully designed (and typically paired-watershed) studies. Therefore, a broad characterization of regional status and trends (Question 1) is coupled with more focused and achievable efforts (Question 2) to support the overarching goals of this project.

Question 1 (TR3, p. 14): What are the status and trends of water quality and stream flow in surface waters?

<ins>Objective 1.1</ins> (status): In wadeable and non-wadeable streams, as stratified by predominant land-use categories in their contributing watersheds[1], evaluate whether water-quality conditions generally support the waterbody-specific beneficial uses identified in WAC 173-201A-602 (http://apps.leg.wa.gov/WAC/default.aspx?cite=173-201A-602) and meet the "Properly Functioning" conditions of NOAA (1996), using the metrics recommended in Section 3.5 of this report.

<ins>Objective 1.2</ins> (trends): For the population of sites measured under Objective 1.1, evaluate whether measured water-quality metrics show a statistically significant trend over a 10-year period towards the best conditions represented by the population of sites in the random draw from the Master Sample, and as described as "Properly Functioning" in NOAA (1996).

[1] From TR3, p. 28: "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."

Question 2: What are the status and trends of water quality in surface waters draining watersheds with a substantial fraction of land that has been cleared for agriculture or recent (<20 years) forest harvests? (In other words, are our forest practices or agricultural BMPs making a difference in the status and trends of these working landscapes?)

Objective 2.1 (status): In wadeable and non-wadeable streams primarily draining agricultural areas outside of Urban Growth Areas, evaluate whether measured water-quality metrics generally support the waterbody-specific beneficial uses identified in WAC 173-201A-602 (http://apps.leg.wa.gov/WAC/default.aspx?cite=173-201A-602).

Objective 2.2 (trends): In wadeable and non-wadeable streams primarily draining subwatershed(s) with recent (<20 years) forest harvest area(s), evaluate whether measured water-quality metrics show a statistically significant trend over a 10-year period towards reference conditions as established by other sites draining relatively undisturbed watersheds (as identified through the "Landscape" evaluation in Section 2.1.1.3, below).

2.1.1.2 Habitat

Habitat status and trends monitoring addresses physical and biological attributes that affect watershed health and salmon recovery. The combined habitat and water Qa/Qx monitoring is designed to integrate with fish status and trend monitoring, being developed and implemented under other programs, to support a comprehensive status and trends monitoring program for watershed health and salmon recovery. This regional habitat and water quality status and trends monitoring strategy will generate the information necessary to support the following questions and objectives.

Question 3: What are the status and trends of in-stream biological health and in-stream/riparian habitat conditions (in terms of both quality and quantity)?

Objective 3.1 (status): In wadeable and non-wadeable streams, as stratified by predominant land-use categories in their contributing watersheds, evaluate the status of biological and habitat conditions according to the habitat metrics (Section 3.5) relative to Properly Functioning Conditions (Appendix A).

Objective 3.2 (trends): Analyze for statistically significant spatial and temporal trends of biological and habitat metrics (annually), recognizing that statistically significant trends may not be evident for many years (Section 3.5.2).

Question 4: Do in-stream biological health and in-stream/riparian habitat conditions correlate to changes in abundance, productivity, spatial structure, and diversity of the natural-origin fish in this population at the reach/subwatershed scale?

Objective 4.1 (trends): Identify statistically significant correlations between trends in select habitat metrics and trends in fish population metrics (e.g., abundance, productivity, spatial structure, and diversity) being conducted by other monitoring programs, recognizing that statistically significant trends may not be evident for many years. Specific habitat metric selection should focus on conditions known to limit fish populations and should be determined before monitoring begins.

2.1.1.3 Landscape

For monitoring in-stream conditions, characterizing status and trends in the surrounding landscape can help separate the regional influence of natural variability from the more localized impacts (both positive and negative) of human actions. Although the following "landscape" monitoring questions are not explicitly addressed by the in-stream monitoring activities that form the majority of the recommendations of this Design Report, the questions remain highly relevant. Furthermore, the analyses they will generate are critical to several of the habitat and Qa/Qx monitoring elements of this program (particularly Questions 2 and 8). For these reasons, the importance of this category has been recognized since Phase 1 of the HSTM project (where it was termed "Landscape-Level Conditions").

Question 5: Where on the landscape are key potential land-use activities occurring, and in what watersheds are one or another of these activities dominant?

Objective 5.1 (status): Identify subwatersheds of the Lower Columbia Region at a suitable size to support other monitoring efforts under this program (i.e., 2.5-50 km^2, the recommended size of the Qa/Qx catchment areas) having "dominant" land uses of urban, agriculture, or recent (<20 year) forest harvest. Also identify subwatersheds with dominant intact (>20 year old) forest cover for use as regional controls (see Objective 2.2).

Question 6: Are land-cover changes occurring at detectable rates across the Lower Columbia Region, and if so where are they occurring?

Objective 6.1 (trends): Identify and quantify areas of land-cover change in subwatersheds of the Lower Columbia Region that drain to habitat and/or Qa/Qx monitoring sites at 5-year intervals. A regionally relevant example of demonstrated utility is the 12 land-cover categories of King County's recent report, "Assessing Land Use Effects". If this presents an infeasible magnitude of GIS and airphoto analysis at the scale of the entire Region, however, then reduce the level of effort required by either (1) restricting the spatial domain to only those subwatersheds that are largely or fully included within Urban Growth Areas, or (2) conducting a GIS-only evaluation of a larger region but using fewer categories that do not require parallel GIS-airphoto analysis.

Objective 6.2 (trends): Identify and quantify how land cover is changing within a selected buffer zone (e.g., 60 m) around channels included in the Qa/Qx and habitat monitoring elements, at 5-year intervals, using the same land-cover categories as for Objective 6.1, and restricting the analysis to a fixed distance (e.g., 1 or 5 km) upstream of each monitoring site.

2.1.2 Municipal stormwater NPDES permit-related questions and objectives

Although fully nested within the regional status and trends monitoring effort, for which questions and objectives are presented above in Section 2.1.1, southwest Washington municipal stormwater NPDES permittees have specific monitoring needs and requirements that are unique to the areas that both are under their jurisdiction and are served by municipal separate storm sewer systems (MS4s).

Several of the following monitoring objectives are intentionally restricted to areas where stormwater management activities are required by the municipal stormwater permits. For purposes of developing objectives, the mapped boundaries of UGAs are assumed to represent the approximate permitted extent of MS4s as well areas targeted for future development and eventual inclusion into permitted cities (i.e., “urban NPDES areas”).

Clark County is the exception to this rule; its stormwater discharges outside of designated Urban Growth Areas (UGAs) is also regulated, under its Phase I Municipal Stormwater NPDES permit. However, because stormwater impacts and management approaches in rural areas are different from those in urban areas, the areas outside Clark County UGAs (but still within the Clark County Phase 1 municipal stormwater permit) are grouped for monitoring purposes with the remainder of the Lower Columbia Region that lies outside of municipal stormwater NPDES permit areas altogether.

2.1.2.1 Water quality and water quantity (Qa/Qx)

For the Qa/Qx NPDES-related monitoring, Question 1 of the “regional” monitoring effort is repeated in this section, because the specific monitoring needs of the MS4 municipal stormwater NPDES permittees may require a different suite of metrics (or the same data collected but at more frequent intervals). A second question in this section targets a specific subset of these potential sampling sites for which additional insight may be derived with the inclusion of opportunistically-selected locations.

Question 7: What are the status and trends of water quality and stream flow in surface waters draining subwatersheds that are primarily within the jurisdiction of municipal stormwater NPDES permittees?

Objective 7.1 (status): In streams in urban NPDES areas, evaluate whether water-quality conditions generally support the watershed-specific beneficial uses identified in WAC 173-201A-602 (http://apps.leg.wa.gov/WAC/default.aspx?cite=173-201A-602), using the metrics as recommended in Section 3.5.1. Locations should include “legacy sites,” to take advantage of the longer record that these can provide for Objective 7.2. Note that the status of water quality and stream flow in the non-UGA but permitted portion of Clark County permit area is addressed in Objective 1.1 above, and so an equivalent effort is intentionally not duplicated here.

Objective 7.2 (trends): For the population of sites measured under Objective 7.1, evaluate whether measured water-quality metrics show statistically significant trends over a 10-year period towards the best conditions as represented by the population of sites in the regional monitoring (i.e., from Objective 1.1) and described as "Properly Functioning" in NOAA (1996).

Question 8: What are the status and trends of water quality and stream flow in surface waters that are being affected by stormwater discharges from urban areas first developed under requirements of the 2013 municipal stormwater permits (recognizing that such areas are limited and will likely require opportunistic selection from the larger population of sites identified for Objective 7.1)?

Objective 8.1 (status): In streams whose catchment areas now drain primarily non-urbanized areas within Urban Growth Areas, evaluate whether water quality generally supports the watershed-specific beneficial uses identified in WAC 173-201A-602 (http://apps.leg.wa.gov/WAC/default.aspx?cite=173-201A-602) and meet the "Properly Functioning" conditions of NOAA (1996).

Objective 8.2 (trends): In the sample population of Objective 8.1, evaluate whether measured water-quality and flow (i.e., stage) metrics show statistically significant trends over a 10-year period in those subwatersheds that have experienced measureable land-use changes while under provisions of the 2013 (or later) municipal stormwater permit.

2.1.2.2 Habitat

For the municipal stormwater NPDES-related monitoring sites, we repeat the text of Questions 3 of the "regional" monitoring effort in this section as a separate inquiry, because the specific monitoring needs of the municipal stormwater permits may require a different suite of metrics from that of the regional effort (or the same data collected but at more or less frequent intervals).

Question 9: What are the status and trends of in-stream biological health and in-stream/riparian habitat conditions that are primarily within the jurisdiction of NPDES stormwater permittees (in terms of both quality and quantity)?

Objective 9.1 (status): In streams in urban NPDES areas, evaluate the status of biological and habitat conditions according to the habitat metrics (Section 3.5.2) relative to Properly Functioning Conditions (NOAA 1996). As with Objective 7.1, non-UGA portions of Clark County will be assessed as part of the regional questions and objectives (Question 3).

Objective 9.2 (trends): Analyze for statistically significant spatial and temporal trends of biological and habitat metrics (annually) in urban NPDES areas, recognizing that statistically significant trends may not be evident for many years.

Question 10: Do in-stream biological health and habitat conditions correlate to changes in observed abundance, productivity, spatial structure, and diversity of the natural-origin fish in this population (reach/subwatershed scale)?

Objective 10.1 (trends): Identify statistically significant correlation between trends in select habitat metrics and trends in fish population metrics (e.g., abundance, productivity, spatial structure, and diversity) being conducted by other monitoring programs, recognizing that statistically significant trends may not be evident for many years. Specific habitat metric selection should focus on conditions known to limit fish populations and should be determined before monitoring begins.

2.2 Target Populations

Within the broad guidance provided by Phase 1 of this project, long-standing considerations for effective monitoring locations were applied to develop the overall spatial design. Monitoring sites should be selected across the Lower Columbia Region within the Washington portion of the ESU, drawing from the "Washington Master Sample," a common set of random sites along the state's rivers and streams developed for use in comparable, complementary monitoring among separate monitoring organizations and across geographic scales. The master site list has 387,237 points in Washington, of which more than 100,000 are located in the Lower Columbia ESU. The Master Sample also includes legacy site locations. If desired, site selection can be based on a combination of preemptive identification of legacy sites having suitable long-term datasets, plus additional randomly selected sites/reaches (pseudo-random site selection); otherwise, a strictly random selection can be made from the Master Sample. The final choice between a pseudo-random and fully random site selection process will be made during preparation of the Implementation Plan.

Within the context of the Master Sample, the target populations from which sites will be selected for Qa/Qx and habitat monitoring sites have not been assumed to be identical, given the intrinsic differences between the chemical characterization of a flowing continuum of water and the physical characterization of a specific location or reach of channel. In other words, there is no *a priori* assumption that these two types of monitoring activities will draw from the identical population of Master Sample sites. The overall goal has been to identify effective monitoring locations that can address the monitoring questions and objectives that are guiding this HSTM program, rather than to require equivalent target populations as an overarching principle.

2.3 Spatial Strata and Site Allocation

Stratifying a sample population ensures that "like" is being compared to "like," and that a subset of that population provides a credible representation of its group as a whole. For example, published reference conditions for large woody debris loading distinguish between values for wide rivers and narrow streams; pool frequency is not equivalent in low-gradient meandering streams and steep cascade channels. Thus, subdividing the population of sample sites on the basis of physical attributes is commonly necessary to align with scientific understanding; subdivision on the basis of jurisdictional or regulatory considerations (e.g., recovery planning) may also be necessary to improve the utility of results for management. The drawback of stratification, however, is that the number of sites necessary to achieve meaningful statistical power increases geometrically with the number of strata and the number of categories within each stratum. Every unique combination of strata and categories requires an adequate sample size to yield a statistically valid characterization of conditions and to detect a specified minimum magnitude of change.

Determining how best to stratify the greater than100,000 points of the Master Sample within the Washington state portion of the Lower Columbia Region was accomplished by using the conceptual framework for stratification developed during Phase 1, followed by extensive querying of the Master Sample using a variety of alternative strata and categories to find combinations that were both meaningful from a technical perspective and feasible to implement. The geographic location of each Master Sample point and its association with river subbasin and regional recovery area were obtained from LCFRB and can also be uploaded from the website https://www.monitoringresources.org/Sites/Master/Detail/5. Gradient and upstream drainage area for each sample point were calculated from a 10-m Digital Elevation Model, along with the determination of additional geographical information (land cover classification, Urban Growth Areas and municipal stormwater NPDES permit areas). The attributes for each sample point were determined in GIS (methods detailed in Appendix B) and downloaded to an Excel spreadsheet for evaluation of various strata combinations. For consistency across data sources and spatial characterization, all areas are expressed in square kilometers; where acreages from TR3 are referenced in this Design Report, they have been rounded to their near-equivalent value in km^2.

Land cover, a recognized determinant of both water-quality and habitat conditions in Pacific Northwest streams, was categorized into three major types using the 2006 National Land-Cover Dataset (NLCD) developed by the Multi-Resolution Land Characteristics Consortium (http://www.mrlc.gov) and published by the US Geological Survey. Its results were applied without modification, except for the grouping of its 16 primary classes into the three categories used for stratification in the HSTM project. They are defined in the NLCD as follows:

HSTM Land Cover Category	2006 National Land Cover Dataset Class and Description
Urban	Developed, Open Space - *Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.*
	Developed, Low Intensity -*Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.*
	Developed, Medium Intensity - *Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79 percent of the total cover. These areas most commonly include single-family housing units.*
	Developed, High Intensity - *Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to100 percent of the total cover.*
Agriculture	Pasture/Hay - *Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.*
	Cultivated Crops - *Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled*
Forested	Definition: Deciduous Forest - *Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.*
	Evergreen Forest - *Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.*
	Mixed Forest - *Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of*

HSTM Land Cover Category	2006 National Land Cover Dataset Class and Description
	total tree cover.
Other classes, not included in the HSTM 3-part classification	Open Water - *All areas of open water, generally with less than 25% cover or vegetation or soil*
	Perennial Ice/Snow - *All areas characterized by a perennial cover of ice and/or snow, generally greater than 25% of total cover.*
	Barren Land (Rock/Sand/Clay) - *Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.*
	Shrub/Scrub - *Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.*
	Grassland/Herbaceous - *Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.*
	Woody Wetlands - *Areas where forest or shrub land vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.*
	Emergent Herbaceous Wetlands - *Areas where perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.*

The Master Sample database includes a field that identifies one of four land-cover categories (urban, agricultural, forested, other) associated with the point itself. For purposes of evaluating the feasibility of various stratification alternatives, this at-a-site land cover determination was assumed to correspond to the predominant land cover over the watershed as a whole. Once prospective sampling sites have been selected during the implementation phase, this assumption will be confirmed through GIS analysis and the land-cover category of the point adjusted if/as needed to reflect the land cover of the *watershed*, rather than just of the *point* (this was not judged feasible nor necessary for the entire 101,341 points in the LCR Master Sample in Washington State, however).

An additional stratum was defined from the management classification established in the Lower Columbia River Salmon Recovery Plan (LCFRB 2004), namely the clustering of subbasins according to the number of primary populations of ESA listed salmonids species that they support. Primary Populations are defined in the 2013 Lower Columbia River Salmon and Steelhead Recovery Plan as "a population that is targeted for restoration to high or very high persistence probability." Selection of subbasins according to the number of primary populations was included in the monitoring design, not because it is presumed to be a driver of habitat conditions but because future monitoring or management actions may be targeted, at least in part, by the relative importance of a subbasin for salmon recovery. To facilitate this application, subbasins were stratified into three groups (0-2, 3, 4+ primary populations) to help identify key subbasins relative to salmonid populations.

Based on expressed stakeholder concerns, information was also acquired to help identify sites subject to tidal or backwater effects from the Columbia River. A set of airphotos taken during the February 1996 flood on the Columbia River (about a 50-year event and the flood of record at USGS gage 14246900) and archived by Clark County (at http://gis.clark.wa.gov/mapsonline/?site=AerialPhotography&ext=1) proved invaluable in identifying extreme elevations for which water quality data might be influenced unduly by non-local-watershed conditions, or where physical habitat was the product of hydraulic conditions not experienced by other sites lying within what might otherwise be thought of as the "same" stratum.

2.4 Temporal Scale

The frequency of sampling has critical implications for both data utility and program affordability. Because the features measured by the two primary elements of the HSTM program, Qa/Qx and habitat, have such different temporal variability, the methods used to determine the appropriate temporal scales for their measurement (as well as the outcomes of those determinations) differ. For Qa/Qx, where water-column metrics can vary hourly or even more frequently, considerations of temporal scale embraces the guidance of NRC (2009), which states unequivocally that "In order to use stormwater data for decision making in a scientifically defensible fashion, grab sampling should be abandoned as a credible stormwater sampling approach for virtually all applications" (p. 8). Although this guidance applies strictly just to the monitoring of stormwater discharges, it is likely to be applicable to receiving waters that are strongly influenced by stormwater discharges as well. Until data prove otherwise, episodic grab sampling is not anticipated to generate statistically meaningful data for water-column constituents and so is not included in the monitoring design recommended here. For less transient Qa/Qx data (such as sediment chemistry), however, and for all of the physical habitat metrics, the preliminary recommendations from Phase 1 as modified by the guidance of other published reports have provided the basis for final recommendations here.

2.5 Signal to Noise

Effective environmental management requires monitoring information that is accurate, precise, and ecologically relevant (Kaufmann et al. 1999). Accuracy reflects the proximity of measurement results to the true value; precision reflects the repeatability of the measurement; and ecological relevance requires meaningful information for interpreting controls on biota (limiting factors) or impacts of human activity.

An important consideration in this long-term, broad-scale monitoring design was to explore precision in the proposed metrics in order to address two key concerns: 1) select repeatable metrics that yield reliable results and 2) consider the sharability of data with varying degrees of reliability and potentially different collection protocols. It's essential to understand the first concern in order to inform the second. Signal to noise (S/N) is a commonly used measure of precision in statistical analyses and for interpreting differences in subpopulation means (Zar 1999).

Signal to noise is the ratio of variance between sites and the pooled variances of repeatedly visited sites. Kaufmann et al. (2014) provide the following explanation: "High noise in habitat descriptions relative to the signal (i.e., low *S/N*) diminishes statistical power to detect differences among subpopulations. Imprecise data limit the ability to detect temporal trends (Larsen et al. 2001, 2004). Noise variance also limits the maximum amount of variance that can be explained by models such as multiple linear regression (Van Sickle et al. 2005, Kaufmann and Hughes 2006). By reducing the ability to quantify associations between variables (Allen et al. 1999, Kaufmann et al. 1999), imprecision compromises the usefulness of habitat data for discerning likely controls on biota and diagnosing probable causes of impairment…noise variance includes the combined effects of within-season habitat variation, differences in estimates obtained by separate field crews, and uncertainty in the precise relocation of the unmarked sample reaches (relocated on subsequent visits using global positioning system (GPS) receivers, map, compass, landmarks, and field notes)."

This variance is assessed by analyzing multiple sampling data during periods in which the measured conditions are believed not to have changed, and the resulting variance is compared to that of measurements made at the design sampling interval. Thus, literature-based ratings for S/N are only strictly applicable if both the sampling protocols and the intervals between sampling are equivalent to the monitoring program in question. Although these conditions of strict applicability are not commonly achieved in practice, useful guidance from prior analyses of S/N is nonetheless available and relatively widespread in published literature.

Initial scoping of this component of the monitoring design was conducted in consultation with LCFRB and PNAMP to fully understand the intended use of the results. Next, a literature review was conducted to explore the extent of existing, applicable S/N studies and determine the need for additional information and analysis. The results of that literature review were used to guide the water quality and habitat metric selection process and to stimulate stakeholder dialogue to determine what further S/N work will be needed as part of the Implementation Plan.

2.6 Metrics

The choice of metrics is closely interwoven with (1) the specific monitoring needs for addressing the questions and objectives, (2) the relative value of some metrics over others in their ability to detect meaningful changes, (3) the instream changes that environmental changes (both positive and negative) are anticipated to create; (4) regulatory requirements; and (5) financial constraints. Phase 1 evaluated a range of metrics and ultimately recommended the least extensive slate of all that had been considered, but subsequent evaluations have suggested that even the final Phase 1 list may still be overly costly to implement and includes metrics unlikely to produce meaningful results (e.g., metrics with low S/N). The integration of these considerations, based on both internal discussions and feedback from project stakeholders in public workshops and frequent conference calls, has led to the final suite of recommended metrics. In particular, development of a final set of metrics focused on identifying those with sufficient precision and replicability in order to select those that yield reliable results that could be shared with other monitoring programs.

The integration of these considerations, based on both internal discussions and multiple consultations with project stakeholders, has led to the final suite of recommended metrics in this Design Report. Although this suite of metrics is tailored to the goals and objectives of this study, they are sufficiently universal in range and applicability that other monitoring programs, even those with a different suite of metrics or focus of study, should be able to achieve meaningful integration of data and understanding.

2.7 Landscape Analysis

Several of the monitoring questions and objectives require some degree of "landscape" analysis (<u>Question 5</u>: Where on the landscape are key potential land-use activities occurring? and <u>Question 6</u>: Are land-cover changes occurring at detectable rates across the Lower Columbia Region, and if so where are they occurring?). They are included in the Design Report because their results will provide necessary support to other monitoring objectives, and the landscape stratification will provide necessary context for much of the monitoring data collected under the HSTM program.

The specific activities envisioned by the monitoring objectives associated with these questions are not further expanded upon in this report, however, because they involve region-wide spatial analysis and thus are not influenced by details of spatial design, target populations, or metrics. The specific methodology for their implementation, and their incorporation into the overall HSTM plan, will be detailed as part of the forthcoming Implementation Plan.

3 RESULTS

3.1 Spatial Design

Most of the monitoring objectives (Section 2.1) will be addressed using a *probabilistic design*, wherein sites are randomly selected across the entire area of interest. This approach stands in contrast to the more commonly implemented *opportunistic design*, with sites selected for ease of access, expert opinion, or other subjective criteria. However, two of the Qa/Qx monitoring objectives (Objectives 2.2 and 8.2) can only be addressed with a more directed, pseudo-randomized approach as first proposed in Phase 1 of this project (Tetra Tech 2013). The affirmation of a pseudo-randomized approach may be evaluated as part of the forthcoming Implementation Plan depending upon further input from the stakeholders and the availability of sufficient data for generating meaningful results.

3.1.1 Target populations for Qa/Qx sampling

Qa/Qx sampling will take advantage of the “continuity” of flowing water, under the assumption that most water-quality metrics vary spatially only gradually, if at all, along a given channel segment in the absence of tributary or manmade inputs. In other words, water quality data are assumed to represent the conditions within an entire *segment* of channel, not just the *point* at which it is taken. Thus, the population of Qa/Qx sites from which sampling locations will be drawn are segments (not individual points), and which have a specified range of drainage areas (see Section 3.2.1 for specific site-selection criteria and the boundaries of an individual segment). Within each selected segment, the location chosen for sampling should have only modest influence on the collected data, and thus ancillary considerations (such as site access or the reoccupation of legacy sampling sites that are located within the selected segments) can be incorporated without undermining the random spatial design.

This approach to target populations for Qa/Qx sampling reflects a modest adjustment of TR3’s recommendation for Qa/Qx sites being selected to drain “randomly selected subwatersheds,” defined in the Washington Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan (LCFRB 2010) as encompassing drainage areas of 3,000-12,000 acres (about 12 to 49 km^2), in order to characterize the cumulative status of the upstream area. In particular, the example provided in TR3 (their Figure 4, reproduced below in Figure 2) identified the set of gold circles as comprising all potential Qa/Qx sampling sites in this watershed. However, many of those sites lie on channels that actually drain as much as 130,000 acres (e.g., the three lowermost points along the mainstem Kalama River), over an order of magnitude greater area than recommended for suitable Qa/Qx sites. There are, in fact, a large number of Master Sampling sites along the river and its tributaries that *do* have drainage areas within the specified range; their positions are not limited to the mouths of designated “subwatersheds,” however, and restricting sampling to these locations is not essential to characterizing Qa/Qx conditions at a regional scale.

Thus, this Design Report recommends that *all* Master Sample sites within a specified range of drainage areas should be used to define stream segments as potential Qa/Qx sampling sites. To maintain data independence, however, no selected segment should drain into any other selected segment.

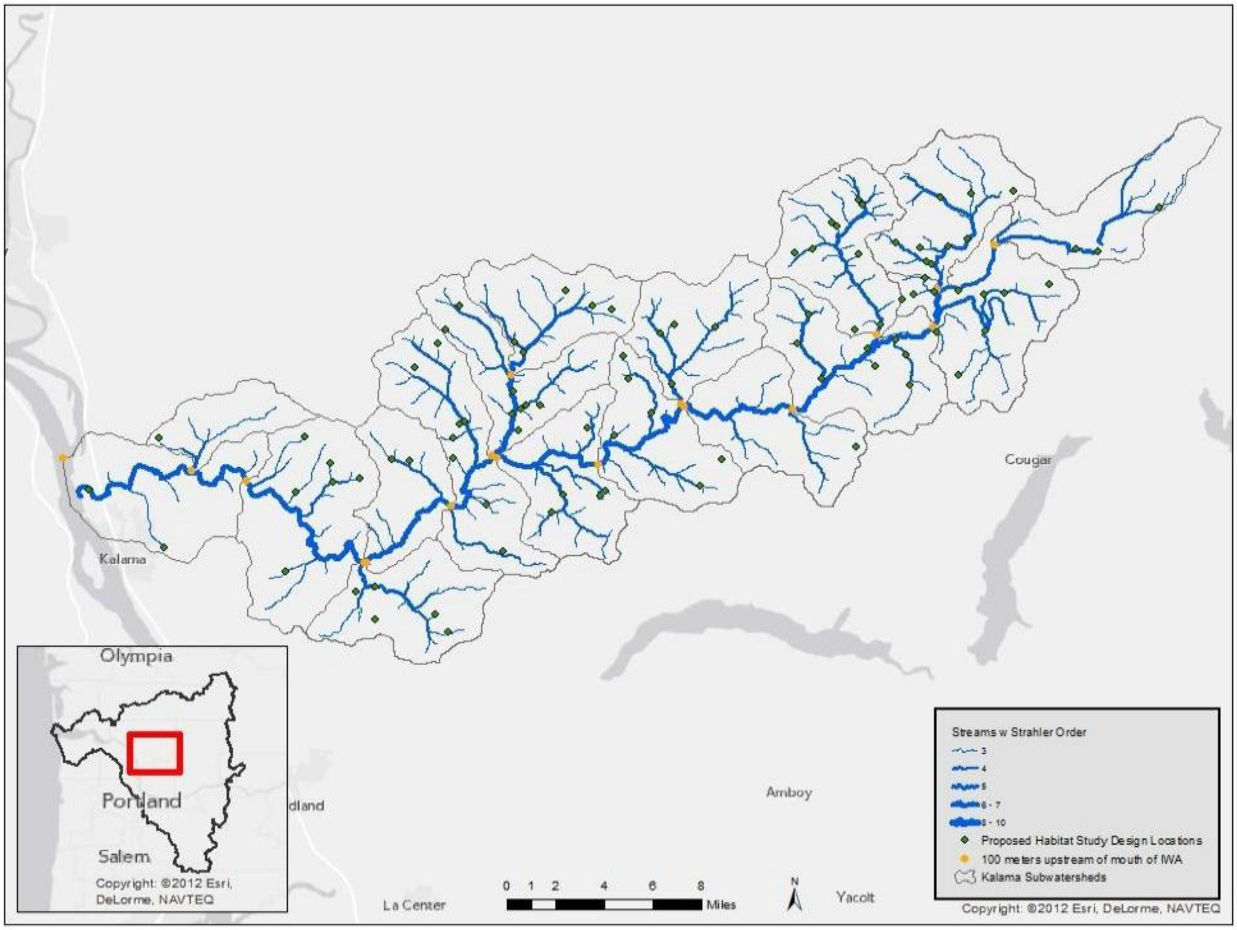


Figure 2. The envisioned distribution of candidate monitoring sites (TR3, their Figure 4). Note that although the gold circles along the mainstem river have subwatersheds associated with them that extend only upstream to the next such point, they in fact drain the entire upstream watershed and so many exceed greatly the target drainage area for Qa/Qx sampling.

Another recommendation of Phase 1 was that the population of potential sites for habitat monitoring should be restricted to those subwatersheds with designated Qa/Qx sampling. Although a laudable criterion for integrating the two types of monitoring, pragmatic limits on the total number of sampling sites would likely result in an overly restrictive population of prospective habitat monitoring sites once the Qa/Qx sites have been identified. Therefore, this earlier guidance is not applied in the analyses and recommendations that follow.

3.1.2 Target populations for habitat sampling

In habitat monitoring, stream reaches associated with selected Master Sample sites are the appropriate target population for assessing habitat, which is consistent with recommendations from Phase 1. Sampling sites will be located in reaches of continuous, freshwater streams with non-constructed channels[2] and lotic, perennial flow. To adequately represent variability across stream reaches throughout the ESU, habitat monitoring will sample randomly-chosen sites selected from all points that meet a specific set of strata-based selection criteria (Section 3.2.2). This design approach reflects a departure from recommendations provided in Phase 1, which as noted above recommended that habitat sites be restricted to those catchments with a Qa/Qx monitoring site at their outlets.

For both Qa/Qx and habitat sampling, areas subject to Columbia River backwater effects should be excluded from further consideration for this monitoring program, insofar as their conditions reflect very different drivers from sites elsewhere in the Lower Columbia Region and would violate the stratification criteria of comparing “like” vs. “like” (Section 2.3). The maximum extent of this potential concern is well-illustrated by the area of inundation from the flood of record (1996) on the Columbia River, focusing in on the Ridgefield-Woodland area just downstream of Vancouver (Figure 3).

[2] *Non-constructed channels* exclude irrigation channels, power canals, drainage ditches, and other waterways that may exhibit many of the following criteria (Washington State Department of Ecology 2012): 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.

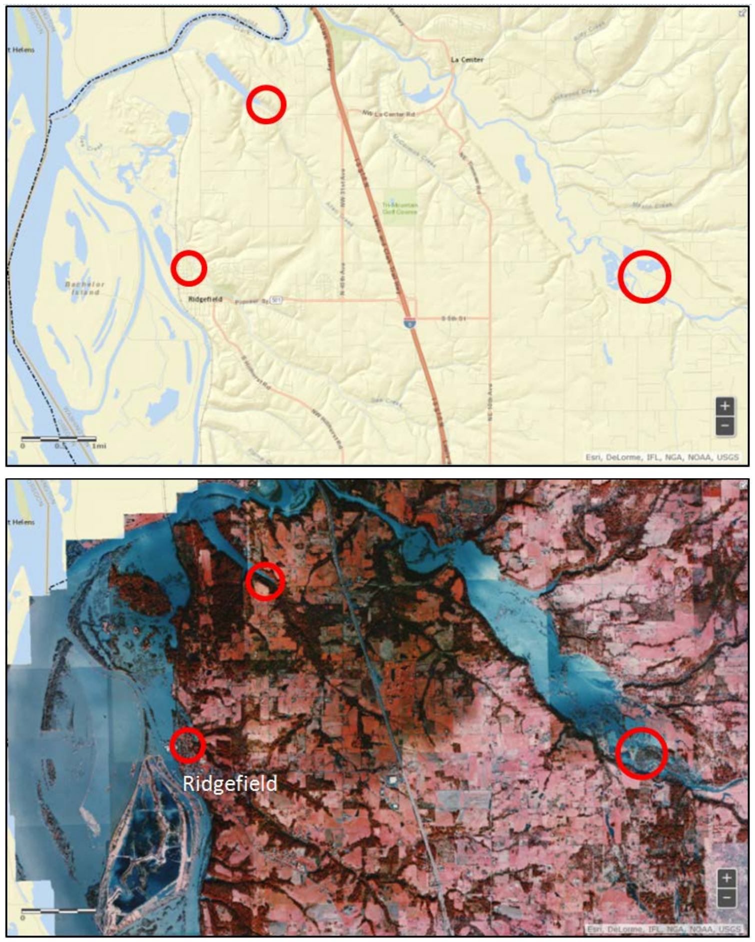


Figure 3. Location map (top) and aerial photo near the peak of the 1996 flood (bottom), showing the extent of backwater inundation on several low-lying steams (red circles). The upper elevation of standing water in the smaller of these channels Gee Creek, just north of Ridgefield) is about 20'. Map and imagery courtesy of Clark County.

These maps suggest that relatively few sites within the Master Sample are likely to be affected, and all lie within about 10' elevation of the low-flow surface of the Columbia River. During implementation, any selected sites should be screened for such a potential, but the likelihood of exclusion on this basis is judged to be quite low (and will be readily identifiable). This evaluation also addresses to the previously expressed concerns about tidally influenced channels, since the tidal amplitude throughout nearly all of the region is at most a few feet.

3.2 Spatial Strata and Site Allocation

3.2.1 Strata for Qa/Qx sites

The recommended stratification for Qa/Qx sampling differs somewhat between the two spatial scales of monitoring. For monitoring within Urban Growth Areas that lie within the jurisdiction of an NPDES stormwater permittee (i.e., urban NPDES areas), stratification should be based only on drainage area. Qa/Qx sampling *outside* of urban areas encompasses a more diverse landscape than found in the urban NPDES areas, however, and so a greater degree of stratification is needed to achieve meaningful representation and adequate coverage of the population of stream segments as a whole, considering a wider range of drainage areas, the predominant land cover of the contributing watershed, and the number of Primary Populations in the subbasin in which the monitoring site is located. Specific criteria and categories for sampling stratification also differ slightly between these two spatial scales and are described in detail below in Sections 3.2.1.1 and 3.2.1.2.

This recommendation reflects a refinement of Phase 1's recommended strata for Qa/Qx sites, which included inside/outside the jurisdiction of a NPDES municipal stormwater permittee (2 categories), Recovery Plan area (Cascade/Coast/Gorge) (3 categories), and drainage area (a single category of 3000–12,000 acres). A reevaluation affirmed this overall framework but recognized that an additional stratum based on predominant watershed land cover is also important to address the monitoring questions of Section 2.1, given the widely recognized, systematic differences in water chemistry from different land covers types. Also recognized were important differences in the application of Qa/Qx data depending on whether or not the sites are located inside of a municipal stormwater NPDES jurisdiction. Thus, the following discussion of site identification and location is separated by this jurisdictional criterion.

For any sampling effort, the number of sites needed to characterize water-quality conditions within a specified level of precision must be determined. This issue has been investigated in greatest detail with respect to monitoring urban stormwater quality, which provides a credible basis for assigning a minimum number of sites per strata combination absent more specific information. NRC (2009), reproducing the findings of earlier studies, offered a now-standard representation of the trade-off between data variability, desired level of analytical certainty, and required numbers of samples (Figure 4). For stormwater data, the coefficient of variation is widely reported to lie between about 0.5 and 1.0; to ensure an error in estimating the median value of a metric that is no worse than 50 to 100% of the true mean of the population requires between about 10 and 20 samples. For purposes of evaluating the consequences and feasibility of the monitoring design, a mid-point value of 15 samples per unique strata combination has been assumed for all monitoring efforts.

Although the quality of such an estimate is rather poor, the number of samples needed to substantially improve it, given the high variability of stormwater data in general, is rather daunting, and so striving for greater precision is not recommended at present for this monitoring program. Furthermore, the actual variability of the data collected from receiving waters may be significantly less than what has been found for stormwater discharges; once data collection begins, either a greater level of statistical confidence or a lower number of required samples may be determined.

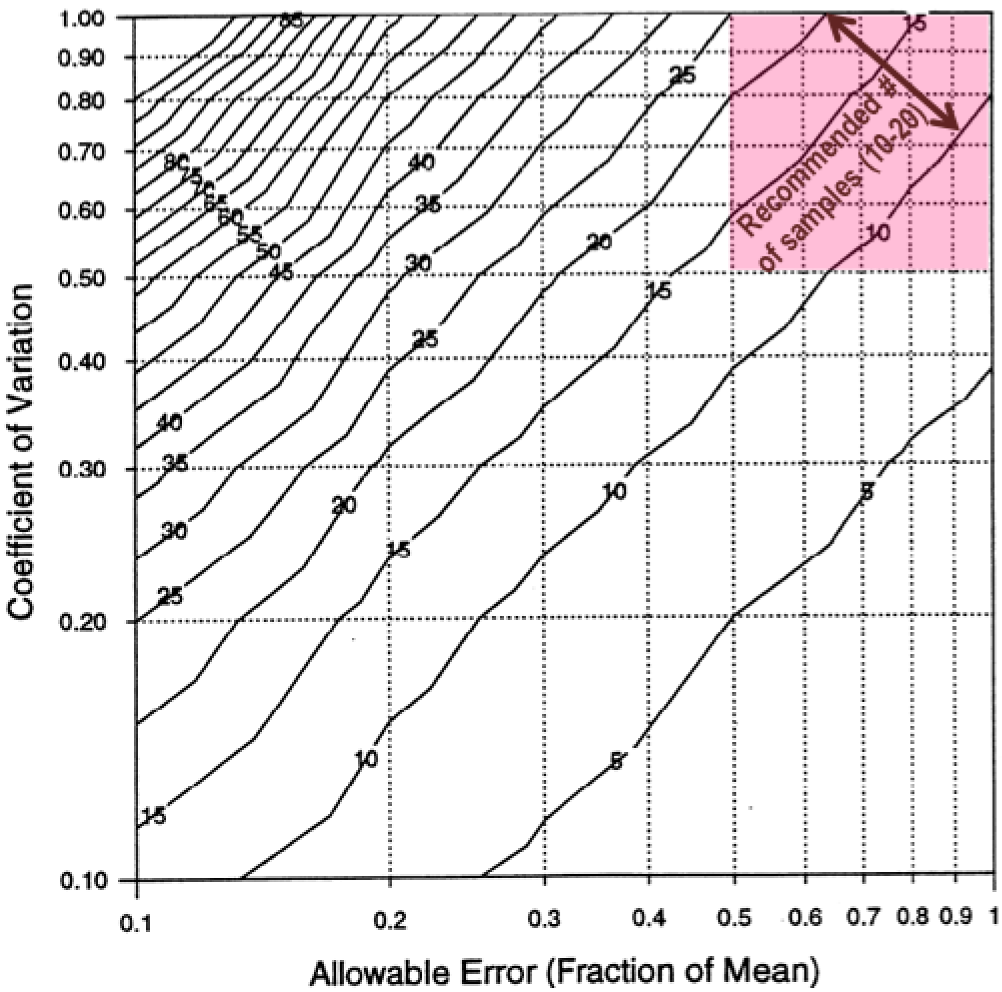


Figure 4. Number of samples (labeled diagonal lines) needed to characterize a sample median with a chosen allowable error, with a power of 80% and confidence of 95%. Figure 4.5 of NRC (2009), reproduced from Burton and Pitt (2002).

3.2.1.1 Qa/Qx within urban NPDES areas

For Qa/Qx sampling within the urban areas of municipal stormwater permittees, stream segments should have a predominant urban land cover in their contributing watershed with drainage areas between 2.5 and 50 km^2. By inspection of the distribution of segments and land cover types in these urban NPDES areas (see below), a total population of about thirty such stream segments exists across the LCR. Several times that number of watersheds with *non*-urban land cover but still within Clark County's jurisdiction exist (and so within their Phase I NPDES permit area), but their conditions should be adequately represented by the regional Qa/Qx sampling program (Section 3.2.1.2). Therefore, they are not recommended for specific inclusion via a distinct stratum.

The following strategy for site allocation for Qa/Qx sites in municipal stormwater NPDES permit areas is therefore recommended, guided by Questions 7 and 8 and their associated objectives:

- From the population of stream segments within urban NPDES areas and draining watersheds with predominantly urban land cover that meet a drainage-area criterion of 2.5-50 km^2, select at least 15 such segments.
    - If desired, selection can be based on a combination of preemptive identification of stream segments with legacy sites having suitable long-term Qa/Qx data, plus additional randomly selected segments that have a predominant coverage of urban land uses; otherwise, a strict random selection can be made. This choice between a fully random and a pseudo-random selection process will be made during preparation of the Implementation Plan, once the inventory of legacy sites is complete.
- Given the continuity of flow along a stream segment, the precise location for sampling should be of limited importance to the quality and applicability of Qa/Qx data (with the possible exceptions of temperature and stream benthos). We recommend beginning at the downstream end of a selected segment and moving upstream, identify the first sampling location guided first by logistical considerations of access and adjacent land ownership as identifiable through GIS and aerial photographs, followed by a field visit to each prospective site to confirm access and overall suitability for monitoring (particularly benthic macroinvertebrate sampling, which has specific requirements for gradient and substrate in order to yield meaningful results) (e.g., Washington State Department of Ecology 2014).

The rationale for this recommendation is based on a variety of considerations. Water-quality sampling to address NPDES-related questions (in particular, Questions 7 and 8 of Section 2.1) requires a sufficient number of independent sites to draw meaningful inferences, and those sites need to be located so as to reflect the predominant influence of the jurisdiction(s) covered by the permit. The present design focuses municipal stormwater-related Qa/Qx monitoring within just the *urban* areas (i.e., within designated UGAs), recognizing that monitoring data from eastern unincorporated Clark County (where the *non*-UGA areas covered under the Phase I municipal stormwater permit are located) will be most meaningful if grouped with data from the rest of the (non-UGA) Lower Columbia Region.

We explored the consequences of this recommended stratification in the Lower Columbia Region by identifying only those sites within municipal stormwater NPDES jurisdictional boundaries of Washington, excluding the small portion of Pierce County (which is fully covered by a Phase I permit) on the flanks of Mount Rainier within Mount Rainier National Park. Each point was coded by its upstream cumulative drainage area, using the following categories: 10-50 km^2 (similar to the original recommendation for Phase 1 of this project), 2.5-50 km^2 (an expansion of that original range to provide more potential sites), and those with greater (i.e., >50 km^2) or lesser (i.e., <2.5 km^2) drainage areas. The raw results within the Lower Columbia Region are shown in Figures 5-7 for the two areas with the largest areas under NPDES jurisdiction.

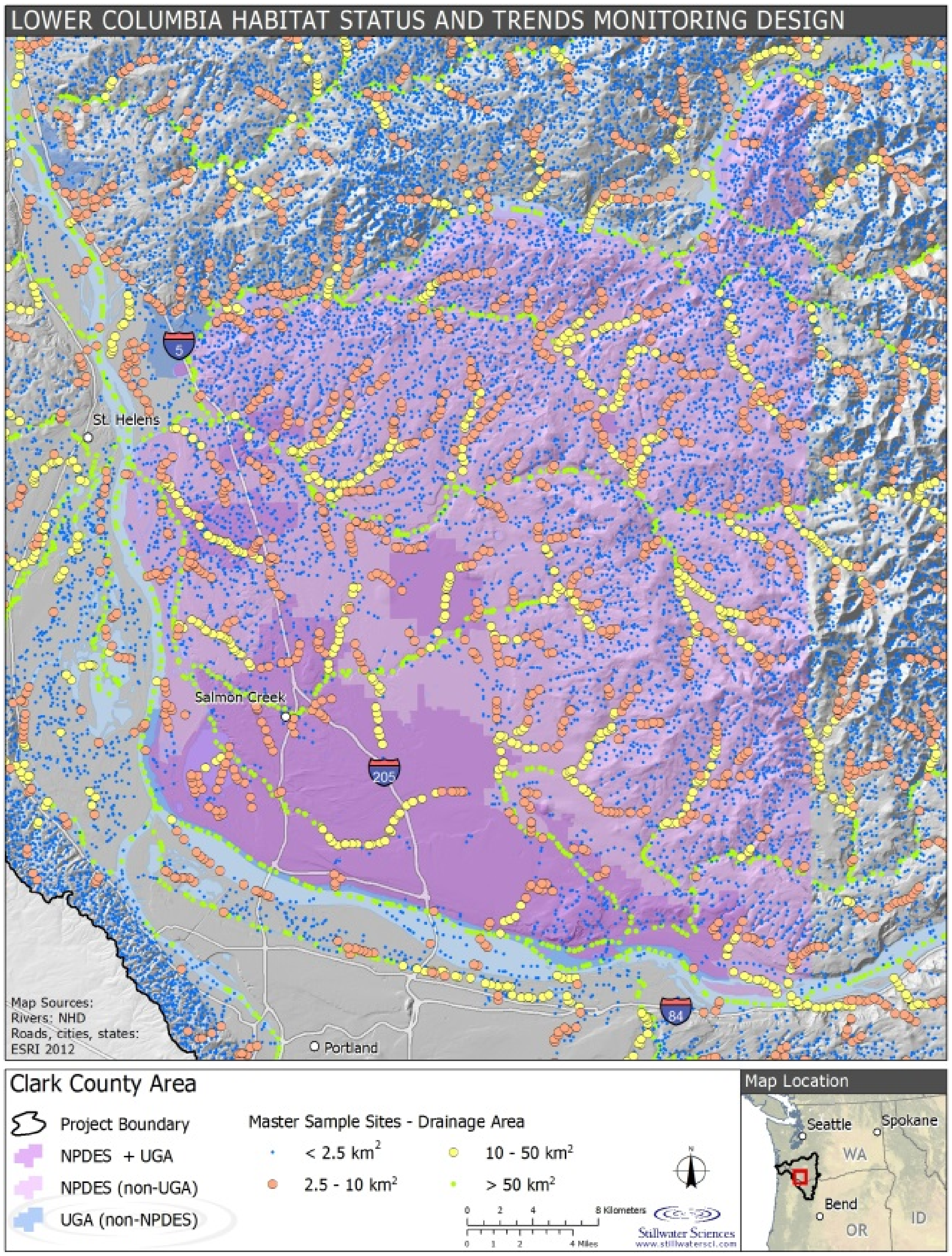


Figure 5a. GIS view of the Master Sample points in two areas covered by municipal stormwater NPDES permits, also highlighting Urban Growth Areas. Individual points meeting the recommended drainage-area criteria are highlighted by red circles (2.5–10 km^2 drainage area) or yellow circles (10–50 km^2). Blue dots are Master Sample sites with too small drainage areas to meet the recommended drainage-area criterion; green circles are sites with overly large drainage areas.

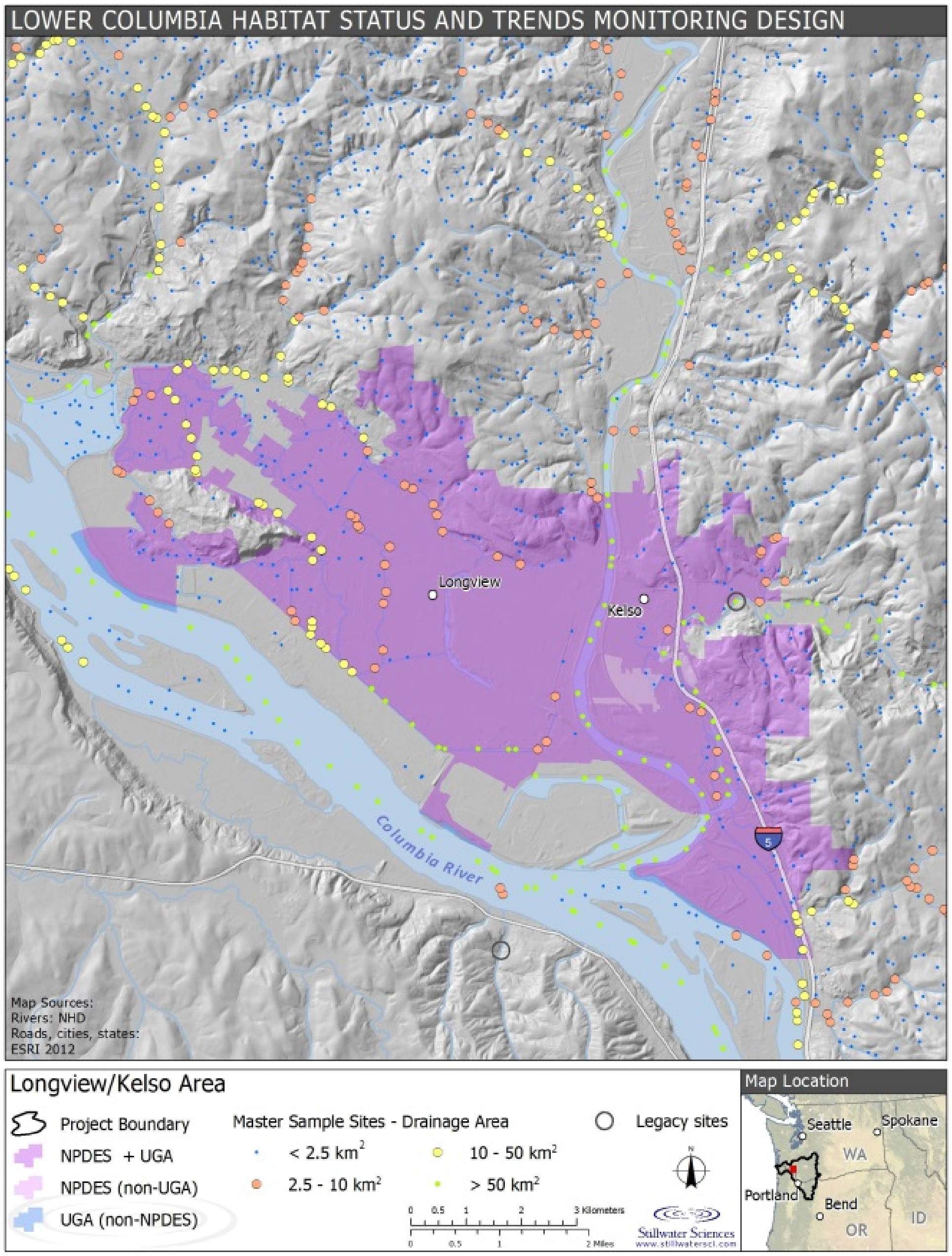


Figure 5b. GIS view of the Master Sample points in two areas covered by municipal stormwater NPDES permits, also highlighting Urban Growth Areas. Individual points meeting the recommended drainage-area criteria are highlighted by red circles (2.5–10 km^2 drainage area) or yellow circles (10–50 km^2). Blue dots are Master Sample sites with too small drainage areas to meet the recommended drainage-area criterion; green circles are sites with overly large drainage areas.

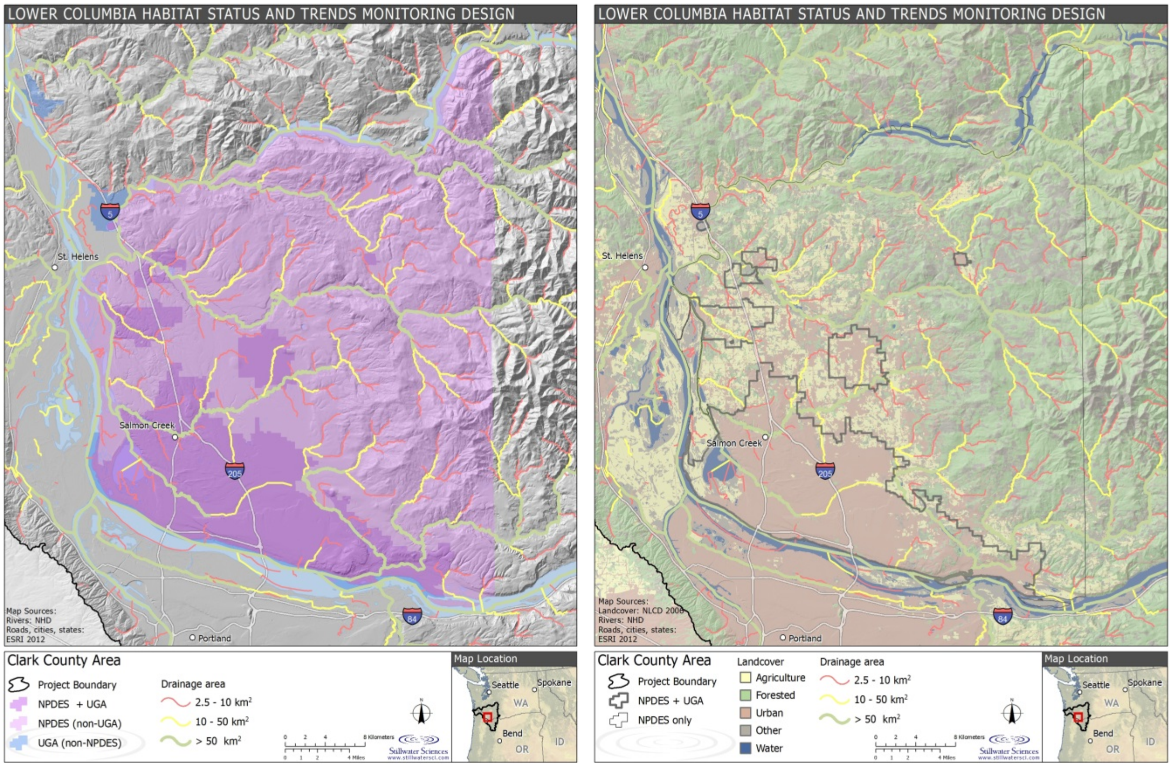


Figure 6. Stream segments of Clark County that contain Master Sample points meeting the recommended drainage-area criteria: red (2.5–10 km^2) or yellow (10–50 km^2). Pale green segments drain larger areas and would not be sampled under this stratification. Darker polygons (left panel) highlight the Urban Growth Areas within this region; other areas in Clark County are largely in agriculture, rural-residential, or forestry land uses (right panel).

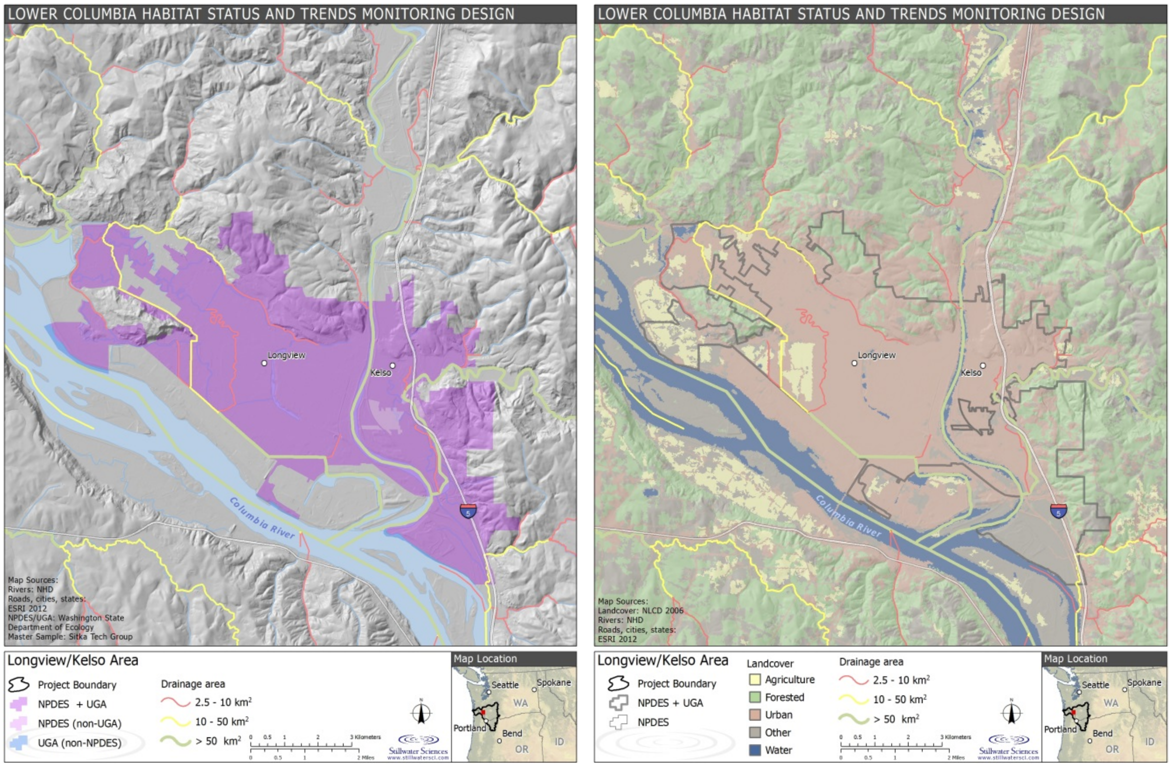


Figure 7. Stream segments in the Longview and Kelso area that contain Master Sample points meeting the recommended drainage-area criteria: red (2.5-10 km^2) or yellow (10-50 km^2). Pale green segments drain larger areas and would not be sampled under this stratification. Virtually all of Longview/Kelso is an Urban Growth Area (left panel); segments with drainage areas outside of the UGA drain primarily forestry land uses (right panel).

Within the two areas highlighted in the figures above, only a few segments with drainage areas of 10-50 km^2 (the "yellow" channels) drain predominately urban areas. In contrast, about two dozen channels with drainage areas between 2.5 and 10 km^2 (the "red" channels") lie within the UGAs; and although not all of these smaller streams have predominately urban watersheds, most of them do. Given this distribution of sites, this Design Report recommends that an expansion of the Phase 1 drainage-area stratum (i.e., to 2.5-50 km^2) be used to select Qa/Qx sites within the urban NPDES areas to ensure a sufficient population of sites that drain predominantly urban land uses, and with the expectation that most of the selected sites will drain no more than 10 km^2.

An additional consequence of this approach is that the Phase-1 recommended "Recovery Plan" stratum is largely irrelevant for municipal stormwater NPDES permit-related sampling. Of the 1,338 Master Sample points within permittees' jurisdictional areas meeting the 2.5-50 km^2 drainage-area criterion (exclusive of the portion of Pierce County on the upper slopes of Mount Rainier), over 96% lie within the "Cascade" subregion, with only one or two independent stream systems in either of the two other subregions. Therefore, there is no opportunity to achieve a statistically meaningful number of samples in any but the Cascade subregion. For this reason, together with the lack of any obvious scientific rationale for anticipating subregion-specific differences between Qa/Qx data sets, this stratum is abandoned altogether.

Although this approach should be sufficient to address Objectives 7.1 and 7.2, most sites selected are unlikely to be useful for addressing Objectives 8.1 or 8.2[3]. For these objectives, a more opportunistic (yet non-random) selection process will be necessary, wherein individual stream segments meeting the watershed-size criterion will need to be evaluated independently for recent development activity within its contributing watershed. Most such watersheds within current municipal stormwater NPDES boundaries are largely developed already, and so the conditions anticipated by Question 8 simply do not apply. However, some such areas already exist within the Region (e.g., Figure 8), and others are likely to be created in the future as urbanization continues and designated Urban Growth Area boundaries are shifted in response.

We recommend the continued inclusion of Objectives 8.1 and 8.2 even if they cannot be addressed feasibly at present with full statistical rigor, because their underlying question is a primary motivation for status and trends monitoring under the municipal stormwater NPDES permits.

Figure 8. Comprehensive Plan Map (Figure 3.1 of http://www.cityofbg.org/DocumentCenter/Home/View/598) for the northwest corner of the City of Battle Ground (left panel). Looking upstream (white arrow) into the 40-acre dark purple area, zoned "Mixed Use Employment," shows fully undeveloped land drained by a stream (right panel) that could be a potential location for long-term monitoring pursuant to addressing Objectives 8.1 and 8.2.

[3] Objectives (from Section 2.1):

7.1: In streams in urban NPDES areas, evaluate whether water-quality conditions generally support the watershed-specific beneficial uses.

7.2: For the population of sites measured under Objective 7.1, evaluate whether measured water-quality metrics show statistically significant trends.

8.1: In streams whose catchment areas now drain primarily non-urbanized areas within Urban Growth Areas, evaluate whether water quality generally supports the watershed-specific beneficial uses.

8.2: In the sample population of Objective 8.1, evaluate whether measured metrics show statistically significant trends in those subwatersheds that have experienced measureable land-use changes.

The magnitude of this recommended monitoring effort can be compared to another broadly analogous regional water-quality monitoring program overseen by the Puget Sound Stormwater Ecosystem Monitoring Program Work Group (SWG; http://www.ecy.wa.gov/programs/wq/psmonitoring/swworkgroup.html), a coalition of federal, tribal, state and local governments, together with business, environmental, agriculture, and research interests that was convened to develop a coordinated, integrated approach to quantifying the problems associated with stormwater in Puget Sound. Their final recommendations (as of July 2014) for regional status and trends monitoring for municipal stormwater permittees are as follows:

- Monitor stream benthos and sediment chemistry at 100 small streams sites; 50 inside UGAs and 50 outside UGAs.
- Sample periphyton at 30 sites inside UGAs.
- Collect small stream Water Quality Index (WQI), metals, and PAH data at no fewer than 30 inside and 30 outside UGAs.
- Monitor nearshore sediment chemistry and mussels at a total of 40 nearshore sites.

Recognizing that the two regions differ substantially in geography, access, population, and financial resources, the magnitude of the SWG effort is surely an upper limit on what is feasible for the Lower Columbia Region, at least insofar as program elements were to be funded solely by municipal stormwater NPDES permittees.

3.2.1.2 Regional Qa/Qx monitoring

As with the Qa/Qx monitoring within urban NPDES areas, the spatial stratification and site allocation for Qa/Qx sampling *outside* of urban growth areas ("regional Qa/Qx monitoring") must be guided by the monitoring questions (Section 2.1): What are the status and trends of water quality and stream flow in surface waters? (Q1); and, What are the status and trends of water quality in surface waters draining watersheds with a substantial fraction of previously forested land that has been recently cleared? (Q2). The spatial scale of these questions spans that of the entire Lower Columbia Region, and so unlike the NPDES-related monitoring there is no obvious reason to restrict the sampling domain to a particular maximum watershed size. Given the expanded range over which the data will be collected, sampling sites are recommended to be stratified into 3 categories of drainage area (0.6-2.5 km^2, 2.5-50 km^2, and 50-200 km^2).

The expanded geographic scope of the prospective sample population, and the organizational value of aligning with the regional habitat monitoring (as much as is both possible and technically relevant), suggest value in having additional strata for the "regional" Qa/Qx monitoring. These additional strata are recommended to be the number of Primary Populations of salmonid species within the contributing subwatershed (Figure 9) and the predominant watershed land cover. In addition to the three categories of contributing drainage area, these strata yield a total of 27 unique combinations of categories. Based on considerations previously discussed for obtaining representative data with sufficient statistical power, this would suggest the need for a total of ~400 sites. There is a potential for fewer sites, either because the variability of these Qa/Qx data may be systematically less than what has been documented for urban stormwater (i.e., less than 15 samples per unique category required for the same level of statistical confidence), or because some combinations of strata categories are not represented in the Lower Columbia Region (e.g., large urban drainages). Should the final tally of sites nonetheless prove infeasible to implement once budgetary other logistical considerations have been determined, then removing one of these strata (likely that for land cover, given the vast predominance of forested types relative to the other two) could reduce the total level of effort by up to two-thirds.

Thus, the preliminary recommended strata for regional Qa/Qx sampling are as follows:

- Number of Primary Populations (0-2, 3, 4+) = **3 categories**
- Drainage area (0.6-2.5 km^2, 2.5-50 km^2, 50-200 km^2) = **3 categories**
- Predominant watershed land cover (forested, agricultural, urban) = **3 categories**

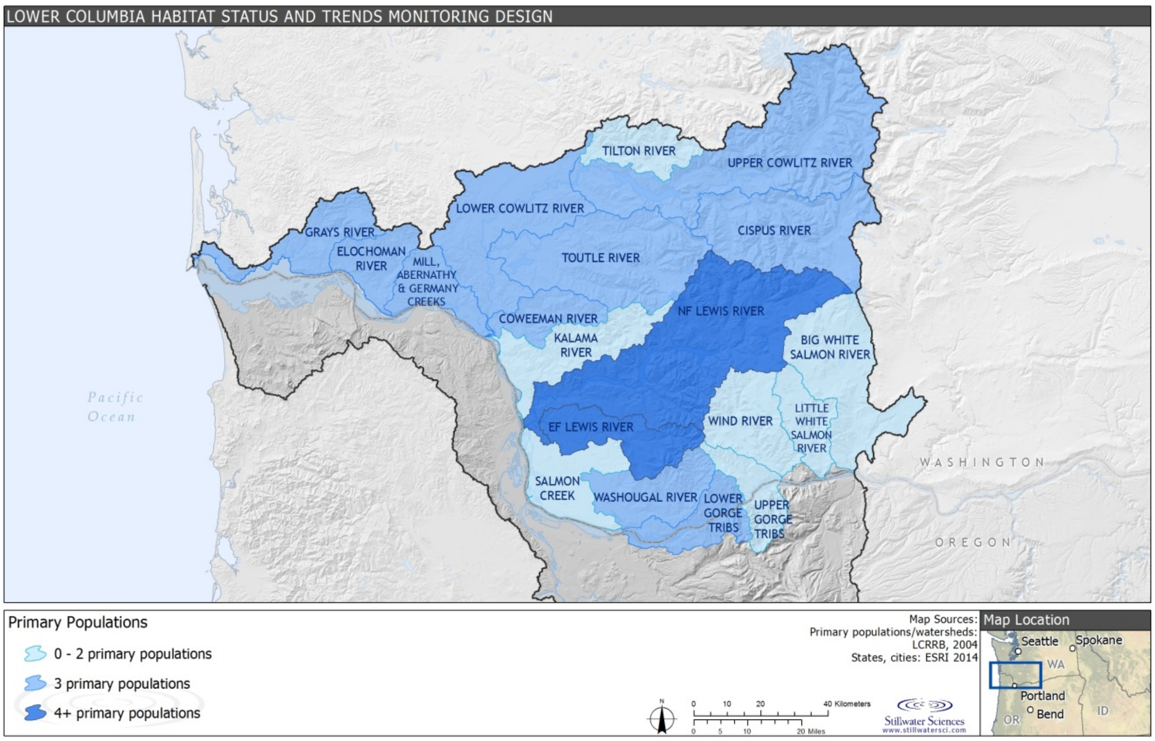


Figure 9. Categories for the number of Primary Populations in each of the subbasins of the Lower Columbia Region in Washington state.

Each of the unique combinations of categories defined by drainage area and Primary Populations have more than 400 Master Sample points (Table 1), indicating ample opportunity for random selection of a sufficient number of sites.

Table 1. Number of Master Sample points under the recommended regional Qa/Qx stratification.

Number of Primary Populations	Drainage area (km^2)			Totals
	0.6–2.5	2.5–50	50–200	
0–2	3,306	2,768	514	6,588
3	8,040	6,596	1,214	15,850
4+	2,952	2,410	468	5,830
Totals:	**14,298**	**11,774**	**2,196**	**28,268**

In addition, the Region is host to 12 rivers in addition to the Columbia (Big White Salmon, Chinook, Coweeman, Elochoman, Gray, Kalama, Lewis, Mill, Cowlitz, Salmon, Toutle, and Washougal) with drainage areas greater than 200 km^2 (about 77 mi^2). Each have unique characteristics such that they probably cannot be treated as part of a randomized, “representative” sampling scheme, and so their relevance to and inclusion in a regional monitoring program is acknowledged but not included in the following discussion. The merits and feasibility of their inclusion in a regional Qa/Qx monitoring program is deferred until the preparation of the Implementation Plan.

Ideally, the logistical and financial benefits of this coordinated HSTM program would be enhanced by using the same sample sites to support both municipal stormwater permit requirements and salmon recovery wherever possible. Unfortunately, in the 2.5-50 km^2 drainage area category for which the two groups overlap, only about 10% of the Master Sample points lie within municipal stormwater NPDES jurisdictions, and even less within their urban areas. This suggests that no more than one or two of the 15 regional Qa/Qx sites in this drainage-area category could be shared by both programs within each Primary Population subbasin category.

Specific locations for conducting the regional Qa/Qx sampling should use the same approach as described for the urban NPDES sampling (Section 3.2.1.1). Segments should be identified and stratified with respect to drainage area and number of Primary Populations. Beginning at the downstream end of a selected segment and moving upstream, identify the first sampling location guided first by logistical considerations of access and adjacent land ownership as identifiable through GIS and aerial photographs, followed by a field visit to each prospective site to confirm access and overall suitability for monitoring. Given the order-of-magnitude ranges in drainage areas, independence of data is likely even for geographically nested sites occupying different drainage-area categories; however, each of the sites selected *within* a given drainage-area category should preclude any additional sites selected up- or downstream along the same channel within the same category.

The two monitoring questions associated with this effort require different treatments. The full population of sites needed to address Question 1 (“What are the status and trends of water quality and stream flow?”) should be identified first, and then these locations should each be evaluated to determine which could also satisfy the conditions needed to address Question 2 (“What are the status and trends of water quality from recently cleared land?”). A rather small number will likely meet this second test, concentrated in the smallest drainage-area category and insufficient to provide statistically meaningful results. However, they may provide some site-specific indications of potential effects with minimal additional cost, offering some indications of whether a more concentrated, directed effort might be worthwhile.

3.2.2 Strata for habitat sites

Habitat monitoring sites do not have identical target populations or strata to those of Qa/Qx sites because the attributes being measured by these two types of monitoring are fundamentally different in several respects. Habitat data are collected on physical features at a site, rather than water-column attributes that are relatively constant over long distances. Habitat features are also more sensitive to instream channel dynamics, and so their dependency on stream power (a function of channel slope and discharge, for which drainage area is a credible surrogate for the latter) must be incorporated into the stratification to ensure representative results for the population as a whole.

Although future habitat-monitoring needs of municipal stormwater NPDES permittees may not differ from those in the rest of the region, the same jurisdictional discrimination for Qa/Qx monitoring is maintained in this monitoring design to retain future flexibility (urban NPDES areas). As such, sites for monitoring in urban NPDES areas and outside an urban growth area of the region are considered independently, albeit with a common set of recommended strata for both:

- Drainage Area (0.6-2.5, 2.5-50, 50-200, 200-1000, >1000 km^2) = **5 categories**
- Stream Gradient Groups (<1.5%, 1.5-3%, 3-7.5%, >7.5%) = **4 categories**
- Predominant watershed land cover (forested, agricultural, urban) = **3 categories**

In addition to these three strata common to both urban NPDES and non-UGA habitat monitoring, the number of Primary Populations in the subbasin [(0-2, 3, 4+) = 3 categories] is recommended as an additional strata for habitat monitoring in non-UGA areas. This supports salmon recovery priorities defined in the 2013 Lower Columbia River Salmon and Steelhead Recovery Plan and is consistent with Qa/Qx stratification.

These strata, modestly revised from Phase 1, are recommended to define habitat monitoring sites, guided by Questions 3, 4, 9 and 10 and their associated objectives[4]. As discussed in Section 2.3, a primary justification for stratification is to reduce environmental variation and compare conditions that are anticipated to be similar ("like" vs. "like"). This logic results in the selection of drainage area, stream gradient and land cover strata as depicted in Figures 10, 11 and 12. Primary Populations stratification serves to support a management goal of focusing restoration efforts in areas of greatest need in support of salmon recovery. However, given the limited number of sample sites within the urban growth area of the municipal stormwater NPDES permittees and the different goals and objectives for this domain, stratification by Primary Populations is not recommended for these areas.

The following logic was applied in defining the final list of recommended habitat strata:

- Drainage area categories align with those identified for regional municipal stormwater NPDES permit monitoring.
- Gradient categories are based on the broadly applied habitat classification established by Buffington et al. (2004). Figures 13 and 14 illustrate the effect of such gradient stratification on site locations.
- The three recommended land-cover classes (forested, agricultural and urban) are readily generated in GIS from the 2006 National Land Cover Dataset (NLCD). Although an additional "cleared" land-cover category would be relevant to address Question 6, it cannot

[4]**Question 3:** What are the status and trends of in-stream biological health and in-stream/riparian habitat conditions?

Question 4: Do in-stream biological health and in-stream/riparian habitat conditions correlate to changes in abundance, productivity, spatial structure, and diversity of the natural-origin?

Question 9: What are the status and trends of in-stream biological health and in-stream/riparian habitat conditions that are primarily within the jurisdiction of NPDES stormwater permittees?

Question 10: Do in-stream biological health and habitat conditions correlate to changes in observed abundance, productivity, spatial structure, and diversity of the natural-origin fish in this population?

be delineated for this phase of the HSTM program due to insufficient detail available in the NLCD 2006 dataset and the limitations noted in Objective 6.1. Accurate representation of changes in this land-cover category will require a combination of GIS and airphoto analysis during subsequent implementation phase(s) of the program.

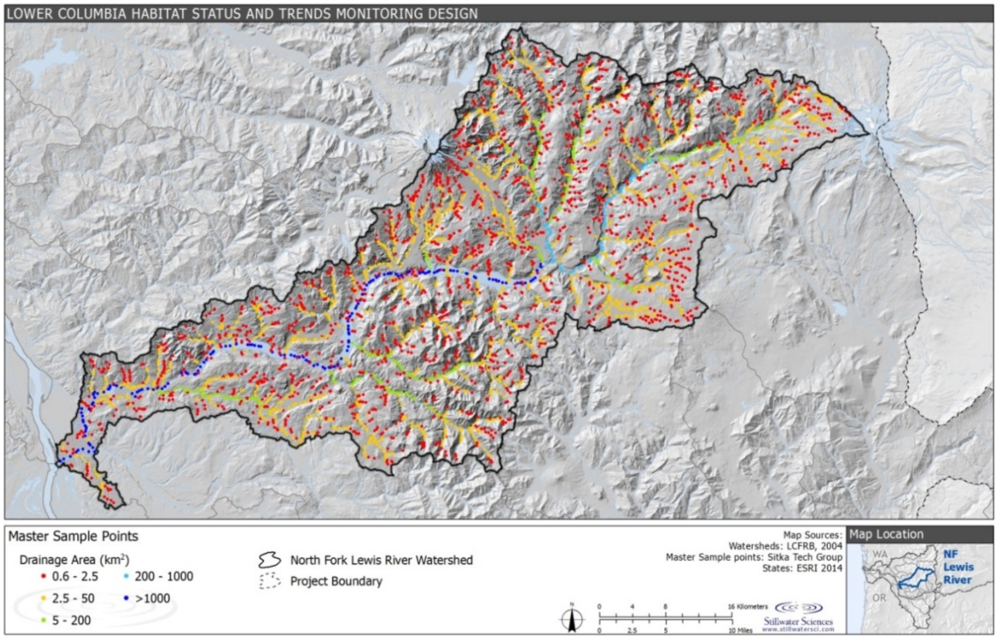


Figure 10. Drainage area categories for Master Sample points in the North Fork Lewis Watershed.

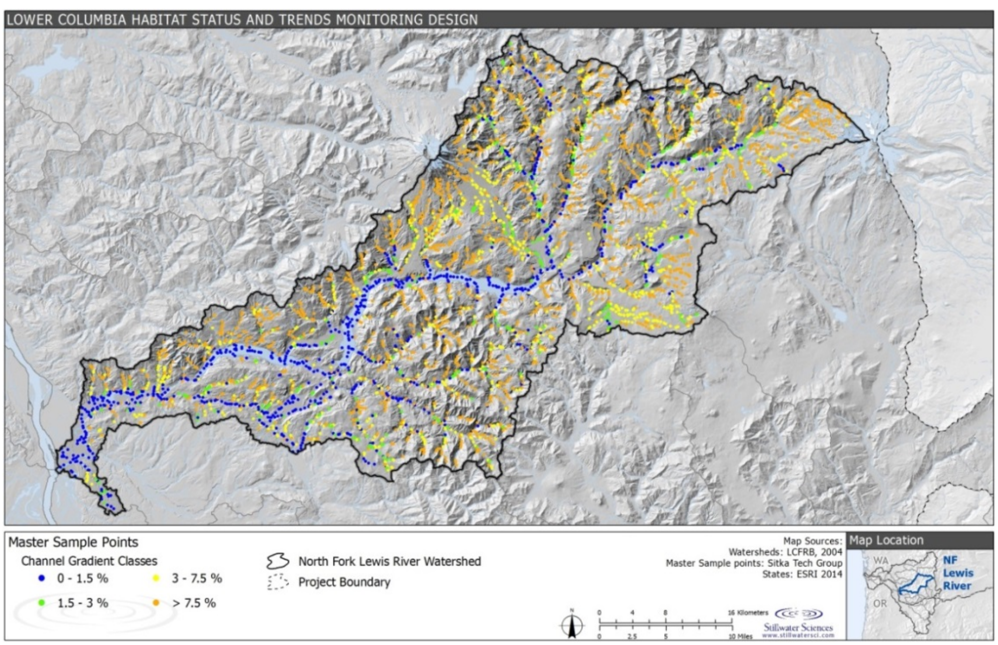


Figure 11. Channel gradient classes for Master Sample points in the North Fork Lewis Watershed.

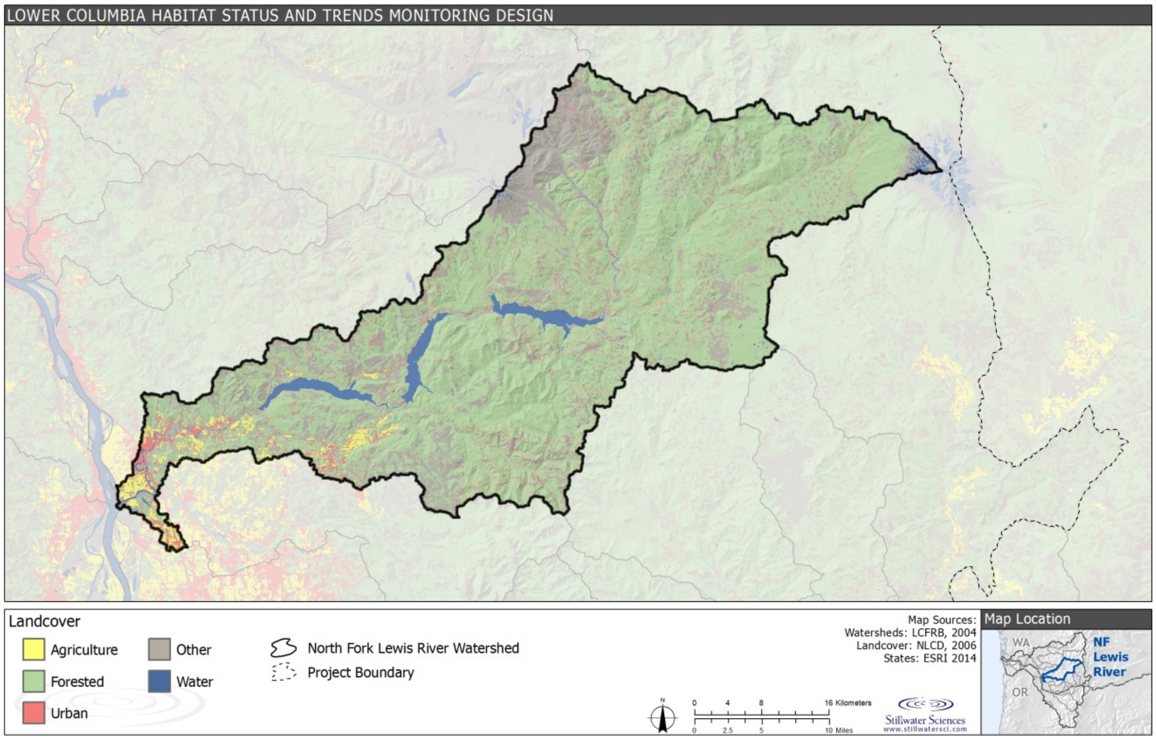
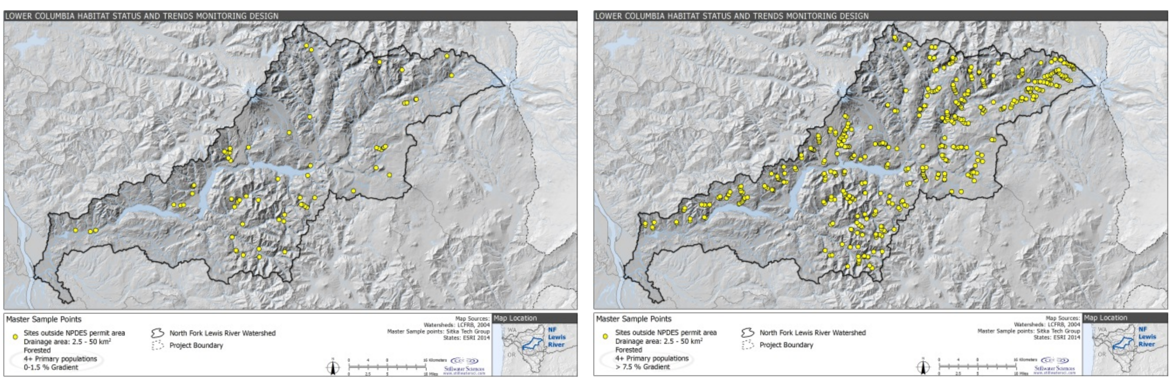


Figure 12. Land cover classes in the North Fork Lewis Watershed



Figures 13 and 14. Master samples points that illustrate the effect of varying gradient classes in the North Fork Lewis River Watershed. Figure 13 (left) shows Master sample points for 0-1.5% gradient; in contrast, Figure 14 (right) shows Master sample points for gradients 7.5% or greater. All other strata are held constant (land cover, drainage area, and location relative to UGA and municipal stormwater NPDES permit areas).

The recommended habitat strata reflect a refinement of the proposed habitat strata in Phase 1 of this project, which included three strata for habitat monitoring sites and resulted in 150 unique combinations (primarily as a result of the "subbasin" stratum): Inside/outside the combined area within an incorporated City boundary and/or an unincorporated Urban Growth Area (UGA) = **2 categories**; Subbasin (as defined in recovery plan) = **25 categories**; and Stream Power (Strahler stream order or channel gradient) = **3 categories**. Subsequent reevaluation of this framework affirmed these three strata in concept, but noted that: (1) replacing the UGA criterion with that of urban NPDES areas would better align the approaches for identifying Qa/Qx and habitat sites and likely serve the needs of municipal stormwater NPDES jurisdictions better, and (2) the sheer number of recovery plan subbasins (25) would likely render any framework that included this stratum infeasible. In an effort to support recovery objectives while maintaining a feasible number of monitoring sites, this Design Report recommends a stratum based on Primary Populations rather than subbasins, resulting in significantly fewer categories while maintaining a link to recovery planning priorities. In addition, "stream power" as a channel attribute requires *both* channel gradient and a measure of discharge, of which drainage area is a more reliable representation than stream order. Watershed land cover has been included in the present recommendation, insofar as it is likely to be as important a determinant of habitat as it is with water quality.

Although the total recommended habitat strata nominally define 240 unique combinations (urban = [5 × 4 × 3] + non-UGA = [5 × 4 × 3 × 3]), a significant fraction of them have too few monitoring sites in the Master Sample (Tables 2 and 3). Given the variability in the proposed habitat metrics and conditions to be monitored, determining the minimum number of sites necessary for valid statistical analyses has proven difficult to determine prior to implementation. An examination of published literature did not reveal a recommended minimum sample size or acceptable level of variability. Therefore, the monitoring design presumes a consistent number of habitat and Qa/Qx monitoring sites (i.e., 15 sites per unique strata combination).

Based on that criterion, only 9 unique strata combinations with 15+ potential monitoring sites are present within urban NPDES areas (Table 2). Outside of urban areas, a preliminary screening of the Master Sample suggests that no more than 75 unique combinations will have sufficient monitoring sites (Table 3). Not all potential monitoring sites will prove viable from consideration of access and other logistics, and so the number of strata combination may be further reduced if the number of viable locations within any given strata combination drops below 15. If contingency plans are necessary, stakeholders will be encouraged during preparation of the Implementation Plan to consider either less rigorous statistical thresholds (to reduce the number of sites) or a further reduced set of metrics. This will require greater certainty in the level of financial resources than is currently available.

Table 2. The number of Master Sample points in a given strata combination (based on land cover, drainage area and slope category) within the urban NPDES areas. Gray shaded cells include 15 or more sites.

Drainage area	Slope	Forested	Agriculture	Urban
0.6–2.5 km^2	<1.5%	9	14	52
	1.5–3%	7	6	17
	3–7.5%	9	0	21
	>7.5%	11	0	8
2.5–50 km^2	<1.5%	15	21	111
	1.5–3%	13	0	16
	3–7.5%	2	0	10
	>7.5%	1	0	1
50–200 km^2	<1.5%	6	2	22
	1.5–3%	1	0	0

Drainage area	Slope	Forested	Agriculture	Urban
	3–7.5%	1	0	0
	>7.5%	0	0	0
200–1,000 km^2	<1.5%	1	1	16
	1.5–3%	0	0	0
	3–7.5%	0	0	0
	>7.5%	0	0	0
>1,000 km^2	<1.5%	0	0	1
	1.5–3%	0	0	0
	3–7.5%	0	0	0
	>7.5%	0	0	0

Table 3. The number of Master Sample points in a given strata combination (based on land cover, Primary Populations, drainage area and slope category) outside of UGAs. Gray shaded cells include 15 or more sites.

Drainage area	Slope	Forested			Agriculture			Urban		
		Primary population categories								
		0–2	3	4+	0–2	3	4+	0–2	3	4+
0.6–2.5 km^2	<1.5%	68	288	32	28	118	28	28	62	17
	1.5–3%	115	304	58	5	21	7	11	31	11
	3–7.5%	434	959	298	9	20	9	46	68	24
	>7.5%	1629	3313	1300	10	20	2	90	130	32
2.5–50 km^2	<1.5%	199	671	123	75	150	33	52	114	29
	1.5–3%	285	594	159	6	15	4	20	50	11
	3–7.5%	687	1111	516	5	8	2	44	44	16
	>7.5%	628	1392	549	0	8	0	0	0	0
50–200 km^2	<1.5%	97	236	101	30	23	1	25	29	3
	1.5–3%	98	138	57	5	4	0	6	6	2
	3–7.5%	44	127	42	1	1	0	0	6	2
	>7.5%	13	32	15	0	0	0	2	0	0
200–1,000 km^2	<1.5%	135	127	70	0	0	0	13	20	7
	1.5–3%	33	35	8	0	1	0	0	2	0
	3–7.5%	33	13	2	0	0	0	0	1	0
	>7.5%	10	9	2	0	0	0	0	0	0
>1,000 km^2	<1.5%	2	40	4	0	1	0	1	5	1
	1.5–3%	0	5	0	0	0	0	0	0	0
	3–7.5%	0	3	0	0	0	0	0	0	0
	>7.5%	0	0	0	0	0	0	0	0	0

The following strategy for site allocation is therefore recommended, guided by Questions 3, 4, 9 and 10 (those pertaining to the status and trends of habitat and biological health) and their associated objectives:

- From each of the unique strata combinations meeting their respective criteria, select 15 sites from the sample population. If desired, selection can be based on a combination of preemptive identification of stream segments with legacy sites having suitable long-term habitat data (such as EMAP metrics collected by Clark County at 10 long-term index sites), plus additional randomly selected sites; otherwise, a strict random selection can be made from the Master Sample. This choice will be made during preparation of the Implementation Plan.
- Identify a reach length segment of 20 times the average bankfull width (Harrelson et al. 1994, p. 10) downstream from the randomly selected site location to be sampled for all metrics requiring a "reach" (instead of a "point"). An example procedure for this identification is given in Washington State Department of Ecology (2014).
- Sites should be given a preliminary review of access and adjacent land ownership using GIS and aerial photographs, given that not all sites will be viable candidates for monitoring due to logistical constraints. If the site appears to be a viable candidate, a field visit will still be necessary to confirm access and overall suitability (see Washington State Department of Ecology 2014 for an example of specific criteria).

Note that the analysis of monitoring data needed to answer Questions 3 and 4 will need to rely on only those sites identified outside of UGAs. Questions 9 and 10 will rely on sites identified within urban NPDES areas.

The closest analogy to the program proposed here is Ecology's Watershed Health Monitoring (WHM) project (http://www.ecy.wa.gov/programs/eap/stsmf/), which collects data on river and stream health by region at approximately 350 sites across the state, most of which are sampled once every four years. Sites are stratified only by Strahler stream order into five categories, with at least 30 sites (total) distributed across these categories within each of the eight statewide salmon recovery regions (of which the Lower Columbia Region is one). In the preliminary document for this program (Cusimano et al 2006) a suite of habitat measurements similar to those recommended for this program (Section 3.5) were specified, requiring about a day's field work for a crew of three:

- % Substrate by size e.g., % fines or % sand/fines
- Embeddedness: % bottom particles' surfaces that are surrounded by sand/fines
- Relative bed stability = observed diameter vs. predicted
- % of bank that is unstable (with actively eroding banks)
- Fish cover by type % of wetted channel with cover
- Mean residual pool vertical profile area
- Thalweg depth; bankfull depth
- Wetted width; bankfull width
- Bankfull or wetted cross-sectional area (channel capacity)
- Sum of length of side channels
- LWD pieces, by length, diameter, and position - standardized to km reach;
- Large wood volume estimated from size class tally

- Riparian vegetation structure (% cover in 3 layers, by type, size)
- Percent canopy as measured with a densiometer
- Riparian disturbance

If this state-wide allocation of effort reflects the general magnitude of effort likely to be feasible in the Lower Columbia Region under the present effort, then a total of about 90 unique combinations of categories is likely to represent an upper bound limit (and for which subsequent constraints may impose further reductions). The tally of currently proposed unique categories exceeds that upper bound limit. Reductions in the number of proposed sampling sites can be achieved in several ways: 1) if lower metric variability is determined, 2) by lowering the targets for statistical power/confidence, 3) by reducing the number of strata, 4) by condensing or truncating strata categories, and 5) by employing cost saving data collection measures (e.g. remotely-sensed data).

3.3 Temporal Scale

In addition to deciding where to sample (spatial scale), it is critical to consider the frequency of sampling (temporal scale). While some conditions change seasonally, others change on annual or longer timeframes. Section 3.5 below provides the appropriate temporal scale of monitoring according to specific metrics. Phase 1assumed that most sites would be visited once every five years, and that a subset of sites would be visited every year. However, a number of habitat metrics are more responsive to chronic or systematic changes in streamflow or sediment loading and so are herein recommended for annual data collection.

3.4 Signal to Noise Analysis – Phase 1

Phase 1 of the signal to noise (S/N) analysis resulted in a compilation of relevant literature from numerous sources (Kaufmann et al. 1999, Cusimano et al., 2006, Whitacre et al. 2007, Roper et al. 2010, Merritt and Hartman 2012) and the identification of an ongoing study to compare CHaMP and PIBO metrics (Jordan and Roper 2014). These S/N studies were conducted by the following monitoring programs and organizations:

AREMP—Northwest Forest Plan Aquatic and Riparian Effectiveness Monitoring Program;
CDFG—California Department of Fish and Game Protocols;
EMAP—EPA Environmental Monitoring and Assessment Program;
NIFC—Northwest Indian Fisheries Commission;
ODFW—Oregon Department of Fish and Wildlife;
PIBO—USDA Forest Service-BLM (effectiveness monitoring program for PACFISH/INFISH biological opinion);
UC—Upper Columbia Monitoring Strategy.

Kaufmann et al. (1999) provided a useful interpretation of S/N values as follows: “the adverse effects of noise variance in environmental monitoring are negligible when S/N >10, becoming minor as S/N decreases to 6, increasing to moderate as S/N decreases to 2, and becoming severely limiting as S/N approaches 0.” Such information is highly valuable when considering the suitability of a given metric to detect meaningful signals (trends). It is also useful to evaluate the potential for monitoring programs to share data. Although some monitoring programs may find their data to be sharable based on standard protocols, if one program produces high S/N ratios and the other low S/N ratios, it would be ill-advised to pool such data.

Along with reported S/N ratios, most studies provided "grades" for each metric to facilitate interpretation (Kaufmann et al. 1999, Cusimano et al. 2006, Whitacre et al. 2007, Merritt and Hartman 2012). S/N values reported by Roper et al. (2010) were converted to letter grades using the scoring scale in Merritt and Harman (2012). These results were compiled (the last column in Tables 4 and 5) and used as a guide for metric selection (Section 3.5). Metrics generating grades of D or F were removed from consideration unless there higher grades reported were in other studies. In such cases, the metrics were retained for additional consideration during the implementation planning process. The sharability issue with respect to protocols will be also be explored during Implementation planning (Phase II of the S/N study).

While the metrics analyzed, methods used, sampling timeframe and areas of application varied in each of the studies, the published literature provides a significant body of evidence from which management decisions can be made and additional study needs identified. In the early stage of monitoring design development, we proposed a compilation and analysis of relevant, existing data to address a subset of metrics not adequately characterized by the literature. However, given the abundant literature results and the significant challenge of obtaining suitable datasets not specifically collected for an alternative S/N study, we believe additional stakeholder input is necessary to determine the best course of action for any subsequent refinement of S/N analysis (e.g. decisions to be made regarding the sharability of data).

3.5 Metrics

The current recommended lists for Qa/Qx and habitat monitoring, subject to further evaluation as the scope of project funding is further refined, are given in the following two sections.

3.5.1 Qa/Qx metrics

The Qa/Qx metrics recommended for this HSTM program (Table 4, first two columns) have been identified on the basis of historic utilization and regional experience, prior recommendations from Phase 1 of this project (and archived in TR3), known issues with data quality and variability, cost of implementation, and direct relevance to the monitoring questions that are guiding this program (Section 2.1) (see Appendix C for a summary of the rationale for metric inclusion or exclusion). Relative to many other water-quality monitoring programs, the most noteworthy aspects of this recommended program are its emphasis on continuously monitored (or otherwise integrative) metrics, and the overall brevity of the list. These outcomes are driven by considerations long-articulated by project partners and stakeholders: statistical and scientific rigor of the chosen metrics, and feasible cost of implementation.

A rigorous, defensible metric that is useful for regional status and trends monitoring needs to meet several goals: it should not be subject to significant variability that is dependent only on the vagaries of the day or hour when it is measured, its variability due to watershed and in-stream conditions should be high relative to the random or non-systematic variability that cannot be eliminated by the sampling protocol (i.e., a high signal-to-noise ratio), it should be responsive to the environmental stressors of greatest concern to resource managers, and its collection and analysis should be affordable.

Many traditional water-quality metrics, including many considered in earlier stages of this project, fail one or more of these criteria. Most problematic are those that have been long-accepted as part of a "normal" or "conventional" stormwater monitoring program (e.g., National

Research Council 2009), but which are known either to have high random variability (e.g., total phosphorus, total suspended solids, pH; Merritt and Hartman 2012) or to express instantaneous conditions that would require continuous water-column sampling that is likely cost-prohibitive because of the required degree of site maintenance (e.g., dissolved oxygen, dissolved metals, dissolved nutrients, turbidity) to generate useful data on regional status and trends. As stakeholder involvement and budget are still being determined, the list of recommended metrics in this Design Report errs on the side of minimizing cost, with the expectation that if additional funds become available the value of spending them on additional data collection can then be evaluated.

Table 4 reflects the integration of these considerations, and in so doing it diverges from the final recommendations of Phase 1 in several important respects (see Appendix C). For the present recommendation, time-integrative metrics are emphasized, either through the use of reliable, low-cost continuous sensors that require little field maintenance (temperature, conductivity, stage), or with metrics that are integrative by nature (sediment metals, macroinvertebrates). The four metrics noted for "future consideration" likely meet the goals for utility, but their incremental benefits for characterizing the status and trends of streams of the Region are uncertain at present. and will be informed by the findings of other programs' efforts in 2015. These metrics will be (re)considered during development of the Implementation Plan, making use of new data and conclusions from other relevant studies across the region as they become available (such as Clark County's long-term index monitoring program) but they are not included in the primary Qa/Qx monitoring program as recommended here.

Table 4. Qa/Qx recommended metrics including the frequency of sampling.

Water-quality metrics	2015 HSTM Recommendation	"Conventional" stormwater pollutants[5]	2015 PS RSMP (7/2013 + 7/2014)[6]	2013 Phase 1 of HSTM (TR3, Table 2)	2015 USGS NAWQA #3[7]	S/N Rating
Water Temperature	X[c]	X	X[m]	hourly	X	B[1]
Sediment metals	X[a]		X[5]	X[5]		
Conductivity	X[c]	X	X[m]	X[m]	X	A[1]
Chloride	*	X	X[m]	X[m]		A[1]
Total Nitrogen	*	X	X[m]	X[m]	X	A[1]
Sediment PAHs	*		X[5]			
Other metrics						
Stage (surrogate for flow)	X[c]		X[m]	X[m]		
Macroinvertebrate Index	X[a]		X[5]	X[a]		C[1]
Periphyton	*		X[5]	X[a]		
Habitat metrics at Qa/Qx sites:						
Bankfull width, depth	one-time		X[5]		?	A[1] A (10.9 AREMP[2]) B (6.8 CDFG[2]),

Water-quality metrics	2015 HSTM Recommendation	"Conventional" stormwater pollutants[5]	2015 PS RSMP (7/2013 + 7/2014)[6]	2013 Phase 1 of HSTM (TR3, Table 2)	2015 USGS NAWQA #3[7]	S/N Rating
						C (2.5 EMAP[2]) A (24.7 NIFC[2]) C (2.8 ODFW[2]) A (58.1 PIBO[2]) A (20.2 UC[2]) A (24)[3] D (1.2 AREMP)[3] D (1.93 EMAP)[3] A (30.32 PIBO)[3]
Wetted width	each visit		X^5			A (14)[4] A[1]
Substrate	one-time		X^5			A/B[1] <u>% fines</u> A (21.73 AREMP)[3] A (69.94 EMAP)[3] A (21.24 PIBO)[3] A(15)[4]

X^a = annual data collection
X^5= data collection once per municipal stormwater NPDES permit cycle (typically 5 years)
X^c = continuous collection
X^m = monthly collection
* = for future consideration based on experience and findings of 2015 monitoring programs
Blank cells in the far right column indicate no signal to noise ratios or ratings identified in the literature search.

Footnotes:
1 Merritt and Hartman (2012)
2 Roper et al. (2010). Numbers indicate reported S:N ratios, converted to letter grades using scoring criteria from Merritt and Hartman (2012). AREMP – Northwest Forest Plan Aquatic and Riparian Effectiveness Monitoring Program; CDFG – California Department of Fish and Game Protocols; EMAP – EPA Environmental Monitoring and Assessment Program; NIFC – Northwest Indian Fisheries Commission; ODFW – Oregon Department of Fish and Wildlife; PIBO - USFS–BLM (biological opinion effectiveness monitoring program; UC – Upper Columbia Monitoring Strategy.
3 Whitacre et al. (2007)
4 Kaufmann et al. (1999)
5 See, for example, NRC (2009)
6 As recommended by dated memos/reports of the Stormwater Work Group for forming the Puget Sound Regional Stormwater Monitoring Program (PS RSMP); see https://sites.google.com/site/pugetsoundstormwaterworkgroup/swg-recommendations
7 Cycle 3 of the US Geological Survey's National Water Quality Assessment

3.5.2 Habitat metrics

The habitat metrics recommended below (Table 5) have been identified on the basis of historic utilization and regional experience, prior recommendations from Phase 1 of this project, known issues with data quality and variability, cost of implementation, and direct relevance to the monitoring questions that are guiding this program (Section 2.1). The habitat metrics, along with a listed subset of Qa/Qx metrics, are to be collected at habitat monitoring sites identified in Section 3.2.2. The majority of these metrics have been presented at workshops and vetted by project partners and stakeholders during the development of this HSTM design.

Metrics recommended for collection at all habitat sites fall in two broad categories: those that are not expected to change rapidly and need be measured only once per five years, and those for which annual re-measurement is appropriate. Five-year metrics comprise bankfull width/depth, reach length (20 times the bankfull width), channel type, number of habitat units, sinuosity, floodplain area, and length of side channel habitat. Annual measurements, to be made during a single day's site visit in summer months, comprise (categorical) bank stability, pools per unit length, residual pool depth, thalweg depth, density/distribution instream wood, substrate particle size (% composition by grain diameter), embeddedness, relative bed stability, shade at mid channel, riparian canopy (% cover), riparian understory (% cover), and flow category. Temperature should be measured at every visit; those sites with critically high values may merit more intensive and frequent measurements, but this can be determined only once implementation has begun.

In support of Objective 4.1 and 10.1 (seeking correlations in trends between habitat and fish-population metrics; Section 2.1), the metrics for habitat sites have been clustered according to categories of limiting factors as defined by NMFS (Hamm 2012) (Table 5). This is consistent with the presentation of metrics in Appendix B of the ISTM habitat monitoring report (PNAMP 2014). Additional detail about the metrics based on extensive prior reviews, including a summary of the rationale for metric inclusion or exclusion from Phase 1 to current, has been provided in Appendix D.

Table 5. Habitat metrics including the frequency of sampling, whether or not the metric was identified in Phase 1 of this HSTM program (TR3), the number of Lower Columbia Monitoring Programs collecting the recommended metric (Puls et al. 2014) and Signal/Noise ratings from various sources.

<table>
<tr><th>Habitat metrics</th><th>Current recommendation</th><th>TM3</th><th>Collected by LC Monitoring Programs</th><th>S/N rating[1]</th></tr>
<tr><td colspan="5">Limiting factor - Channel Structure and Form</td></tr>
<tr><td>Reach length</td><td>once</td><td>X</td><td>5</td><td>C (2.83 AREMP)[2] | B (9.16 EMAP)[2]
B (8.37 PIBO)[2]</td></tr>
<tr><td>Channel type</td><td>once</td><td>X</td><td>7</td><td></td></tr>
<tr><td>Density of habitat type</td><td>every 5 years</td><td></td><td>3</td><td></td></tr>
<tr><td>Sinuosity</td><td>every 5 years</td><td>X</td><td>7</td><td>A (10.9 AREMP)[3] | B (6.8 CDFG)[3]
D (1.28 AREMP)[2] | C (2.32 PIBO)[2]
C (2.5 EMAP)[3] | A (24.7NIFC)[3]
C (2.8ODFW)[3] | A (58.1PIBO)[3]
A (20.2 UC)[3] | A[4] | D (1.1)[5]</td></tr>
<tr><td>Bankfull width/depth</td><td>every 5 years</td><td>X</td><td>4</td><td>C (2.1 AREMP)[3] | D (1.7 CDFG)[3]
F (0.53 AREMP)[2] | C (4.01 PIBO)[2]
D (1.7 EMAP)[3] |B (6.1 NIFC)[3]
C (3.5 ODFW)[3] | D (1.5 PIBO)[3]
D (1.6 UC)[3] | B (6.5)[5]</td></tr>
<tr><td>Bank stability (categorical)</td><td>annually</td><td>X</td><td>7</td><td>A[4] | D (1.3)[5] (bank condition)</td></tr>
<tr><td>Pools per unit length</td><td>annually</td><td></td><td>5</td><td>D (1.0 AREMP)[3] | F (0.2 CDFG)[3]
D (1.8 EMAP)[3] | D (1.1 NIFC)[3]
B (5.5 ODFW)[3] | F (0.8 PIBO)[3]
D (1.6 UC)[3]</td></tr>
<tr><td>Residual Pool depth</td><td>annually</td><td></td><td>7</td><td>B (6.3 AREMP)[3] | F (0.2 CDFG)[3]
B (6.1 EMAP)[3] | C (4.9 NIFC)[3]
C (3.2 ODFW)[3] | B (7.4 PIBO)[3]
A (11.9 UC)[3] | A (pool unit depth)[4]
A (37.31 PIBO)[2] | B (9)[5]</td></tr>
<tr><td>Thalweg depth</td><td>annually</td><td></td><td>7</td><td>A[4] | B (6.9)[5]</td></tr>
<tr><td>Density/distribution instream wood</td><td>annually</td><td>X</td><td>7</td><td>A (53.3 AREMP)[3] | C (4.4 CDFG)[3]
A (10.8 EMAP)[3] | A (87.1 NIFC)[3]
A (24.5 ODFW)[3] | A (19.4 PIBO)3
A (13.6 UC[3])** | B,D[4]|B (7)[5]
B (AREMP)[2] | F (0.74 EMAP)[2]
D 1.19 (PIBO)[2]</td></tr>
</table>

Habitat metrics	Current recommendation	TM3	Collected by LC Monitoring Programs	S/N rating[1]
Limiting factor - Sediment Conditions				
Substrate particle size (% comp by particle size category)	annually	X	7	C (3.7 AREMP)[3] | B (6.9 EMAP)[3] B (9.4 PIBO)[3] | C (2.3 UC)[3*] A/B(percent fines)[4] | A (15)[5] A (21.73 AREMP) % fines[2] A (69.94 EMAP) % fines[2] A (21.24 PIBO) % fines[2]
Embeddedness	annually		5	C,A[4] | B (7.7)[5]
Relative bed stability	annually	X	3	
Limiting factor - Riparian Condition				
Shade at mid channel	annually	X	3	A[6] | A (15)[5]
Riparian canopy (% cover)	annually		3	A[6] | A (17)[5]
Riparian understory (% cover)	annually			B[6] | F (0.9)[5]
Limiting factor - Water Quantity				
Flow Category[7]	annually		7	
Limiting factor - Peripheral and Transitional habitats				
Floodplain area	every 5 years			
Length of side channel habitat	every 5 years		3	
Limiting factor - Water Quality				
temperature	TBD	X[ai]	3	B[4]

Blank cells indicate no signal to noise ratios or ratings identified in the literature search
1 When two grades are present, the first is for wadeable streams and the second is for larger rivers
2 Whitacre, Roper, and Kershber 2007;
3 Roper et al. 2010. Converted to letter grades using scoring in Merritt and Hartman 2012;
4 Merritt and Hartman, 2012
5 Kaufmann et al. 1999
6 Cusimano et al. 2006
7 free-flowing, sluggish (<1ft /sec), stagnant, dry
* $\log_e$ of D_{50} performed best
** $\log_e$ of LWD/100 m performed best

As previously discussed, a rigorous, defensible metric for regional status and trends monitoring needs to meet several goals:

- It should be tied to program-specific questions and objectives
- It should be responsive to the environmental stressors of greatest concern to resource managers,
- Its variability due to watershed and in-stream conditions should be high relative to the random or non-systematic variability that cannot be eliminated by sampling protocol (i.e., a high signal to noise ratio), and
- Its collection and analysis should be affordable.

Some traditional habitat metrics fail under one or more of these criteria. The table above reflects the integration of these considerations, and in so doing it diverges from the final recommendations of Phase 1 in some cases (see Appendix C).

3.6 Next Steps

Following this Phase 2 monitoring design will be the development of a full-scale Implementation Plan for the Lower Columbia Integrated HSTM Design, which will represent Phase 3 of the HSTM program. Prior to or concurrent with its execution, however, several outstanding issues will need to be addressed. They have been noted individually throughout the above Design Report where relevant, and they are restated below for ease of reference:

- Establish fiscal sideboards for Regional and NPDES-related monitoring to define the scope of a "feasible" program and so constrain the details of the final Implementation Plan;
- Choose between a pseudo-random and fully random site-selection process with respect to inclusion of legacy sites;
- Finalize the specific criteria for identifying sampling sites within a selected Qa/Qx segment;
- Quality-check GIS data for all selected sample sites with respect to drainage area, stream gradient, and watershed land cover;
- Specify the details of implementing the landscape analysis into the overall HSTM plan
- Identify the criteria for achieving adequate sharability of data; and
- Identify opportunities to link HSTM with specific fish monitoring programs and metrics

The Implementation Plan will be conducted in two parts: (1) Planning - Data Collection and Management, and (2) Reporting - Data Analysis and Interpretation. As included in the application for the Centennial Clean Water Grant issued by Ecology to fund Phase 3 of the HSTM project, LCFRB (in collaboration with Stillwater Sciences and HSTM stakeholders) have characterized the primary elements of the Implementation Plan. The effort, as described below from the Grant application text, will result in a complete implementation plan that describes how data will be collected, how quality will be ensured, and how the data will be interpreted (and not just reported).

At its most fundamental level, the implementation plan for the Lower Columbia ESU will describe how the monitoring design will be carried out in sufficient detail to ensure that data is shareable, and of adequate quality to answer the management questions and objectives. This implementation plan will outline protocols for data collection and quality assurance, develop data management protocols, develop indicators based on the management questions and objectives, and develop timelines, roles and responsibilities. Criteria for the identification of specific sampling locations once prospective sites have been selected identified from the Master Sample will be developed as part of this Implementation Plan (see Washington State Department of Ecology 2014 for one such example).

The Data Collection and Management task will use the results of a thorough signal to noise analysis to finalize metrics and measurements and guide discussion and identification of sampling procedures and field protocols. Sampling procedures refer to the collection of samples that are collected from the field site and are subsequently analyzed in a lab (water, sediment, macroinvertebrates, and periphyton). Field protocols refer to the methods used to make measurements of conditions at the site. This task will also outline Quality Control procedures for both field and lab work, data management procedures (storing and sharing of raw data), describe reporting conventions, and provide guidance on data verification, validation, and QA. These elements will be compatible with Ecology's Quality Assurance Monitoring Plan (QAMP) to the extent possible. Formatting the implementation plan to include these elements will facilitate the creation of a QAMP for entities who would conduct monitoring under the Lower Columbia HSTM design to address Ecology's management questions and objectives.

The Data Analysis, Interpretation, and Reporting task will describe the pertinent components of Water Quality, Habitat, and Landscape Indicators. These components include the sampling and measurement procedures, measurement quality objectives, quality control, how results are interpreted beyond just reporting the numbers, and data management, review and validation of metrics and indicators.

The effort described above will provide a complete implementation plan that describes how we will collect the data, how we will ensure quality, and how we will interpret (not just report on) the data.

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Appendices

Appendix A

Table of Properly Functioning Conditions

TABLE OF PROPERLY FUNCTIONING CONDITIONS (NOAA 1996)

The ranges of criteria presented here are not absolute; they may be adjusted for unique watersheds.

PATHWAY	INDICATORS	PROPERLY FUNCTIONING	AT RISK	NOT PROPERLY FUNCTIONING
Water Quality:	Temperature	50-57° F[1]	57-60° (spawning) 57-64° (migration &rearing)[2]	> 60° (spawning) > 64° (migration & rearing)[2]
	Sediment/Turbidity	< 12% fines (<0.85mm) in gravel[3], turbidity low	12-17% (west-side)[3] 12-20% (east-side)[2] turbidity moderate	>17% (west-side)[3], >20% (east side)[2] fines at surface or depth in spawning habitat[2], turbidity high
	Chemical Contamination/ Nutrients	low levels of chemical contamination from agricultural, industrial and other sources, no excess nutrients, no CWA 303d designated reaches[5]	moderate levels of chemical contamination from agricultural, industrial and other sources, some excess nutrients, one CWA 303d designated reach[5]	high levels of chemical contamination from agricultural, industrial and other sources, high levels of excess nutrients, more than one CWA 303d designated reach[5]
Habitat Access:	Physical Barriers	any man-made barriers present in watershed allow upstream and downstream fish passage at all flows	any man-made barriers present in watershed do not allow upstream and/or downstream fish passage at base/low flows	any man-made barriers present in watershed do not allow upstream and/or downstream fish passage at a range of flows
Habitat Elements:	Substrate	dominant substrate is gravel or cobble (interstitial spaces clear), or embeddedness <20%[3]	gravel and cobble is subdominant, or if dominant, embeddedness 20-30%[3]	bedrock, sand, silt or small gravel dominant, or if gravel and cobble dominant, embeddedness >30%[2]
	Large Woody Debris	Coast: >80 pieces/mile >24"diameter >50 ft. length[4]; East-side: >20 pieces/ mile >12"diameter >35 ft. length[2]; and adequate sources of woody debris recruitment in riparian	currently meets standards for properly functioning, but lacks potential sources from riparian areas of woody debris recruitment to maintain that standard	does not meet standards for properly functioning and lacks potential large woody debris recruitment

PATHWAY	INDICATORS	PROPERLY FUNCTIONING	AT RISK	NOT ROPERLY FUNCTIONING
	Pool Frequency channel width # pools/mile[6] 5 feet 184 10 " 96 15 " 70 20 " 56 25 " 47 50 " 26 75 " 23 100 " 18	meets pool frequency standards (left) and large woody debris recruitment standards for properly functioning habitat (above)	meets pool frequency standards but large woody debris recruitment inadequate to maintain pools over time	does not meet pool frequency standards
	Pool Quality	pools >1 meter deep (holding pools) with good cover and cool water[3], minor reduction of pool volume by fine sediment	few deeper pools (>1 meter) present or inadequate cover/temperature[3], moderate reduction of pool volume by fine sediment	no deep pools (>1 meter) and inadequate cover/temperature[3], major reduction of pool volume by fine sediment
	Off-channel Habitat	backwaters with cover, and low energy off-channel areas (ponds, oxbows, etc.)[3]	some backwaters and high energy side channels[3]	few or no backwaters, no off-channel ponds[3]
	Refugia (important remnant habitat for sensitive aquatic species)	habitat refugia exist and are adequately buffered (e.g., by intact riparian reserves); existing refugia are sufficient in size, number and connectivity to maintain viable populations or sub-populations[7]	habitat refugia exist but are not adequately buffered (e.g., by intact riparian reserves); existing refugia are insufficient in size, number and connectivity to maintain viable populations or sub-populations[7]	adequate habitat refugia do not exist[7]
Channel Condition & Dynamics:	Width/Depth Ratio	<10[2,4]	10-12 (we are unaware of any criteria to reference)	>12 (we are unaware of any criteria to reference)
	Streambank Condition	>90% stable; i.e., on average, less than 10% of banks are actively eroding[2]	80-90% stable	<80% stable
	Floodplain Connectivity	off-channel areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession	reduced linkage of wetland, floodplains and riparian areas to main channel; overbank flows are reduced relative to historic frequency, as evidenced by moderate degradation of wetland function, riparian vegetation/succession	severe reduction in hydrologic connectivity between off-channel, wetland, floodplain and riparian areas; wetland extent drastically reduced and riparian vegetation/succession altered significantly

PATHWAY	INDICATORS	PROPERLY FUNCTIONING	AT RISK	NOT ROPERLY FUNCTIONING
Flow/Hydrology:	Change in Peak/ Base Flows	watershed hydrograph indicates peak flow, base flow and flow timing characteristics comparable to an undisturbed watershed of similar size, geology and geography	some evidence of altered peak flow, baseflow and/or flow timing relative to an undisturbed watershed of similar size, geology and geography	pronounced changes in peak flow, baseflow and/or flow timing relative to an undisturbed watershed of similar size, geology and geography
	Increase in Drainage Network	zero or minimum increases in drainage network density due to roads[8,9]	moderate increases in drainage network density due to roads (e.g., ~5%)[8,9]	significant increases in drainage network density due to roads (e.g., ~20-25%)[8,9]
Watershed Conditions:	Road Density & Location	<2 mi/mi^2[11], no valley bottom roads	2-3 mi/mi^2, some valley bottom roads	>3 mi/mi^2, many valley bottom roads
	Disturbance History	<15% ECA (entire watershed) with no concentration of disturbance in unstable or potentially unstable areas, and/or refugia, and/or riparian area; and for NWFP area (except AMAs), ≥15% retention of LSOG in watershed[10]	<15% ECA (entire watershed) but disturbance concentrated in unstable or potentially unstable areas, and/or refugia, and/or riparian area; and for NWFP area (except AMAs), ≥15% retention of LSOG in watershed[10]	>15% ECA (entire watershed) and disturbance concentrated in unstable or potentially unstable areas, and/or refugia, and/or riparian area; does not meet NWFP standard for LSOG retention
	Riparian Reserves	the riparian reserve system provides adequate shade, large woody debris recruitment, and habitat protection and connectivity in all subwatersheds, and buffers or includes known refugia for sensitive aquatic species (>80% intact),and/or for grazing impacts: percent similarity of riparian vegetation to the potential natural community/ composition >50%[12]	moderate loss of connectivity or function (shade, LWD recruitment, etc.) of riparian reserve system, or incomplete protection of habitats and refugia for sensitive aquatic species (~70-80% intact), and/or for grazing impacts: percent similarity of riparian vegetation to the potential natural community/composition 25-50% or better[12]	riparian reserve system is fragmented, poorly connected, or provides inadequate protection of habitats and refugia for sensitive aquatic species (<70% intact), and/or for grazing impacts: percent similarity of riparian vegetation to the potential natural community/composition <25%[12]

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Appendix B

Attribution of the Lower Columbia Master Sample

ATTRIBUTION OF THE LOWER COLUMBIA MASTER SAMPLE

In order to stratify the Lower Columbia Master Sample (LCMS), Stillwater Sciences developed additional attribution of the LCMS by calculating and incorporating contributing drainage area (DA), stream slope, urban growth area (UGA), municipal stormwater permit area (MSWPA) - synonymous with the National Pollutant Discharge Elimination System (NPDES) permit area, and National Land Cover Dataset (NLCD) to each LCMS site. The following text provides GIS methods and pertinent information.

Contributing drainage area

Drainage area was developed from the USGS 1/3 Arc National Elevation Dataset (NED) and the USGS National Hydrographic Dataset at High resolution (NHD High). The 1/3 NED for the study area was extracted and downloaded from the USGS website and then projected to a 10-m DEM. Sinks were removed from the original 10-M DEM and a filled 10-m DEM created.

NHD High features representing streams and connector or artificial paths were selected from the whole NHD High dataset, excluding ditches, canals and waterways obtaining a representation of the “natural” channel network. NHD High streams were used to excavate or “burn” their alignments into the filled 10-m DEM to adjust for inconsistencies with the DEM-derived channels. Standard ArcGIS flow direction and flow accumulating routines were run on the “burned” DEM to obtain a grid with drainage areas.

Contributing area to each LCMS site was obtained from the “burned” drainage area grid. LCMS site locations were adjusted (or moved) to the closest “burned” DEM drainage area grid. Several iterations of the same process were run, starting with a low snapping tolerance value and increasing the value in each iteration for LCMS sites that did not obtain the drainage area from the grid (were further away from the burned drainage area grid than the snapping tolerance).

Channel slope

Channel slope was developed by overlaying the NHD High streams on the filled 10-m DEM. The elevation for the upstream and downstream ends of each NHD High arc-segment was obtained. From these elevations, the elevation drop and the slope for each arc-segment was calculated. The LCMS sites were then linked to the closest streams and the channel slope from the NHD High stream-segment was transferred to the LCMS sites.

Land use and land cover classification

2014 Urban Growth Areas and 2013 Municipal Stormwater Permit Areas were downloaded from the Washington State GIS download website. The 2006 NLCD was downloaded from the USGS GIS download website. All three datasets were overlaid with the LCMS Sites to find whether the sites were inside or outside of each area.

Appendix C

Table of Recommended Water-Quality Metrics

Table of water-quality metrics recommended in Phase 1 report (Tetra Tech 2013), and final recommendations. Metrics listed in muted font are not recommended at this time.

<table>
<tr><th>WATER-QUALITY METRICS:</th><th>Phase 1, TR3, Table 2</th><th>THIS REPORT</th><th colspan="2">Rationale for inclusion or omission</th><th>"Conventional" stormwater pollutants</th><th>RSMP (Puget Sound)</th><th>WQI S/N "grade"</th><th>USGS NAWQA #3</th></tr>
<tr><td>Water Temperature</td><td>hourly & monthly</td><td>X[c]</td><td colspan="2">Key metric with biological consequences, for which only continuous data can suffice. Data recorders inexpensive, reliable.</td><td>X</td><td>X</td><td>B</td><td>X</td></tr>
<tr><td>Sediment metals</td><td>Once per 3 yr (Cu, Pb, Zn)</td><td>X[a]</td><td colspan="2">Good integrator of heavy metal contamination. Expanded suite (Cd, Cr, Cu, Ni, Pb, and Zn) aligns with current literature for modest additional cost.</td><td></td><td>X</td><td></td><td></td></tr>
<tr><td>Conductivity</td><td>monthly</td><td>X[c]</td><td colspan="2">Good general indicator of water-quality conditions; continuous data easily obtained.</td><td>X</td><td>X</td><td>A</td><td>X</td></tr>
<tr><td>Sediment PAHs</td><td>Once per 3 or 5 yrs</td><td>*</td><td colspan="2">Potential utility but cost, value uncertain in widespread S&T monitoring. Await findings of RSMP (Puget Sound region).</td><td></td><td>X[a]</td><td></td><td></td></tr>
<tr><td>Chloride</td><td>monthly</td><td>*</td><td colspan="2" rowspan="2">Potentially useful indicators, excellent S/N, but non-continuous sampling a potential drawback. Await findings of RSMP.</td><td>X</td><td>X</td><td>A</td><td></td></tr>
<tr><td>Total Nitrogen</td><td>monthly</td><td>*</td><td>X</td><td>X</td><td>A</td><td>X</td></tr>
<tr><td>Total Phosphorus</td><td>monthly</td><td></td><td rowspan="9">Non-continuous sampling is problematic; continuous samplers do not exist or require significant maintenance.</td><td rowspan="4">Very poor S/N characteristics.</td><td>X</td><td>X</td><td>D</td><td>X</td></tr>
<tr><td>Total Susp. Solids</td><td>monthly</td><td></td><td>X</td><td>X</td><td>D</td><td>X</td></tr>
<tr><td>pH</td><td>monthly</td><td></td><td>X</td><td>X</td><td>F</td><td></td></tr>
<tr><td>Turbidity</td><td>monthly</td><td></td><td></td><td>X</td><td>F</td><td>X</td></tr>
<tr><td>Ammonia</td><td>monthly</td><td></td><td rowspan="5"></td><td>X</td><td>X</td><td></td><td></td></tr>
<tr><td>Nitrate+Nitrite-N</td><td>monthly</td><td></td><td>X</td><td>X</td><td></td><td></td></tr>
<tr><td>Dissolved Oxygen</td><td>monthly</td><td></td><td></td><td>X</td><td>B</td><td></td></tr>
<tr><td>Fecal Coliform</td><td>monthly</td><td></td><td>X</td><td>X</td><td></td><td></td></tr>
<tr><td>Total Solids</td><td>monthly</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">OTHER METRICS:</td><td colspan="7"></td></tr>
<tr><td>Flow</td><td>monthly</td><td>stage[c]</td><td colspan="2">Flow data meaningful as a continuous time series; stage provides most of the contextual information without expense of full gauging.</td><td></td><td>X</td><td></td><td></td></tr>
<tr><td>Macro-invertebrate Index</td><td>annually</td><td>X[a]</td><td colspan="2">Well-established biological metric for PNW; standardized protocols.</td><td></td><td>X[5]</td><td></td><td></td></tr>
<tr><td>Periphyton</td><td>annually</td><td>*</td><td colspan="2">Less well-established biological metric for PNW; await findings of RSMP.</td><td></td><td>X[5]</td><td></td><td></td></tr>
</table>

Xc = continuous data collection
Xa = annual data collection
* = for future consideration

Appendix D

Table of Recommended Habitat Metrics

Table of habitat metrics: current recommendations, Phase 1 recommendations (Tetra Tech 2013), rationale and S/N ratings. Metrics listed in muted font are not recommended at this time.

Habitat metrics	Current recommendation	Phase 1, TM3	Rationale for inclusion or omission	Collected by LC Monitoring Programs	S/N rating[1]
Limiting factor - Channel Structure and Form					
Reach length	once		Baseline information for the monitoring site	5	C (2.83 AREMP)[2] | B (9.16 EMAP)[2] B (8.37 PIBO)[2]
Channel type	once	annually	Baseline information for the site	7	
Density of habitat type	every 5 years	annually	Standard measurement with value to salmon recovery	3	
Sinuosity	every 5 years	annually	Useful metric with conflicting S/N grades	7	A (10.9 AREMP)[3] | B (6.8 CDFG)[3] D (1.28 AREMP)[2] | C (2.32 PIBO)[2] C (2.5 EMAP)[3] | A (24.7NIFC)[3] C (2.8ODFW)[3] | A (58.1PIBO)[3] A (20.2 UC)[3] | A[4] | D (1.1)[5]
Bankfull width/depth	every 5 years	Annually/once every 5 years	Valuable metric with conflicting S/N grades. Retain due to value and carefully define measurement procedures to improve precision	4	C (2.1 AREMP)[3] | D (1.7 CDFG)[3] F (0.53 AREMP)[2] | C (4.01 PIBO)[2] D (1.7 EMAP)[3] | B (6.1 NIFC)[3] C (3.5 ODFW)[3] | D (1.5 PIBO)[3] D (1.6 UC)[3] | B (6.5)[5]
Bank stability (categorical)	annually		Valuable metric with conflicting S/N grades. Applying a categorical metric is likely to improve precision (raise the S/N grade)	7	A[4] | D (1.3)[5] (bank condition)
Pools per unit length	TBD		Valuable metric with poor S/N grades. Consider further given the value to fish populations	5	D (1.0 AREMP)[3] | F (0.2 CDFG)[3] D (1.8 EMAP)[3] | D (1.1 NIFC)[3] B (5.5 ODFW)[3] | F (0.8 PIBO)[3] D (1.6 UC)[3]
Residual Pool depth	annually		Valuable metric with acceptable S/N grades	7	B (6.3 AREMP)[3] | F (0.2 CDFG)[3] B (6.1 EMAP)[3] | C (4.9 NIFC)[3] C (3.2 ODFW)[3] | B (7.4 PIBO)[3] A (11.9 UC)[3] | A (pool unit depth)[4] A (37.31 PIBO)[2] | B (9)[5]

<table>
<thead>
<tr><th>Habitat metrics</th><th>Current recommendation</th><th>Phase 1, TM3</th><th>Rationale for inclusion or omission</th><th>Collected by LC Monitoring Programs</th><th>S/N rating[1]</th></tr>
</thead>
<tbody>
<tr><td>Thalweg depth</td><td>annually</td><td></td><td>Valuable metric with good S/N grades</td><td>7</td><td>A[4] | B (6.9)[5]</td></tr>
<tr><td>Density/distribution instream wood</td><td>annually</td><td>annually</td><td>Valuable metric with good S/N grades</td><td>7</td><td>A (53.3 AREMP)[3] | C (4.4 CDFG)[3]
A (10.8 EMAP)[3] | A (87.1 NIFC)[3]
A (24.5 ODFW)[3] | A (19.4 PIBO)3
A (13.6 UC[3])[**] | B,D[4]|B (7)[5]
B (AREMP)[2] | F (0.74 EMAP)[2]
D 1.19 (PIBO)[2]</td></tr>
<tr><td colspan="6">Limiting factor - Sediment Conditions</td></tr>
<tr><td>Substrate particle size (% comp by particle size category)</td><td>annually</td><td>annually</td><td>Valuable metric with good S/N grades</td><td>7</td><td>C (3.7 AREMP)[3] | B (6.9 EMAP)[3]
B (9.4 PIBO)[3] |C (2.3 UC)[3*]
A/B(percent fines)[4] | A (15)[5]
A (21.73 AREMP) % fines[2]
A (69.94 EMAP) % fines[2]
A (21.24 PIBO) % fines[2]</td></tr>
<tr><td>Embeddedness</td><td>annually</td><td></td><td></td><td>5</td><td>C,A[4] | B (7.7)[5]</td></tr>
<tr><td>Relative bed stability</td><td>annually</td><td>annually</td><td>Easy to measure and consistent with objectives</td><td>3</td><td></td></tr>
<tr><td colspan="6">Limiting factor - Riparian Condition</td></tr>
<tr><td>Shade at mid channel</td><td>annually</td><td>annually</td><td>A measure of habitat quality with good S/N grades</td><td>3</td><td>A[6] | A (15)[5]</td></tr>
<tr><td>Riparian canopy (% cover)</td><td>annually</td><td></td><td>A measure of habitat quality with good S/N grades</td><td>3</td><td>A[6] | A (17)[5]</td></tr>
<tr><td>Riparian understory (% cover)</td><td>annually</td><td></td><td>A measure of habitat quality with conflicting S/N grades. To be further considered</td><td>3</td><td>B[6] | F (0.9)[5]</td></tr>
<tr><td colspan="6">Limiting factor - Water Quantity</td></tr>
<tr><td>Flow Category[7]</td><td>annually</td><td></td><td>Useful and efficient measure of relative flow conditions to provide context for the other metrics</td><td>7</td><td></td></tr>
</tbody>
</table>

Habitat metrics	Current recommendation	Phase 1, TM3	Rationale for inclusion or omission	Collected by LC Monitoring Programs	S/N rating[1]
Limiting factor - Peripheral and Transitional habitats					
Floodplain area	every 5 years		An important measure of rearing habitat		
Length of side channel habitat	every 5 years		An important measure of rearing habitat	3	
Limiting factor - Water Quality					
pH	Omit	Once per year	Very low S/N grade	3	F[4]
Alkalinity	Omit	Once per year	Commonly sampled, but not particularly useful as it largely reflects bedrock/groundwater chemistry and is unlikely to change	2	
Conductivity	TBD	Once per year	Good general indicator of water quality conditions; continuous data easily obtained, but costly to implement	3	A[4]
Turbidity	Omit	Once per year	Very low S/N grade	3	F[4]
Temperature	TBD	X[ai]	Highly valued data if continuous, but costly to maintain. Consider a two tiered plan: 1) sample temp the first time. If close to a predetermined threshold, then 2) install a temp thermister and measure for 3 months	3	B[4]

Blank cells indicate no signal to noise ratios or ratings identified in the literature search

1 When two grades are present, the first is for wadeable streams and the second is for larger rivers
2 Whitacre, Roper, and Kershber 2007;
3 Roper et al. 2010. Converted to letter grades using scoring in Merritt and Hartman 2012;
4 Merritt and Hartman, 2012
5 Kaufmann et al. 1999
6 Cusimano et al. 2006
7 free-flowing, sluggish (<1ft /sec), stagnant, dry
* $\log_e$ of D_{50} performed best
** $\log_e$ of LWD/100 m performed best
X[ai] annual instantaneous

Appendix E

Stakeholder Review Comments and Responses to the Draft HSTM Report

The following table documents stakeholder comments provided on the Draft HSTM Monitoring Design and Report. Responses to each comment are provided by Stillwater Sciences and were used to guide the Final HSTM Monitoring Design and Report. Scrolling page numbers corresponding with comment location are provided for the body of the report (e.g. the main body of the document starts on page 15). Due to extensive revision, page numbers for the Executive Summary are not applicable (NA)

COMMENTER	ORGANIZATION	DOCUMENT	PAGE NUMBER	COMMENT	RESPONSE
Karen Adams	LCFRB	Design	NA	That doesn't look like the CD site, but more like the tribes restoration further upstream… Check the email dated Jan 5 at 2:34pm…	The photo documentation was checked as requested and the documentation is correct.
Karen Dinicola, Brandi Lubliner	Ecology	Design	NA	An abstract that boils the high points into 1-2 pages is needed for communication of the findings of this report to folks outside the project.	Given conflicting input by other reviewers, LCFRB was consulted regarding this request. A resulting decision was to retain the Executive Summary and refrain from adding an abstract.
Chad Larson	Ecology	Design	NA	Ultimately, as proposed in this document, very few of these (physical and chemical) parameters will be measured at the Qa/Qx sites. Especially with regards to the habitat metrics that will be assessed, it may make it difficult to relate invertebrate communities to any habitat degradation.	Making such relationships on a site-by-site basis is not the purpose of S&T monitoring, and so no effort was made in achieving this outcome. It could not be accommodated under any feasible design.
Karen Dinicola, Brandi Lubliner	Ecology	Design	NA	Include "municipal stormwater" throughout document to clarify that this program isn't addressing construction, industrial, gravel, POTW, etc. – other types of NPDES permits that are issued to jurisdictions	Agreed.
Jeff Fisher	NOAA	Design	NA	There are multiple ESUs, identified by species…text descriptor should be used before acronym.	Agreed and text revised
Jeff Fisher	NOAA	Design	NA	But it (the study design) actually only includes the WA areas—based on the first paragraph…either need to modify first paragraph, or this one…	Clarified.
Jeff Fisher	NOAA	Design	NA	(Insert) tributaries in (in front of "Washington" on line 38)? Don't believe we are focused in on the mainstem yet…	Constraining the project areas to tributaries would be too narrow given the current design. We have identified monitoring sites in both wadeable and nonwadeable streams (e.g. larger rivers with drainage areas >1000km^2)

COMMENTER	ORGANIZATION	DOCUMENT	PAGE NUMBER	COMMENT	RESPONSE
Jeff Fisher	NOAA	Design	NA	Referencing the ESUs in this manner is not correct—it's not a portion of the ESU (there are multiple anyway) it is a portion of the geographic recovery domain that supports multiple ESUs—an ESU is a biological entity, not a geographic entity.	Duly noted and text revision appreciated
Mindy Fohn	Kitsap County	Design	NA	Fully support this approach - should "metrics" be replaced with "parameters"? I see this throughout the document -	For the sake of consistency, we will use metrics throughout the report and strike the use of "parameters" as a term
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	NA	Consider using the term "water quality and hydrology" rather than Qa/Qx. I don't recall ever seeing this before.	This is the terminology from the Phase 1 report. It is unique to this project but has a history with it, and so it has been retained in this report.
Jeff Fisher	NOAA	Design	NA	First use of this term (master sample)…should define what it means…	Addressed in text revisions.
Jeff Fisher	NOAA	Design	NA	Question: does this design preclude future habitat restoration actions in the Master Sample site reaches?	No. Such exclusion applies when needing control conditions for effectiveness monitoring. That is not the case with STM
Mindy Fohn	Kitsap County	Design	NA	Incorporation of legacy sites, when appropriate, is a strength of this program	Acknowledged
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	NA	We were impressed with the phase I approach to including legacy sites.	We agree that the Phase 1 approach, in concept, was appropriate, and there has been no change to that framework--both Phase 1 and Phase 2 provide the ability to include legacy sites and noted the statistical ramifications. Phase 2 has also updated the Master Sample to include previously missing legacy sites. Because neither Phase 1 nor Phase 2 has had a truly complete representation of where legacy sites actually are located relative to prospective sampling sites, however, a final evaluation of the feasibility of the Phase 1 approach is warranted and will be necessary. In part, this depends on whether the stakeholders want a truly random or pseudorandom sampling scheme, and this decision has not yet been made (nor needs to be made as part of the design, only as part of implementation).

COMMENTER	ORGANIZATION	DOCUMENT	PAGE NUMBER	COMMENT	RESPONSE
Karen Adams	LCFRB	Design	NA	You will see that I have highlighted every instance that it is explained that something will be done during the next phase. This is a valid and necessary caveat. However, it ends up reading like our work is incomplete. If you don't know all the info, you might wonder what happened to the money and time that was slated for these tasks. Did the consultant not do a good job, did the project manager mis-manage the project or team leadership not push hard enough. I would recommend saving these up for the next steps section at the end. It is important to let people know where there are loose ends and why. When it is sprinkled throughout, it is possible that folks misinterpret what happened here.	The concern is understood, but it is challenging to retain an understanding of the issue when not discussed in context. As such, we advise retaining the current structure.
Karen Dinicola, Brandi Lubliner	Ecology	Design	NA	Need to clearly define (reaches). Also need to use this term consistently throughout the report.	Clarified in the revision.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	NA	Good (with respect to Qa/Qx sampling of reaches, not points).	Thank you.
Mindy Fohn	Kitsap County	Design	NA	This conversion of points to reaches is a strength of this approach. However, is there a description of this conversion? Such as how many points are to a reach, and the reach length? I was unable to understand this conversion. The interest comes from the desire to adopt this approach.	It is clarified in the main body of the report, but not in the Executive Summary given a desire for conciseness.
Karen Adams	LCFRB	Design	NA	Bringing reaches up at this point will be confusing to a reader. Habitat is sampled at sites using a reach based approach, but that detail is not necessary at the Exec. Summary level.	Addressed in text revisions
Karen Dinicola, Brandi Lubliner	Ecology	Design	NA	These considerations also apply to the stream benthos sampling included in Qa/Qx. Results for this metric are expected to vary along a hydrologic reach.	Agreed. Need for a consistent, meaningful setting for IBI sampling has been added.

COMMENTER	ORGANIZATION	DOCUMENT	PAGE NUMBER	COMMENT	RESPONSE
Karen Adams	LCFRB	Design	NA	Organization is going to be key here. Some folks are having a hard time following the logic of the document and I think a little reorganization and formatting would go a long way. I would add some subheadings here… one above line 6 to indicate that you are discussing site allocation and strata for Qa/Qx/ Move this paragraph to line 14 on the next page above where you start listing out the site allocation and strata for habitat and include a subheading for habitat there.	The Executive Summary was fully revised to address this and similar concerns
Karen Adams	LCFRB	Design	NA	I would make the ES match the workshop… present all WQ stuff then present Habitat stuff. Right now there is a lot of jumping around, especially in the Executive Summary.	Upon further discussion with LCFRB, the ES structure was not changed to match the workshop, but retained to match the report. The ES was revised for increased reader clarity
Jeff Fisher	NOAA	Design	NA	Question: does this design preclude future habitat restoration actions in the Master Sample site reaches?	If restoration happened AT a site, clearly it would no longer be representative of a class of stream reaches and would need to be abandoned and/or replaced.
Karen Dinicola, Brandi Lubliner	Ecology	Design	NA	I still think we want all urbanized areas within the basin included as "inside UGA" or at least excluded from "outside UGA" – we can exclude them from sampling as a 3rd strata. As smaller cities grow they become candidates for inclusion in the permits. We want the S&T design to be lasting.	This suggestion has already been incorporated--the smaller cities within a UGA (but not currently NPDES permittees) are explicitly excluded from the "not UGA or NPDES" category.
Karen Adams	LCFRB	Design	NA	Recall our discussion during the meeting that this notation needs to be clear that we are looking at urban land uses. You used "Urban NPDES Areas" in the workshop and I thought that was great. Keep it in plain English as much as possible.	Addressed in text revisions.

COMMENTER	ORGANIZATION	DOCUMENT	PAGE NUMBER	COMMENT	RESPONSE
Karen Dinicola, Brandi Lubliner	Ecology	Design	NA	I doubt this will be meaningful for Qa/Qx – fish don't impact wq, it's vice versa	We agree, but this is a management-driven stratum, not a presumed causal factor.
Karen Adams	LCFRB	Design	NA	The term Primary Population will need to be defined somewhere.	Addressed in text revisions
Karen Adams	LCFRB	Design	NA	Start using "Urban NPDES areas" here for consistency, exchanging all UGA+NPDES for "Urban NPDES" throughout.	Addressed in text revisions.
Karen Dinicola, Brandi Lubliner	Ecology	Design	NA	Very few of the 24 segments appear to have legacy sites associated with them: how many, precisely? To be transparent and clear about teeing up this choice, more context needs to be provided. Most legacy sites are outside UGA+NPDES areas.	We have updated the Master Sample to include additional legacy sites from the City of Vancouver and Clark County. Additional data is available from Oregon agencies for inclusion in later phases of this process.
Karen Dinicola, Brandi Lubliner	Ecology	Design	NA	At the October workshop you suggested finding the downstream-most accessible sampling location and going with it. That seems perfect for all parameters except perhaps IBI. Is where you have sufficient sediment accumulated also likely to provide suitable/comparable IBI sites?	Although have a default approach to site selection is reasonable, a variety of logistical issues (including, but not limited to, site access, security for continuous samplers, suitability for IBI data collection, etc.) are likely to render most default guidance irrelevant. Nonetheless, we agree that an initial protocol is warranted and has been included.
Karen Dinicola, Brandi Lubliner	Ecology	Design	NA	Is this outside UGA+NPDES? Not clear.	Yes. Revised wording is appreciated.

COMMENTER	ORGANIZATION	DOCUMENT	PAGE NUMBER	COMMENT	RESPONSE
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	NA	Rural Residential is a common Land Cover in Clark County	"Rural Residential" is a land-use category and not discriminated as such in coarse-level NLCD. There are the following categories in the NLCD (of which the first is the closest land-COVER category corresponding to this land USE): • Developed, open space (mostly grass and large-lot single-family housing) • Developed, low intensity • Developed, medium intensity • Developed, high intensity Although some (indeterminate) combination of the first two likely encompasses the land use "rural residential", at the present time we recommend retaining only the three primary land-cover classifications, insofar as they are sufficient to address the monitoring questions as currently posed. The data will always be available for more specialized post-stratification. In addition, the application of the 2006 NLCD has now been expanded in the methods section to make its composition more transparent to the reader.
Karen Dinicola, Brandi Lubliner	Ecology	Design	NA	I don't think this strata (inside/outside urban UGA) is appropriate for habitat. Stick with predominant LC.	This is a significant recommendation and one to be discussed. The recommendation has not been previously proposed and the report authors can make such a change to the design without broader stakeholder guidance.
Karen Dinicola, Brandi Lubliner	Ecology	Design	NA	Also consider the variation within urban. The Hobbs report showed differences between commercial/industrial and residential for both seasons and parameters. Impervious surface rules for flow impacts, but not necessarily for wq	There is no question that such WQ variations in urban land-use types exist, but up to this point the HSTM monitoring project has not sought to discriminate them. Were this to be required under a future NPDES permit then such a refinement would be necessary; at present, however, there is no precedent in either Phase 1 or Phase 2 for including it.

COMMENTER	ORGANIZATION	DOCUMENT	PAGE NUMBER	COMMENT	RESPONSE
Karen Adams	LCFRB	Design	NA	We should include “cleared” as a category and in discussion acknowledge that we don’t have this one ironed out yet. It isn’t so much that it doesn’t apply (this isn’t an insignificant amount of land in an area dominated by timber harvest); we just haven’t figured out how to reliably identify what “cleared” means, and it is a shifting target over time. Lots are cleared and sometimes allowed to grow back or are purposefully replanted so what is clear in one year, may not be clear in another. Lots that are regrowing toward a forest outcome only demonstrate the impacts of clearing for about 15 to 20 years tops anyway, at least in terms of the benthic community.	Although the "cleared" land cover category is laudable, it is not a land cover defined in the NLCD and would require additional analysis to determine its feasibility in any but specialized, localized applications. Beyond noting the interest, we do not advise actually including design elements that do not have a clear path to resolution, even if desirable. Data limitations on the design are a practical reality and establish constraints to a realistic monitoring design.
Karen Adams	LCFRB	Design	NA	I like this section (regarding the logic in defining the list of recommended strata) and it is missing from the WQ discussion above. I see opportunities to expand here though. Why do we care about drainage area? Why do we care about gradient, what is its relevance to our goals and objectives? Similar issue with land cover.	The Executive Summary (ES) was fully revised to address a range of comments. The text suggested in this comment is educational in nature and thus more appropriate for the body of the report, rather than an ES. However, the spirit of the recommendation was addressed in the revised ES with a reminder of relevant differences between water quality and habitat monitoring
Karen Dinicola, Brandi Lubliner	Ecology	Design	NA	Why (should the number of sites be consistent with QaQx)? Is the data variability similar?	It widely varies across the suite of proposed metrics and thus a rule of thumb for habitat data variability could not be readily applied
Karen Dinicola, Brandi Lubliner	Ecology	Design	NA	Why is there no recommendation for “pseudo-random” here (for habitat)? Most of the legacy sites are outside the Qa/Qx urban focus.	Addressed in the ES revision
Mindy Fohn	Kitsap County	Design	NA	Excellent discussion on frequency. Another strength of this analysis is the practicality of frequency and it’s based on science.	Thanks.

COMMENTER	ORGANIZATION	DOCUMENT	PAGE NUMBER	COMMENT	RESPONSE
Karen Dinicola, Brandi Lubliner	Ecology	Design	NA	This paragraph probably belongs in the methods section, perhaps along with the preceding paragraph. This is the results section. You could also just drop it and leave these details in the body of the report.	Agreed and deleted
Chad Larson	Ecology	Design	NA	This (substrate) is a broad term potentially encompassing many different measures	Clarified.
Karen Dinicola, Brandi Lubliner	Ecology	Design	NA	Need to list them (the metrics under consideration based on future findings). This also merits a bit more discussion here: what, besides cost, would recommend their inclusion or exclusion based on the experience and findings of other programs?	The list of potential future metrics ("still under consideration") was not part of the original ES text and is judged to be an unnecessary level of detail (in part, because more explanation would be needed than just a list).
Chad Larson	Ecology	Design	NA	A definitive plan for this should be outlined and put in place so that it does not get forgotten once implementation begins.	This is what the implementation plan will outline.
Karen Adams	LCFRB	Design	NA	We should specify here that you are referring to the reach length represented by the sampled reach of 20XBFW. Especially for the on the ground folks who only deal with the on-the-ground data collection, the 20BFW sampling reach is what comes to mind first and is less a metric and more of a definition.	Revised as suggested
Karen Adams	LCFRB	Design	NA	Include Macros in habitat as well? It might be worth it to call out (later in the document) that a percentage of sites will be “trend sites” and continuous recorders of temperature, conductivity and stage will be utilized at these sites.	Macros are recommended for Qa/Qx sites, not habitat sites--their inclusion in the latter would likely represent a substantial increase in total program cost without any obvious benefit, since many of the drainage-area and slope categories for habitat are unsuitable for determining comparable IBI scores.
Karen Dinicola, Brandi Lubliner	Ecology	Design	NA	Decisions yet to be made (i.e., pseudo-random design) need to be articulated here (in next steps).	Addressed in the ES revision
Mindy Fohn	Kitsap County	Design	NA	This summation provides clear and logical next steps. Excellent approach.	Thanks.

COMMENTER	ORGANIZATION	DOCUMENT	PAGE NUMBER	COMMENT	RESPONSE
Karen Adams	LCFRB	Design	15	Assuming the word "draft" will be deleted for the February Final report.	Yes.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	16	What are the project deliverables?	Because this report is a description of the monitoring design (not the monitoring design contract), they have not been explicitly listed here.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	17	Nice figures but make them bigger.	Revised, as possible.
Karen Adams, Rod Swanson, Karen Dinicola	LCFRB	Design	18	City of Centralia and Aberdeen folks have not participated, though they may be affected by the work… They will be dealt with separately and need not be included.	Ok.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	18	Aberdeen and Centralia are not in the Lower Columbia	Ok.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	18	The maps highlight Ridgefield as a city/UGA area. Where does this unpermitted city area fit in?	Good point--it IS a UGA within an NPDES permit area (that of Clark County) but is not itself a municipal NPDES permittee. It would be included in the "urban NPDES" monitoring strata, as indicated on the map.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	18	I didn't see that much feedback, mainly presentation of results.	The text was not meant to imply feedback only at workshops; many avenues for comments have been pursued throughout this project.
Chad Larson	Ecology	Design	19	Perhaps a statement or two about the various workshops that have been held with the goal of engaging the various stakeholders, as well as refining monitoring objectives and sampling design?	This ES was not intended to be a summary of the process of developing this plan, but a summary of the plan itself. To the extent that feedback was part of the "Methods," however, it has been mentioned here.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	19	There should be more description of the way we use metrics/parameters. For example, how do we use wetted width, how do we use stage to calculate flashiness, is there a function relating wetted width to stage or flashiness?	These are worthwhile issues but not obviously associated with monitoring design itself.

COMMENTER	ORGANIZATION	DOCUMENT	PAGE NUMBER	COMMENT	RESPONSE
Karen Dinicola, Brandi Lubliner	Ecology	Design	19	Use of NPDES as shorthand to describe guiding questions throughout this report is better served by consistently using the term “municipal stormwater permittees”. Many types of NPDES permits are issued and cover jurisdictions (and businesses) throughout the region for quite different activities.	Agreed; meaning was always intended as indicated here, and the text has been modified to avoid any ambiguity.
Chad Larson	Ecology	Design	19	Please provide specific references to support these statements (regarding the impacts of land use on water quality). Additionally, if turbidity has been implicated as reducing watershed health and salmon habitat, then shouldn’t there at least be an initial attempt to assess whether or not it will be meaningful in the Lower Columbia Region rather than eliminating it all together based on S/N analyses from other regions or different studies?	This report is not intended as a literature review of the effects of land use practices on water quality, although such information is abundant. Two examples have been added, and the wording changed to avoid any suggestion that specific studies concerning the LCR are being implied (although these likely do exist). As for specific metrics, relevance does not always translate into something that is easily measured. This topic is better handled in the Metrics section of the report, not the Q&Os.
Karen Dinicola, Brandi Lubliner	Ecology	Design	19	Further discussion of the 51% threshold (for describing predominant land cover) is appropriate – the location of the LU might dominate over the percentage. In the next stage, we need to hammer out a better definition. Add to next steps.	Ok, although the level of analysis (and the disagreement in the scientific literature about what, exactly, to "analyze") is likely to confound future efforts to refine this. Note that this definition has been part of the project since Phase 1; there has been no change made here.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	19	Perhaps the beneficial uses are water-body specific rather than watershed specific.	Ok. Referenced WAC has specific water bodies within specific watershed--either way is fine.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	19	Many of the water-bodies have generic designated beneficial uses.	Ok.

COMMENTER	ORGANIZATION	DOCUMENT	PAGE NUMBER	COMMENT	RESPONSE
Karen Adams	LCFRB	Design	19	It might be nice to excerpt the pages of the WAC for WRIA’s 25-29 in an appendix to reference as well.	We advise sticking with the web link as the best source of original and complete information
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	19	Do we need to specify a trend direction or target? That seems like a management goal rather than a monitoring goal.	These are not monitoring goals but monitoring objectives. As such, they do need something tangible to compare to (or at least a direction).
Karen Adams	LCFRB	Design	19	So are we looking at the best conditions among the sites visited or the best conditions as described in the WAC?	Recommendation is to use actual data to determine what "best conditions" look like. That's very much the point of an S&T monitoring program.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	19	Perhaps better define what “best conditions represented by the master sample” is. Will this information be available to permittees who are required to support a monitoring program under the 2018 permit?	Prior comments on the Q&Os have not raised this as an issue requiring more definition at this time. Availability of results will depend solely on implementation of this program but is unlikely to affect any element of future NPDES permit requirements.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	20	Are these areas mapped as part of this project? Should they be? Most arable land was cleared in Clark County over 100 years ago.	Addressing this objective will require subsampling and post-data-collection analysis.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	20	These, such as temperature will be stream specific depending on the salmon use designation. That is more than one standard will apply.	Agreed. Wording changed.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	20	Does this report define statistically significant?	Yes, but this is not the section for such details.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	20	Why would anyone expect a trend toward reference conditions? What management actions are in place to do this? Also, this is a management goal not a monitoring objective.	This is not a goal at all, but an objective--as such, it defines a tangible analysis (for which "positive progress" is an obvious evaluation to make).
Jeff Fisher	NOAA	Design	20	While I agree that it is a management goal, evaluating the monitoring data trends as to whether there is evidence of moving towards reference conditions is an appropriate context for data interpretation in my mind…	This comment is responding to the immediately preceding comment by Rod Swanson, Jeff Schnabel, and Ian Wigger. We concur with the Fisher response

COMMENTER	ORGANIZATION	DOCUMENT	PAGE NUMBER	COMMENT	RESPONSE
Mindy Fohn	Kitsap County	Design	21	Excellent WQ Questions	Thanks.
Jeff Fisher	NOAA	Design	21	Glad to see this (NOAA's properly functioning conditions) as the metrics from which to evaluate results of monitoring. I think we could just append the table…	Included as an Appendix
Karen Adams	LCFRB	Design	21	Include this table of properly functioning conditions somewhere.	Included as an Appendix
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	21	Does this mean the metrics will be assessed for trends each year? If so, that is excessive because it will take a number of years to see any trends based on what we see in Clark County. Maybe five year time steps on any statistical analysis.	If data are collected annually then they should be analyzed annually. Agreed, not all will be expected to show significant trends year-over-year, but the analysis should not be deferred.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	21	Should these be identified somewhere in the report? How many watersheds have good data?	A reasonable question for the implementation report; not in-scope for the design, except to confirm that such programs do exist (e.g. WDFW Fish In/Fish Out monitoring).
Mindy Fohn	Kitsap County	Design	21	(Re: the ability to identify significant correlations between habitat and fish metrics among various programs) Does the interface with these other programs need to be linked/connected in a more clear way in the “next steps”?	This is a laudable suggestion and was added to "next steps"
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	21	Wouldn’t this be part of this report?	The objective and key metrics, but nothing more at this stage. We have identified the limiting factor associated with each metric. During Implementation Planning, species-specific limiting factors can be highlighted which will in turn focus an analysis of the correlation between trends in select habitat metrics and trends in fish population metrics habitat conditions known to limit fish populations.

COMMENTER	ORGANIZATION	DOCUMENT	PAGE NUMBER	COMMENT	RESPONSE
Jeff Fisher	NOAA	Design	21	As a filter to the monitoring questions in this (Landscape) section, is there a way to consider not just what land uses have occurred over the monitoring period that may translate to wq and habitat endpoints, but what bmps may have (or have not) been applied to these land use actions? For example, forestry land uses will be required to comply with forest practices rules and/or forestry HCP conditions (largely the same); actions in critical areas would also be required to be compliant with SMP provisions. What we don't really have a handle on, as data are still coming in (if they are coming in at all) is if the bmps are effective. Since the bmps are often prescribed to minimize effects to the endpoints that are the focus of the monitoring program, it would be useful to consider this, though I confess that it would take me some time to figure out statistically how that might be covered. I see this point was also brought forward in comment 94…	This is something that could be evaluated post stratification. It is not directly within the scope of this monitoring design, but could certainly be supported by the data to be collected
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	21	What are potential land use activities? Would this be characterizing predominant land use by catchment? Is the method left to another project?	This is a "question," and those specifics (which are indeed important) are fleshed out in the objective that follows. No specific methods are included in this section.
Karen Adams	LCFRB	Design	21	Should we add descriptions of what these key activities are related to? For example, those that affect salmon habitat or stormwater impacts	See previous response.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	21	The LCFRB did subwatershed-scale limiting factor analysis in the early 2000s. Is that work relevant?	Certainly. It will be valuable information for the Implementation Plan
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	21	Is it worth considering other drivers such as state shoreline program and local GMA implementation monitoring?	Regulations have presumably affected land-cover change in the Region, but this question/objective is focusing on simply characterizing those changes. Analysis of the effects of regulation is well outside the scope of the HSTM project.

COMMENTER	ORGANIZATION	DOCUMENT	PAGE NUMBER	COMMENT	RESPONSE
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	21	Is this report going to propose a method or is that for another project?	It is for another section of this report. Please recall, this is a "Questions and Objectives" section, not a methods section.
Jeff Fisher	NOAA	Design	21	This (text in objective 6.2) seems to leave the buffer zone question an open question. Can't we just spell it out discretely as to what the buffer width for analysis will be? (60m seems reasonable to me).	It may be, however the identification of a buffer zone is suited for the Implementation Phase
Mindy Fohn	Kitsap County	Design	22	RE: NPDES permit related Questions and objectives) This NPDES portion is very logical in stratification, site numbers, frequency, parameters. It is very doable and including legacy sites, addresses the key issue of losing historical data. However, one weakness may be the lack of establishing a few key long term continuous flow stations in order to collect a 20 year record for a few undeveloped basins vs. developing basins. This would answer "are our management actions – for flow control – adequate?" Kitsap County Public Works partners – via an Interlocal Agreement (contract) with Kitsap PUD to establish a monitoring these sites. The benefit is KPUD already has an established flow data collection program and we just piggy back onto it. Also – all the data is available via the web – including key flow metrics (TQmean, RB index, etc.) see http://64.146.148.103/Streams/Flow_Metrics_Summary/BC_Stream_Metrics_Summary.pdf	A parallel program of stream gaging would unquestionably enhance the value of monitoring data, but the cost of a full flow-monitoring component to the recommended program was judged too high to advocate concurrent implementation. However, continuous stage readings are a parameter to be collected at all Qa/Qx sites, which in the judgment of project partners appears to provide highly useful information without the cost of full discharge gaging.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	22	Is it the permittees or the permitting agency that has the monitoring needs? We had a monitoring program that met our needs but it was not allowed to meet 2013 permit requirements.	Any jurisdiction whose needs were not being met by the HSTM would presumably have the option of non-participation. The purpose of having had multiple reviews and iterations of these Q&Os has been to minimize those shortfalls as much as possible. In the end, however, every jurisdiction will need to decide whether or not participation satisfies their needs (which will include, presumably, the "need" to comply with requirements of future NPDES permits).

COMMENTER	ORGANIZATION	DOCUMENT	PAGE NUMBER	COMMENT	RESPONSE
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	22	This only works for urban MS4. Clark County has a vast rural MS4 where public ROW exists. See our MapsOnline or GIS data provided to this project or phase I. Maybe separate rural and urban permit areas or just ignore the rural permit area?	The differences are recognized in this monitoring design, and the two areas are treated differently as a result.
Karen Dinicola, Brandi Lubliner	Ecology	Design	22	This is all fine (regarding the use of UGA inside NPDES). But other urban areas may “grow into” the permit as well. I think they should be included in the urban areas stratum to support longevity of this study design. We’re asking questions about stormwater management in urban and urbanizing areas. The permit seems to introduce unnecessary complexity to the design.	Wording has been clarified, but a problem is not evident. The creation of a "new" NPDES area in some future iteration of the stormwater permit does not require that it now be included in a S&T monitoring program, only that its conditions be reasonably well-represented by sampling sites having similar conditions--and this is already accomplished.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	22	What are these specific needs of the permits? Ecology would specify the needs of a general permit.	As noted above, the "needs" of Ecology as expressed in a permit are most likely going to become the "needs" of the permittees in short order.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	22	Generally refer to the permit as a (general) municipal stormwater permit. The MS4 is the permitted conveyance system owned by each permittee.	Wording improved by DOE.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	22	How about legacy sites dating to the inception of the SWMP in Clark County?	Value of their incorporation is acknowledged at several points in the document.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	22	Perhaps list the legacy sites or show them on a figure in the results?	We have continued to request an up-to-date list of such sites for inclusion in the maps and analysis, but as of this report's preparation have not received a full list from all participants. The Master Sample is clearly incomplete and thus has not been relied upon.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	22	No separate strata for non-urban permit areas.	This is correct.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	22	This is a reasonable time and perhaps consider after each permit cycle – 5 years.	Agreed--we expect that analysis would occur annually, but that recognizing any meaningful trend would require much longer.

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Jeff Fisher	NOAA	Design	22	‘Best’ conditions is somewhat vague. Earlier, we say we will compare trends to the NMFS PFC’s. Why wouldn’t we use the same metrics here to gauge trends? Even if ‘best’ is to be interpreted in terms of the narrative standards of beneficial use, these are different criteria (though somewhat related) than the wq PFCs. Why are only the physical habitat metrics of PFCs being considered and not also the wq metrics? (Note that EPA has not consulted on their WQ standards in WA state for their ability to be protective of salmonids, or supportive of recovery efforts…a notice of intent to sue EPA over this has been filed with the courts…)	Agreed--reference to PFC's has been added to several objectives.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	23	How do we find comparable sites to represent Willamette valley ecoregion sites? Are they in Washington or the balance of the Willamette Valley region in Oregon?	We have not addressed the Oregon portion of the ESU in this design to date, however the strata, site selection and metrics recommended herein would apply to Oregon as well
Karen Dinicola, Brandi Lubliner	Ecology	Design	23	Conversion from what condition to urban: from cleared, ag, forest? From low-density to high density?	Given the likely limited number of locations where this will apply, no restriction on the prior non-urban condition is recommended. And "first developed" should imply non-urban to urban conversion, not redevelopment or low-density to high-density urban development.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	23	Also consider that these areas are likely converted ag and rural residential cleared for crops and pasture 100 years ago.	Agreed--this is why the reference condition should be drawn from the region, not from a belief in what's "best" without any consideration of what's also "attainable"

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Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	23	Consider going back to areas developed under the 2005 SWMMWW and forward. People use infiltration wherever possible to deal with the forested predevelopment condition.	Given the time frame over which this is likely to be implemented (relative to the 2013 permit), our recommendation is to stick with the existing wording.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	23	Do we include flow metrics?	This was intended but not stated explicitly. Corrected.
Karen Dinicola, Brandi Lubliner	Ecology	Design	23	Refer to permittees consistently throughout the report. This represents others not relevant to the stormwater monitoring but doesn't make sense to call this "opportunistic selection." The strata for answering this question is limited to a small subset of the UGA+NPDES, therefore limiting the number of sites. If any sites exist that meet the criteria that would be established to answer this question, sample them all.	Comment unclear--"opportunistic selection" means choosing from the entire population of sites of Objective 7.1, not a selection from amongst the (small) number of sites that have been developed under the new permit. That would be "subsample the opportunistically selected sites from the larger population of sites identified for Objective 7.1," and that is not what this question states.
Karen Adams	LCFRB	Design	23	You've specified "over a 10 year period" above. Does that apply here as well?	In part. The period over which TRENDS should be considered needs to be short enough to be relevant, long enough to be meaningful given inherently variable data. But any discussion of duration is relevant only to TRENDS objectives, not STATUS objectives. The frequency of Qa/Qx and habitat metric sampling is presented in greater detail in Tables 4 and 5 of this report. And although analysis will occur annually, SMART objectives would evaluate trends over a longer period of time (e.g. 5-10 years). There is no inconsistency--trends in naturally variable data require multiple years to express themselves; based on other monitoring efforts, ~10 years is a reasonable expectation for seeing management-relevant changes in naturally variable data.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	23	Are these annual evaluations or evaluation of annually collected metrics?	Annual evaluation of annually collected metrics.

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Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	23	Is there more detail about how this will be accomplished?	Yes, but not in the section on Questions and Objectives.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	23	Seems like this could be part of this project.	The reviewer is correct. This is an Objective of the project
Dorie Sutton	City of Vancouver	Design	23	RE: Objective 10.1 - This analysis would be at the regional level, not NPDES permittees. Fish studies outside the scope of permit requirements.	Given the previous reviews of the Questions and Objectives, we hesitate to make such a change at this time without broader input. If it's found at the outset of Implementation, that Objective 10.1 should be removed, that can be readily accomplished.
Jeff Fisher	NOAA	Design	24	I agree that fish monitoring is beyond NPDES permittee requirements, but this language seems to capture that in recognizing that other programs are doing this…	Agreed
Chad Larson	Ecology	Design	24	It is unclear what is trying to be said in this paragraph regarding target populations for monitoring sites	Clarified.
Chad Larson	Ecology	Design	26	It is unclear why this (primary population strata) should be established as a stratum? Is this not a consequence of habitat/conditions rather than something to stratify? Better justification for inclusion as a unique stratum should be provided.	Clarified.

COMMENTER	ORGANIZATION	DOCUMENT	PAGE NUMBER	COMMENT	RESPONSE
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	26	Is the project going to include this map product?	It is presented as Figure 3
Karen Adams	LCFRB	Design	27	I agree to the extent that the metrics are not overlapping in purpose… temperature, conductivity, and stage for example are only useful in either case if you have continuous data for at least a critical season and would also be informative for habitat assessment. It might be worth acknowledging that WQ metrics ARE equally critical habitat metrics in aquatic habitats. Given the limited number of water quality metrics, I would like to see more overlap in the habitat portion with the exception of sediment metals, which are expensive and may not provide a signal at most sites.	As stated in section 2.1.1.2, "Habitat status and trends monitoring addresses physical and biological attributes that affect watershed health and salmon recovery." Unless it is assumed that there are insufficient numbers of Qa/Qx sampling sites/strata, the S&T for WQ throughout the region should be adequately characterized without adding several hundred additional sites. In addition, the level of effort needed to implement continuous data collection at habitat sites would probably increase the cost of this program many-fold without providing commensurate value.
Chad Larson	Ecology	Design	27	Who embraces this guidance (NRC 2009)? Not clear from this statement.	Clarified.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	27	I've heard some folks say that low S/N parameters might be less useful simply because they don't change much or may be insensitive to management actions.	This may also be true, but a low S/N ratio provides no information on the responsiveness of a metric to management actions, only that it's very difficult to detect any such trends if they do exist.

COMMENTER	ORGANIZATION	DOCUMENT	PAGE NUMBER	COMMENT	RESPONSE
Karen Adams	LCFRB	Design	27	I feel like this is a KEY statement, not just a parenthetical. For the layperson, a “statistical perspective” doesn’t really describe what result we are working toward. It would be good to call out in a separate sentence that what we are doing is identifying what data is reliable and what data isn’t so we know what data we would WANT to share (the reliable data). No one wants to incorporate data of questionable quality into their data set. THIS is the key aspect of how signal to noise informs sharability. First, do we want to incorporate or share someone’s data… well, let’s look at its S:N and get a sense of our confidence in the data? THEN we talk about how we share those data that are reliable even if they are not collected in the same way. That is a separate step. I think this is a key link that has not been called out in a way for some people to understand what they get from Signal to Noise and why we are doing this as part of the shareability discussion.	The text has been revised to address this concern
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	27	Here they are talking about precision. What if the data are fairly accurate and precise such as lab data and turbidity? But still have a wide range of results?	If data are highly variable, you need more data points (monitoring sites) to detect a significant change. The current recommendation of 15 sites/strata combination is based on a CV of 0.5-1.
Chad Larson	Ecology	Design	27	Collecting too little data can have the same effect (as imprecision, which compromises the utility of data for diagnosing causes of impairment)	Agreed.
Karen Dinicola, Brandi Lubliner	Ecology	Design	28	Tell us where to find these results (of the literature review) in this report, please	This is the methods section and as such not appropriate for reporting results. However to answer the spirit of the question - the literature review resulted in S/N data presented in Tables 4 and 5 as well as Appendix A and B

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Chad Larson	Ecology	Design	28	It is important to note that a significant part of the cost of sampling any particular stream reach is the initial efforts to get there. Overall, the biggest issue will likely be how many total sites can be reasonably sampled with the eventual budget, with the number of metrics gathered at each site being decided once a final budget is available. Having a list available of the metrics with the highest potential for useful information is a very good idea at this point, but we also feel deciding on the final list of metrics that will be measured at each site is secondary to the overall experimental design. Hashing out which metrics will eventually be measured should be a major part of the next phase of this project.	We fully agree, and don't believe that anything in this passage contradicts this sentiment. It also restates why a "final" design cannot be determined without clear financial boundaries on what can be afforded, something that is not likely to be developed until reaching the implementation phase.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	29	Can you provide any detail at all on the upcoming implementation plan?	An overview is provided in Section 3.6 of the report.
Karen Adams	LCFRB	Design	29	Water quality objectives? It might be helpful to provide that descriptor here to give the reader a bit of context. I find myself going back up to the Q&Os to recall what the gist was…	Brief tagline added.
Karen Dinicola, Brandi Lubliner	Ecology	Design	29	Regarding the directed pseudorandom approach - I disagree that this is a different approach – it's more that the sites with the unique characteristics to answer these questions are quite limited and therefore the total target populations are reduced. The answer may end up having less statistical confidence. It is up to the stakeholders to decide if it's worth the extra cost to answer the questions at a reduced confidence level.	The contrast made in the text was between probabilistic and opportunistic sampling which are fundamentally different methods of selecting sites. The pseudorandom approach is a hybrid of the two and we concur that it will be necessary to address some of the objectives and it will lower the statistical confidence. Statistical confidence should never trump a meaningful design!

COMMENTER	ORGANIZATION	DOCUMENT	PAGE NUMBER	COMMENT	RESPONSE
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	29	Reference Phase I work when talking about the pseudo-random sample draw	Addressed in text revisions
Karen Dinicola, Brandi Lubliner	Ecology	Design	29	This (that the water quality parameters vary gradually) is not true for the stream benthos sampling and that consideration needs to be recognized and addressed.	Stream benthos isn't a "water quality parameter," although it is recommended for sampling at Qa/Qx sites. The text says "most" (not "all") and the need for specific conditions for meaningful sampling is well recognized and won't be forgotten. This point in the text, however, is not the place for it.
Karen Adams	LCFRB	Design	29	Suggested insert: "More specifically, water quality data are assumed to represent the conditions within that reach, not just the point at which it is taken. Thus…"	Included
Karen Dinicola, Brandi Lubliner	Ecology	Design	29	Please include a footnote defining what marks the end of one reach and the beginning of another. Because this can be subjective to a certain degree (i.e., what tributary input is relevant?) it needs to be defined. We came up with a definition for Puget Sound that was applied in site selection and confirmation. Let me know if you need criteria and/or the reference.	Clarified at this point in the main text.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	29	Temperature may be influenced by localized conditions within a reach if the reach is long and the stream small.	Correct. Text revised to soften statement

COMMENTER	ORGANIZATION	DOCUMENT	PAGE NUMBER	COMMENT	RESPONSE
Karen Adams	LCFRB	Design	29	Is this true? What if there is a discharge point downstream of your sampling location? You won't capture that impact. This is one of the only reasons I feel like trying to sample toward the bottom of a reach makes sense. You capture more of the impacts in the reach that way. Not sure this needs to change, but it is a point I would like to understand better.	Yes, this is true, by virtue of the limitations placed on the range of drainage areas that bracket the definition of "reach." Of course, tributary inputs can still keep the reach within the specified drainage-area range, and they will certainly make a contribution to the constituents in the water. But we are seeking to characterize reaches as a population, not a specific 'reach' in question. The greater concern might be whether a systematic bias might be introduced in the specifics of site selection, e.g. always just above or just below a tributary or outfall--but as long as the sample locations are random (or at least not systematically biased) they results should still be suitably representative.
Jeff Fisher	NOAA	Design	29	Given that I am not clear just how long each reach may be—and they could be of some significant length, I agree with Karen's comment above…	See above response, and text addition. Concrete examples appear somewhat later in the text on Figure 6.
Karen Dinicola, Brandi Lubliner	Ecology	Design	29	This (idea that no reach should drain into any other reach) doesn't recognize that a reach is defined by major tributary inputs or other changes deemed significant. Adjacent land use, outfalls, etc. can have a notable Qa/Qx impact.	Reaches for this purpose is defined strictly by drainage area. As for the last point, yes, this is true. See prior response.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	31	How is this determined beforehand? Or is it part of site evaluation after the sample set is selected?	We expect that this is largely addressed in the make-up of the Master Sample; but as with all such remotely sensed data, they will need to be field-verified before certainty is achieved.

COMMENTER	ORGANIZATION	DOCUMENT	PAGE NUMBER	COMMENT	RESPONSE
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	31	It might be good to make a distinction between stormwater runoff monitored from MS4 outfalls and receiving waters heavily influenced by stormwater runoff from various nonpoint sources.	Addressed in text revisions
Karen Dinicola, Brandi Lubliner	Ecology	Design	31	This quote (from NRC 2009) is not applicable in this context. The study design is for sampling of receiving water, not stormwater.	Proposed revision accepted
Karen Adams	LCFRB	Design	31	We discussed how sites impacted by the Columbia River are an important area for consideration in habitat monitoring given the importance of these areas for rearing and acclimation of juveniles (particularly chinook). It would be helpful to incorporate a discussion of how those sites could be incorporated into an Estuary Scale design at some point in the future.	Addressed in text revisions
Karen Adams	LCFRB	Design	32	In figure 3, it would be helpful to have the red circles on the top map to help georeferenced these images in our heads.	Addressed in text revisions
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	32	Will there be a data layer to define the area for exclusion (tidally influenced areas)?	This will not be part of the Design Report.
Karen Dinicola, Brandi Lubliner	Ecology	Design	33	Recommend dropping this (subbasin per primary population strata) for Qa/Qx. Can keep for habitat if the fish folks prefer – but really they should just densify the design in the Lewis River basin.	Interest has been expressed in other quarters for keeping it. Re-combining the categories at a later date, however, would be easily accomplished. Note that it is only applied for the "regional" monitoring component of Qa/Qx monitoring (i.e., "outside" of urban NPDES areas).
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	33	There aren't any now. We only monitor stormwater at outfalls and do effectiveness studies.	We are quite aware of this, but DOE has all-but-guaranteed a future change. If this plan cannot anticipate/accommodate that eventuality then it's not going to be very useful.

COMMENTER	ORGANIZATION	DOCUMENT	PAGE NUMBER	COMMENT	RESPONSE
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	33	Perhaps qualify this in that the project is looking at receiving water, while stormwater monitoring is at MS4 outfalls to receiving waters. Not exactly the same thing. But likely nearly the same in intensely urbanized catchments.	Agreed.
Karen Adams	LCFRB	Design	33	RE: Figure 4. Unless I am interpreting this wrong, this does not sound like useful data to me then… just as metrics have poor signal, the data will have poor signal if we don't collect enough data at enough sites. While affordability is key, what we need to know is what is an ideal situation would be and then we can figure out how to scale this down the road. With the metric reductions I feel that the S:N analysis justifies the cuts. Please discuss how this will impact our ability to detect significant trends if we have 50%-100% error in our data due to too few sites.	As previously discussed, building an "ideal situation" led to a guidance document in the previous phase that had almost no transferability into a potential real-world application. We ARE "down the road," and now is the time to begin tackling these issues head-on. It is very unlikely that project partners will be able to afford to "buy" greater certainty--the best that can be hoped for is that the actual variability of the data is less than is anticipated here, and that errors will be reduced commensurately.
Mindy Fohn	Kitsap County	Design	34	RE: Figure 4. This correlation of samples needed for highly variable stormwater and applying it to receiving waters may not be "like to like" but it's probably the best that can be done.	It is admittedly not ideal and likely a worst-case condition. Systematic data collection (here and elsewhere) will likely clarify the actual variability.
Karen Dinicola, Brandi Lubliner	Ecology	Design	34	Confusing to introduce this term (channels). Suggest using reaches. But you might mean sites, so I added that choice in my edits.	Agreed.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	34	Will there be perennial flow in the 2.5 k catchments? Does that matter?	Based on anecdotal experience these are likely to be perennial. And yes, it would be a problem if they're not.
Karen Dinicola, Brandi Lubliner	Ecology	Design	34	Please give a more precise idea of how many (watersheds with non-urban land cover but within the NPDES jurisdiction of Clark County) you mean	Unclear why greater precision is needed. It's about 50, but they are not called out for specific sampling. In any case, there are clearly "enough" to achieve a meaningful sample population.

COMMENTER	ORGANIZATION	DOCUMENT	PAGE NUMBER	COMMENT	RESPONSE
Mindy Fohn	Kitsap County	Design	34	Stream gradient is not a strata for WQ. That makes sense except for Macroinvertebrates. We're finding that the gradient and stream order may be relevant in interpreting trends. Stream power relates to the population – and if relying on EPT – this may result in unwanted noise.	The need for consistency in channel gradient for IBI is recognized and will be incorporated into the protocols for this metric. That need does not require the creation of a new stratum, just a screening for those sites that are selected to ensure that the data collected there are meaningful.
Karen Adams	LCFRB	Design	34	We need to define urban in a way that is in addition to the Urban Growth Area Boundary. I have fielded the following question: There are areas outside of a UGA that have every bit as high density of parcelization and development as within the UGA, particularly adjacent to these boundaries. If those areas are lumped into the Non-Urban category are they not skewing the data? I have responded that the number of actual sites/stream reaches within this situation is minimal and they should not have an impact. Also it is possible that in the screening process, they would not meet the non-urban criteria and would be eliminated during site selection. I'm not sure if I'm right on those responses, but they are my current hypotheses regarding what this means on the ground and how to deal with it. Perhaps a definition of Urban in terms of not only jurisdiction but density of residents would be useful here. Perhaps an acknowledgement of this situation and some discussion or recommendation on how to deal with it would be beneficial as well.	The text has been careful to distinguish "urban", as a category in the 2006 NLCD, from "urban areas" as defined by the location of UGA's. The question that was posed to you points out that these are not the same thing, and that a meaningful stratification needs to distinguish between them. That is exactly what is being recommended here: a "jurisdictional" stratification, for which the state has chosen to use the term "Urban Growth Area" (and so we do, too); and a land-cover stratification taken directly from the 2006 NLCD, and for which we believe the term "urban" is most intuitive. It is also true that these ex-UGA, urban land cover areas are not extensive and should be no more "skewing" of the data than their actual presence/importance would indicate.
Chad Larson	Ecology	Design	34	(is non-urban the same as) Non-UGA?	Yes, in the context of the jurisdictional stratification. See above comment regarding the different uses of "urban."

COMMENTER	ORGANIZATION	DOCUMENT	PAGE NUMBER	COMMENT	RESPONSE
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	34	What (GIS) data sources (used to help id site within a reach)? Parcel data, etc.	An example approach has been added by citation; but the specifics are best handled in the implementation stage--not particularly relevant/critical for design.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	34	Legacy sites will generally have this taken care of.	True, but we will be sampling more than legacy sites
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	34	This is an interesting issue because there are large areas where the county MS4 exists in the rural area (outside UGA). And large areas of state and industrial forest where there is no permitted MS4.	We fully agree, and we believe that there is no benefit (or scientific justification) to combine monitoring data from these "rural MS4" areas with those from the "urban NPDES" areas.
Chad Larson	Ecology	Design	34	Since this is supposed to be a long-term monitoring project, future growth will mean that this statement (regarding the adequacy of regional sampling to address non-urban permitted sites) may not always be true.	Given the relative proportions of urban to non-urban land (presently), this statement--though probably not true forever--is likely to be true enough for a long time to come.
Chad Larson	Ecology	Design	35	Why 15? Was this number chosen because it is between 10 and 20? Please provide rationale for why this specific number (for QaQx sites) was chosen.	Yes. Noting that it lies between 10 and 20 seems unnecessary for most readers, but it can be added if needed.
Karen Dinicola, Brandi Lubliner	Ecology	Design	35	Might also tease up the question of whether we need representations of industrial, commercial, residential urban land uses rather than dumping them all in one category (urban). Refer to outfall monitoring data findings (Hobbs et al, 2015) for most relevant differentiation of land uses.	Not judged to be a critical discrimination for regional S&T monitoring.
Karen Dinicola, Brandi Lubliner	Ecology	Design	35	Yet another term (segments)! Again, I suggest reach.	Agreed.

COMMENTER	ORGANIZATION	DOCUMENT	PAGE NUMBER	COMMENT	RESPONSE
Karen Dinicola, Brandi Lubliner	Ecology	Design	35	Need to define this – what change in flow is meaningful (in defining a site location along a stream reach)? 10%? 25%? The Puget Sound experience was that 20xbankfull width is too little length for locating WQ sites if truly considering logistics first. We like the hydrologic reach approach for Qa/Qx.	20x bankfull width is not recommended for the Qa/Wx monitoring--anything within the "reach" will do.
Karen Dinicola, Brandi Lubliner	Ecology	Design	35	This (logistic considerations of access and land ownership) is among the reasons that we liked the October approach of finding a suitable site as close to the downstream end of the reach as possible.	The text has been clarified to be consistent with the October approach
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	37	Map figures are too small	They are small on paper, but we believe most readers will review the document electronically which allows a magnified view. Splitting the figures apart to enlarge them would lose the benefit of side-by-side presentation.
Karen Dinicola, Brandi Lubliner	Ecology	Design	37	Identify this (criteria for identifying a location along a sample reach) as a next step in the conclusion of the report.	Agreed.
Chad Larson	Ecology	Design	37	This (defining criteria for locating sites in a reach) will be important; as sites are revisited, sampling approximately the same stream reach will be necessary for evaluating changes in habitat metrics.	Agreed--a site once chosen should be maintained. Note, however, that this section is for Qa/Qx monitoring, not habitat monitoring.
Mindy Fohn	Kitsap County	Design	37	Fully support the tidal influence analysis and omitting these sites.	Thanks.

COMMENTER	ORGANIZATION	DOCUMENT	PAGE NUMBER	COMMENT	RESPONSE
Karen Adams, Rod Swanson, Karen Dinicola	LCFRB, Clark County	Design	40	Suggested insert “(undeveloped areas within the UGA)” to describe what questions 8.1 and 8.2 were about so we don't have to go back and look. It would be helpful to the reader to add a short-hand description of the question “S&T of Qa/Qx in UGA+NPDES” rather than sending us back in the report to find the list of objectives.	This and related comments suggest that the readers would prefer a brief recap of these objectives rather than looking back 13 pages. We can do that.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	40	Questions 8.1 and 8.2 tend to fall into what might be better described as a long-term targeted effectiveness study.	A reasonable comment--the division between a "long-term effectiveness study" and "status and trends" is fuzzy. Given the long period of presentation/review/revision that the Q&Os have already been through, however, our plan is to retain them in this design document.
Karen Dinicola, Brandi Lubliner	Ecology	Design	40	Add a new section heading here, perhaps “Sustainable Level of Effort”	A reasonable suggestion but nut judged necessary.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	41	Notably, the SWG study only examines only the Puget Sound lowlands while the SW WA work extends to the top of the cascades and coast range mts.	Agreed--good reminder to insert.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	41	See the PS geographic area (regarding the upper limit on what is feasible in the LC).	Same response as above.
Chad Larson	Ecology	Design	41	What are they? (compelling reasons to stratify sample sites by drainage area)	Reworded for clarity.
Karen Adams	LCFRB	Design	41	Given the scale of regional monitoring, why would we not just expand the metrics to include the 3 not already shared between Qa/Qx and Habitat (Conductivity, Stage, and Sediment Metals)? Cost and continuous monitoring are two reasons I can think of, but if we are recommending them for 400 sites, then perhaps 400 of the 1200 sites required for habitat monitoring would need to have this level of effort and it could be our “trends” data set.	This would represent a tremendous increase in cost for uncertain increase in value. See prior discussion of the likely feasible limits of a LCR-funded effort on Qa/Qx sampling, based on the Puget Sound experience. This recommendation would probably increase the cost of this program beyond the limits of both.

COMMENTER	ORGANIZATION	DOCUMENT	PAGE NUMBER	COMMENT	RESPONSE
Karen Dinicola, Brandi Lubliner	Ecology	Design	41	This is the first mention of primary populations and the term needs to be defined. It is not relevant to the stormwater monitoring objectives, but readers of this report should be informed what it is and what it means and why it would drive the monitoring design. Also, the grant was directed at fish beyond salmon. How if at all does this represent other important aquatic resources?	The term appears and is first defined on page 10. "Fish beyond salmon" benefit in the same manner as salmon from the HSTM which provides a systematic characterization of the conditions and changes in watershed health
Dorie Sutton	City of Vancouver	Design	41	Organizational comment - Puget Sound population discussed above, just as reminder that we are now back to fish populations.	Good point, thanks for the clarification.
Karen Adams	LCFRB	Design	42	"Primary Population" needs to be defined somewhere. Primary populations are those populations that we are required to recovery to a high viability, that is there has to be a 95% chance of persistence of a primary population over the next 100 years. Only after all of the viability goals (high to maintenance levels) for all populations are achieved can we delist salmon in the lower Columbia ESU.	Addressed in text revisions
Karen Dinicola, Brandi Lubliner	Ecology	Design	42	Based on stormwater characteristics and the driving questions for Qa/Qx, commercial/industrial and residential should be split out in lieu of Primary Populations which have no effect on Qa/Qx.	As explained earlier, the document never implies that PP's are a "cause" of Qa/Qx conditions--just that management applications may want to ensure that the subwatershed supporting the most populations are sufficiently well-represented in the monitoring.
Mindy Fohn	Kitsap County	Design	42	This (Primary Populations) is such an interesting idea for strata. I do hope it's not lost. Maybe in the future discuss the goal of "preservation" vs. "recovery". Both are so important and one should not be sacrificed over the other.	Thank you for your understanding of its value. Clearly, not fully shared by all other reviewers.
Karen Dinicola, Brandi Lubliner	Ecology	Design	42	Not sure exactly what is meant by this (Land cover discrimination).	Clarified.

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Karen Dinicola, Brandi Lubliner	Ecology	Design	43	I’m not sure why this (description of the region as broken out by watersheds) is discussed in such detail here. It’s distracting – seems like you’ve moved to the “outside UGA” strata but you haven’t.	Reviewer is mistaken--this is in the subsection "3.2.1.2 Regional Qa/Qx monitoring", which clearly IS outside the UGA.
Karen Dinicola, Brandi Lubliner	Ecology	Design	43	Please also recognize that urban areas exist between these watersheds as do other aquatic resources besides salmon. For the “inside/outside” UGA+NPDES Qa/Qx strata we still have work to do here.	Comment unclear, likely related to the (mis)understanding of the prior comment.
Chad Larson	Ecology	Design	43	(Is eliminating land use cover strata) More likely (to reduce the level of effort) than potentially removing the number of primary populations?	No response required
Chad Larson	Ecology	Design	43	As mentioned previously, not sure why this (Primary Populations) needs to be a strata of interest. Additionally, sites selected in the 4+ primary populations will likely be more spatially clustered than sites from other categories.	Rationale explained previously. Unclear why greater spatial clustering is anticipated, except perhaps that the total area of 4+ subwatersheds is modestly smaller than that of the others. Is that a problem?
Karen Dinicola, Brandi Lubliner	Ecology	Design	43	Above, where? There are several descriptions (of how to locate sites), including deferred decisions.	Clarified. Section reference is rather unambiguous, however.
Karen Dinicola, Brandi Lubliner	Ecology	Design	43	This is a slightly different approach (for selecting QaQx sites) than what was described at the October workshop and I don’t remember this shift in thinking/approach being articulated in January. I have made other relevant comments in previous sections about LU changes and tributary inputs as well as site selection considerations. “Along the same reach” needs to be clearly defined.	The approach is described more completely here but is unchanged from the intentions expressed at the last workshop. Agreed that "along the reach" needs to be made more explicit, to the extent that this is possible in a design report absent any actual sites.
Chad Larson	Ecology	Design	44	Unclear how this (urban land cover) differs from sampling that will already be conducted in UGA?	UGAs do not always have the urban land cover classification according to the NLCD, albeit, most of the time they do

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Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	44	Can you describe how rural suburban (such as areas of ~ 5 acre lots) is separated from Ag?	This is a land COVER classification, not a land USE classification. These are primary categories of the NLCD data and have been applied without further interpretation. Rural residential development is most likely to be categorized as "Developed, Open Space"; if it is truly interspersed with true agriculture, then at the scale of the 2006 NLCD each 1/4-acre pixel will be classified accordingly. Note that tater subsampling will always be possible for specific jurisdictional applications.
Chad Larson	Ecology	Design	44	How many urban-outside UGA are there expected to be? (in terms of the urban land cover strata)	Few and they are analyzed in a later section.
Karen Adams	LCFRB	Design	44	Cleared is not feasible to assess right now, but is a needed land cover and should be included, especially if it is among the items to be continued in the next phase. Again, we want to know what a robust design is, and we can determine how we want to scale the work in the next phase.	issue addressed in a previous comment
Chad Larson	Ecology	Design	44	This needs to be outlined better. How will this (Habitat monitoring) information be linked to stormwater monitoring? Perhaps a conceptual diagram of the overall experimental design and how the various components are linked would help clarify this for the readers?	The linkage of habitat monitoring to stormwater monitoring has not been clearly articulated to date in any Phase 1 report or project document. There is a broad expectation that coordinated monitoring will yield synergistic benefits, and that expectation has been articulated in this document as well. There is no conceptual framework that provides greater detail, and this report is not scoped to create one on its own.
Karen Adams	LCFRB	Design	44	Primary populations serve to support management goals that include focusing restoration efforts and/or understanding limiting habitat factors	Suggested revision noted

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Chad Larson	Ecology	Design	44	This (justification for using primary populations as a means to guide restoration efforts to support salmon recovery) assumes that the number of returning salmon populations is completely deterministic (i.e. a direct indication of impairment or health, which it may not be).	This text is an example of how the information could be used and why it is judged to be a useful stratification. Certainly there are factors other than water quality and habitat that affect the number of returning salmon. This complexity is not directly tied to the suitability of a management stratification such as Primary Populations
Karen Adams	LCFRB	Design	44	We should maintain this in our strata though we may not use it to start or pin it down until later. This follows the same logic used to defend keeping objectives 8.1 and 8.2. We know it is important even if it is not well defined or populated with sites at this time.	issue addressed in a previous comment
Chad Larson	Ecology	Design	47	Still unclear how this (inside/outside UGA in Permitted area strata for habitat) differs from Qa/Qx UGA sites. Why not collect the same metrics at those sites?	Different stratification for in/out of urban NPDES areas is necessary because the character of the watersheds and their receiving waters are very different. The same metrics are collected at both (next section, not this one), but they are subdivided differently to ensure that all major receiving-water types in these two (very) different areas are all adequately represented by the monitoring.
Karen Dinicola, Brandi Lubliner	Ecology	Design	47	I disagree with replacing UGA with UGA within NPDES, particularly for habitat it makes more sense to distinguish all urban and designated UGAs from other rural land uses because stormwater management practices, though permit-required, happen at different levels throughout urban areas regardless of permit specifications	We agree that from the perspective of the physical features, there is no "meaning" to the NPDES jurisdictional boundary. However, the NPDES permittees appear to be rather supportive of having this regulatory discrimination called out explicitly. If project partners support a distinction between Qa/Qx monitoring (which will likely be required by the next municipal stormwater permit) and habitat monitoring (which likely will not), however, then the monitoring design will not suffer or be greatly altered. The number of UGA's that are NOT within an NPDES permit area are a vanishingly small fraction of the total Master Sample sites in any case, so functionally this decision is unlikely to make any difference to the site selection outcome at all.

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Jeff Fisher	NOAA	Design	47	I don't agree that stratifying by primary populations presumes a deterministic approach necessarily. Yes, many other factors play out in determining reach abundance and productivity. That doesn't mean that stratifying by this method necessarily means anything other than a reflection of how the different populations have been tiered for recovery purposes, and is a pragmatic way to explore the trend relationships. Clearly though, a positive trend in abundance in a monitored reach that correlates with a trend towards PFCs for wq and habitat, cannot necessarily be construed to causation; making that leap would pose a potential type 1 error without some further study.	The stratification by Primary Population is not intended to demonstrate causation between wq/habitat and abundance. In fact, none of the STM strata can achieve that target. At best we will detect significant correlation between wq/habitat metrics and fish abundance and productivity. However with respect to the Primary Population strata, it is included to ensure adequate weight (think of it in terms of site distribution) is placed on site selection relative to the salmon recovery priorities in a given watershed. This is specifically designed as a management tool to demonstrate progress towards salmon recovery.
Mindy Fohn	Kitsap County	Design	47	This (The lack of consistency in published literature for setting acceptable levels of variability) is unfortunate and a frustration for many of us.	Agreed. Despite the tremendous amount of resources invested by the region in *collecting* monitoring data over the past decade, remarkably little progress has been made in actually *analyzing* it and drawing useful recommendations for others.
Chad Larson	Ecology	Design	47	This is redundant information. This paragraph is one example of how this report could be made to be much more concise.	"Much"? We welcome any such suggestions, but the primary gist of nearly all comments has been to increase the level of detail and explanation in the document.
Karen Adams	LCFRB	Design	47	For habitat, I don't think the limitations will be as much about the cost of the metrics as for the time for a team to collect data at the site. Most of the metrics are measured with tapes and observation… there are no sample costs. Reducing the number of metrics would not be likely to increase the number of sites we can do simply because of logistics of driving and hiking to the site.	As long as the activities can be conducted within a "unit" of time (i.e., a day), then this is true. So cost reductions may be a step function, not a continuous relationship to number of metrics…but there does come a point where "more data" really does translate into "more cost."

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Karen Dinicola, Brandi Lubliner	Ecology	Design	47	None (financial resources) are currently available!	Agreed, thus the inability to move to a truly final design.
Mindy Fohn	Kitsap County	Design	47	This table (Table 2) is a good summary and brings it home that you're selecting from strata that are dominant.	Thanks for the understanding.
Karen Adams	LCFRB	Design	47	While this is great news overall in terms of limiting the number of sites, I would imagine that we would want to know something about the condition of forested lands in small drainages. Especially on lower slopes, there could be a lot of habitat value in some of those for coho and steelhead who like to use the headwaters for spawning and some rearing. Likewise for the other categories that are removed from consideration as viable strata combinations. If this is just for the NF Lewis rather than the region, then on a regional scale could we still get enough sites perhaps? If is on a regional basis, then could we sample all sites in each combination and have a representative sample by virtue of having sampled all reaches.	Please note that this table is ONLY for the urban NPDES areas. There simply aren't very many small forested watersheds in these areas (that's why they're "urban").
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	47	(Some of the strata combinations have numbers of sites that are pretty close to the best estimate of 15… How would we deal with these?	Presumably, they would be reviewed for suitability; if the project partners hold firm to the desire to maintain a strict level of statistical confidence then those less than 15 would be dropped or relegated to a lower level of priority. Thus, this depends in part on available resources and so cannot be resolved at this stage of design.

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Mindy Fohn	Kitsap County	Design	48	In the workshop it was mentioned Puget Sound lost 50% of sites. They used points, and not reach. Also, they did not stratify. Kitsap had several sites, including legacy sites nearby, but these were not included. By converting to reaches and stratifying – my guess is you will only lose 20-25% of sites.	This would be great news, given the number of categories that are pretty close to 15 right from the start.
Karen Adams	LCFRB	Design	48	A valid exclusion is those combinations with NO sites… But for the 8 sites in Ag with 3 primary pops and high slope in a 2.5 -50 km drainage we could sample them all. Then it isn't stats but actual condition as we have sampled all reaches.	True, however would need to be done on a case-by-case basis and driven by limiting factors for listed populations are not thought to be represented by the current monitoring design and for which we anticipate the conditions might change. For example,
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	49	Clark has EMAP metrics for the 10 long-term index sites.	Excellent. Duly noted in the text
Jeff Fisher	NOAA	Design	49	How did you guys set on 20x bfw; typically habitat surveys are considered valid by sampling reaches 10x bfw…within the UGAs this might place some constraints (access, private property, etc.). No real problem with using 20x bfw, it just seems like, in practical purposes, this could be a challenge for sampling in some areas.	Reference added. That said, logistical constraints may well limit the feasible distance in some locations.
Karen Dinicola, Brandi Lubliner	Ecology	Design	49	How much flexibility is available here – why not upstream of or inclusive of (the randomly selected site rather than just downstream)?	If the choice of direction is at the discretion of the surveyor, it's not "random". Specific protocols for site/reach selection will be part of Implementation. It does not affect design.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	49	Include summer base flow as a criterion for site selection.	Why? For habitat metrics flow is not required.
Karen Dinicola, Brandi Lubliner	Ecology	Design	49	This sentence (regarding an analogous program for comparing feasibility) is not followed up with information about costs, only metrics are listed. The following "level of effort" paragraph can stand alone.	The paragraph ends with the level of effort required by a field crew. This has not been translated into "cost," but since field crew time represents the dominant expense for such a monitoring program we respectfully disagree with this comment.

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Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	49	Are these metrics (responsive to changes in stream flow or sediment load) identified in the report?	Yes, these are the metrics recommended for HSTM monitoring
Chad Larson	Ecology	Design	49	Without fishing, habitat can be collected at a reach by a crew of two and completed in approximately 3-4 hours, yielding over 250 habitat metrics (rather than a team of 3 requiring a day).	This is without fishing or macroinvertebrate/periphyton collection. Still the time required to get to the site and deal with data after the site visit makes more than one site visit in a day unlikely. As noted previously, the number of metrics collected at a site is not the strongest determinant of cost (number of sites are), but it's not irrelevant either. "More metrics" is not necessarily equivalent to "more information."
Jeff Fisher	NOAA	Design	49	Is this (Mean residual pool vertical profile area) something different than residual pool depth? If not, why not use the simpler term?	They are not the same. From monitoringmethods.org: "The mean residual pool vertical profile area is the calculation of an accumulation of areas over the course of the reach. The input data includes the thalweg depths of the channel, taken at 10 stations dived equally between Transects, the slope of the reach, and the increment which is the distance between stations. At each station we calculate a residual pool profile area, and we accumulate those areas to determine Mean Residual Pool Vertical Profile Area in meters squared per reach. The calculations used to determine Mean Residual Pool Vertical Profile Area are derived from the EPA EMAP program and additional information may be obtained from Phil Kauffman of the EPA."
Scott Anderson	NOAA	Design	49	For this HSTM effort, need to specify where LWD pieces are measured- everything in the floodplain? Bankfull? Wetted perimeter?...ideally within the bfw, as wood provides different functions under different flow stages.	Agreed, this will be necessary and will be part of the protocols in the implementation report. Such details do not affect the monitoring design (this report), however.
Mindy Fohn	Kitsap County	Design	50	Excellent analysis. S/N feedback to metric selection and anticipated variability. This is a strength of this program.	Thanks.

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Karen Dinicola, Brandi Lubliner	Ecology	Design	51	Regarding additional stakeholder input: It would be appropriate to include a discussion of the questions posed as to whether the S/N for metrics in urban settings are realistically represented by the S/N found by rural-based programs.	The most developed datasets and analysis for S/N are for stormwater monitoring in urban settings. We realize it's not ideal to apply the same conclusions to rural settings, but we do not have a better available alternative.
Chad Larson	Ecology	Design	51	Considerable data from the Lower Columbia is readily available in Ecology's EIM/STREAM database. An S/N analysis of statewide data is already underway.	We are aware of several such 'ongoing' efforts, but none that were willing to share their results in time for this report. We fully expect, however, that the intensive efforts being made throughout the region will be incorporated as they become available.
Karen Adams	LCFRB	Design	51	Include some alternatives here, what are some options for the best course of action for phase II?	Addressed in text revisions
Dorie Sutton	LCFRB	Design	51	Funding decisions won't change the design, but will affect implementation. I would take this statement out.	We respectfully disagree with this comment--funding imposes fundamental, and commonly irrevocable, constraints on the design of a monitoring program. Its exclusion for consideration during Phase 1 of this project, for example, rendered much of that prior work irrelevant by virtue of its utter implausibility of ever being implemented.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	51	Are there sources (monitoring programs) that identify metrics associated with urban runoff?	Yes--identified in Table 4 and Appendix A.
Karen Dinicola, Brandi Lubliner	Ecology	Design	51	This table belongs after the four paragraphs of text remaining in this section. I have made multiple suggested edits to make this table more clear and accessible to stand-alone use	The table has been moved as requested

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Jeff Fisher	NOAA	Design	51	The footnote referenced here (for conventional stormwater pollutants) is confusing…are we saying the list could be expanded based on 2015 monitoring? Can we be more specific as to the rule set that would modify this list? None of the parameters monitored correlate with the pre-spawn mortality recognized in Seattle's urban streams…a comment I thought I made a long time ago.	I assume this comment is misplaced. The footnote indicated merely identifies those stormwater pollutants that have been commonly measured over the last 30 years, without any reference to (for example) the Seattle pre-spawn mortality study. I note that the 2011 PLoS ONE abstract for that study states " The weight of evidence suggests that freshwater-transitional coho are particularly vulnerable to an as-yet unidentified toxic contaminant (or contaminant mixture) in urban runoff." Such constituents are particularly challenging to list in a table of metrics, and the lack of correlation with prior or current recommended parameters is not surprising.
Karen Dinicola, Brandi Lubliner	Ecology	Design	51	In Puget Sound, the full suite of habitat metrics associated with the IBI (watershed characterization) is proposed to be collected once per 5 years.	Agreed (see next comment)
Mindy Fohn	Kitsap County	Design	51	(Table 4, RE: frequency of data collection) Once per 5 year period?	Yes. Corrected.
Chad Larson	Ecology	Design	52	This (EPT) is only one of many other metrics associated with macroinvertebrates.	Agreed and removed
Karen Dinicola, Brandi Lubliner	Ecology	Design	52	If the broader habitat program is never implemented, is it not a concern that there would be no full habitat data at any of the Qa/Qx sites? Will this monitoring to inform how to improve B-IBI scores without habitat data?	There is little published evidence that *any* direct causality can be drawn between BIBI scores and physical habitat, except insofar as substrates are either suitable or not, grain-size-wise. If we could afford only one metric, period, to characterize instream health then I would advocate for this one. Other metrics will provide additional information, but they're the "optional" ones if funding is an issue.

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Karen Dinicola, Brandi Lubliner	Ecology	Design	52	Are flow, sediment chemistry and substrate size sufficient to support interpretation of B-IBI scores?	As noted above, there is no set of physical parameters that are "sufficient" to support interpretation of BIBI scores…but every little bit helps. The scientific literature is replete with examples of weak correlations, plausible explanations without controlled experiments to prove, and complex factor-ceiling and factor-floor relationships that defy simple explanations or direct causal mechanisms. This program is not going to change that state-of-the-science.
Karen Dinicola, Brandi Lubliner	Ecology	Design	52	My colleagues here have asked that you consider adding embeddedness and relative bed stability to help explain the B-IBI results at Qa/Qx sites that are not selected as habitat sites – that would likely be most of them.	Yes, owing to the number of Master Sample points, it should be assumed that no Qa/Qx and habitat sites will overlap. We have no quibble with either of these metrics (they are included in the recommended ste of habitat metrics), except for their potential to increase field time (and so potentially the cost). Note that RBS is simply the ratio of data already collected (substrate and bankfull depth) so this suggestion is moot. We would encourage your colleagues to share their analyses that explain BIBI results in terms of these two metrics.
Chad Larson	Ecology	Design	52	This is a very limited set of habitat metrics. Inevitably, if macroinvertebrate metrics suggest impairment, municipalities will want to know what is causing the low scores. Without habitat data, it will be difficult to determine potential causes of the impairment. Some of these habitat metrics are also related with storm water issues and tractable through time (e.g. relative bed stability, embeddedness, etc.). Consideration should be given to measuring the same set of habitat metrics as will be measured at the other sites.	Duplicating all habitat metrics at Qa/Qx sites will almost certainly reduce, substantially, the total number of sites that can be afforded. As noted previously, the ability to deduce the cause(s) of poor BIBI scores from habitat data has no clear support in the scientific literature; rather, the accumulation of effects from watershed alteration seem to be the most consistently reported finding. This program could, indeed, provide another data set to support this elusive pursuit of causality, but that has not been articulated as a primary driver (nor one of the Questions and Objectives) for this program.

COMMENTER	ORGANIZATION	DOCUMENT	PAGE NUMBER	COMMENT	RESPONSE
Karen Dinicola, Brandi Lubliner	Ecology	Design	52	NAWQA is collecting habitat metrics as well. Please contact Patrick Moran at pwmoran@usgs.gov or Bob Black at rwblack@usgs.gov	Presumably, their guiding monitoring Q's and O's provide a basis for this effort. Ours do not.
Karen Dinicola, Brandi Lubliner	Ecology	Design	52	Are “substrate size” and “substrate particle size (% composition” the same thing?	Yes - for some programs. We intentionally did not specify the method for characterizing substrate because protocols differ between programs
Chad Larson	Ecology	Design	52	Substrate is a very broad parameter	Agree. See comment above
Mindy Fohn	Kitsap County	Design	52	(The Kauffman 1999 study) If I understand correctly – this is from Atlantic region. The concern is that these grades may not correlate well with PNW references and be applicable.	Kaufmann et al. (1999) reports S:N from both the "Mid-Atlantic" and "Oregon" (their terms). We are reporting here the Oregon values, with the expectation that they are the most applicable.
Karen Dinicola, Brandi Lubliner	Ecology	Design	53	This is a good place to explore and reference the Hobbs paper and other efforts for typical stormwater indicator parameters.	The Hobbs data are exemplary in their reliance on continuous, flow-weighted sampling to provide meaningful data on pollutant concentrations in stormwater. As such, that study implicitly embraces this paragraph's (and the study's) rejection of water-column grab sampling as a meaningful source of data. However, we assume that Hobbs et al. selected parameters for evaluation on the basis of much prior work, and this is what is being discussed here.
Chad Larson	Ecology	Design	53	Unless you cite specific examples of this (substituting grab samples for more cost prohibitive continuous monitoring) occurring, including this is unnecessary	Ok.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	53	Take a look at the phase II permit to see the status and trends cost allocations by permittee for Puget Sound region. That should give an indication of what is acceptable.	At present, we are relying on the prior analysis by the city of Longview to assess order-of-magnitude "affordability." More detailed investigations will be necessary but not at this stage of the project.
Karen Dinicola, Brandi Lubliner	Ecology	Design	53	This study is not really applicable to this paragraph, but it is definitely applicable above and to other discussions elsewhere in this section and overall report.	Agreed.

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Karen Dinicola, Brandi Lubliner	Ecology	Design	53	The stormwater characterization data and findings deserve a paragraph of their own in this section. Clark County puts a substantial effort in collecting those data and they are highly relevant to the objectives of this monitoring program.	We added text to recognize the work being conducted by Clark County, but greater detail to a specific program is beyond the purview of a design report.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	53	We once used the EPA "rapid assessment" protocol in EPA 841-B-99-002 and found them useful for quick assessment of good fair poor conditions. Good accuracy but poor precision… according to EMAP reporting as I recall.	That matches my experience as well--coarse, but time-consuming.
Chad Larson	Ecology	Design	55	A reference to our bank stability (a score from Puget Sound summertime 2009) shows up as an "A". That is actually a method we decided to re-work due to failing score. The now-defunct method has been replaced.	Good to know. The Merritt and Hartmann 2012 report lists the score as an "A". Perhaps it reflects the new method.
Rod Swanson, Jeff Schnabel, Ian Wigger	Clark County	Design	57	What are the deliverables for the current project?	This is the deliverable… a design report. Other deliverables include a partial QAPP, and GIS layers

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Chad Larson	Ecology	Design	58	RE: Data collection and management task - We should consider that: Studies using a once-annual summer index sample may not reflect on how signal to noise would express in monthly (e.g. WQI) measurements. Habitat sampling will express difference signal-to-noise depending upon i-Region monitored (e.g. variance of large wood would be different in Columbia Plateau than other regions). ii-Temporal scale (1x annually vs. monthly, daily or every 30 minutes) iii - Spatial scale – We expect less noise when limiting analysis to a set of small streams within a given watershed. iv - Signal to noise for routine measurement systems like habitat are best used in the analysis phase rather than deciding upon which things to measure - It may take more effort to disassemble routine measurements from established forms, database scripts, and training than it would to measure it all.	All of these are good points; some (e.g., the last) is better addressed during the implementation report; others will be dependent on having data collected by the identified protocols or analyzed by others who have already collected those data. Should the results demonstrate that variance is lower than anticipated then either the level-of-effort can be scaled back, or a greater level of statistical confidence will have been achieved without additional effort. Good news in either case.
Chad Larson	Ecology	Design	58	Additional comments: 1. Please consider major re-editing to streamline text. 2. Many jargon terms (e.g. primary population) are found throughout the document; please consider a glossary of terms.	Suggestions taken to heart.
Chad Larson	LCFRB	Design	General	Overall, I think we have a pretty strong design here. In terms of the report, <u>edits with an eye to organization and formatting would be helpful</u>. I know that a few people have mentioned that they have a hard time following the logic/storyline as you are telling it. The ideas jump around somewhat. Look at this document in terms of organization and see if moving text around and some formatting (using headings, bullets, etc.) would improve that. The second general comment I have is that <u>this report needs to be presented in plain English</u>... I heard at the workshop that people had a difficult time	We have significantly revised the Executive Summary to scale back the details and present a more user-friendly overview. As for the organization, we have retained the integration of Qa/Qx and habitat in each major element (e.g. strata, site selection, metrics). It is somewhat more cumbersome than first presenting the Qa/Qx monitoring and then the habitat as was done in the workshop; however upon consultation with LCFRB, it was decided to retain the current report organization given the importance of integration.

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				following the report, but if it said exactly what you all said in the workshop, it would be great. It was presented in plain English and folks got it. Also, the design should inform folks of what components help us answer management questions (this includes relevant strata and metrics), and the addition of discussing how we might scale up or down, or what components we could alter to fit budgets and time/staffing constraints. Actually making those alterations should come at an implementation planning or management level. Finally, and very importantly, more appendices could be valuable to explain the methodology in a bit more detail. We may need to come back to this in a few years and we would like to be able to follow the decision making process. There is some question about whether the text in this report is sufficient to allow us to do this.	As suggested, we have revised the report to make it easier to follow/understand where possible. Rather than adding appendices, we expanded methodology, definitions, source documents and design rationale.
Abby Barnes, Dorie Sutton	DNR Aquatic Division, City of Vancouver	Design	General	A glossary of terms and list of abbreviations is needed. There are several terms (i.e. "Primary populations) that are never defined that I would imagine many of us are not familiar with. Also a lot of acronyms. Having a list would give us a convenient place to refer to when we can't remember what it is and we don't know what page it was first spelled out on.	Addressed in text revisions
Nikki Guillot	Ecology	Design	General	Please use the term “Ecology” as the short name of the Washington State Department of Ecology instead of “DOE”. “DOE” is the federal Department of Energy.	Addressed in text revisions.
Nikki Guillot	Ecology	Design	General	Please use “Lower Columbia Region” in place of “Lower Columbia ESU” in the title. This is consistent with previous documents and the grant agreement.	Due to conflicting comments on this topic, the title was revised to be " Lower Columbia" without the inclusion of "Region" or "ESU" per direction from the LCFRB

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Nikki Guillot	Ecology	Design	General	Please refer to the Phase I and Phase II Western Washington Municipal Stormwater NPDES Permits as “municipal stormwater NPDES permits” throughout the document. Ecology issues multiple types of NPDES permits to local jurisdictions and this clarity is important.	Except where the need for abbreviation and the context are unambiguous, this has been done.
Nikki Guillot	Ecology	Design	General	Please include with this final report a summary of the GIS work attempted or compiled from Oregon agencies as well as a brief section on stream gauge network feasibility assessment, in accordance with the grant agreement.	Addressed in text revisions
Nikki Guillot	Ecology	Design	General	Please provide an abstract of the report. The executive summary is not accessible to important members of the target audience.	This will be developed following completion of the report
Nikki Guillot	Ecology	Design	General	Please include and briefly describe the stakeholder feedback process including workshops, and task team and leadership team meetings in the background section. It should be clear this is a step in a multi-phase project.	The concept of a multi-phase project was added to the Background section. The stakeholder feedback process was added to the Participants section 1.4
Nikki Guillot	Ecology	Design	General	Please narrow the use of terms and define segments, channels, reaches, sites, etc. These terms are used somewhat interchangeably and inconsistently. In particular, “reach” needs to be clearly defined for use in the site allocation sections.	Addressed in text revisions.

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Nikki Guillot	Ecology	Design	General	Please clarify the process of site selection. While the body of the report appropriately defers decisions on pseudo-randomization questions to the next project phase, some of the transitions from what was proposed in October to what is proposed in the report are not clear in this report.	Sites have NOT been selected--that is not the purpose of a design report. The target populations from which the sites will be selected have been identified, together with the stratification that will ensure that all important sub-categories of the Master Sample are adequately represented. But that is all, so it is not surprising that the outcome is not clear.
Nikki Guillot	Ecology	Design	General	In particular, for site selection, the proposal presented in October was to identify the most accessible Qa/Qx sampling location at the downstream end of a candidate urban subbasin. Please confirm that the discussion in section 3.2.1.1 is not departing from this recommendation and that the 20xbankfull width reach length definition is limited to the habitat sites. This shift was not highlighted at the January workshop. The October proposal gained favorable reviews from stakeholders familiar with stormwater issues. It also addressed the frequent site disqualification problems encountered in Puget Sound. Please reconsider the shift or articulate that this issue, like the pseudo-random approach, needs to be settled in the next phase.	Thank you for your comment. We have incorporated these considerations, and clarified the text, as indicated.
Nikki Guillot	Ecology	Design	General	Selecting tributary areas based on hydrology is a sound approach but outfalls and tributaries can significantly affect water quality. This is not an issue for the most-downstream-sampling-site approach described in October, but it becomes one if the site selection process goes back to a strict GRTS approach.	The point of a randomized sampling scheme is to avoid pre-selecting sites on the basis of prior expectation or skewing of impacts. This approach is no better or worse than others.

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Nikki Guillot	Ecology	Design	General	Please more fully consider the Hobbs et al 2015 stormwater discharge monitoring report that was provided to you last month and what implications the findings may have for parameter selection and further stratification by urban land uses.	As stated in that report's Executive Summary, "The primary goal for monitoring under the permit was to gather data directly from stormwater discharges and establish a regional (western Washington) baseline of data representing municipal stormwater quality." Its measurement protocols are appropriate to a water-column-focused stormwater sampling program, and I understand that the cost is somewhere north of $1M. None of these attributes make it a particularly close analog to the HSTM program, but their findings have definitely informed the current design.
Nikki Guillot	Ecology	Design	General	Please describe what would be required to elevate the parameters under consideration into the final program design. Please indicate when this evaluation will be done, even if it is approximate.	If additional information from other programs becomes available early in the Implementation Plan development, particularly with regard to the precision and importance of a particular parameter (stemming from stakeholder recommendations), it would be reconsidered at that time. The cost to include the additional parameter would also need to be evaluated in light of available resources.

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Nikki Guillot	Ecology	Design	General	Please consider adding non-permitted urban areas to the UGA+NPDES strata. It may be informative to consider more detailed urban land use types, specifically industrial and commercial uses versus residential uses.	From the perspective of municipal stormwater permittees it's easy to imagine that the more targeted (regulatory-based) category, as recommended here, will make the "sale" of this program to their respective jurisdictions (internally) more simple than if monitoring sites combine permit-required and non-permit-required locations. There is no pressing technical value to include these points in the "urban NPDES" stratum (there are plenty, already), although from a strictly technical perspective there's no need to exclude them, either. If a monitoring question was articulated that expressed the value of a finer stratification of urban land uses, then a monitoring design could surely be formulated to answer it. Indeed, the current design may achieve that goal through post-stratification--but it was not designed with that explicit need in mind, and a retooling of the monitoring questions and objectives would be necessary to incorporate that interest now.
Nikki Guillot	Ecology	Design	General	Please consider what value the Primary Populations categories add to answering the water quality and quantity questions. This new stratum came into the design without full explanation. The number of Primary Populations present in a water body is not a factor that affects water quality - or habitat - but rather results from instream and other conditions.	As noted in other comments, there is no presumption that PP's are a causal agent of water quality--only that management concerns may want to ensure that sufficient monitoring has been conducted in high-priority subbasins to support recovery efforts.
Nikki Guillot	Ecology	Design	General	Please consider adding the possibility of densifying the site allocation in the Lewis River basin instead of imposing this stratification on the overall design.	If the Lewis River subbasin is the only area of high priority, then the current stratification need not be changed and only the categories would need to be redefined: two, from 0-3 PP's and 4+. This change can be made at any time prior to implementation without affecting the structure of the monitoring design, but it should probably happen only with the full concurrence of project partners.